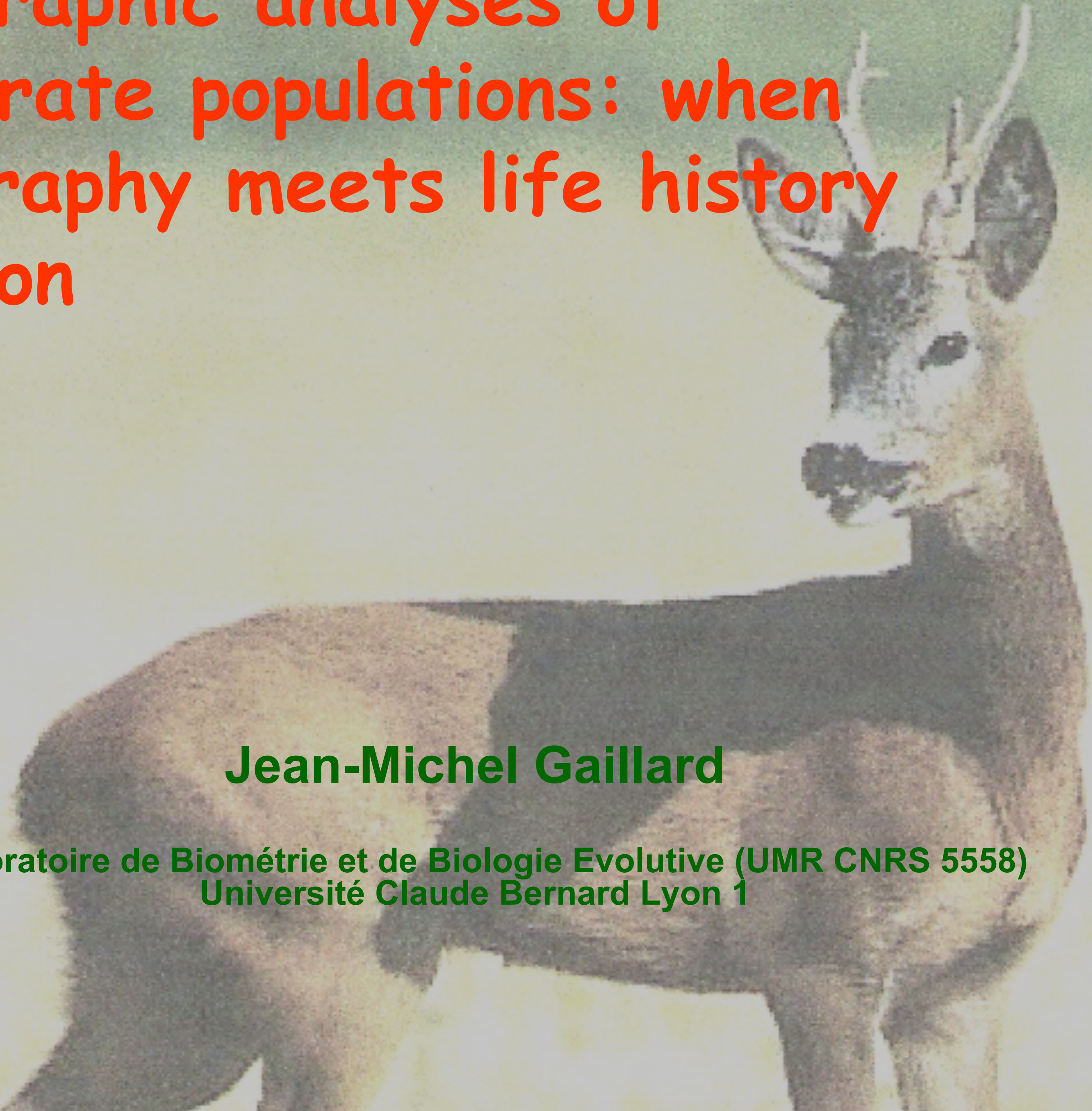
Demographic analyses of vertebrate populations: when demography meets life history evolution



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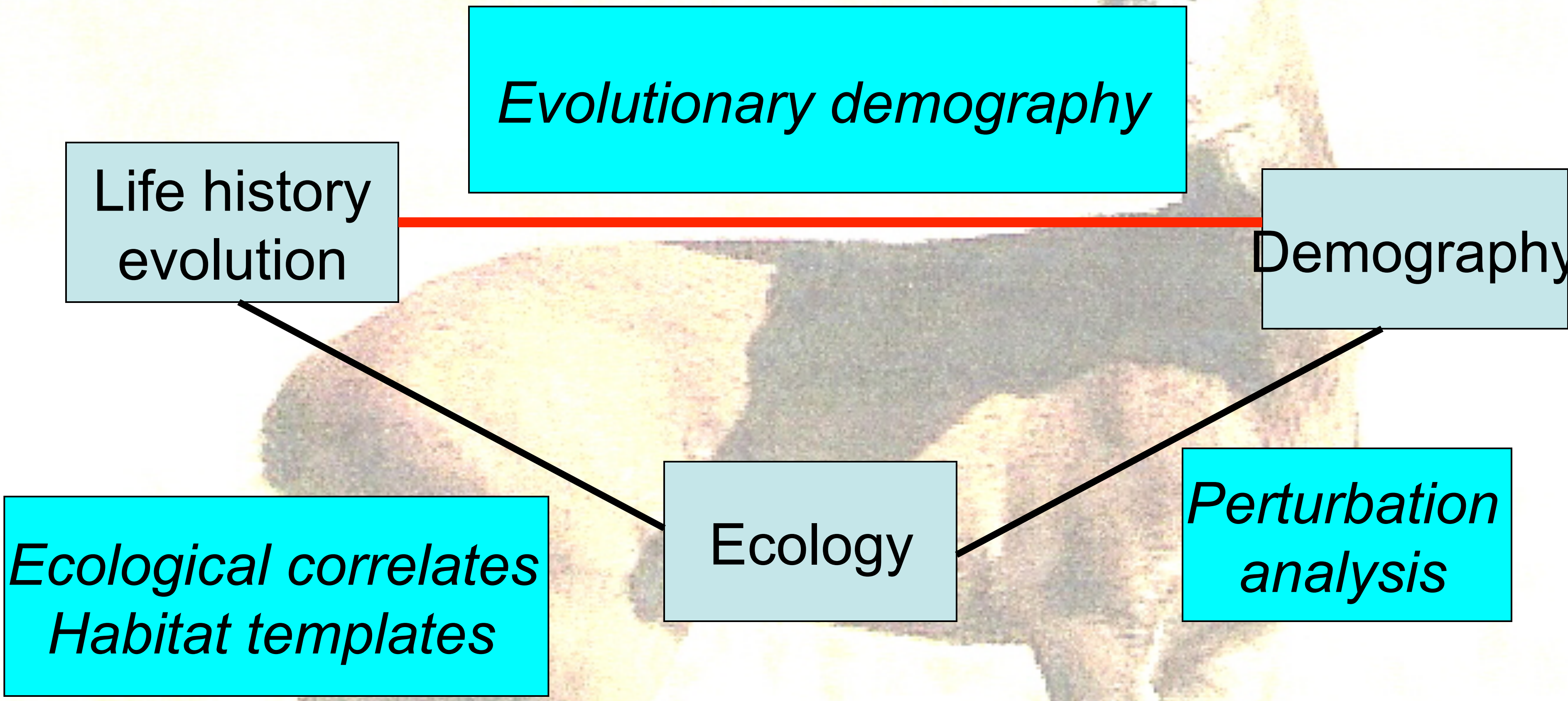
A tryptic in Evolutionary Ecology



