Population growth rates (lambda) of *Lepanthes eltoroensis*

Assume
****Continuous growth rate
No demographic, environmental nor temporal variation exists

Pop 1	0.9912
Pop 2	0.9984
Pop 3	0.9857
Pop 4	0.9982
Pop 5	0.971

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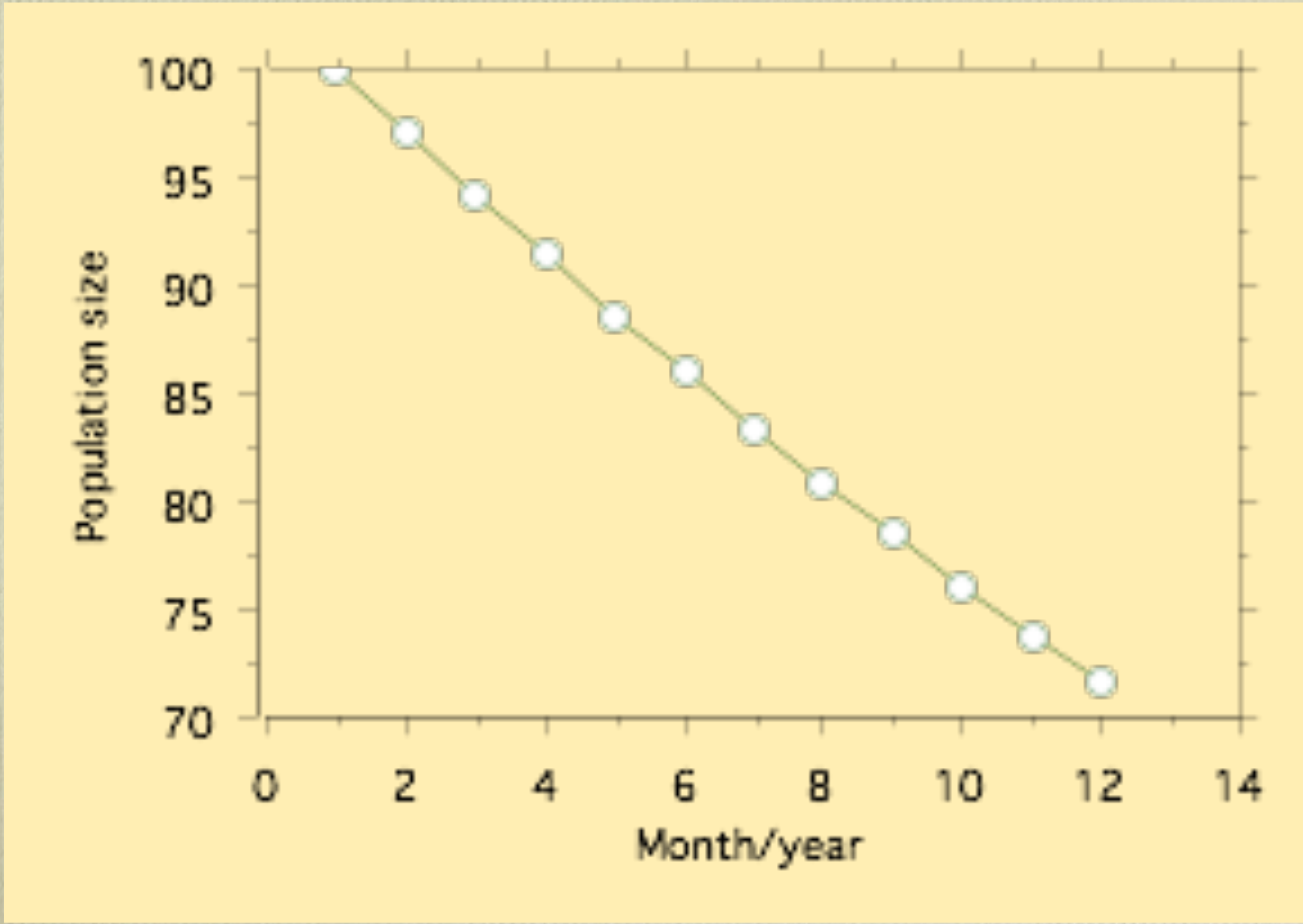
Deterministic population growth rate, "λ"

- Predict population growth rate → Persistence
  - $\lambda = 1.0$ stable
  - $\lambda > 1.0$ growth
  - $\lambda < 1.0$ decrease

