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Testing tools in experimental areas to improve the management of red deer (*Cervus elaphus*) populations

Maryline Pellerin¹, Christophe Bonenfant², Adrien Gérard³, Etienne Guillaumat³, Vivien Siat⁴

In the current context of increase in number and geographic expansion of wild ungulates, combined with decreasing hunting pressure, wildlife managers need efficient tools for better control of populations. In general, managers use theoretical maximal growth rates of population and/or abundance estimates to set hunting plans. Concerning the use of population growth rates, these can vary greatly depending on the year, status of the population (e.g. in the colonisation phase), or others factors, and therefore lead to poor management decisions. Relying on population abundance only does not, however, provide a comprehensive picture of population functioning. To become more insightful, abundance needs to be complemented by additional biological measurements such as individual performance (e.g. body mass) or browsing pressure. The complementary use of several aspects of the population-environment system is the heart of **indicators of ecological change (IEC)** proposed to manage large herbivore populations. Although the use of IEC makes it possible to improve ungulate management by adjusting quotas according to population temporal trends, the numerical adjustment of hunting plans is based on expert opinion. To achieve more objective decisions, we suggest to **combine IEC, hunting data and demographic parameters to improve the setting of annual hunting quotas** (quantitatively and qualitatively by age and sex classes).

Methods

1. **Biological model:** red deer (*Cervus elaphus*) females

2. **2 study areas:** La Petite Pierre & Chambord (France)
2 forest & hunting reserves

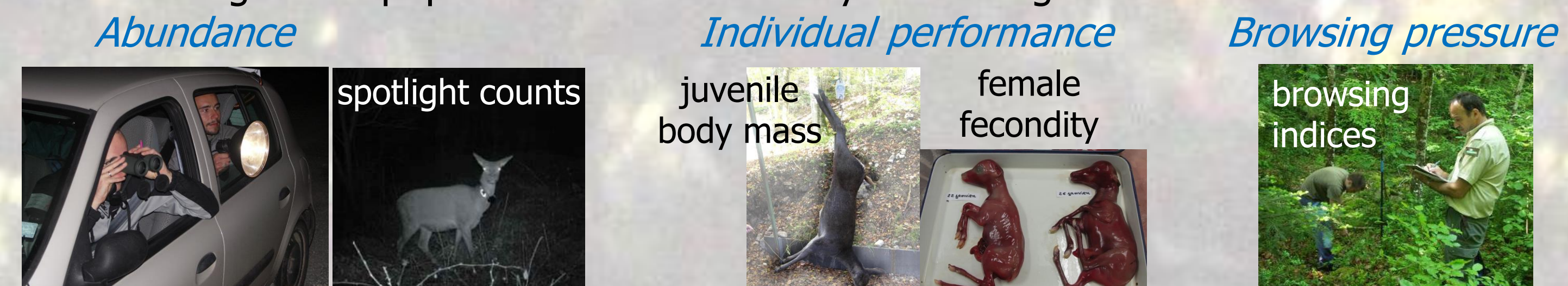


3. **Study period:** respectively since 1978 & 1983

4. **Protocol:**

Estimation of survival using longitudinal observations (capture-mark-recapture 'CMR' since 1978) at La petite Pierre and literature values at Chambord

+ Monitoring of the population-environment system using IECs:



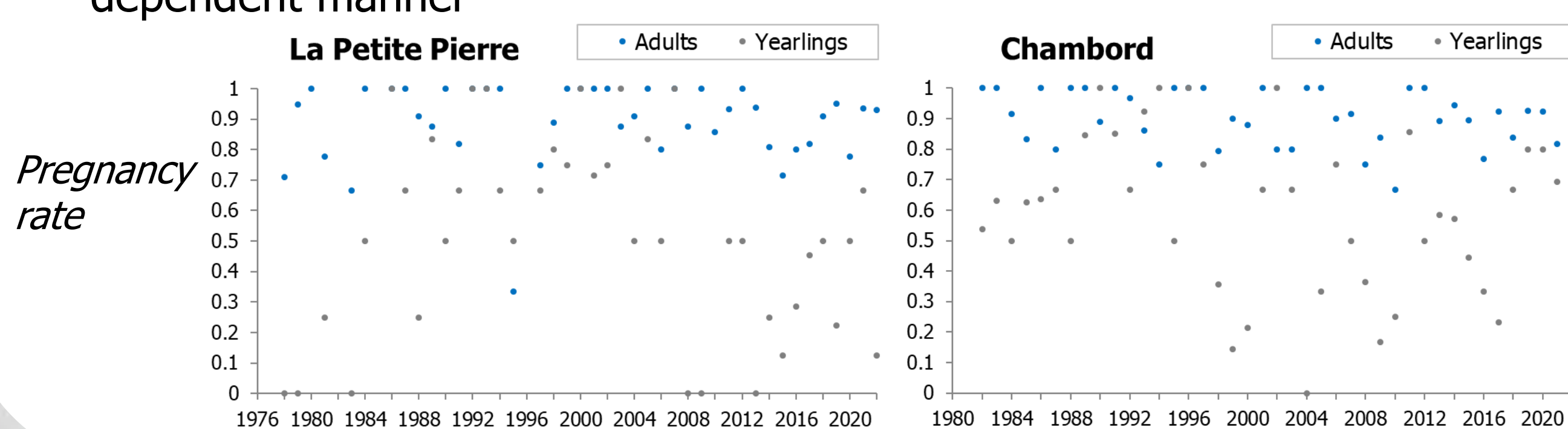
Estimates of demographic parameters (females) to parametrize the model

As expected for a long-lived species:

1. **Natural survival:** Variation with age (simplified in 3 classes for hunting) but no variation according to season

Study area	Fawns	Yearlings	Adults
La Petite Pierre	0.92	0.85	0.87
Chambord	0.90	0.90	0.90

2. **Fecundity:** Variation with age class and according to season in a density-dependent manner



Demographic model to predict past & future population trajectories

1. **Age-structured matrix model:**

$$\begin{matrix} \text{For each season } t \\ \text{Survival } (S, \text{ constant}) \\ \text{Fecundity } (f, \text{ variable}) \\ \text{Sex ratio of fawns} = 0.5 \end{matrix} \begin{pmatrix} 0 & S_{\text{Fawn}} \times f_{\text{Yearling}}(t) \times 0,5 & S_{\text{Fawn}} \times f_{\text{Adult}}(t) \times 0,5 \\ S_{\text{Yearling}} & 0 & 0 \\ 0 & S_{\text{Adult}} & S_{\text{Adult}} \end{pmatrix}$$

Study area	Period	Mean	Min.	Max.
La Petite Pierre	1978-2022	13.4	8.5	15.8
Chambord	1983-2022	16.9	9.9	20.7

