Tree, Sex and Size: Ecological determinants of male versus female fecundity in three Fagus sylvatica stands

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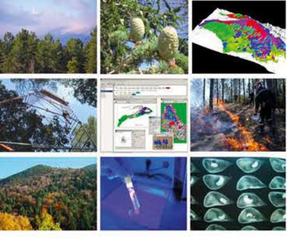

Tree, Sex and Size: Ecological determinants of male versus female fecundity in three *Fagus sylvatica* stands

Sylvie Oddou-Muratorio*, Julie Gauzere*, Aurore Bontemps*, Jean-François Rey # & Etienne K. Klein#

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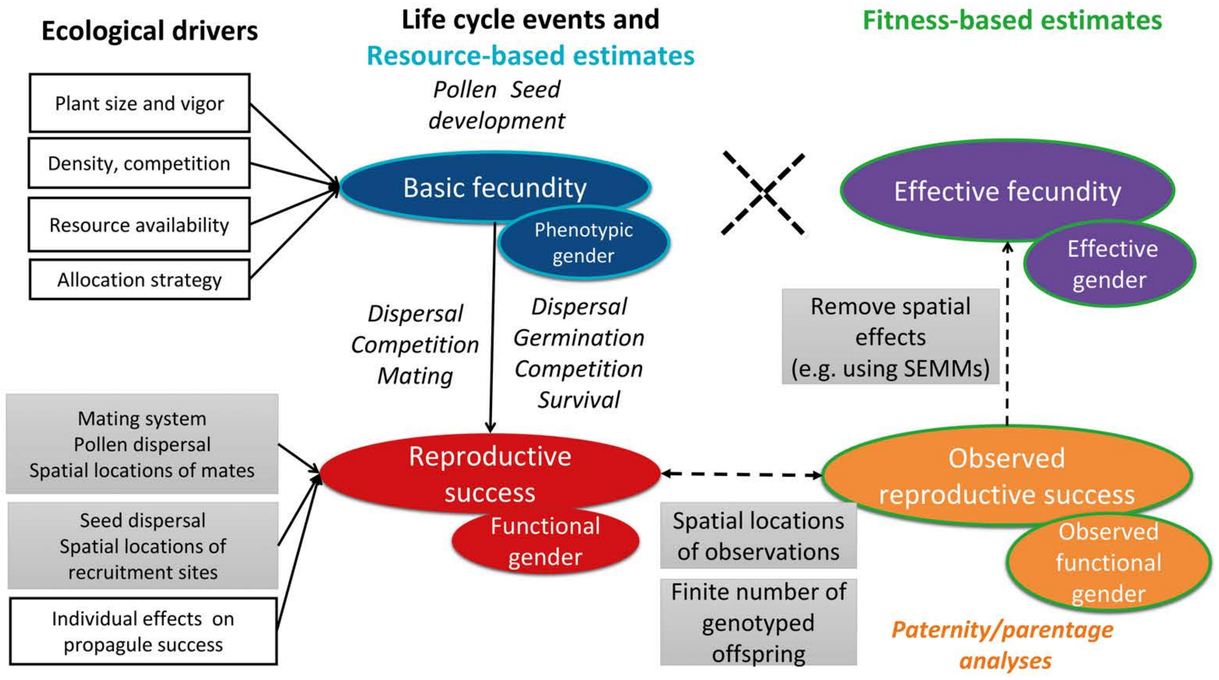
Context and objectives

Inter-individual variations in female (♀) and male(♂) fecundities have major consequences on population evolutionary potential, through genetic drift and selection. In plants, basic fecundities are classically estimated before dispersal through the resource allocated to ♀ (i.e. the biomass/number of ovules, seeds, ovuliferous flowers or fruits) and ♂ (i.e. the biomass/number of pollen grains or staminate flowers) functions. Alternatively, paternity and parentage reconstruction can provide fitness-based estimates of effective fecundity and reproductive success, though the numbers of offspring assigned to a given individual. However, we miss a conceptual framework linking resource-based and fitness-based estimates of fecundity to reproductive success, and tools to obtain comparable estimates of ♀ and ♂ effective fecundities. The present study aims to feel this gap, first by **providing a new method to estimate together ♀ and ♂ effective fecundities accounting for a spatial configuration effect** (implemented in the MEMM program). Then we apply this method to **study the variation in ♀/♂ fecundities and gender in relation to plant size and competition in a major monoecious tree species, the European beech.**

