

**Are desert ungulates sensitive to global change?  
Predicting the future dynamics of reintroduced  
Asiatic wild-ass under environmental stochasticity.**



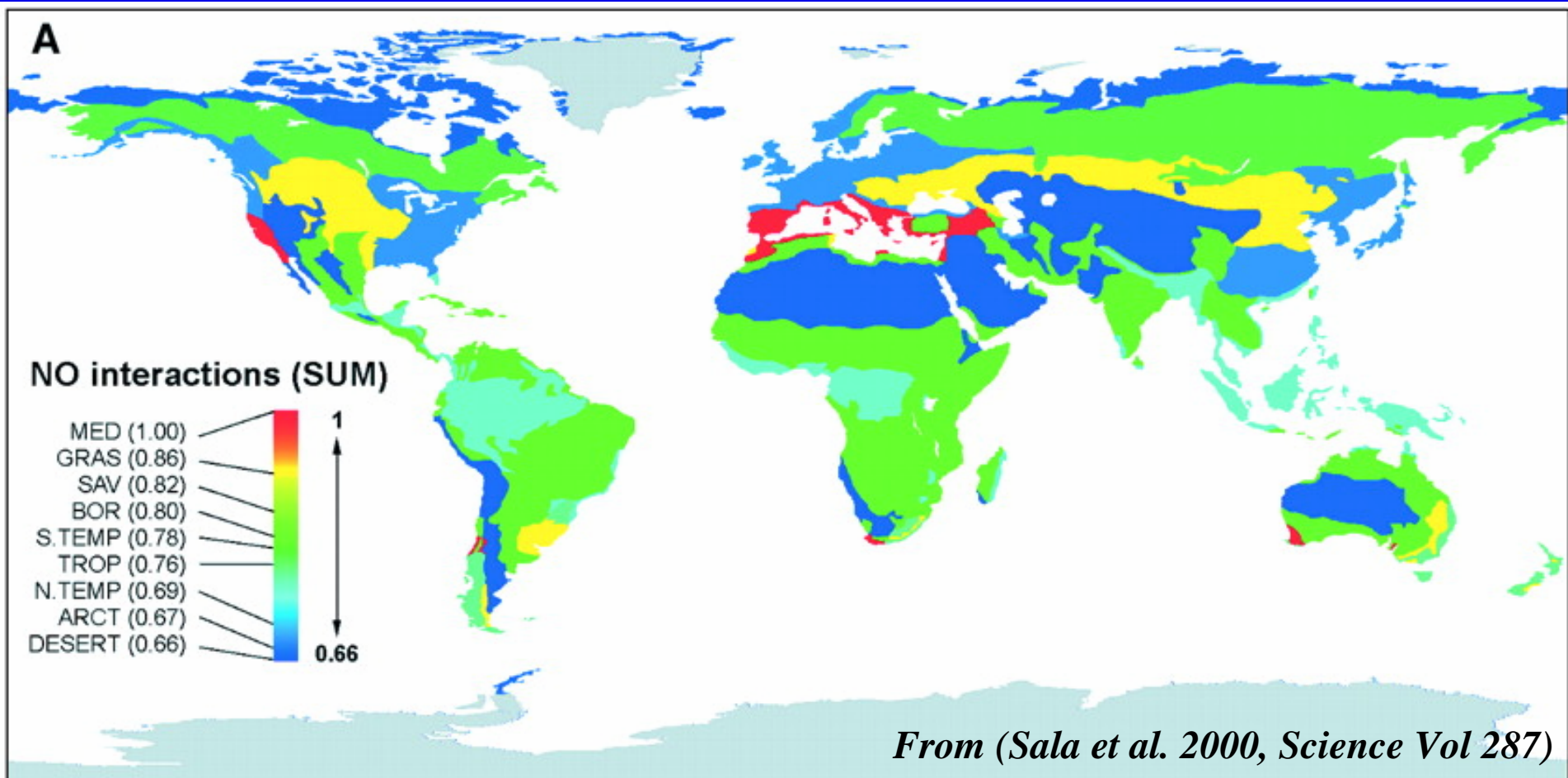
**David Saltz - Ben-Gurion University**

**Photographs by Gertrud Denzau**

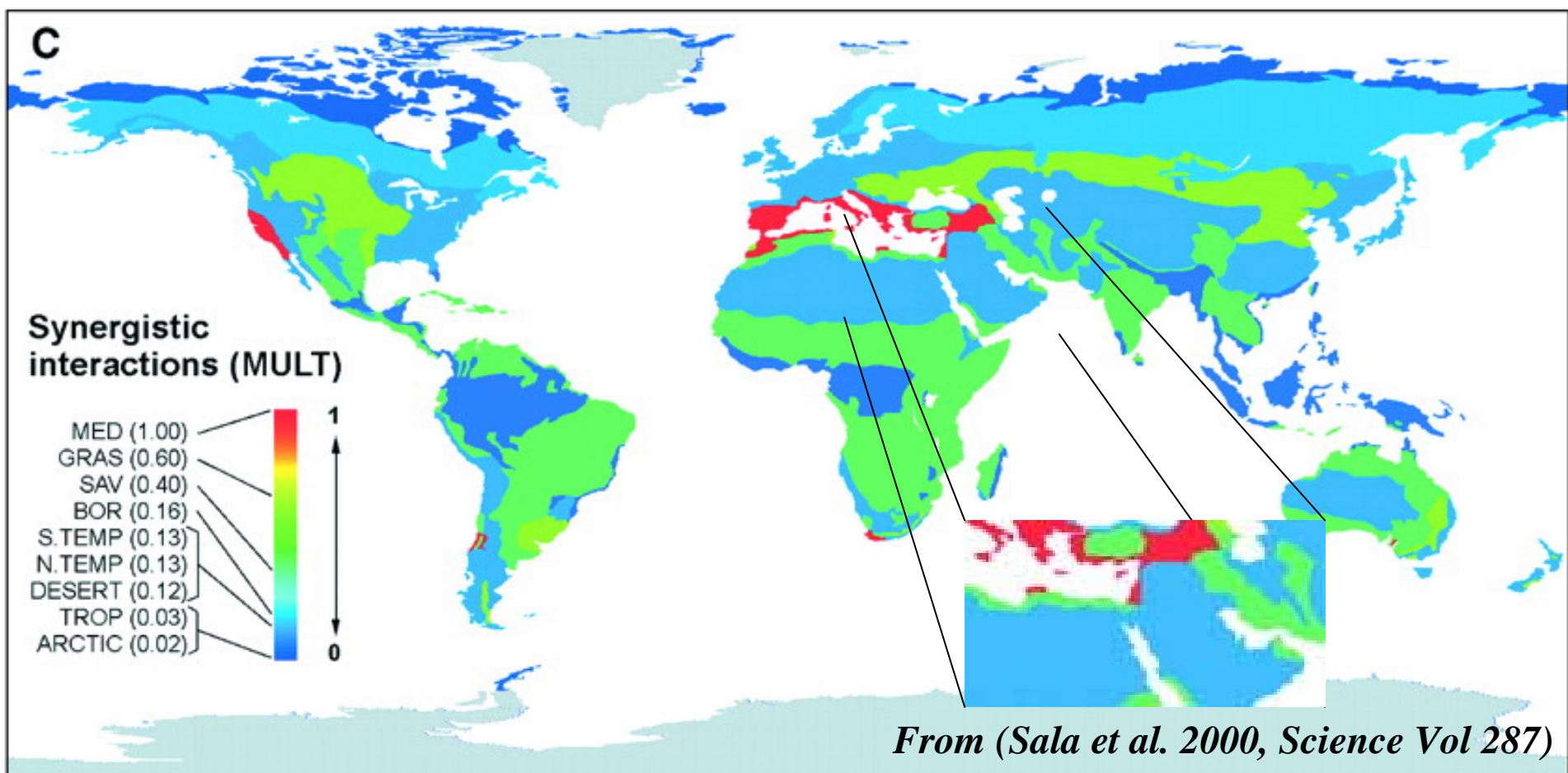
## Overview

1. **What are the projections for the Negev under GC?**
2. **Some background on Asiatic wild ass and their dynamics**
3. **The model for assessing GC impacts on the dynamics of the sp.**
  - **Parameterizing the model.**
  - **Encorporating stochasticity.**
  - **Possible scenarios.**
4. **Model results.**
5. **Conclusions**

