Estimation conjointe de la courbe de dispersion du pollen et des facteurs conditionnant la fertilité male chez les plantes

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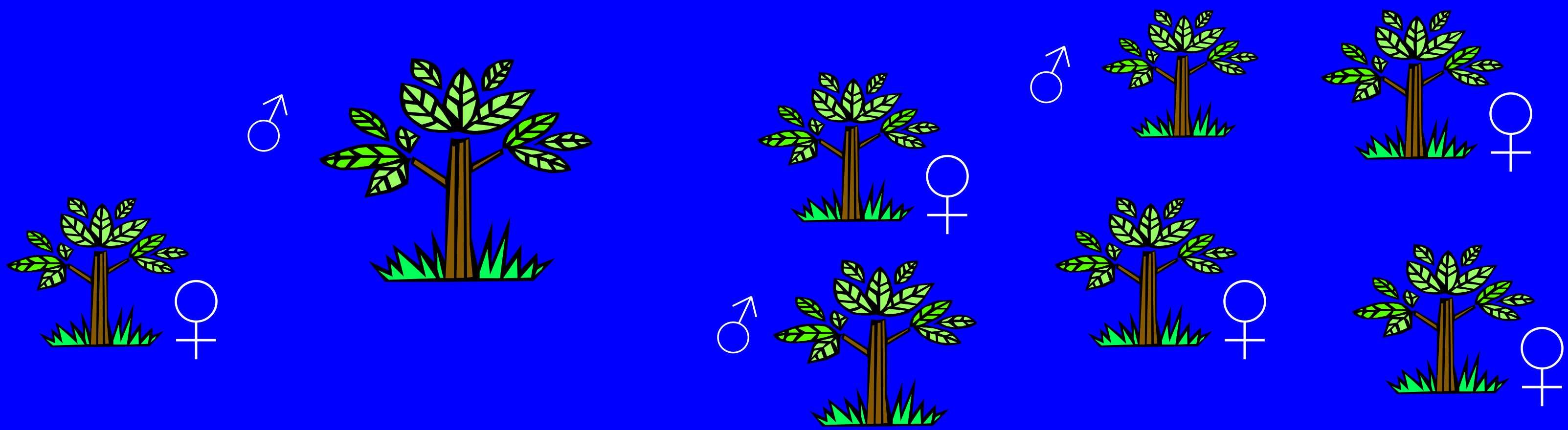
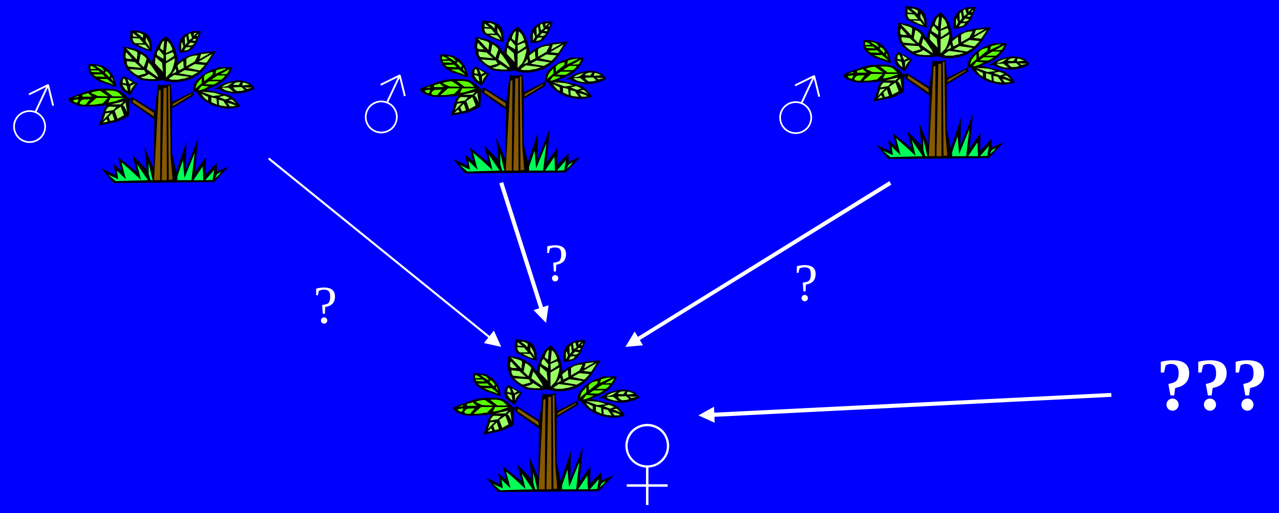
Male reproductive success

- Male reproductive success in plants is conditioned by at least two factors
  - The male fertility of the individual
  - The availability of females around (which is connected with the dispersal rate of pollen).



Paternity analysis

- We genotype a sample of
  - females.
  - seeds sampled on these females.
  - potential fathers around these females.
- For each seed, we try to find its father among he sampled males.



MICROSATELLITES

- séquence d'A.D.N. constituée par la répétition d'un court motif (2 à 5 bases).

  ➥exemple : AGTCACTCTCTCTCTCTCTCTCATGAT

- Polymorphisme au sein des populations : un allèle d’un individu = son nombre de copie
  - AGTCACTCTCTCTCTCTCTCTCATGAT: 8
  - AGTCACTCTCTCTCTCTCTCTCTCTCTCTCATGAT: 12
  - AGTCACTCTCTCTCTCTCATGAT: 6

- Un individu aura par exemple le génotype 12/8 à un locus donné

Paternity likelihood (1 locus)

$$\text{Female}: \frac{4}{8} \qquad \text{Offspring}: \frac{4}{6}$$

$$\text{male 1}: \frac{4}{7} \qquad \text{likelihood} = 1/2$$

$$\text{male 2}: \frac{3}{8} \qquad \text{likelihood} = 0$$

$$\text{male 3}: \frac{4}{4} \qquad \text{likelihood} = 1$$

$$\text{male 4}: \frac{3}{4} \qquad \text{likelihood} = 1/2$$

Paternity likelihood (2 loci)

$$\text{Female:} \quad \frac{4}{8}\frac{2}{2} \qquad \text{Offspring:} \quad \frac{4}{6}\frac{2}{4}$$

$$\text{male 1:} \quad \frac{4}{7}\frac{3}{4} \qquad \text{likelihood} = 1/2 \times 1/2 = 1/4$$

$$\text{male 2:} \quad \frac{3}{8}\frac{4}{4} \qquad \text{likelihood} = 0 \times 1 = 0$$

$$\text{male 3:} \quad \frac{4}{4}\frac{4}{5} \qquad \text{likelihood} = 1 \times 1/2 = 1/2$$

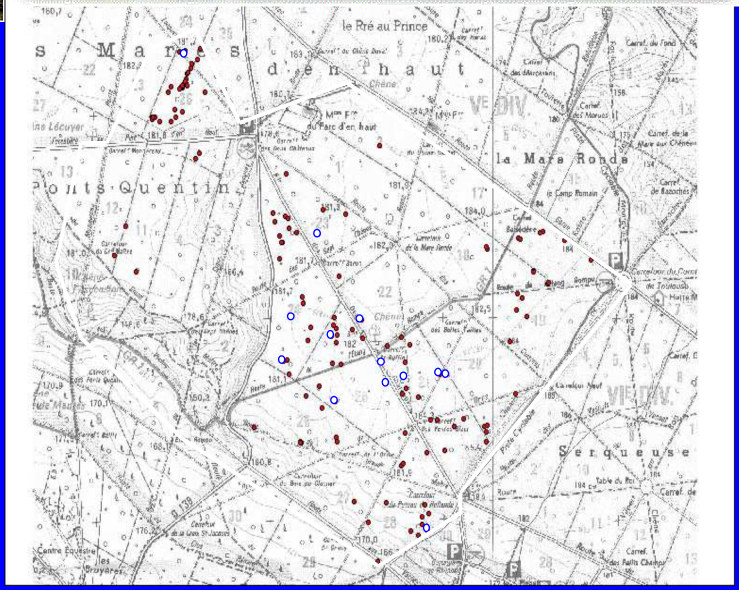
$$\text{male 4:} \quad \frac{3}{4}\frac{3}{6} \qquad \text{likelihood} = 1/2 \times 0 = 0$$

Sorbus torminalis

Wildservice tree

Rambouillet forest (Yvelines)