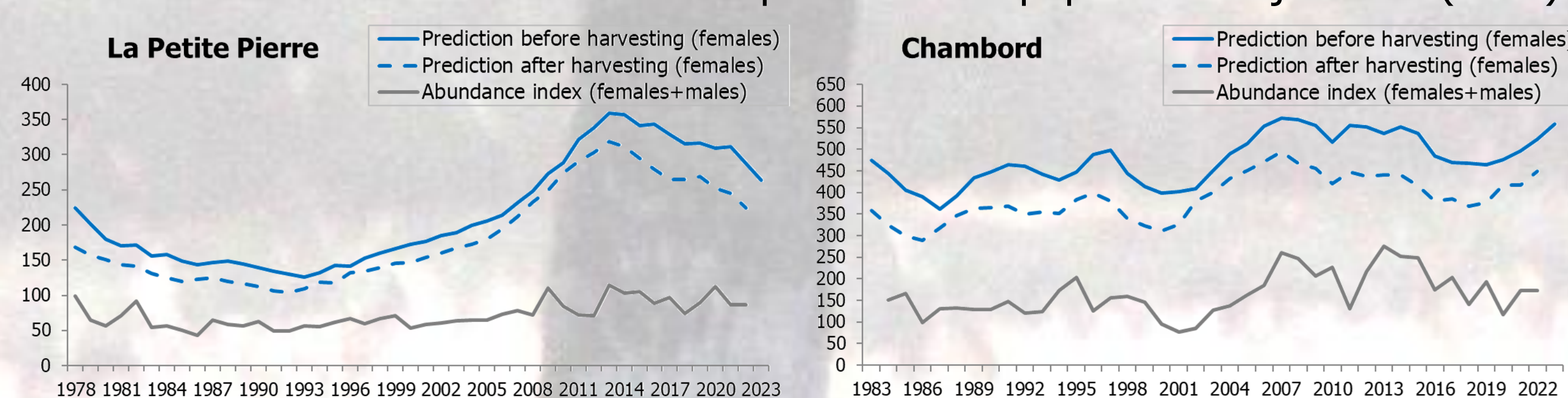
→ Growth rate of the population (%)

$$\begin{matrix} \text{For each season } t \\ \text{Abundance } (N) \\ \text{Harvest } (H) \end{matrix} \begin{pmatrix} \text{Fawns} \\ \text{Yearlings} \\ \text{Adults} \end{pmatrix} = \begin{pmatrix} \text{Fawns} \\ \text{Yearlings} \\ \text{Adults} \end{pmatrix} \times \begin{pmatrix} \text{Matrix } (t) \end{pmatrix} - \begin{pmatrix} \text{Fawns} \\ \text{Yearlings} \\ \text{Adults} \end{pmatrix} \begin{pmatrix} \text{Harvest } (t) \end{pmatrix}$$