**Expected change in biodiversity for the year 2100. Different colors represent expected change in biodiversity from moderate to maximum ranked according to total expected change. Numbers in parentheses are total change in biodiversity relative to the maximum value projected. Figure is based on 5 drivers: 1, land use; 2, climate; 3, nitrogen deposition; 4, biotic exchange; 5, atmospheric CO<sub>2</sub>.**



**Expected change in biodiversity for the year 2100. Different colors represent expected change in biodiversity from moderate to maximum ranked according to total expected change. Numbers in parentheses are total change in biodiversity relative to the maximum value projected. Figure is based on 5 drivers: 1, land use; 2, climate; 3, nitrogen deposition; 4, biotic exchange; 5, atmospheric CO<sub>2</sub>.**

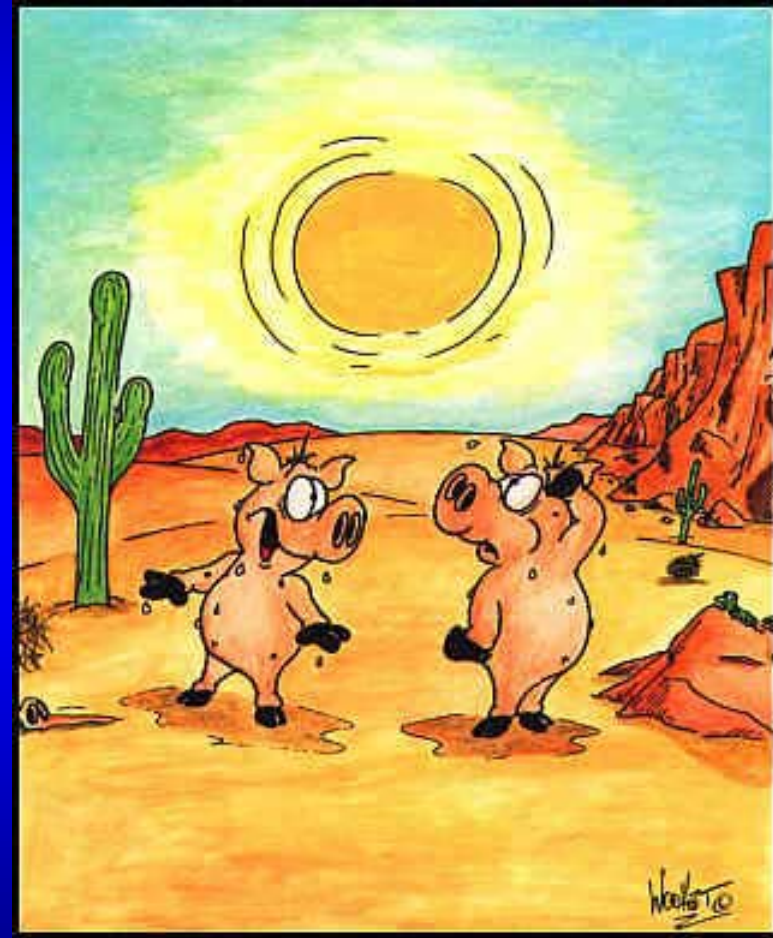


**These projections are based on predicted minor changes in land-use and mean annual atmospheric values.**



**However, while the mean annual precipitation in many hyper-arid environments is not expected to change much, the inter-annual variation in precipitation is expected to increase (P. Alpert- pers. Comm.).**

**This, in-turn, may have a profound effect on the dynamics of populations (e.g. Lande 1993).**



"Geez.... I'm so hot.... I'm Bacon!"

Here I test these ideas and evaluate the effect of environmental stochasticity under a hypothetical global change scenario using data on the dynamics of Asiatic wild ass (*Equus hemionus*) reintroduced into Makhtesh Ramon between 1982 and 1987 and projecting their growth into the future under various scenarios.