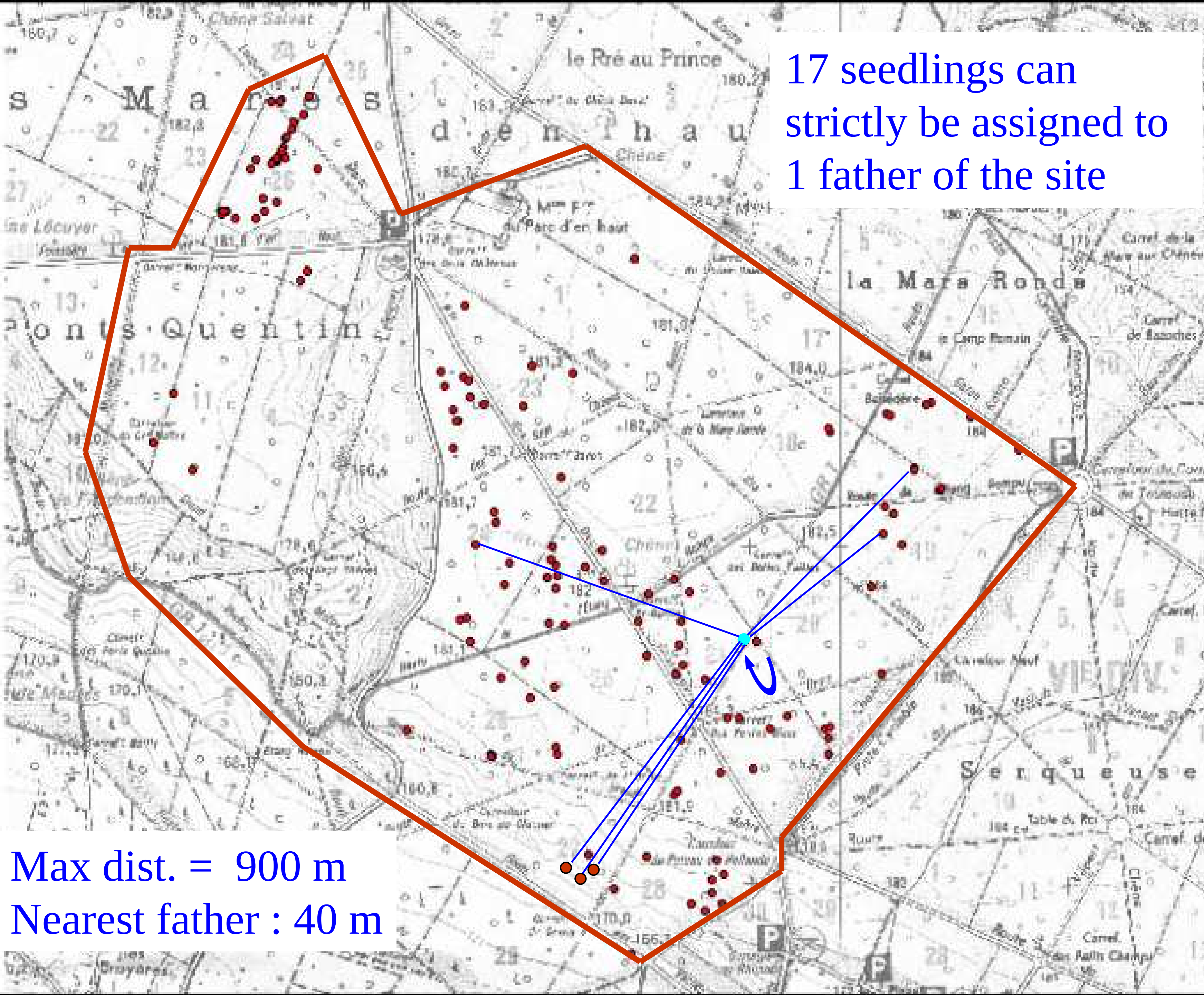
450 hectares
Low density
(0.33 trees/ha)



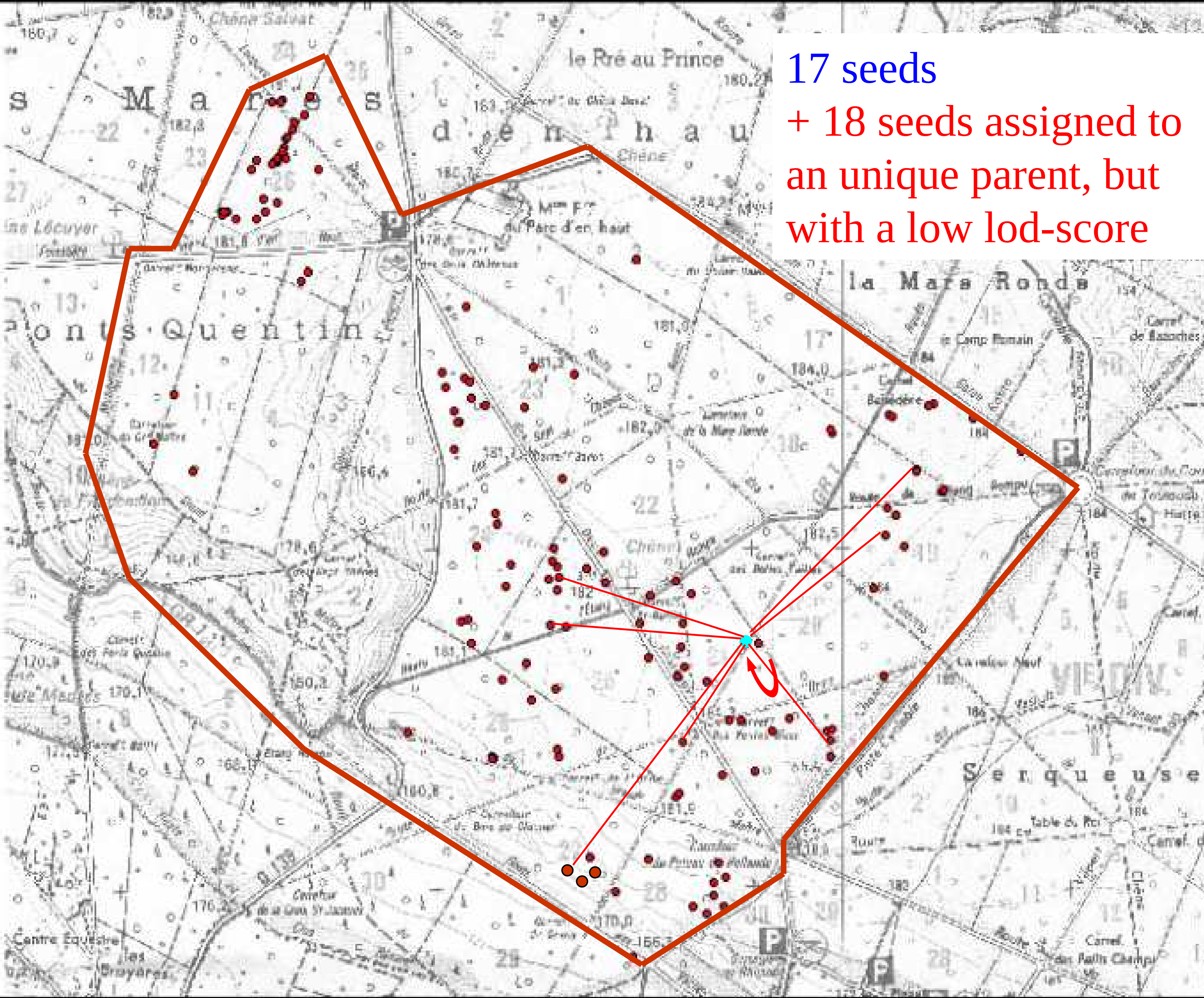
185 adult trees
1999: 14 mothers,
46.6 offspring/mother
2000: 60 mothers,
17.9 offspring/mother

Oddou-Muratorio, S., Houot, M.-L., Demesure-Mush, B. & Austerlitz, F. 2003. *Molecular Ecology* ***12: 3427-3439.***
Oddou-Muratorio, S., Klein, E. K. & Austerlitz, F. 2005. *Mol Ecol* ***14: 4441-52.***