Bridging the gap between resource-based and fitness-based estimates of fecundity and gender in plants



- **Basic fecundity** and **phenotypic gender** encompass only the production of pollen and seed and are estimated before dispersal by the number/biomass of seed/pollen (**resource-based estimates**).
- **Reproductive success** is driven by basic fecundity together with additional factors, including spatial processes and individual effects on propagule success.
- **Reproductive success** and **functional gender** are **observed** after dispersal using **parentage/paternity analyses,** which are potentially biased by spatial and sampling effects.
- **Spatially Explicit Mating Models (SEMM)** get rid of these confounding effects to retrieve the **effective fecundity and gender**, which accounts for individual effects on propagule success.

Estimating ♀ and ♂ individual fecundities with MEMM

THE DATA

N adult genotypes & positions

Open-pollinated progeny genotypes

Established seedlings genotypes & positions

Codominant genetic markers (SNP, microsatellite)

MAJOR HYPOTHESIS

- Each tree can contribute as a ♀ or ♂ to seedlings rain (**monoecious species**)
- A same pollen or seed dispersal kernel for all adult trees.

THE SPATIALLY EXPLICIT MATING MODEL (SEMM)

$$likelihood(G_i) = \sum_{origins} P(origin|x_i, y_i) \times P(G_i|genes(origin))$$

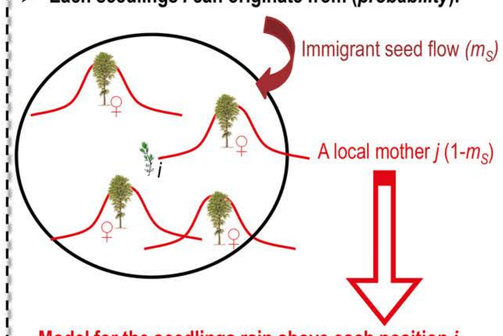
G_i= Genotype of offspring *i*

MOVEMENT MODEL
From an origin (adult, pop, …) to a sampling point {x0,y0} (mother, trap, quadrat…)

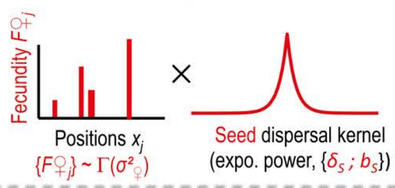
GENETIC TRANSMISSION LAW
From individual to individual (Mendel), from pop to individual (Hardy-Weinberg)

The SEMM movement model considers that :

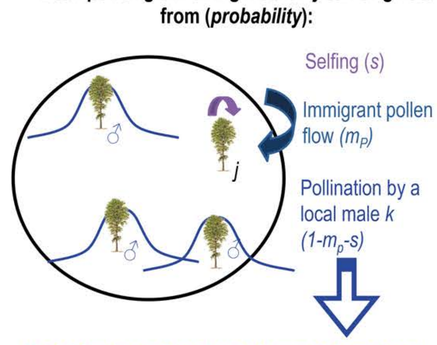
- **Each seedlings *i* can originate from (*probability*):**



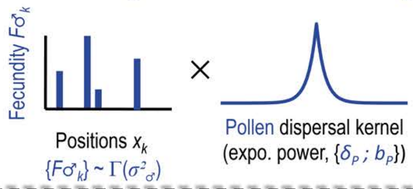
Model for the seedlings rain above each position *i*



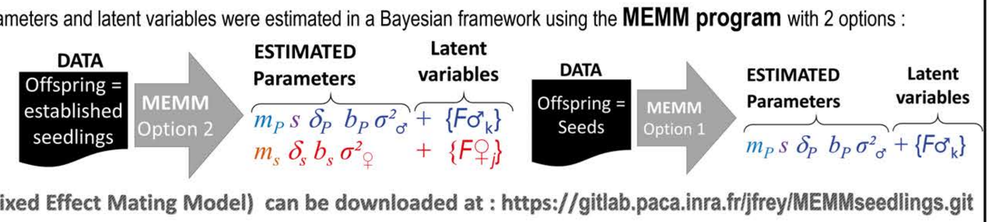
- **Each pollen grain siring mother *j* can originate from (*probability*):**