Evolutionary demography

Life history evolution

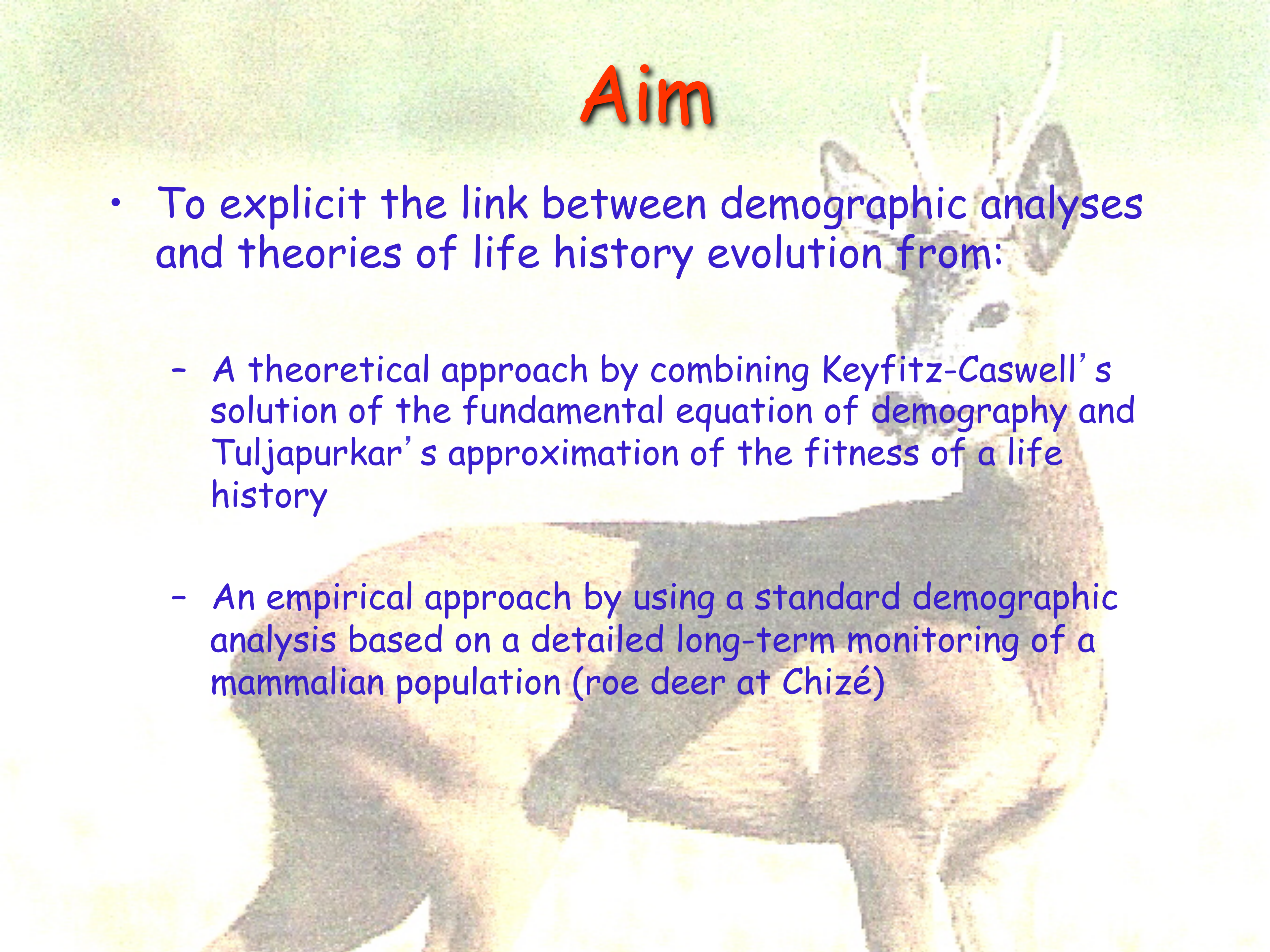
Demography

Ecology

Ecological correlates
Habitat templates

Perturbation analysis

Aim



- To explicit the link between demographic analyses and theories of life history evolution from:
  - A theoretical approach by combining Keyfitz-Caswell’s solution of the fundamental equation of demography and Tuljapurkar’s approximation of the fitness of a life history
  - An empirical approach by using a standard demographic analysis based on a detailed long-term monitoring of a mammalian population (roe deer at Chizé)

Fundamental equation of demography (Euler-Lotka):

$$1 = S\ l_x\ m_x\ e^{-rx}$$

r well approximated by (Keyfitz & Caswell 2005):

$$\frac{\ln R_0}{T} + \frac{(\ln R_0)^2 \sigma_R^2}{2T^3}$$

Fitness of a life history well approximated by (Tuljapurkar 1982):

$$a = r - Vs - Vc + S$$

when

r is the growth rate determined by the average fertility and mortality,

Vs is the contribution of within - year variances of all vital rates,

Vc is the contribution of within - year covariances of all vital rates,

S is the contribution of between - year serial correlations of all vital rates.

Combining both approximations, we obtain
(Tuljapurkar et al. 2009):

$$a = \frac{\ln R_0}{T_0} + \frac{(\ln R_0)^2 \sigma_R^2}{2T^3} - \left[\frac{1}{2T^2} \Sigma c^2 e^2 + \mathrm{cov} \right] + \left(\frac{\partial^2 \lambda}{aij}, \rho autocorrelation.........\right)$$

r = A + B + C + D

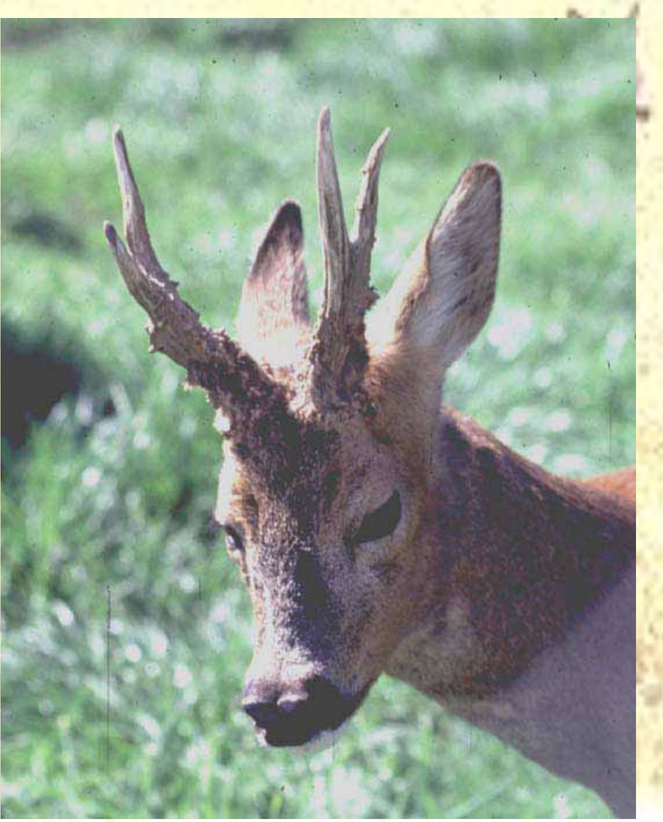
Linking the demographic terms with theories of life history evolution

- Based on patterns of population growth, one can recognize 3 main demographic states:

- 1. Colonizing populations ($\lambda>1$)

- 2. Stationary populations ($\lambda=1$)

- 3. Declining populations ($\lambda<1$)



1. Colonizing populations

A.