17 seedlings can strictly be assigned to 1 father of the site

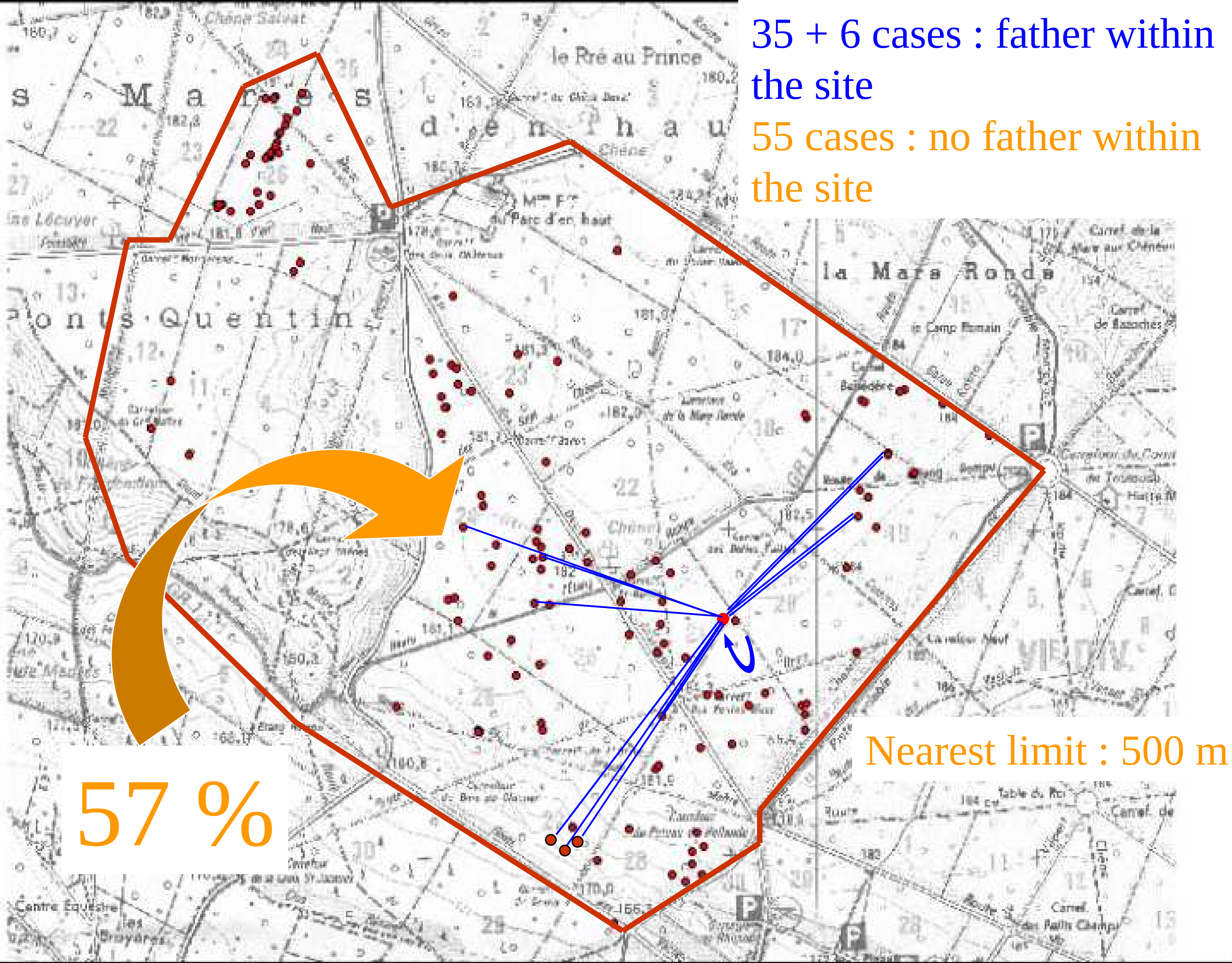


Max dist. = 900 m
Nearest father : 40 m

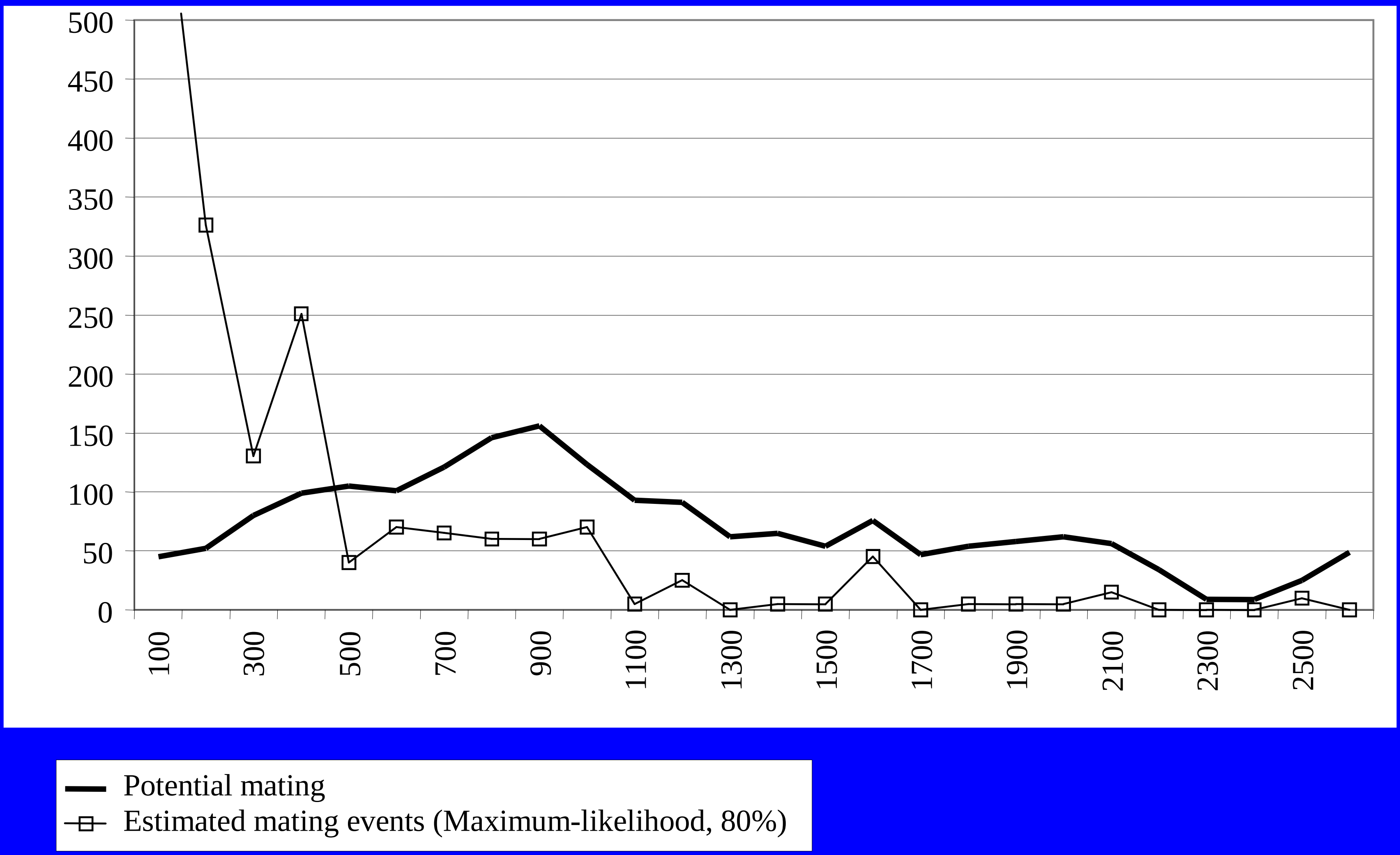


17 seeds

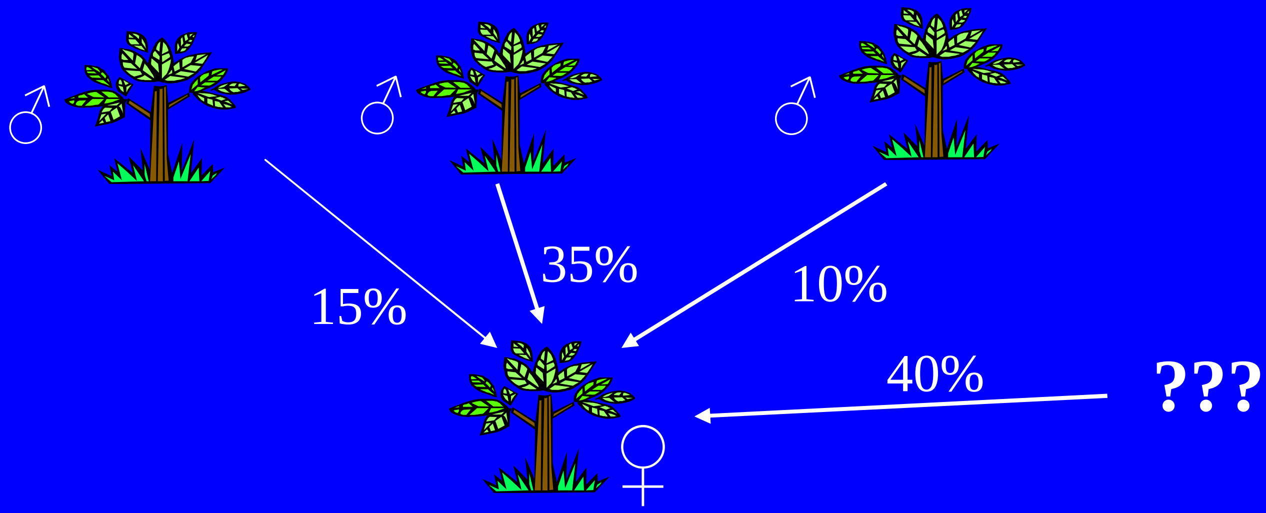
+ 18 seeds assigned to an unique parent, but with a low lod-score