Population growth: lambda = 97.1%
Population 5 of *Lepanthes eltoroensis*



Elasticities and Sensitivities

- Measures of the contribution of each matrix element to the population growth rate (lambda)

- Indicates how sensitive is the population growth rate (lambda) to changes in the different elements of the matrix

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Sensitivities

- Sensitivity analyses measure the change in the model's prediction in response to changes in the value of the parameters of the matrix
  - It tells us what parameters have the most impact on the population growth rates

Sensitivity Analysis:

$$\begin{vmatrix} 0.0804 & 0 & 0 & 0.1945 \\ 0.2141 & 0.0806 & 0 & 0 \\ 0 & 0 & 0.2882 & 0.5365 \\ 0 & 0.0854 & 0.2958 & 0.5508 \end{vmatrix}$$

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Elasticity

- It’s a way to measure the effect of changes in the parameters (including fecundities) on lambda.

- Uses a similar scale : Adds to 1.

Elasticity analysis:

Measures the effect of changes in the transition parameters (including fecundities) on lambda, Sum = 1.0

$$\begin{vmatrix} 0.0785 & 0 & 0 & 0.0046 \\ 0.0046 & 0.0787 & 0 & 0 \\ 0 & 0 & 0.1867 & 0.0978 \\ 0 & 0.0046 & 0.0046 & 0.4467 \end{vmatrix}$$

Stable stage distribution

- Structured population in a deterministic environment
  - We can predict the population structure if the population is stable and mature
  - We use the eigenvector on the right, "*w*"

Seedling	0.022
Sterile Adult	0.198
Fertile Adults	0.105
Dormant	0.675

Prasophyllum correctum

Stable-stage distribution of *Prasophyllum correctum*

Number of observed individuals per year

Stage	1993	1994	1998	Expected
Seedlings	0	0	2	0.022
Sterile adults	0	15	15	0.198
Fertile adults	53	1	21	0.105
Latent	67	104	64	0.675
R x C Contingency Test Table	< 0.0001	= 0.001	0.21	

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Reproductive value

- The relative contribution of population growth rate to the future population size that is expected from particular individuals
  - eigenvector on the left, "*v*"

Prasophyllum correctum

Seedlings	1
Sterile adults	1.093
Fertile adults	1.334
Latent	0.967

The model is a simplification of the real world

Biology and the causes of bad interpretations

Errors

Errors

Errors

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Uncertainties

- What happens if our assumptions are wrong?????
- Demography
- Environment
- Error of measurement
- Stochasticity
- Inter-population dynamics (Metapopulation)

5 types of errors

- Sampling errors = Start again
- Throw the data to the rubbish

- Demographic variation
  - The results of a finite population

$$V_x = \frac{x(1-x)}{N_x}$$

Calculating demographic stochasticity

Trans	Transition (x)	N	Variance σ^2	Sensitivity	Contribution of σ^2 to lambda
P_{11}	0.94737	180	0.00027		
G_{12}	0.02105	4	0.00412		
P_{22}	0.94712	197	0.00029		
G_{24}	0.05288	11	0.00238		
P_{33}	"	"	"		
etc.	"	"	"		
Sum					

$$V_\lambda = Sensitivity^2 * \sigma^2$$

	Transition (x)	N	Variance σ^2	Sensitivity	Contribution of σ^2 to lambda
P_{11}	0.94737	180	0.00027	0.0831	0.0000004
G_{12}	0.02105	4	0.00412	0.2187	0.0001971
P_{22}	0.94712	197	0.00029	0.0833	0.000002
G_{24}	0.05288	11	0.00238	0.0875	0.0000183
P_{33}	"	"	"	"	"
etc.	"	"	"	"	"
Sum				Varianza	0.00071

Variance in lambda with demographic stochasticity estocasticidad demográfica

$$CI(\lambda) = \lambda \pm 1.96 se(\lambda)$$

$$= .9921 \pm 1.96(sqrt(0.00071))$$

$$= .9921 \pm 1.96 * 0.02665$$

$$= .9921 \pm 0.0522$$

$$Range = 0.9399 - 1.0443$$

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Assumptions

- Normal distribution of lamba and errors
  - Each data point is independent
    The parameters are not correlated

Determine the confidence interval of lambda

- Lambda ± Errors?
- Model of demographic stochasticity
- Monte Carlo simulation
  - 45 of 594 ind. are selected at random and the growth rate was calculated
  - 5,000 repetitions
  - The 95% confidence interval can be calculated from the frequency of distribution