$$\frac{\ln R_0}{T_0} > 0, \quad r \downarrow \text{ when } T \uparrow$$

1. Colonizing populations

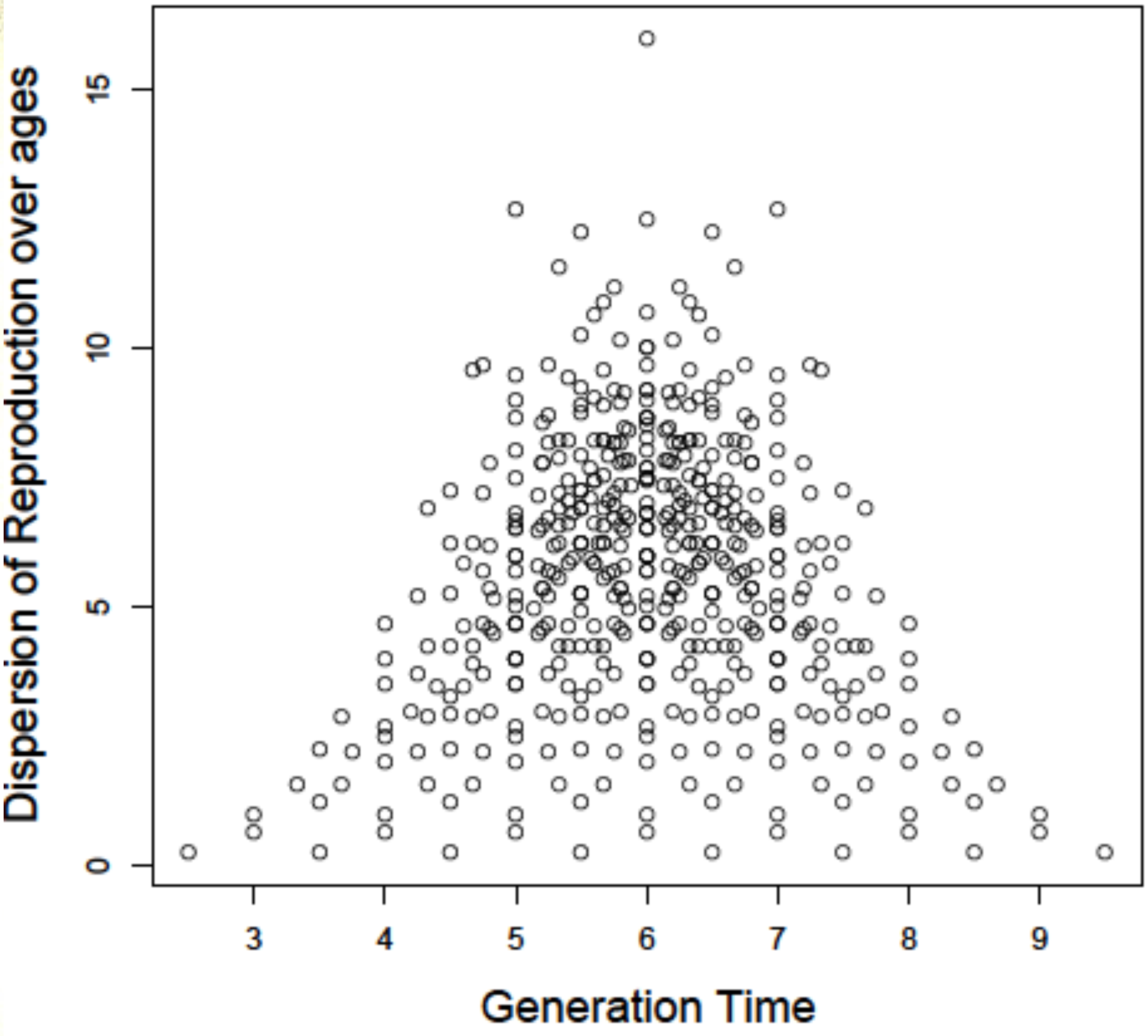
B.

$$\frac{(\ln R_0)^2 \sigma_R^2}{2T^3} > 0, \quad r \downarrow \text{ when } T \uparrow$$

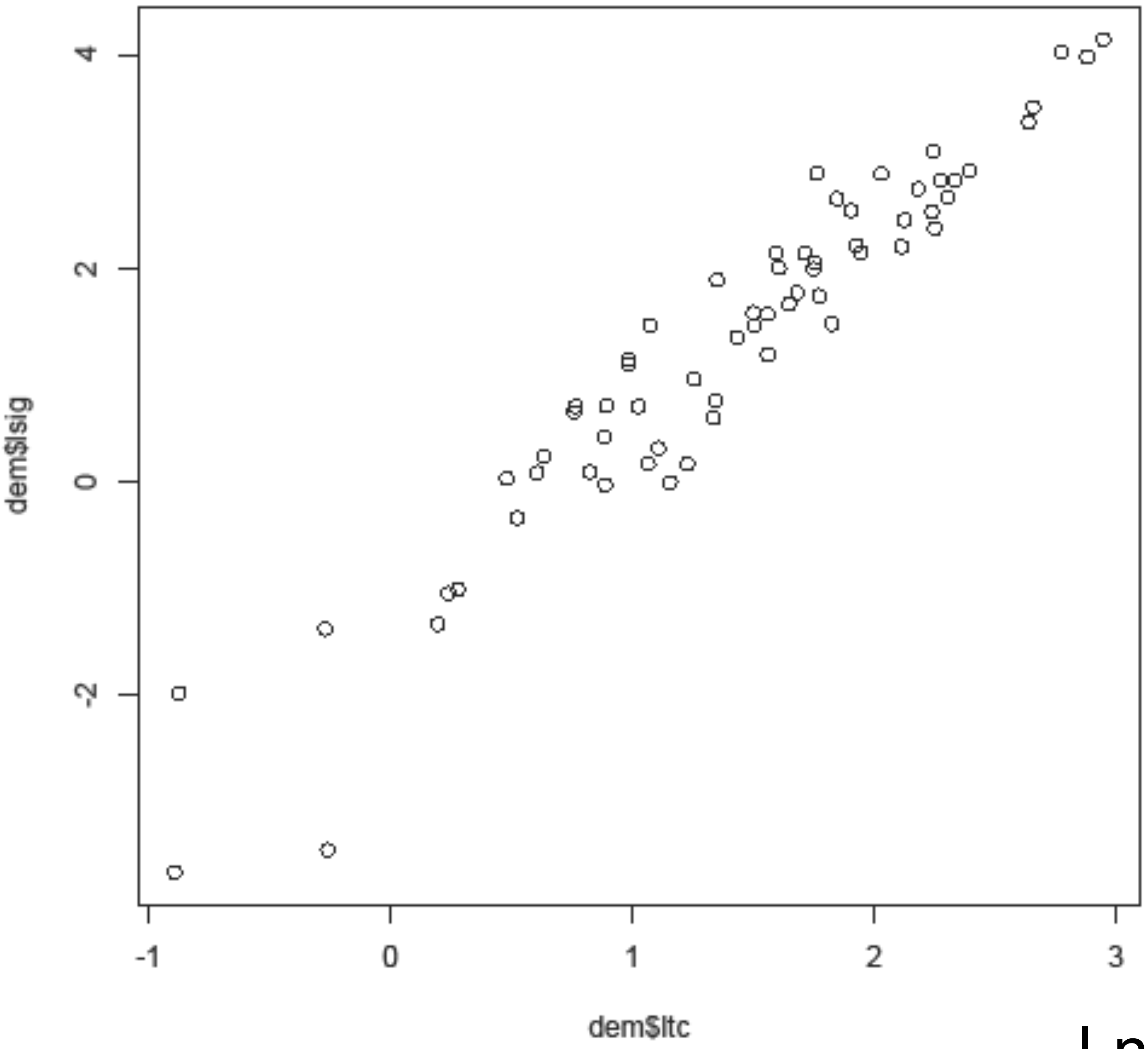
r ↑ when the dispersion of reproduction over ages ↑

Bet-Hedging (Risk spreading)

All Reproductive attempts



Ln(sigma2)



Ln(T)

1. Colonizing populations

C.