35 + 6 cases : father within the site
55 cases : no father within the site
Nearest limit : 500 m
57 %
le Pré au Prince
la Mare Ronde
Ponts Quentin
Chêne Saïvat
Centre Equestre
les Bruyères

Potential vs. observed mating events (Sorbus 1999)



Estimating dispersal curve

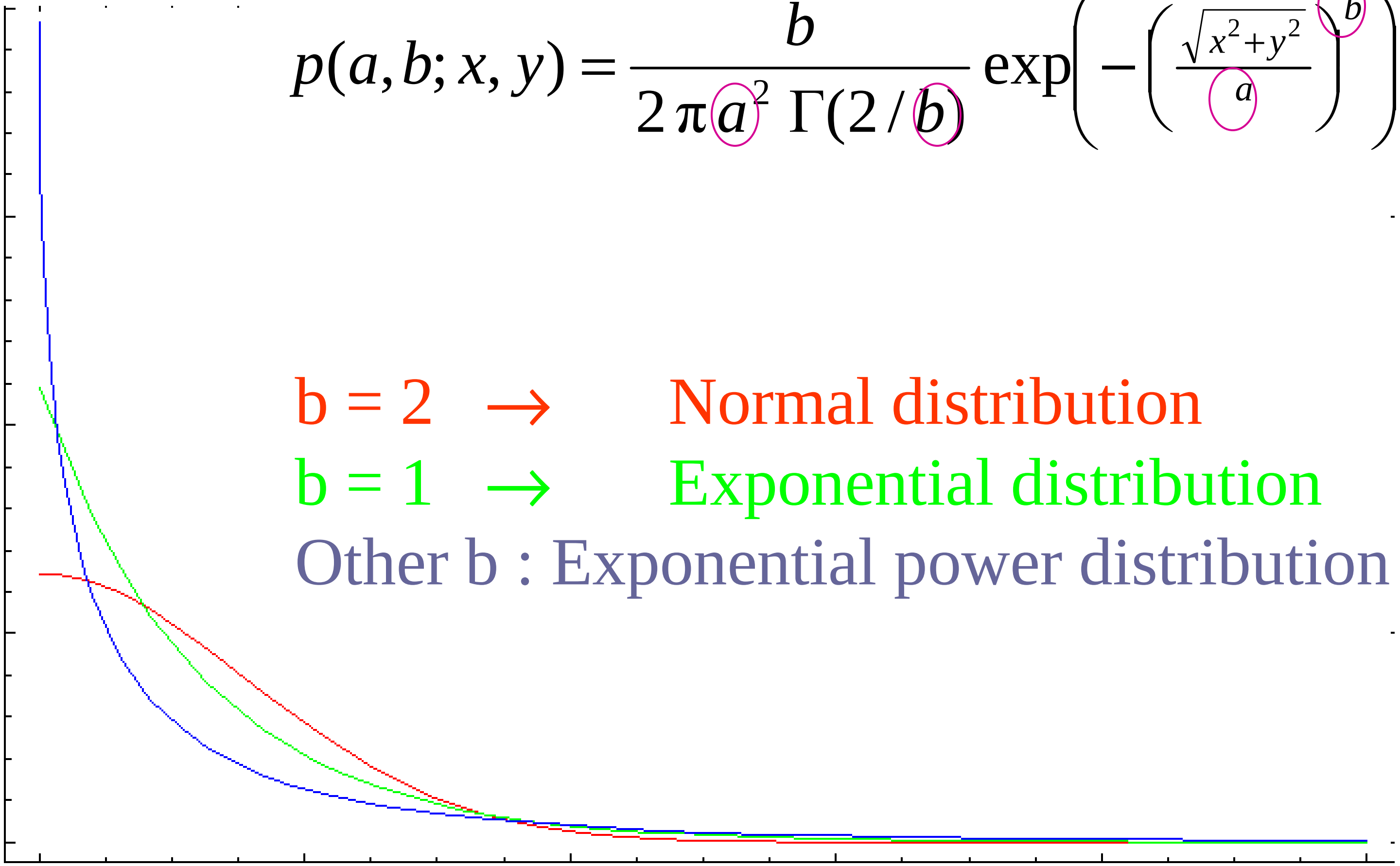


- Thanks to the inferred events of pollen dispersal, we make a maximum-likelihood estimate of the dispersal curve.

$$p(a,b;x,y) = \frac{b}{2\pi a^2\,\Gamma(2/b)} \exp\left(-\left(\frac{\sqrt{x^2+y^2}}{a}\right)^b\right)$$

a : scale parameter
b : shape parameter

$$p(a,b;x,y) = \frac{b}{2\pi a^2\,\Gamma(2/b)} \exp\left(-\left(\frac{\sqrt{x^2+y^2}}{a}\right)^b\right)$$



b = 2 → Normal distribution

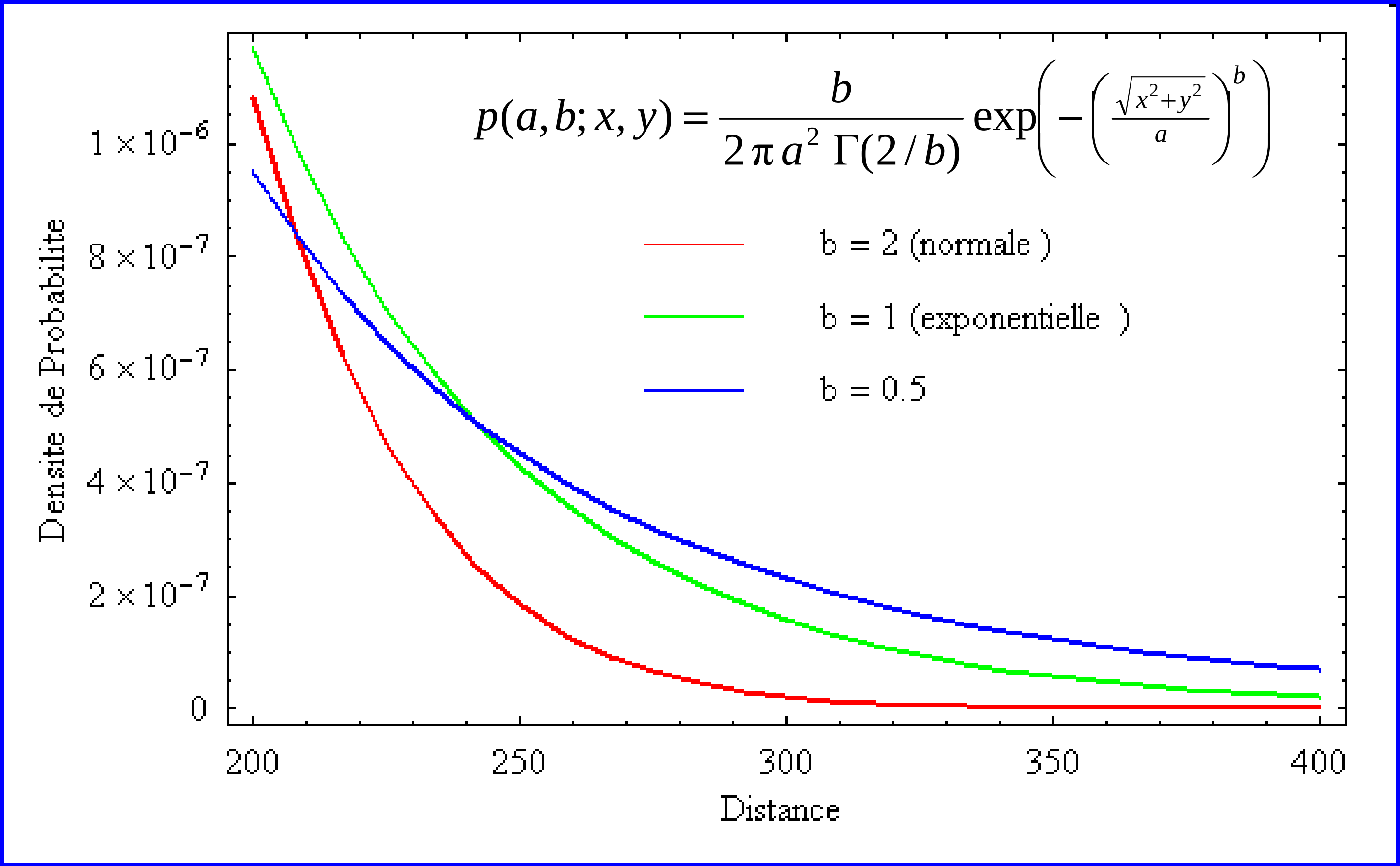
b = 1 → Exponential distribution

Other b : Exponential power distribution

b > 1 → « light-tailed »

b < 1 → « fat-tailed »