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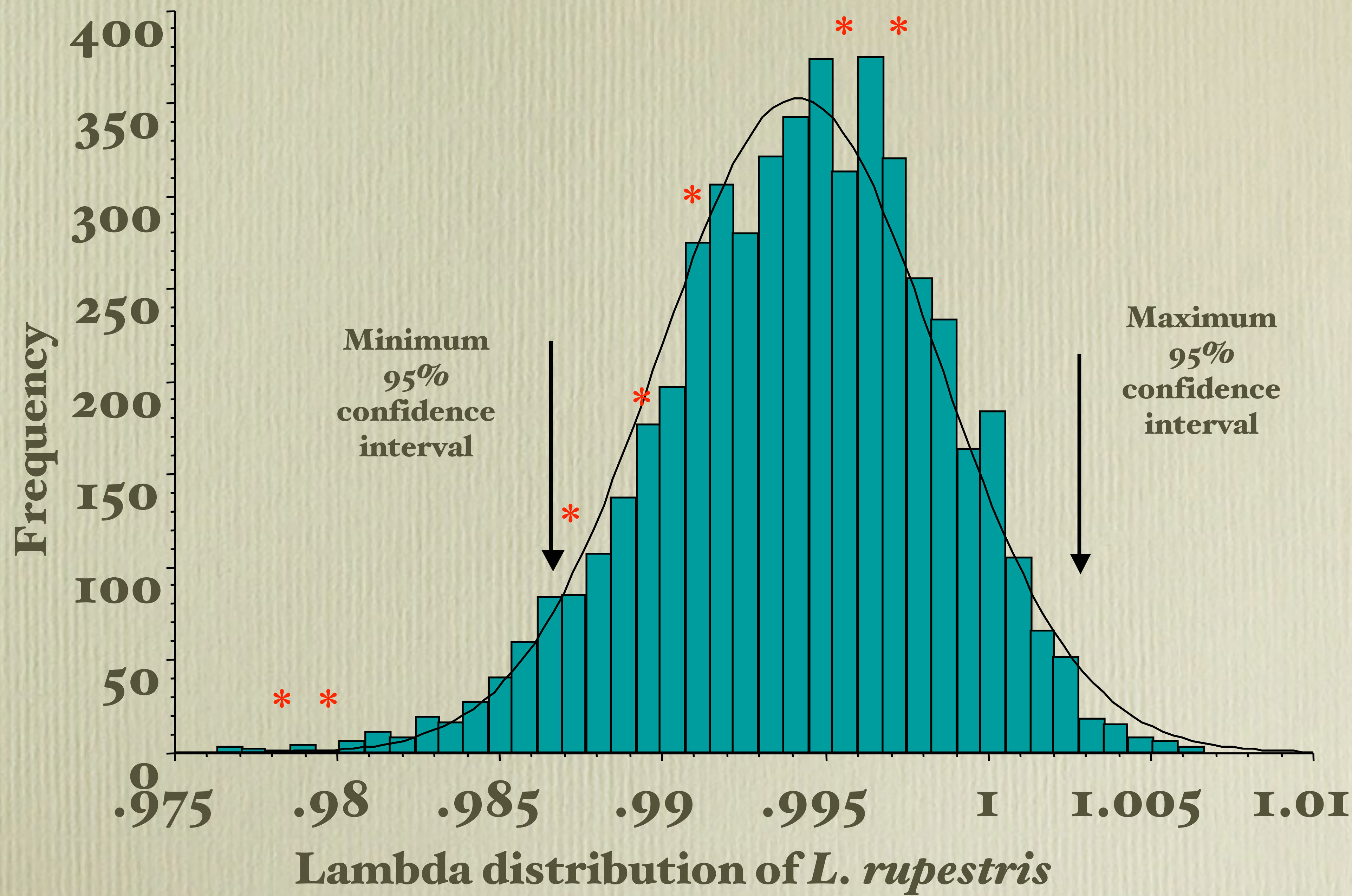


Frequency
400
350
300
250
200
150
100
50
0
.975
.98
.985
.99
.995
1
1.005
1.01
Minimum 95% confidence interval
Maximum 95% confidence interval
Lambda distribution of *L. rupestris*