Estimation of initial abundance: abundance index (spotlight counts) + CMR

Simulation of population change

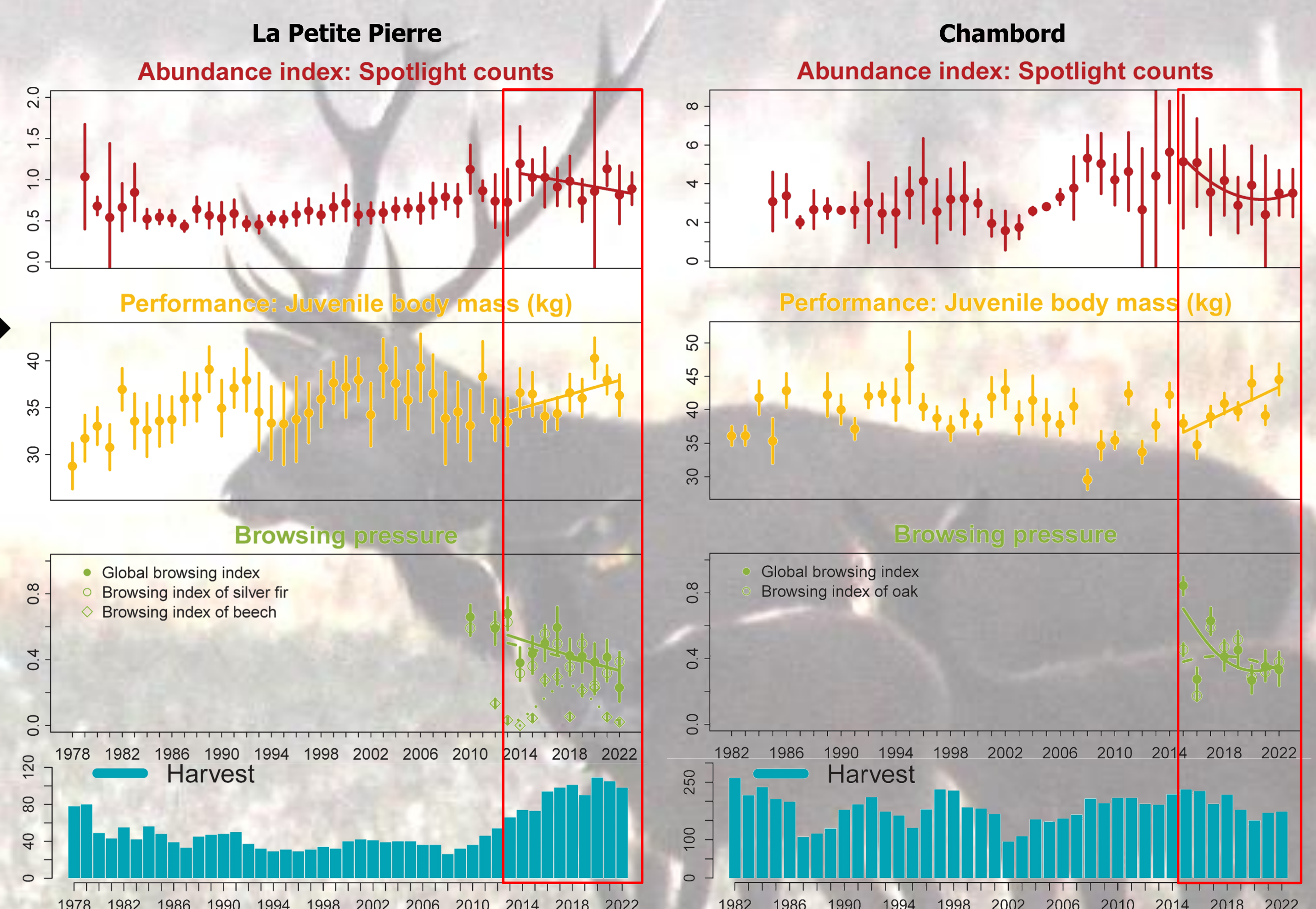
We could back-cast (to 2022) population trajectories using relative abundance time series from spotlight counts (IEC), to force simulations within biologically realistic boundaries. We then used this model to predict future population trajectories (2023):