# Reproduction



**Monotacous**

**Foaling in spring**

**Gestation – 11 months**

**May produce in consecutive years**

**Primiparity – at age 3**

**Sex of foals is dependent on maternal age**

# Survival

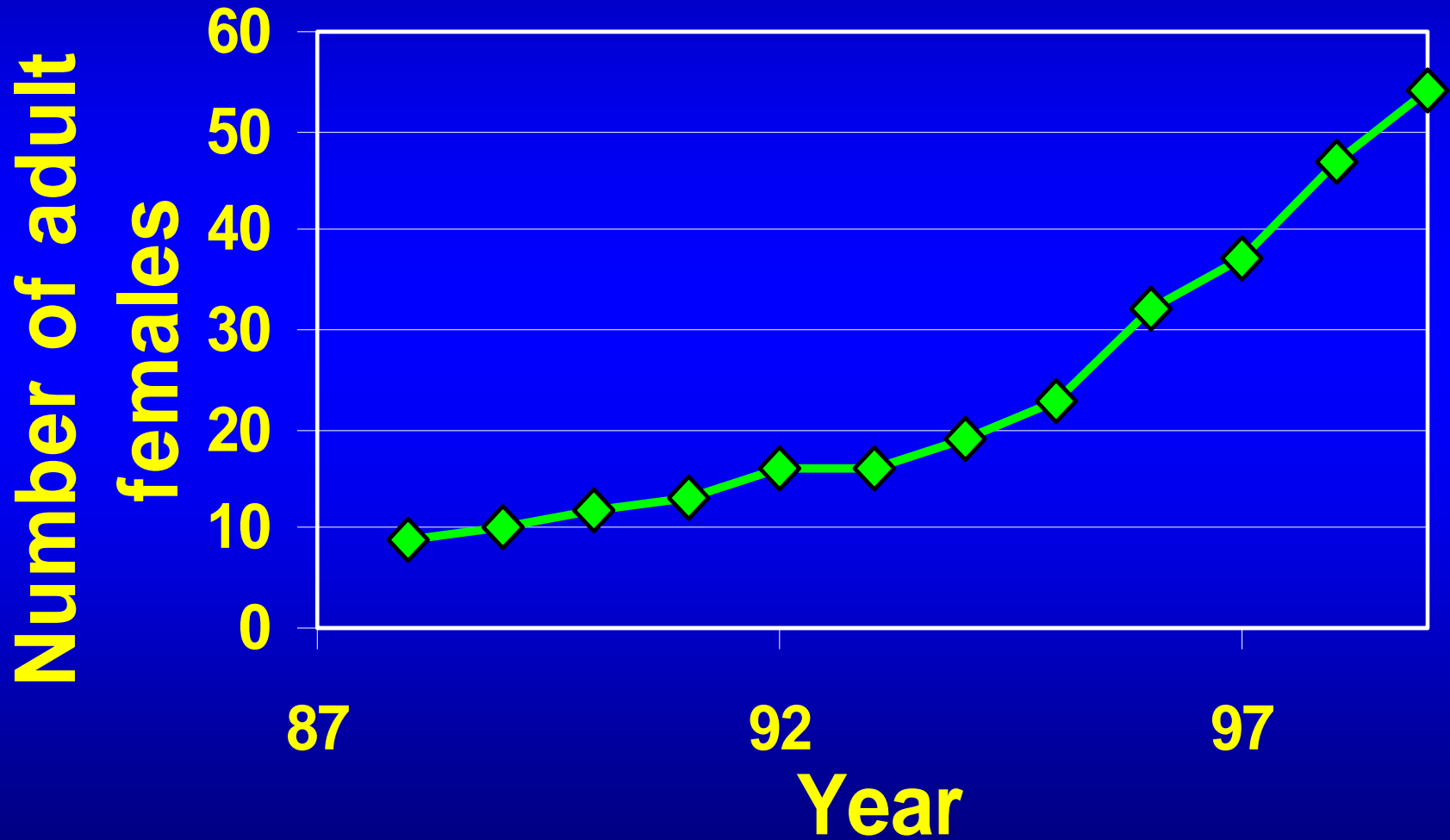
**Generally, as in most ungulates, survival is high (dynamics depend mostly on reproduction).**