5 types of errors

- Sampling error
- Demographic variation
- Spatial variation
  - Gather data from different populations

$$\begin{vmatrix} 0.94737 & 0 & 0 & F_{41} \\ 0.02105 & 0.94712 & 0 & 0 \\ 0 & 0 & 0.65800 & 0.18300 \\ 0 & 0.05288 & 0.33643 & 0.81572 \end{vmatrix}$$

$$\begin{vmatrix} 0.96805 & 0 & 0 & F_{41} \\ 0.00319 & 0.92241 & 0 & 0 \\ 0 & 0 & 0.79592 & 0.38720 \\ 0 & 0.07758 & 0.18707 & 0.60061 \end{vmatrix}$$

$$\begin{vmatrix} 0.72727 & 0 & 0 & ? \\ 0.27273 & 0.98788 & 0 & 0 \\ 0 & 0 & 0.74775 & 0.15517 \\ 0 & 0.00606 & 0.24324 & 0.84483 \end{vmatrix}$$

$$\begin{vmatrix} 0.94318 & 0 & 0 & F_{41} \\ 0.01136 & 0.93396 & 0 & 0 \\ 0 & 0 & 0.72465 & 0.30839 \\ 0 & 0.04717 & 0.26392 & 0.68481 \end{vmatrix}$$

$$\begin{vmatrix} 0.93243 & 0 & 0 & F_{41} \\ ? & 0.95833 & 0 & 0 \\ 0 & 0 & 0.93103 & 0.15385 \\ 0 & 0.02083 & 0.05172 & 0.76923 \end{vmatrix}$$

Lambda

0.9857

0.9984

0.9982

0.9912

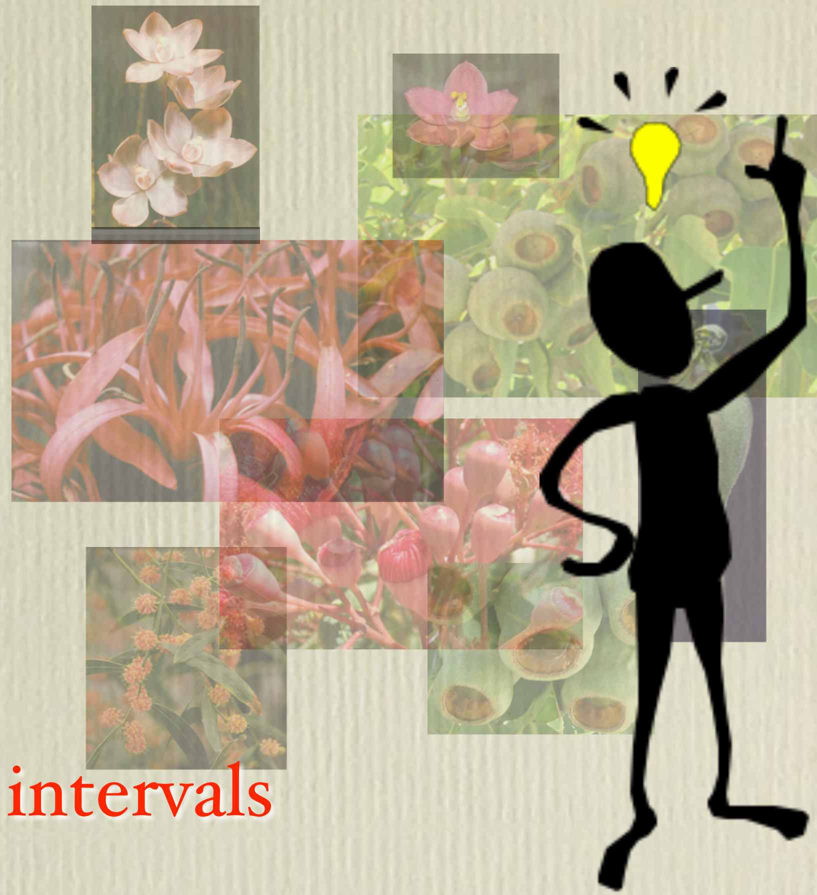
0.9710

Calculate the 95% CI for spatial variation

- Spatial stochasticity 0.9725 — 1.1322
  - Range of variance

5 types of errors

- Sampling error
- Demographic variation
- Spatial variation
- Temporal stochasticity
  - Gather data at different time intervals