Zooming on the tail of the dispersal curve



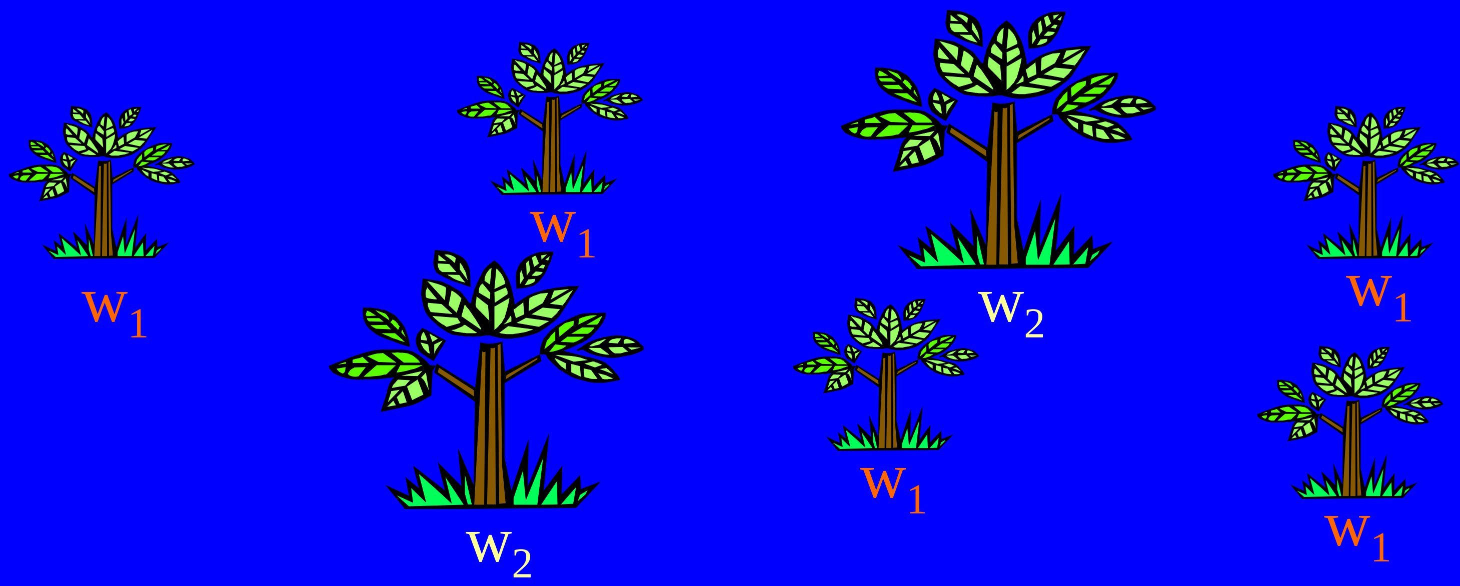
a : scale parameter

b : shape parameter

$b > 1 \rightarrow$ queue légère

$b < 1 \rightarrow$ **queue lourde**

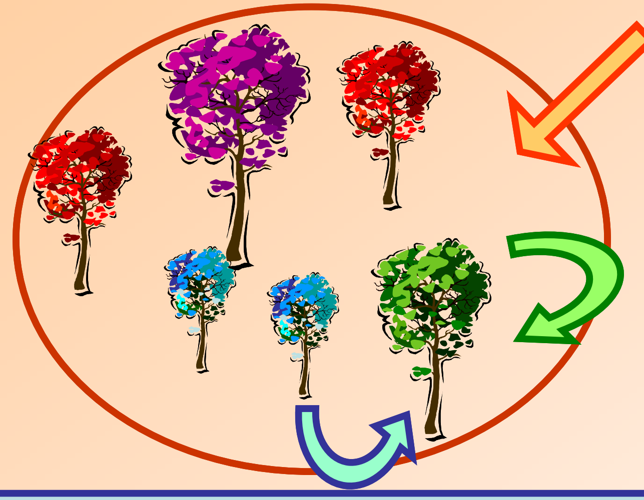
Estimation of variance in reproductive success



- Individuals are grouped into classes of diameter, level of flowering, level of isolation…
- From the inferred paternity inferences, we estimate jointly the relative male fertility of the different classes along with the dispersal curve.

Method

The neighborhood model

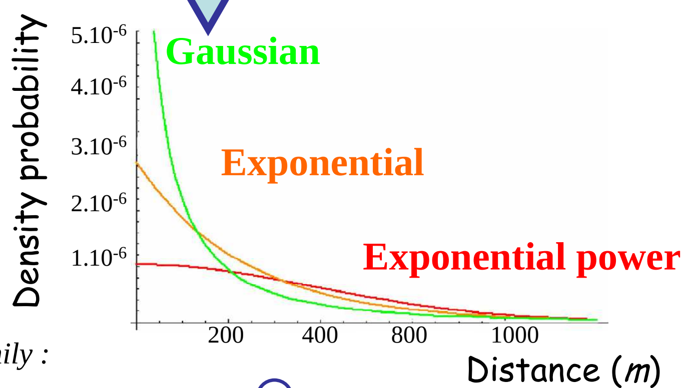


Immigrant Pollen Flow (m)

Selfing (s)

Pollen of a Sampled Male ($1-m-s$)

Dispersal Kernel (θ_d)



Exponential power family :

$$p(a,b;x,y) = \frac{b}{2\pi a^2\,\Gamma(2/b)} \exp\left(-\left(\frac{\sqrt{x^2+y^2}}{a}\right)^{b}\right)$$

b = shape parameter

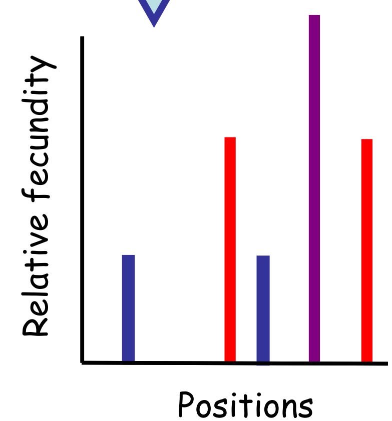
a = scale parameter

+

Male Fecundity (F)

$\mathbf{F} = \{1, \ldots, f_{c-1}\}$

where c is the number of classes of the ecological factor determining male fecundity



Maximum-Likelihood Estimation

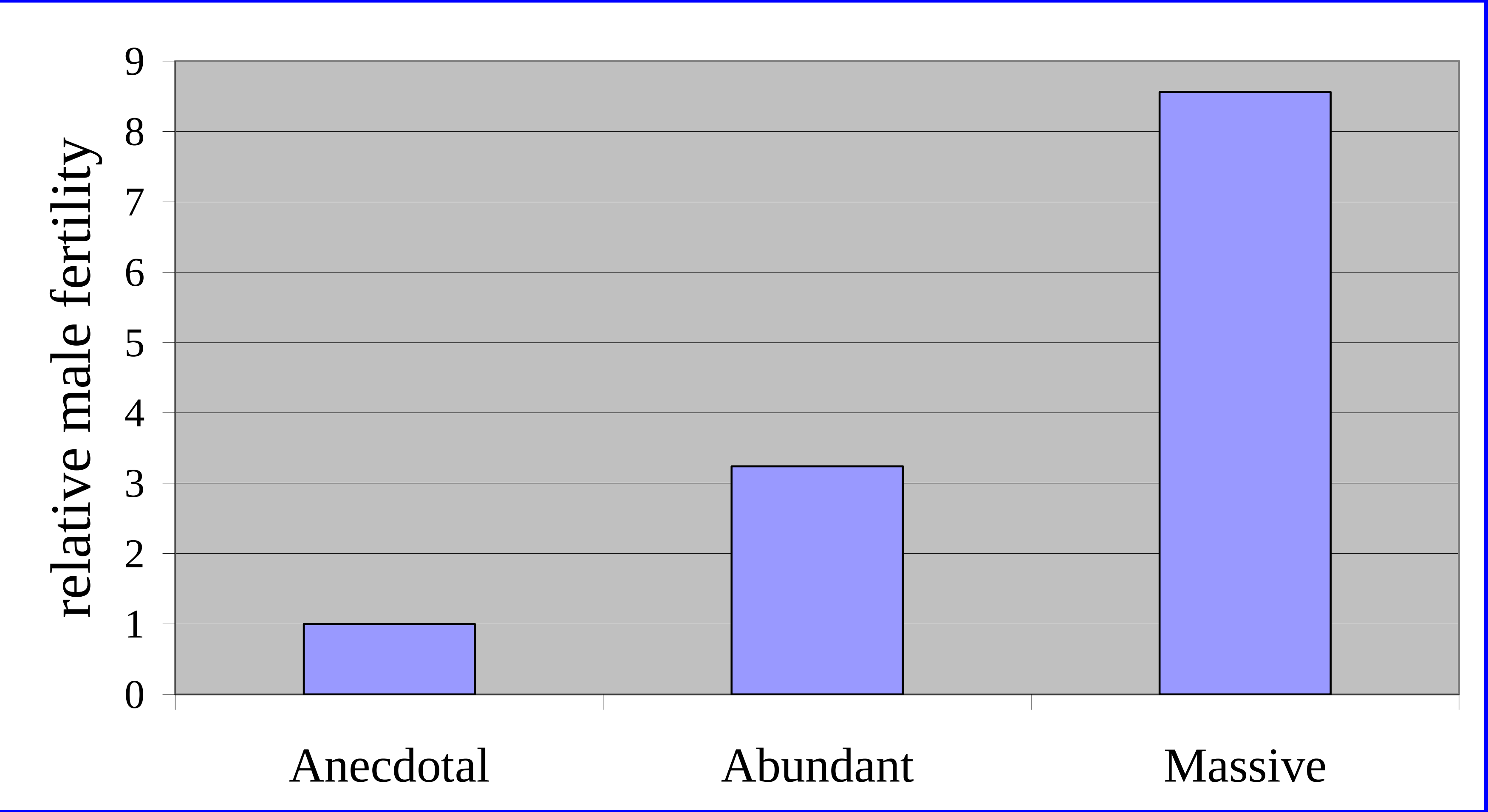
$$\log L(\theta_d, \mathbf{F}, s, m,) = \sum_{o=1}^{O} \log\left[\underbrace{sT\left(g_o \middle| g_{j_o}, g_{j_o}\right)}_{\text{Selfing}} + \underbrace{(1-s-m)\sum_{l\in F} \pi_{j_o,l}(\theta_d, \mathbf{F})T\left(g_o \middle| g_{j_o}, g_l\right)}_{\text{Mating within the neighborhood}} + \underbrace{mT\left(g_o \middle| g_{j_o}, AF\right)}_{\text{Immigrant pollen}}\right]$$