Model for the pollen cloud above each mother *j*



IMPLEMENTATION : All parameters and latent variables were estimated in a Bayesian framework using the **MEMM program** with 2 options :



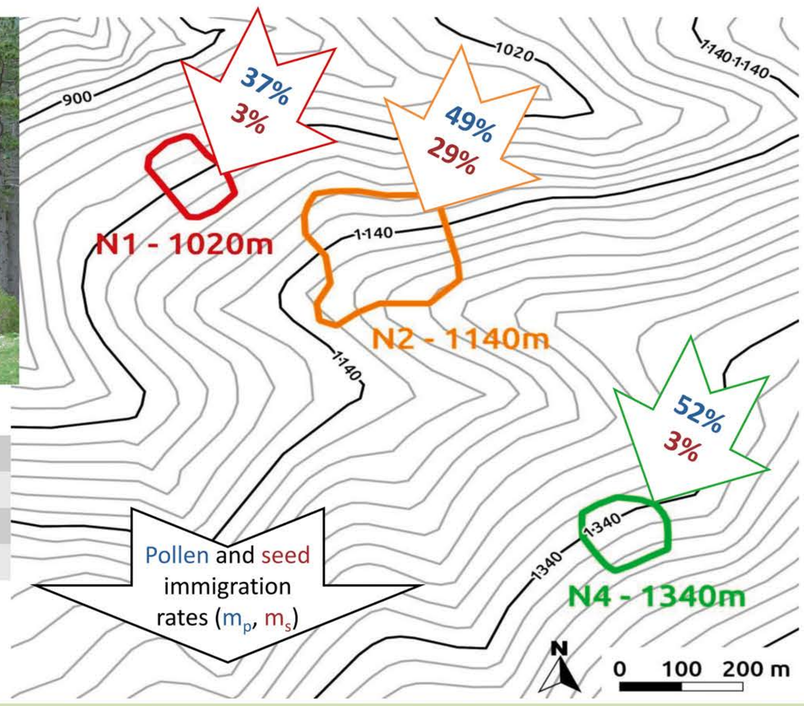
The MEMM program (Mixed Effect Mating Model) can be downloaded at : https://gitlab.paca.inra.fr/jfrey/MEMMseedlings.git