$-\left[\frac{1}{2T^2}\Sigma c^2 e^2+\text{cov}\right]<0$ $\quad a\downarrow$ when $T\uparrow$ **Bet Hedging (Risk avoidance)**

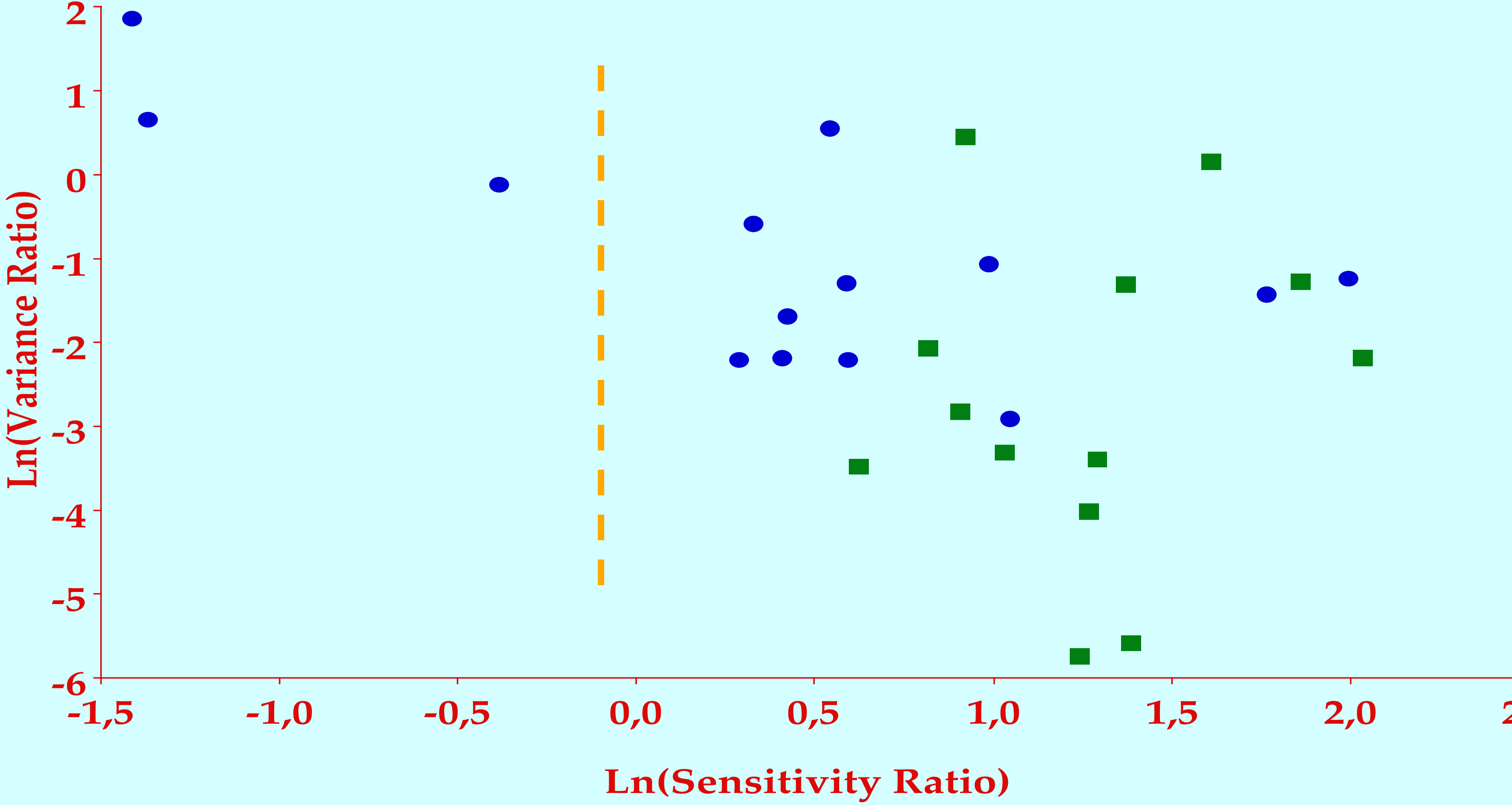
$a\uparrow$ when $\Sigma c^2 e^2+\text{cov}\downarrow$ **„Buffering“, canalisation**

True when negative covariances increase (especially for demographic parameters with high elasticity) and/or when variance decreases (buffering, canalisation)

Strong trade-offs between demographic parameters lead to decrease canalization

Environmental canalisation of age-dependent survival in mammals

Ln (Variability ratio)



2. Stationary populations

A. $$\frac{\ln R_0}{T_0} = 0$$

B. $$\frac{(\ln R_0)^2 \sigma_R^2}{2T^3} = 0$$

C. Same patterns as for colonizing populations

3. Declining populations

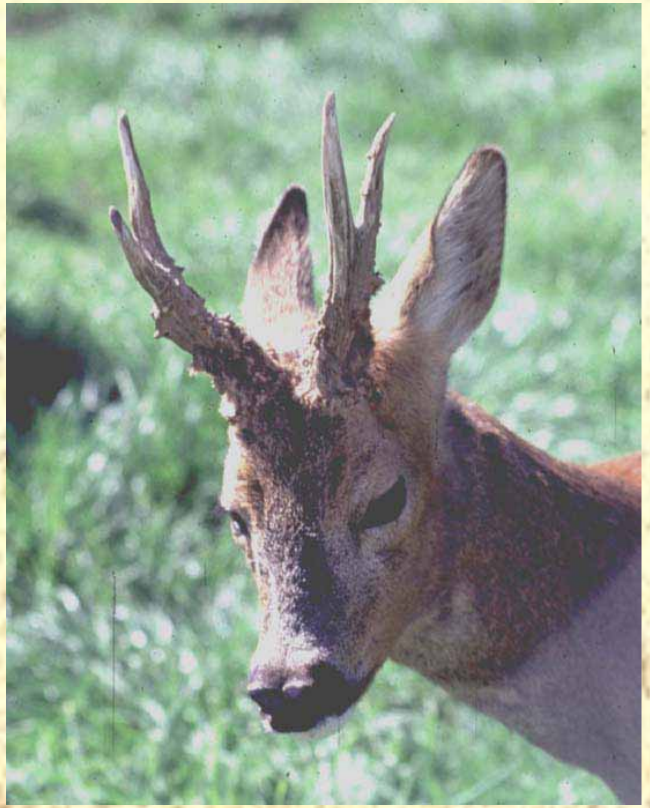
A. $\frac{\ln R_0}{T_0} < 0,$ r ↓ when T ↓