Results for the two years of study

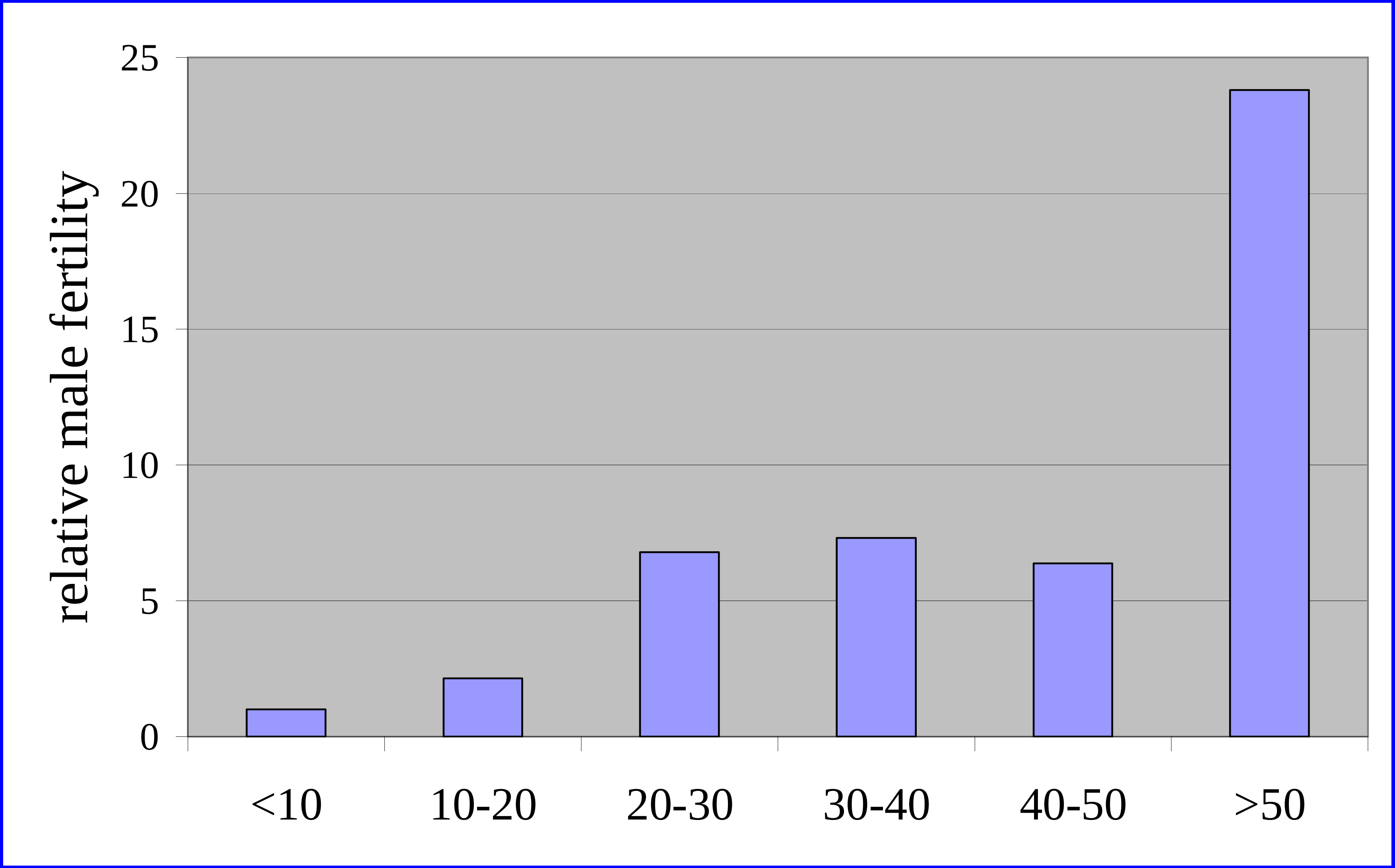
Year	$\hat{a}$	$\hat{b}$	$\hat{\delta}$ (meters)
1999	0.10	0.25	648
	[-0.3, 0.53]	[0.16, 0.35]	[238, 1059]
2000	4.2	0.35	847
	[-2.9, 11.4]	[0.27, 0.44]	[468, 1225]