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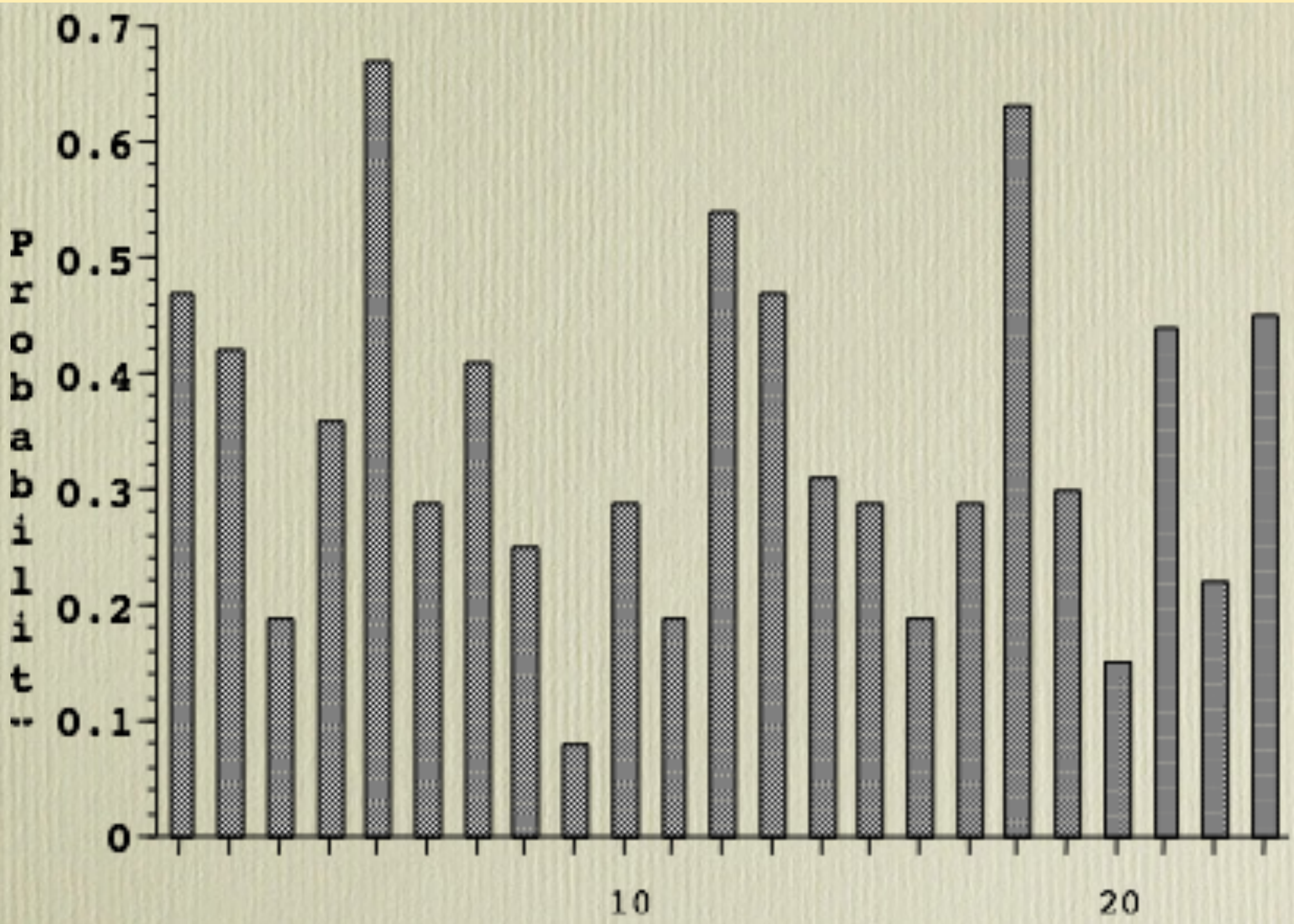
Temporal variation in the probability of non-reproductive individuals (A0) to transition to reproductive individuals (A+) from time (N_t) to (N_{t+1}).