B. $\frac{(\ln R_0)^2 \sigma_R^2}{2T^3} > 0,$ r ↓ when T ↑

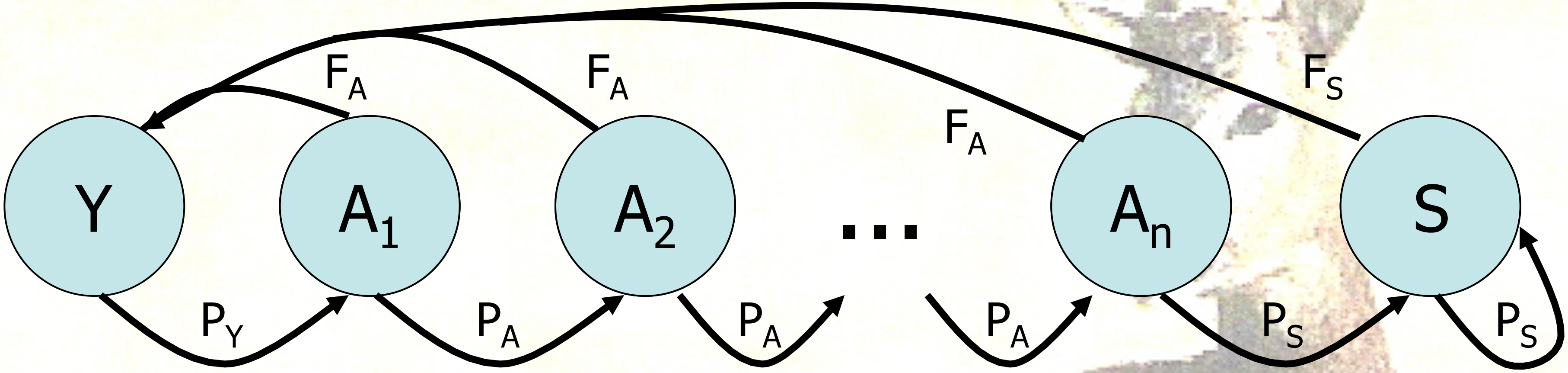
r ↑ when the dispersion of reproduction over ages ↑

C. Same patterns as for colonizing populations

Demographic analysis of the roe deer population at Chizé



Life cycle graph "Pre-census"



- Y: Yearlings
- A_i: Adults
- S: Senescents
- n: Age at the onset of senescence

- P: Survival
- F: Fecundity

(fertility x juvénile survival)

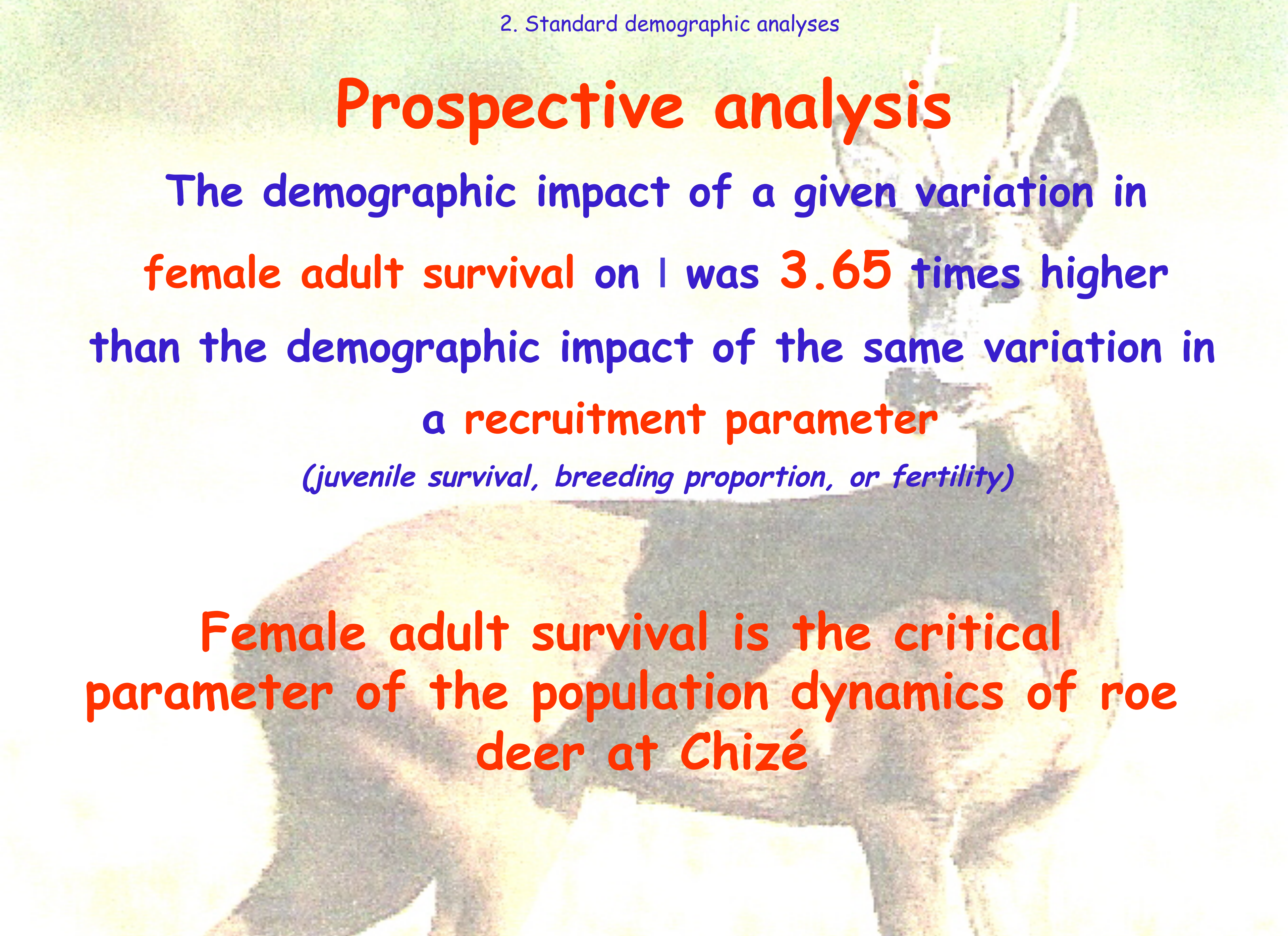
Application:

l = 1.188

Generation time = 5.37 yrs

Colonizing population

Prospective analysis

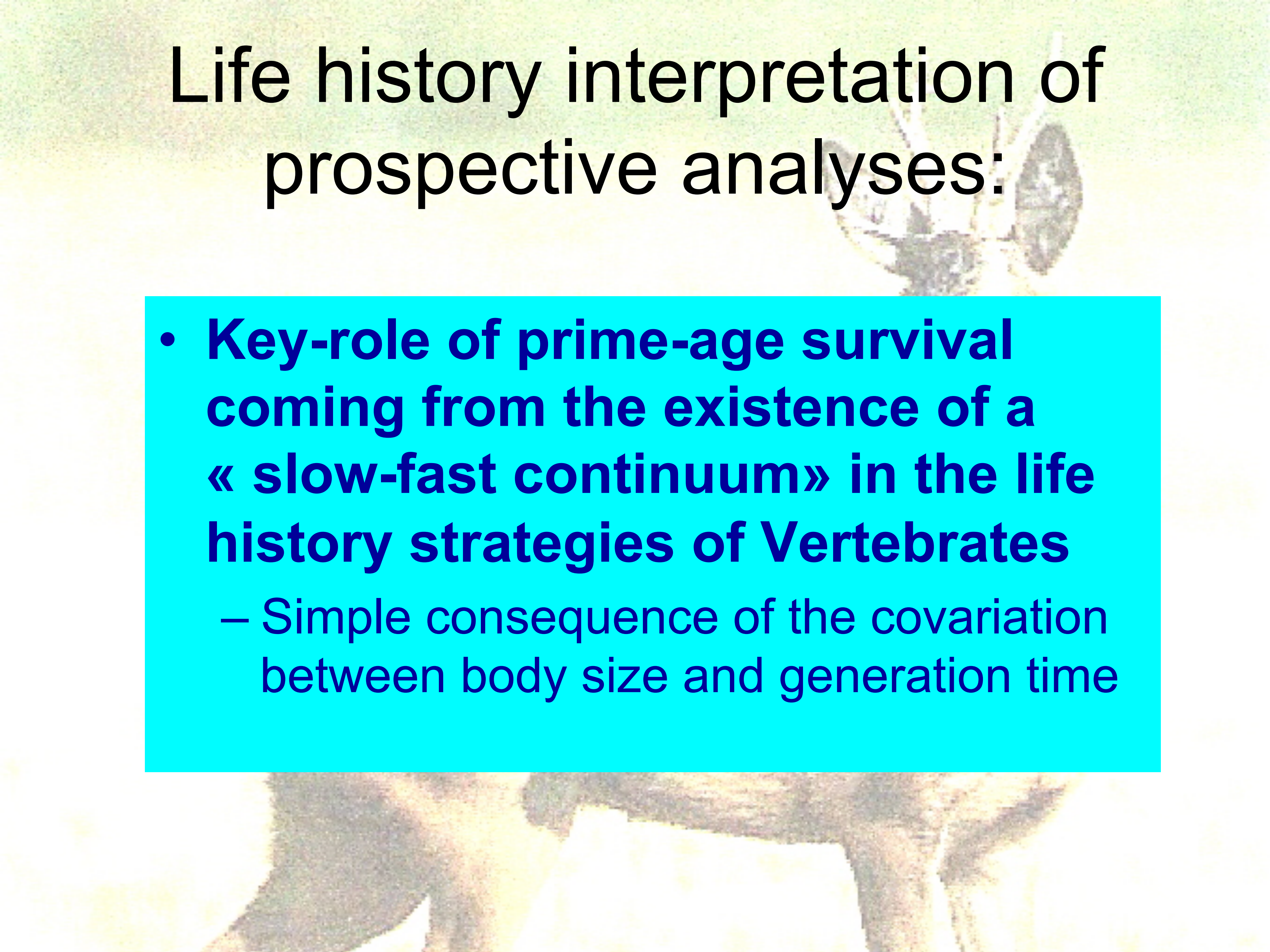


The demographic impact of a given variation in female adult survival on l was 3.65 times higher than the demographic impact of the same variation in a recruitment parameter

(juvenile survival, breeding proportion, or fertility)

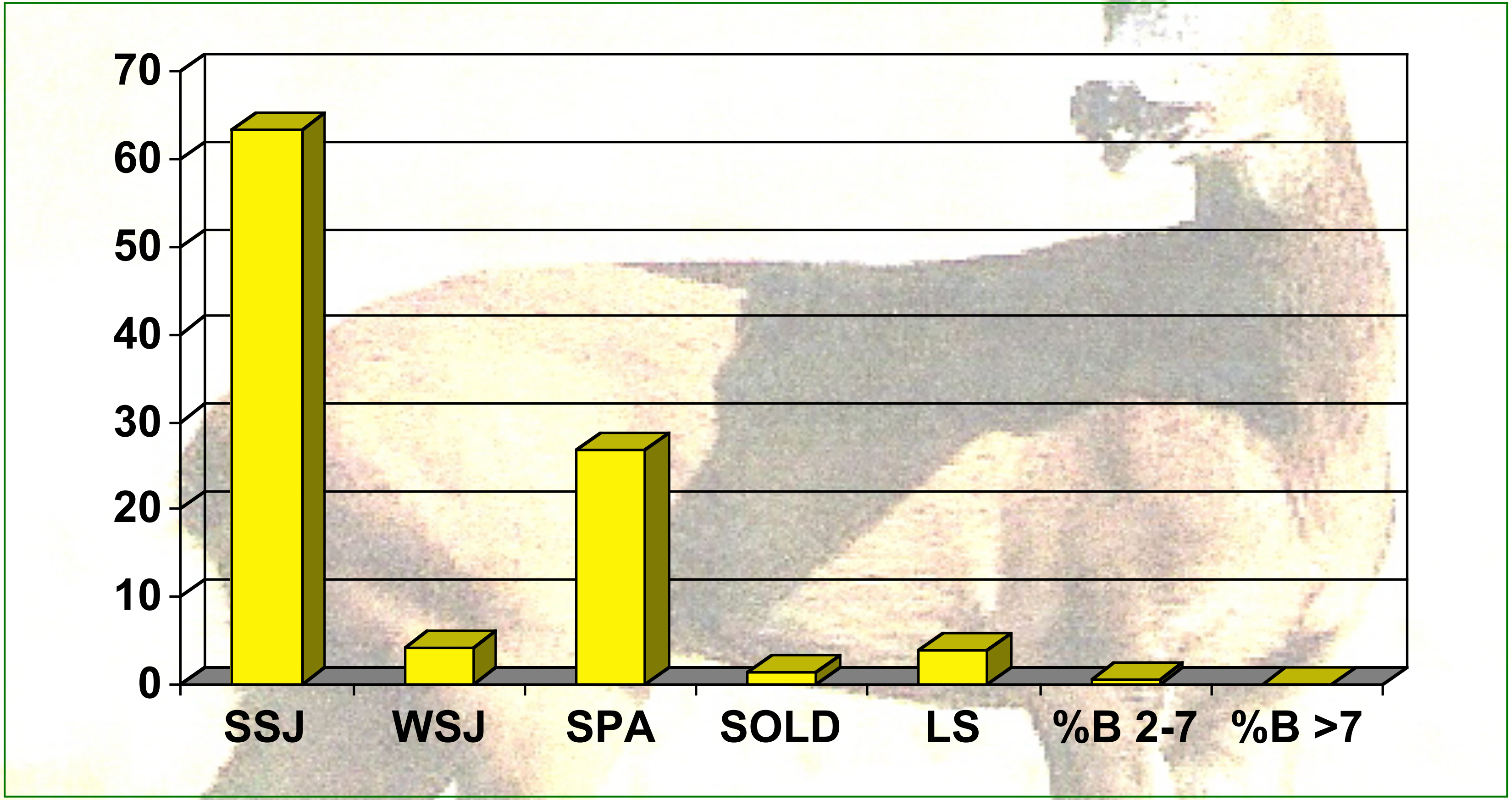
Female adult survival is the critical parameter of the population dynamics of roe deer at Chizé

Life history interpretation of prospective analyses:

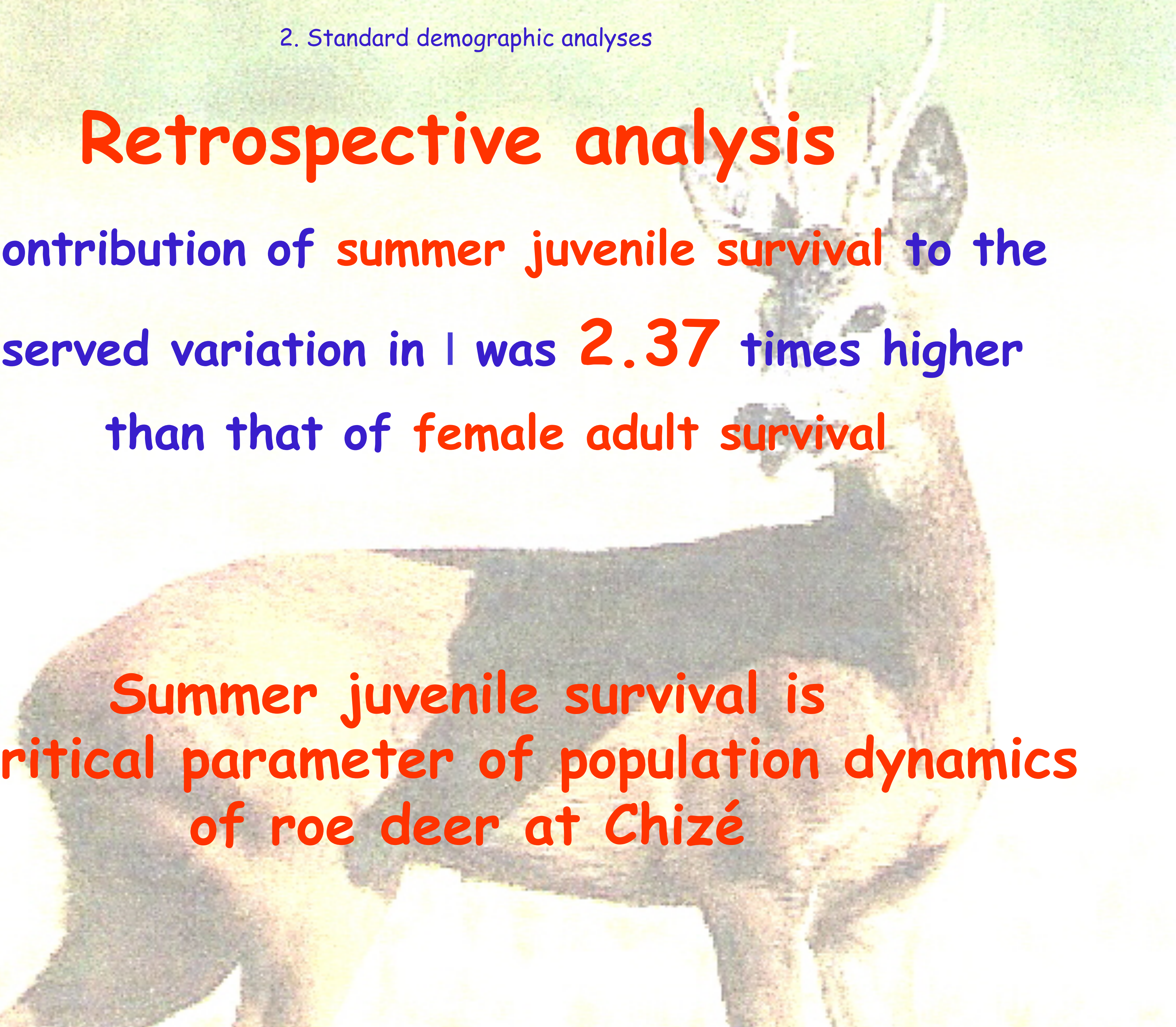


- **Key-role of prime-age survival coming from the existence of a « slow-fast continuum» in the life history strategies of Vertebrates**
  - Simple consequence of the covariation between body size and generation time

Contribution of demographic parameters to the variance of population growth observed in roe deer at Chizé



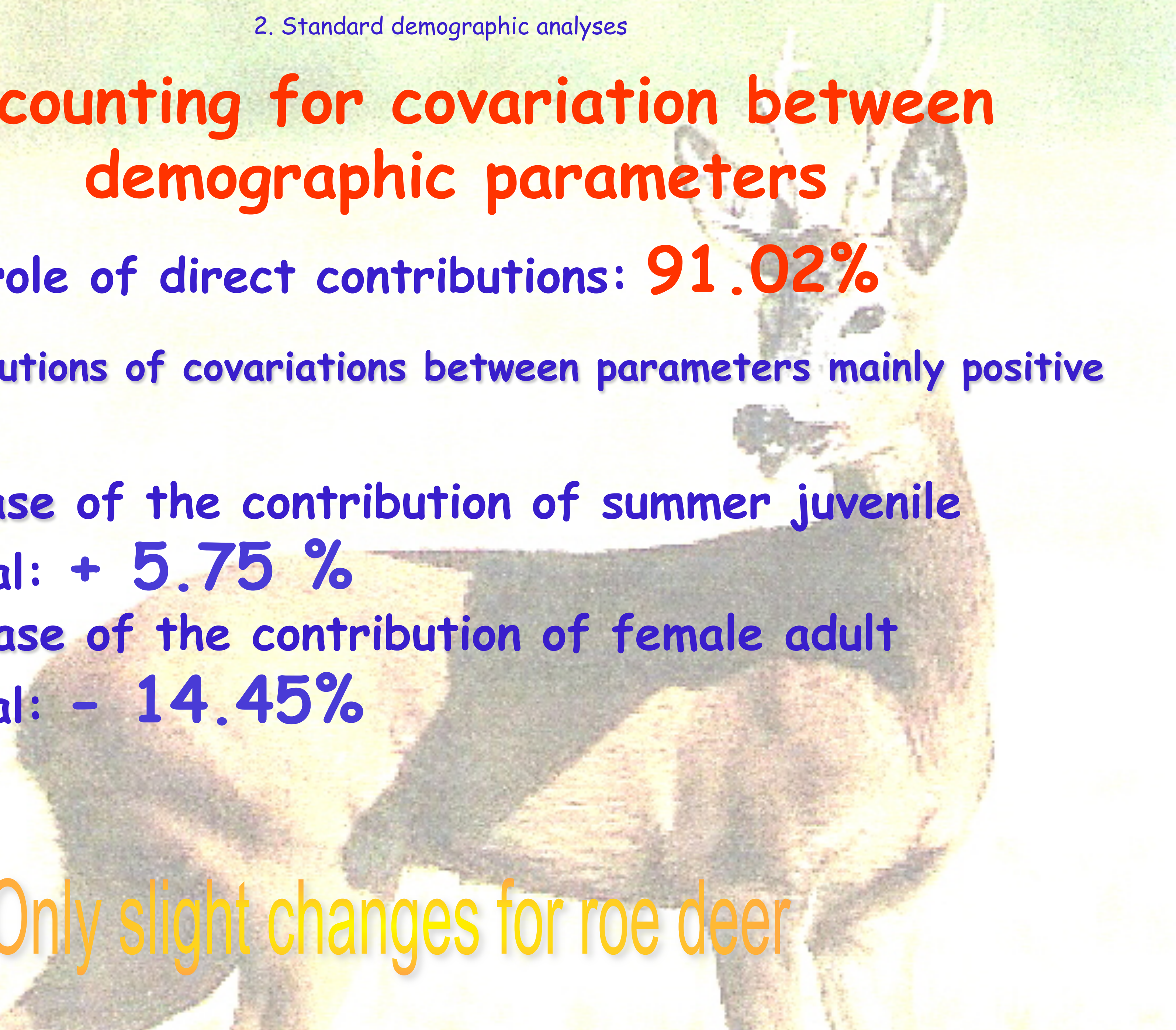
Retrospective analysis



The contribution of summer juvenile survival to the observed variation in λ was 2.37 times higher than that of female adult survival

Summer juvenile survival is
The critical parameter of population dynamics
of roe deer at Chizé