- Fat tailed dispersal in both cases

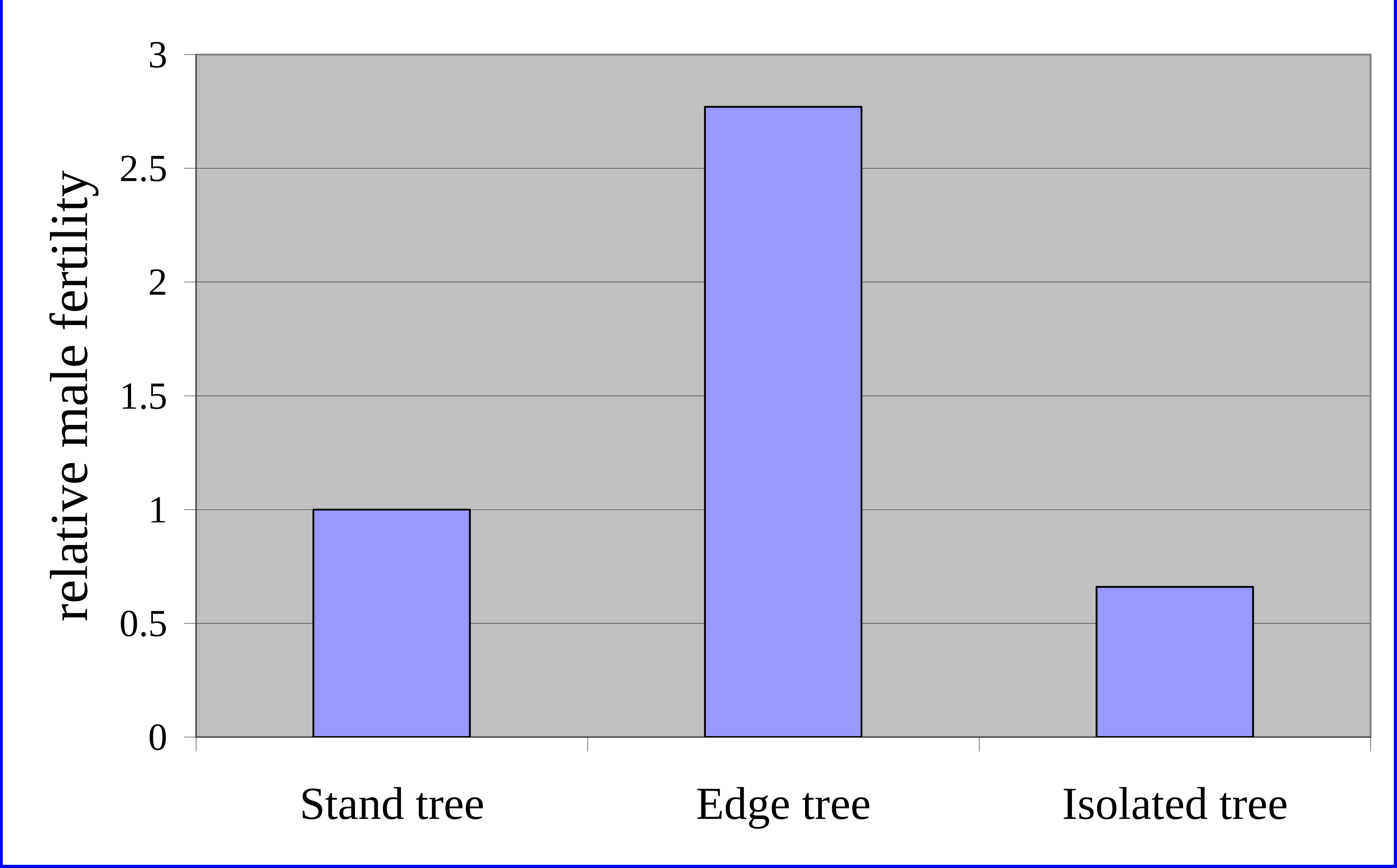
Effect of intensity of flowering



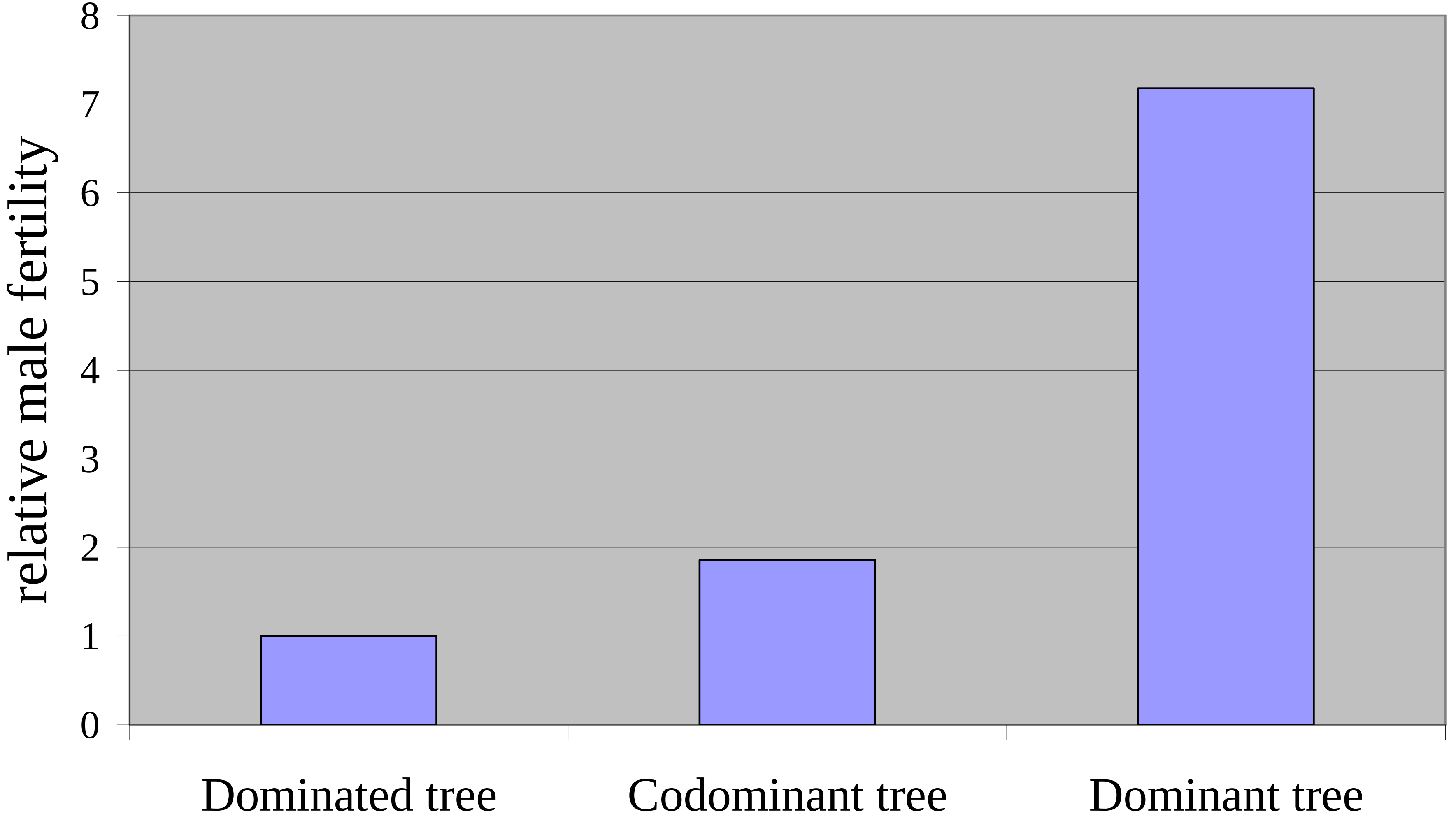
Effect of diameter



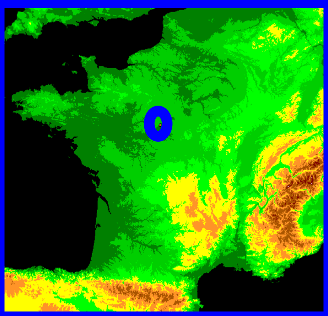
Effect of the relative position of trees