Time

Temporal standard deviation

$$
\begin{vmatrix}
0.0496 & 0 & 0 & X \\
0.0246 & 0.1465 & 0 & 0 \\
0 & 0 & 0.1589 & 0.1553 \\
0 & 0.1205 & 0.1653 & 0.1653
\end{vmatrix}
$$

5 types of errors

- Sampling error
- Demographic variation
- Spatial variation
- Temporal stochasticity
- Stochastic variation (extremely rare events)

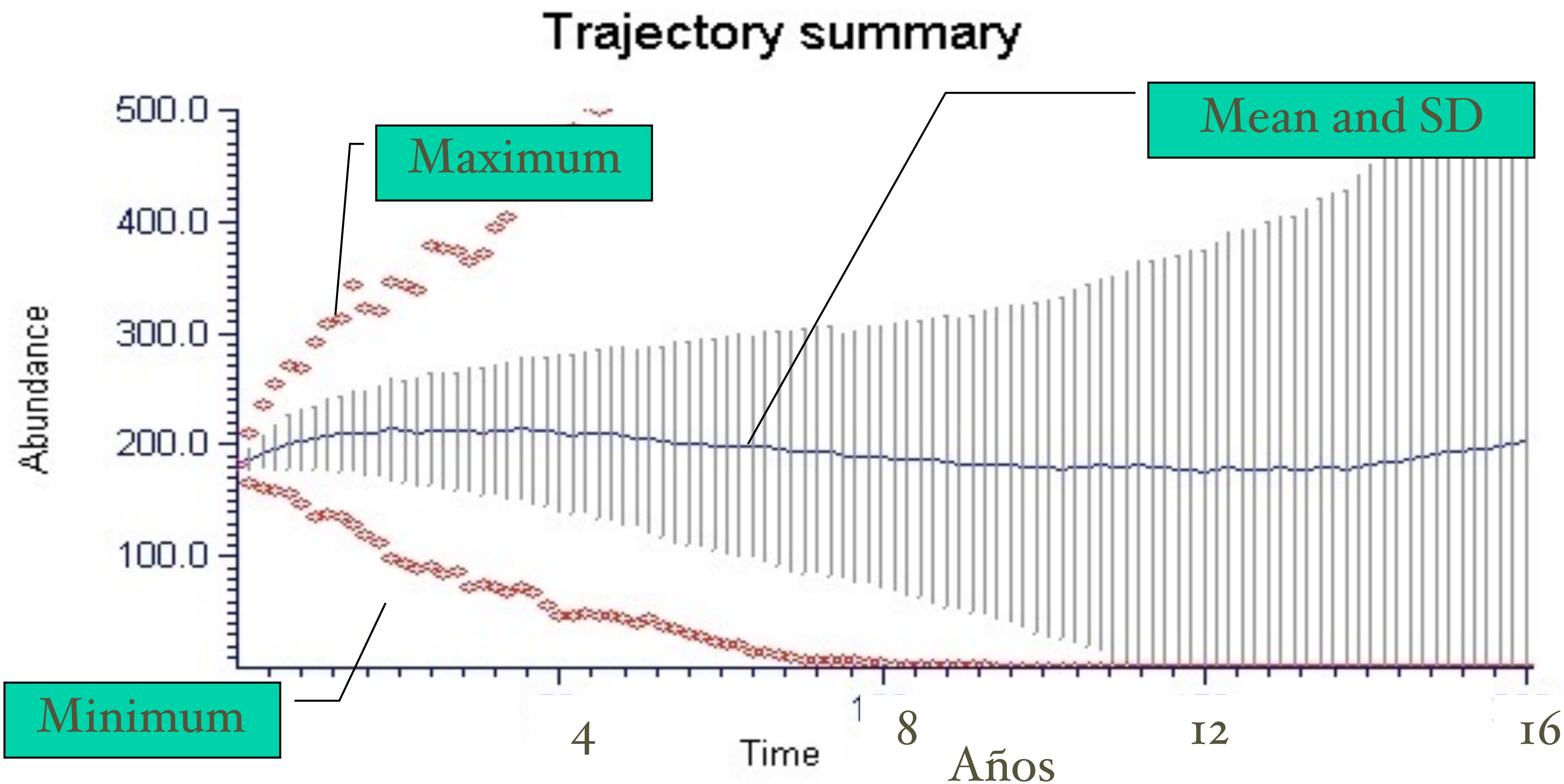
Which one is most important?