Proposal of hunting quotas

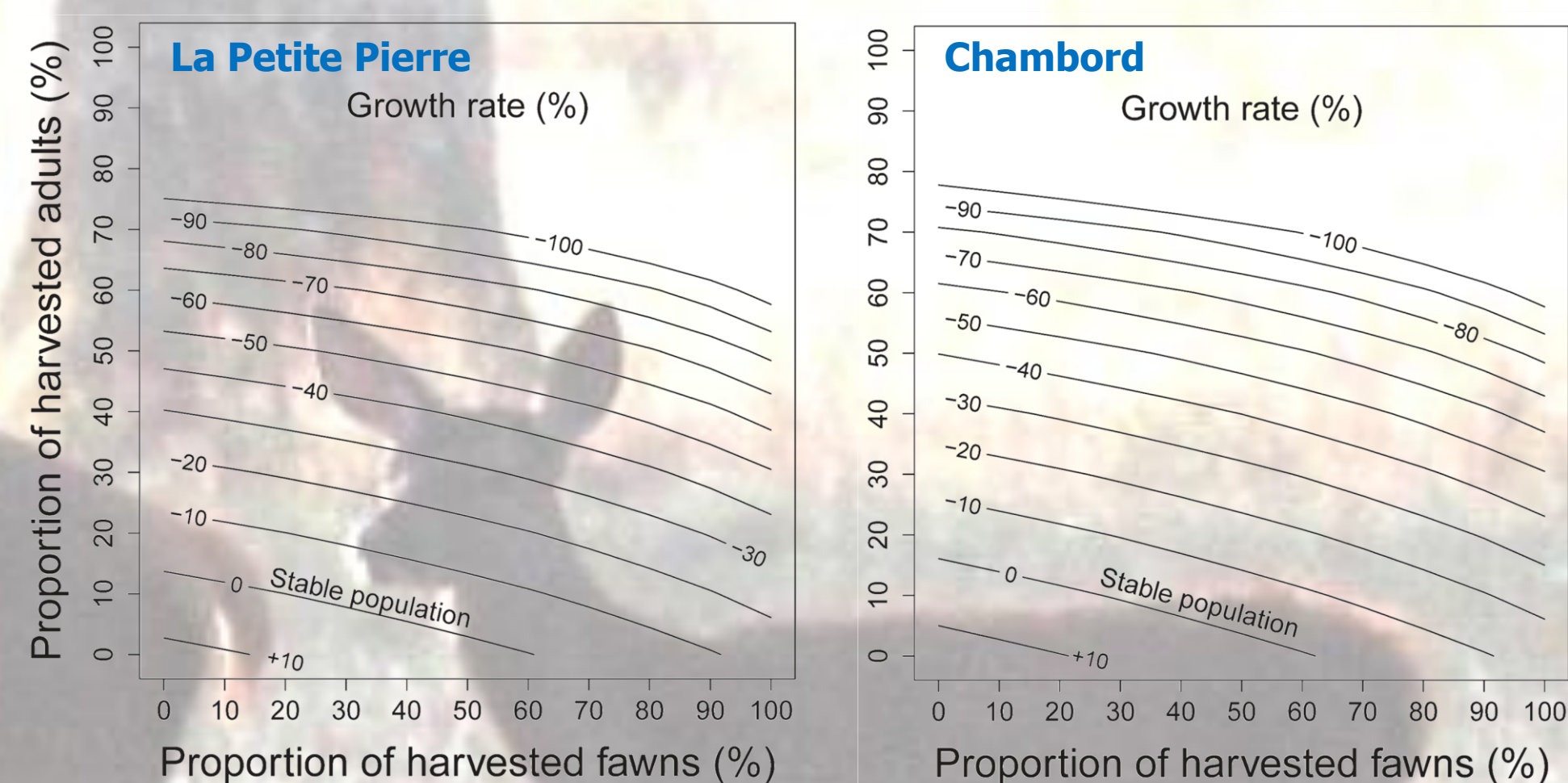
According to the management objectives, which are based on the analysis of IECs, we have proposed quotas that have been applied to La Petite Pierre and Chambord since 2013 and 2015 (red box) respectively:

Objectives: decrease abundance and browsing pressure + increase performance



Simulation of harvesting policies

In order to define both quantitatively and qualitatively (by age and sex categories) the hunting plans according to the targeted growth rate, we simulated different harvesting scenarios:



For example at Chambord, the removal of 43 female fawns (hence 86 male and female fawns) and 29 female adults lead to the same rate, -20%, than the removal of 24 female fawns (48 male and female fawns) and 51 female adults.

Proposed annual hunting quotas

Study area	Period	Fawns (females+males)	Yearlings+Adults (females)	Expected annual growth rate
La Petite Pierre	2013-2023	50	38 to 48	-10% to -15%
Chambord	2015-2023	80 to 84	70 to 80	-6% to -10%

Management results

Study area	Abundance	Performance (juvenile body mass)	Browsing pressure
La Petite Pierre	-24%	+8%	-61% (global)/-35% (silver fir)
Chambord	-32%	+17%	-61% (global)/-16% (oak)

Conclusions

At La Petite Pierre and Chambord, we successfully experimented this approach to help managers both decreasing abundance population and improving demographic performance. We are still working to improve this demographic model by adding variance for demographic parameters, improving the estimate of initial abundance, adding annual variation of juvenile survival (based on body mass) and adding males. To achieve this, we are currently developing an integrated population model 'IPM'. This model will be transferable to other areas where no survival estimates are available from CMR, by using rates taken from the literature (as in Chambord) combined to local IECs and hunting data. Lastly, with regard to population regulation, we would draw managers' attention to the revitalisation phase (in particular increased fecundity) which follows a population decline and which means that hunting pressure must not be relaxed too quickly to maintain the benefits of this drop in abundance.

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