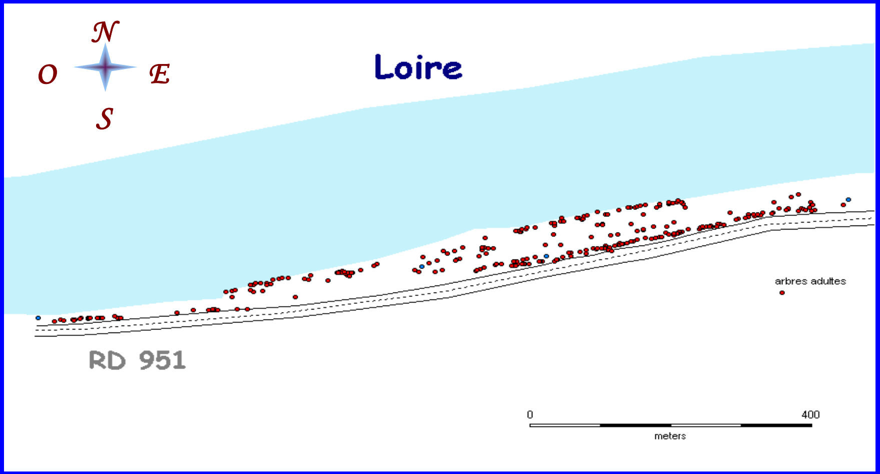


Effet of status



Fraxinus excelsior / Fraxinus angustifolia hybrid population





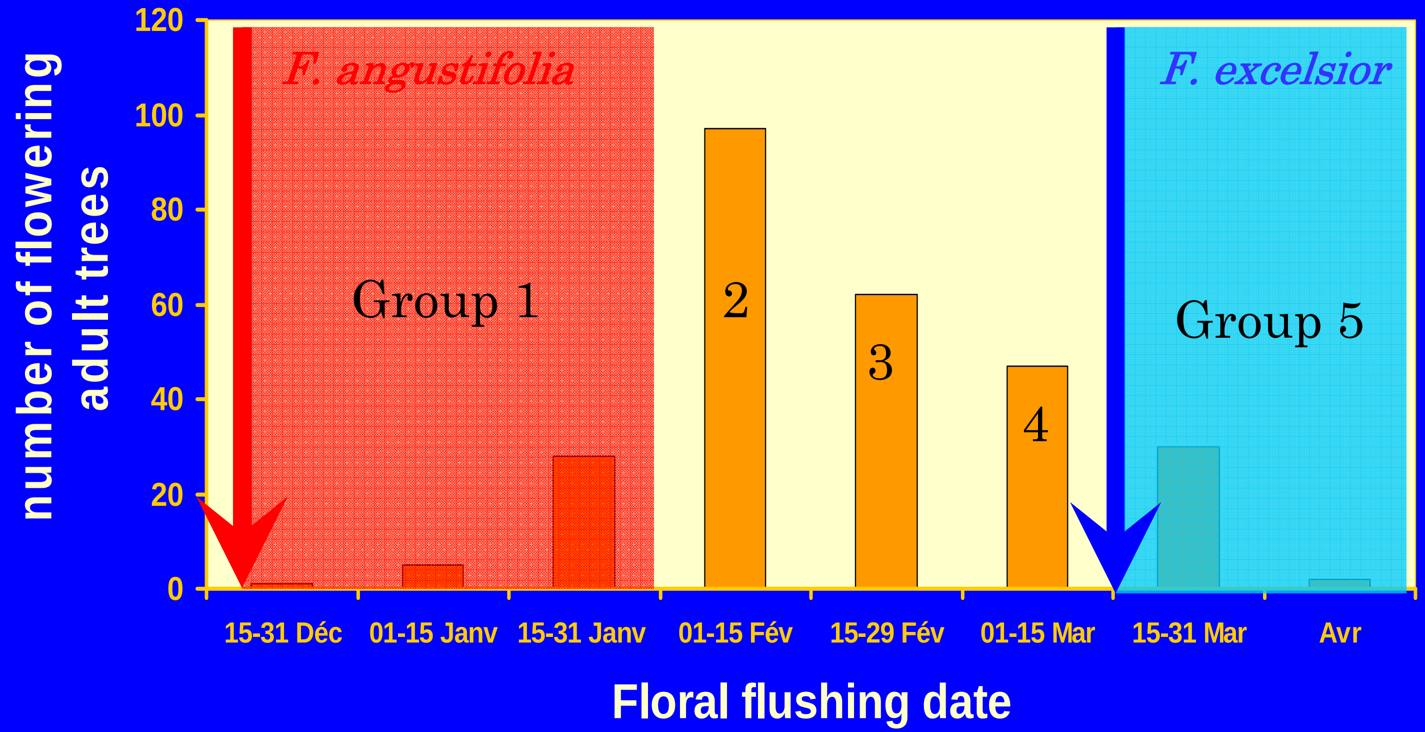
- Wind-pollinated
- Population density of 41 trees/ha
- Presence of both species and of various intermediate individuals
- 8 microsatellite loci
- 27 mothers, 232 seeds in total
- 269 potential fathers

F. excelsior

F. angustifolia

Gerard, P. R., Klein, E. K., Austerlitz, F., Fernandez-Manjarres, J. F. & Frascaria-Lacoste, N. 2006 *BMC Evol Biol* **6**, 96.

Phenology



- Trees are grouped in five phenological groups, from early flowering to late flowering.
- Do males mate with females of similar phenological groups?

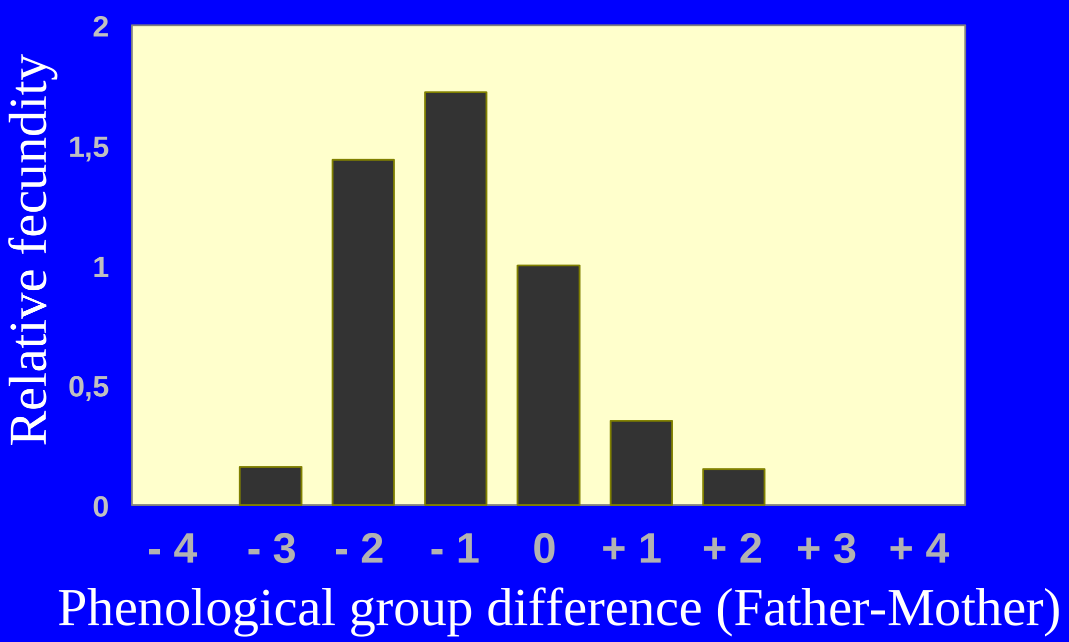
Assortative mating and gene flow

- Estimated shape parameter: $\hat{b} = 0.42$

  ↪ Occurrence of long-distance dispersal events.

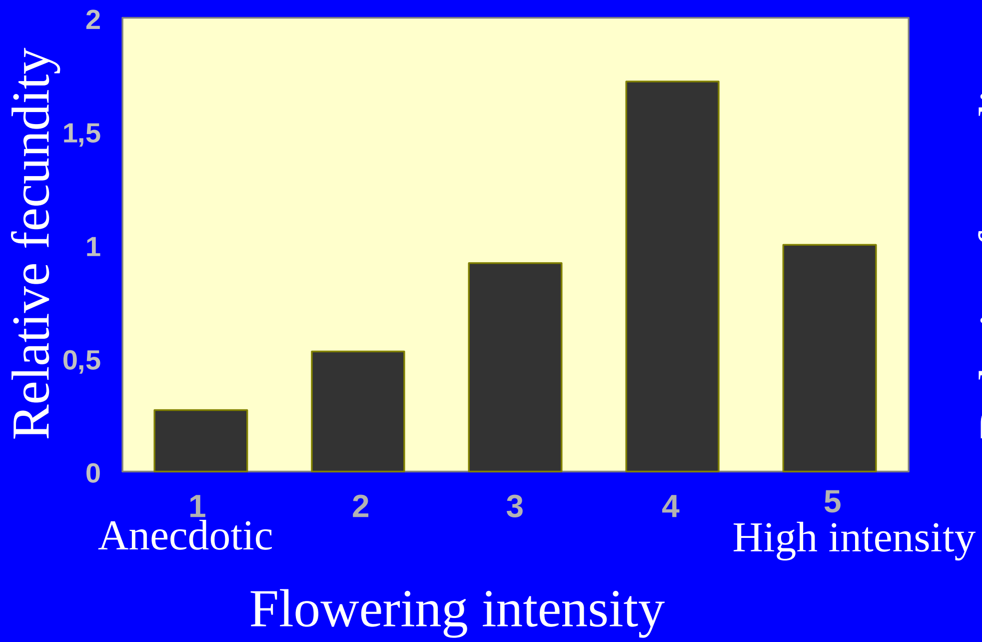
- Low estimated mean dispersal distance: $\hat{\delta} = 142m$

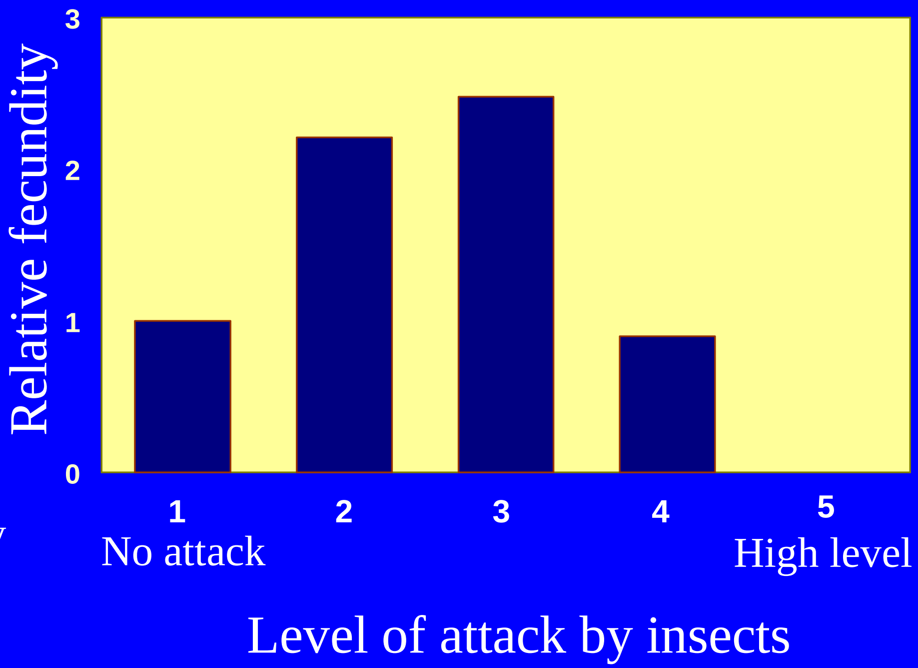
- Assortative mating and asymmetric gene flow



Females are sired by males that start flowering simultaneously or during the preceding month

Factors influencing male fecundity





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