- Sampling error
- Demographic variation
- Spatial variation
- Temporal stochasticity
  - Gather data at different time intervals
- Stochastic variation (extremely rare events)

Summary of *Lepanthes eltoroensis*

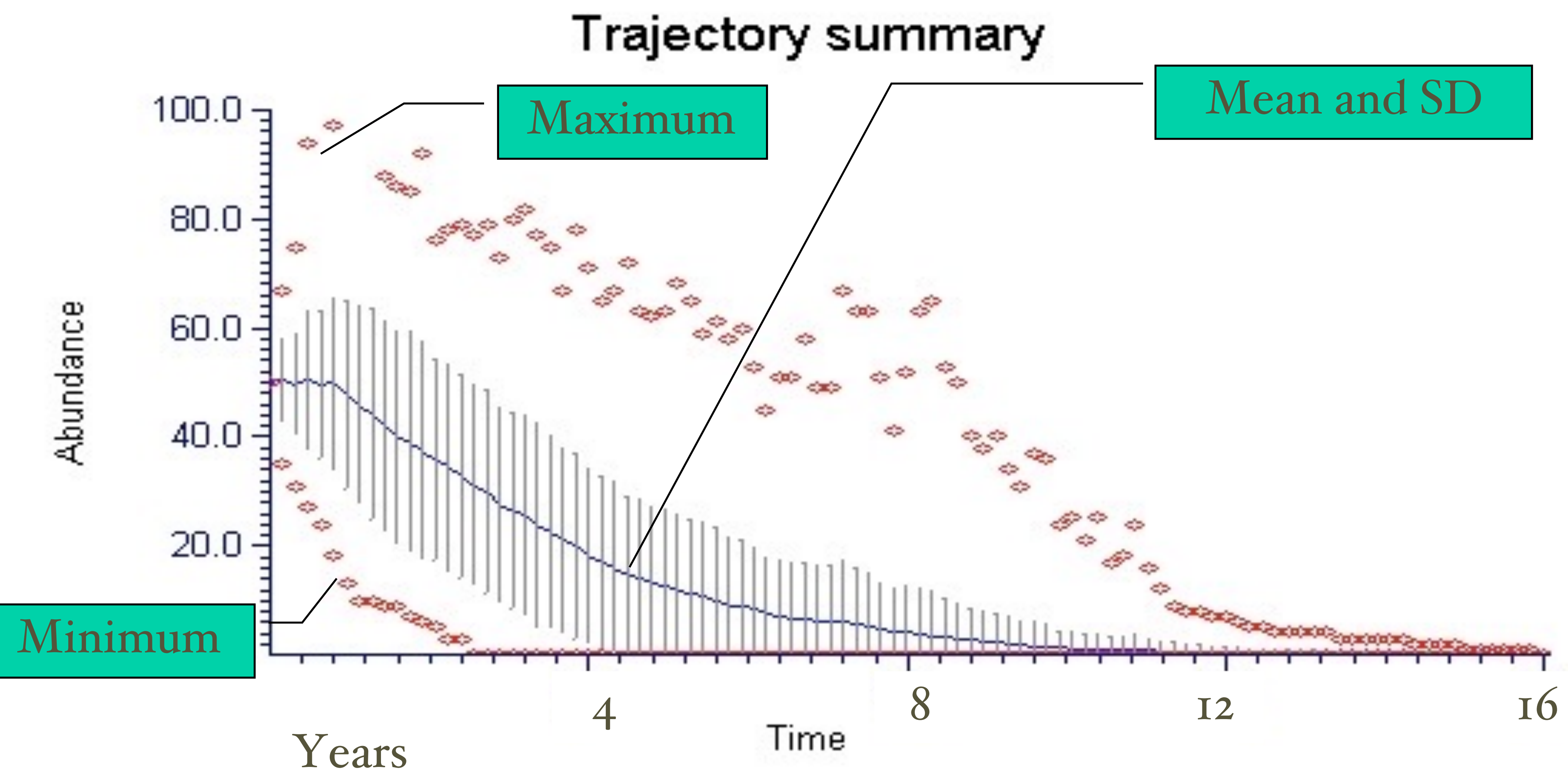
Cause of variation	95% CI of Lambda	Range of 95% CI	Total variation %
Demographic	0.9600-1.0308	0.0708	10%
Spatial	.9725-1.1322	0.1597	24%
Temporal	0.7834-1.2114	0.428	65%

Simulation of 100 populations and their growth rate with 180 individuals at time t



Simulation of 100 populations and their growth rate with 50 individuals at time t

The same matrix and in the previous simulation



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Application to Conservation

- Extinction risk (Mace and Lande 1991)
  - Critically endangered (CR): 50% extinction probability in 5 years or 2 generations
  - Endangered (EN): 20% extinction probability in 20 years or 5 generations
  - Vulnerable (VU): 10% extinction probability in 100 years

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