Sampling three *F. sylvatica* plots along an altitudinal gradient

Mont Ventoux, South-East France

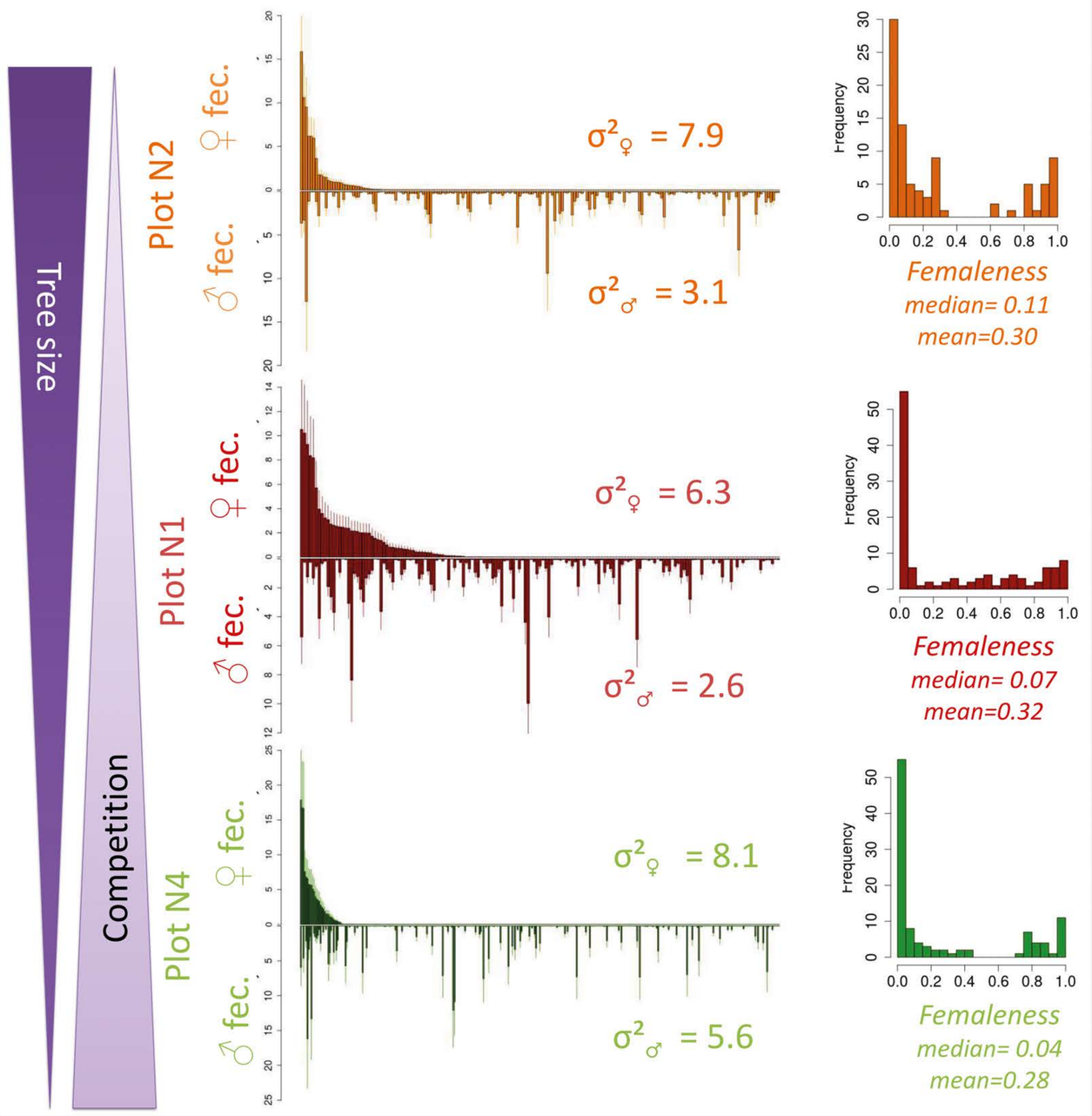
	N1	N2	N4
# Adults	164	193	365
# Seeds	694	674	720
# Seedlings	223	248	250

Genotyping at 21 microsatellite markers (>95 alleles within each cohort)



Previous result : Pollen immigration increased with altitude: protogyny combined with temperature variation may result in oriented pollen flow from bottom to top (Gauzere et al. Mol Ecol. 2013)

Result: ♀ and ♂ effective fecundities and femaleness



- Both ♂ and ♀ fecundities distribution were L-shaped (Y-scale is relative, and vary among plots)
- The variance in ♀ fecundities ($\sigma^2_♀$) tended to be higher than the variance in ♂ fecundity ($\sigma^2_♂$)
- The variance in fecundities tended to be higher at high elevation (significant for $\sigma^2_♂$)
- The three plots were male-biased, without significant correlation between ♂ and ♀ fecundity

Result: ecological drivers of fecundity and gender

	Ecological driver	♀ fecundity	♂ fecundity	Femaleness
Individual size	Maximum stem diameter	↗		
	Sum of stems' diameter		↗	
	Tree stature (dominated, dominant)		↗	
Competition	Conspecific competition	↘	↘	↘
	Total competition	↘		↘

- The effects of size and competition were consistent across the three plots.
- Both ♀ and ♂ effective fecundities were resource-limited in the studied species.
- Size effects were sex-specific and consistent with the higher unit cost of ♀ as compared to ♂ reproduction, and with the limitation of ♂ fecundity by mating opportunities.
- Effective gender was independent of size, but femaleness decreased under limited resources (i.e. with increasing competition and density), consistent with the higher unit cost of ♀ reproduction

Conclusions

- SEMM- and resources-based estimates of fecundity are complementary: the latter estimate the resources allocated to reproduction while the former can only estimate a relative amount of pollen or seed produced. Moreover, SEMM-estimates account for individual effects that act independently on location to modify the success of mating.
- In the monoecious tree *Fagus sylvatica*, both ♂ and ♀ fecundities increased with tree size and decreased with competition in the neighborhood (with sex-specific strategies to deal with limited resources).
- This study suggests that the evolutionary potential of *Fagus sylvatica* population is enhanced by low variance in fecundity at low elevation, and high pollen flow at high elevation.

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