Accounting for covariation between demographic parameters



Main role of direct contributions: **91.02%**

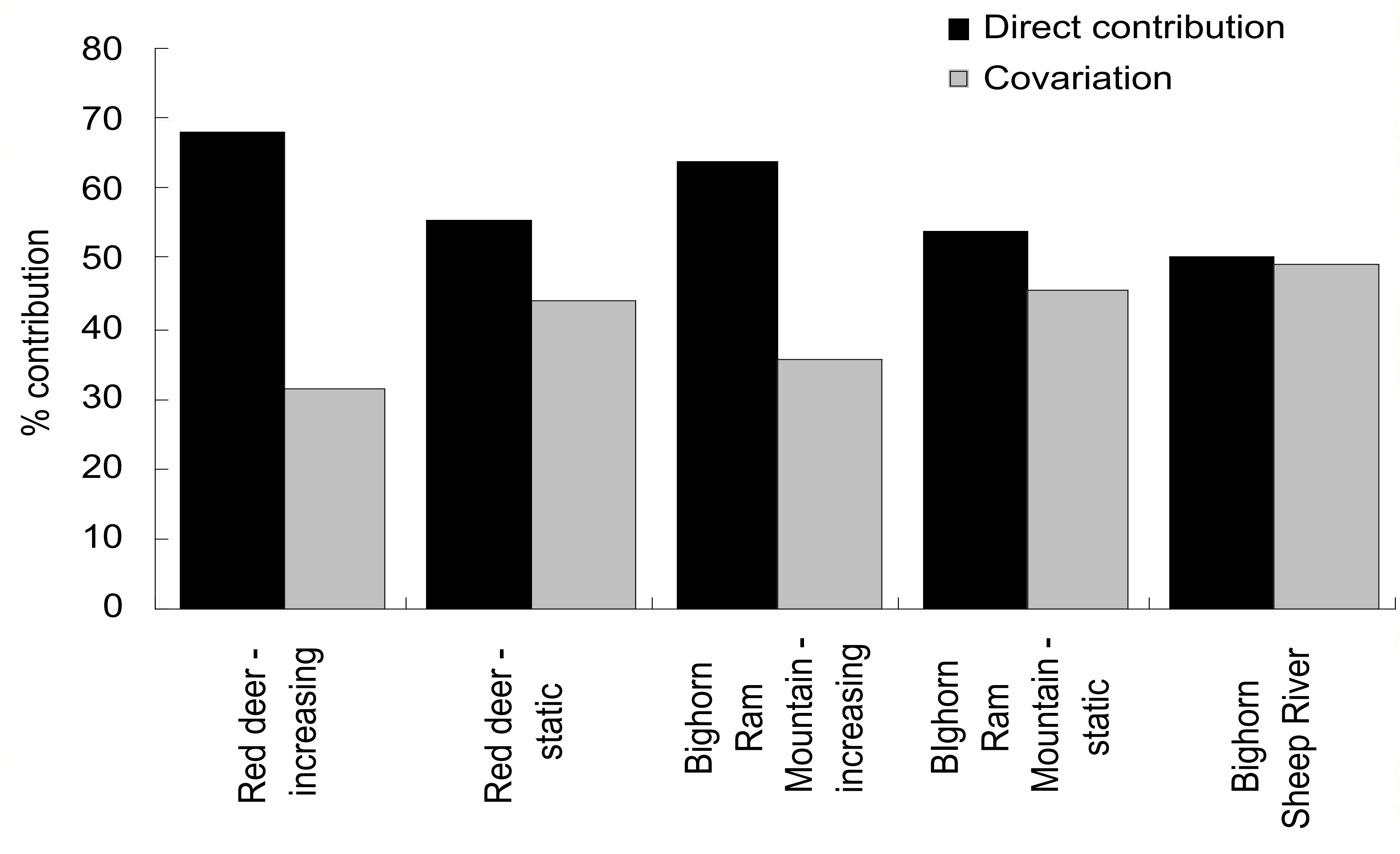
Contributions of covariations between parameters mainly positive

Increase of the contribution of summer juvenile survival: + **5.75 %**

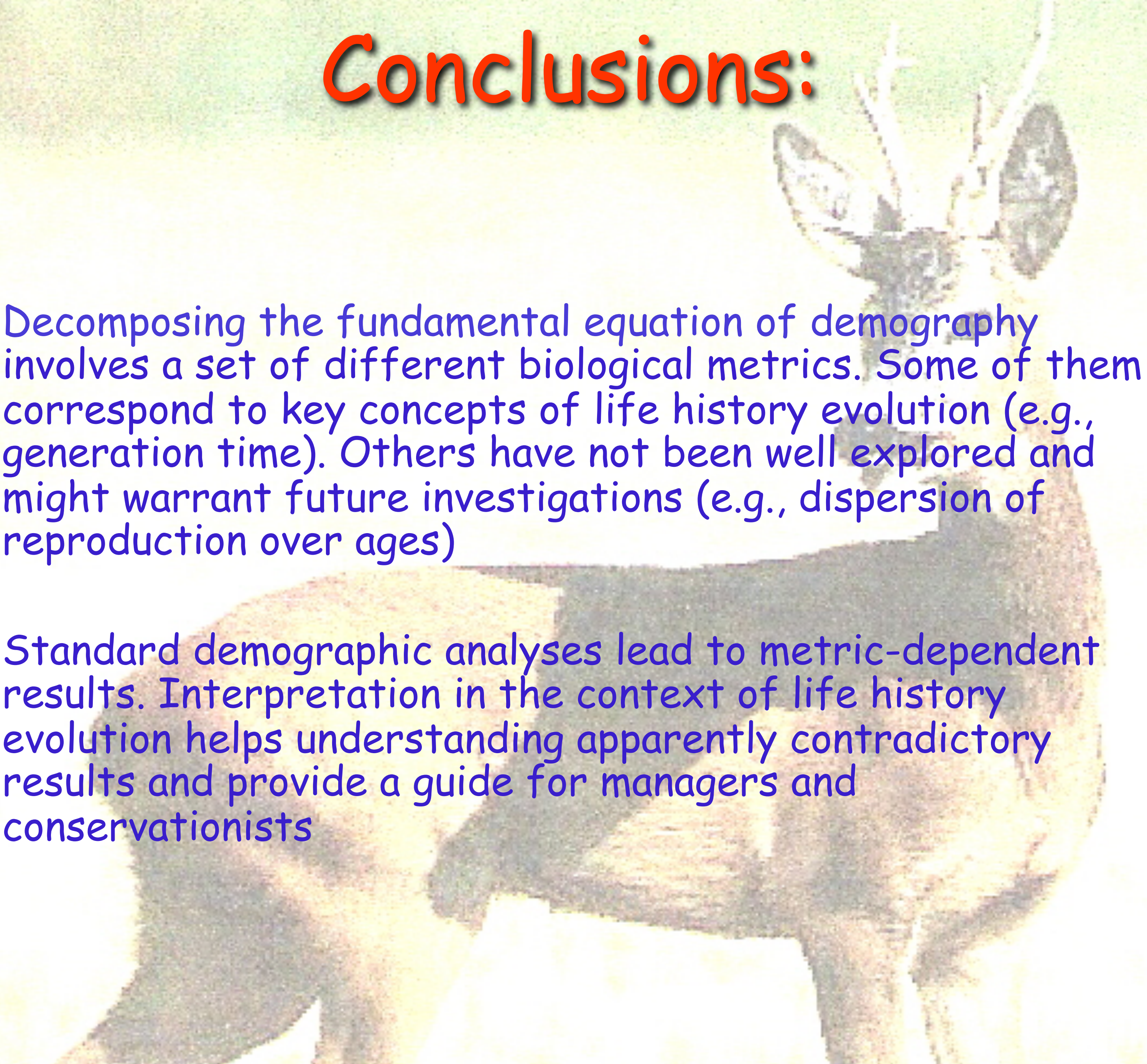
Decrease of the contribution of female adult survival: - **14.45%**

➡ Only slight changes for roe deer

Role of covariations between demographic parameters



Conclusions:



- Decomposing the fundamental equation of demography involves a set of different biological metrics. Some of them correspond to key concepts of life history evolution (e.g., generation time). Others have not been well explored and might warrant future investigations (e.g., dispersion of reproduction over ages)

- Standard demographic analyses lead to metric-dependent results. Interpretation in the context of life history evolution helps understanding apparently contradictory results and provide a guide for managers and conservationists

Thank you for your attention