**May live in captivity up to 25 years.**

**No data on survival in wild (sample size from Makhtesh population too small).**

**However, there is anecdotal data that population may crash when droughts are extreme.**

# Number of adult females in the reintroduced population as a function of time



# The Model

## General

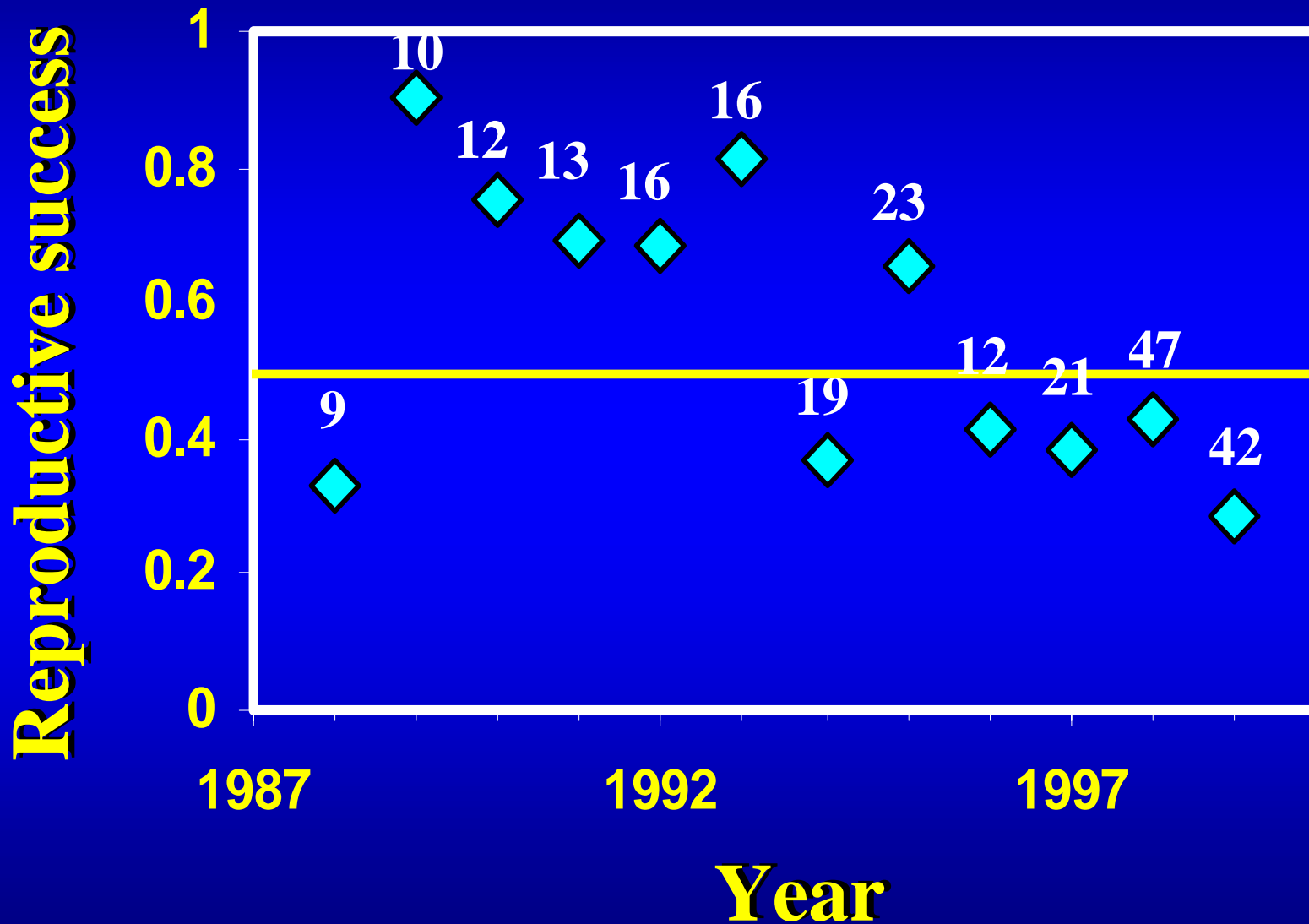
**A Leslie matrix Monte Carlo simulation model, projecting the growth of the adult female population, starting with the number of adults (30) and age distribution that existed in 1997, and under various conditions.**

**The model should include environmental and demographic stochasticity.**

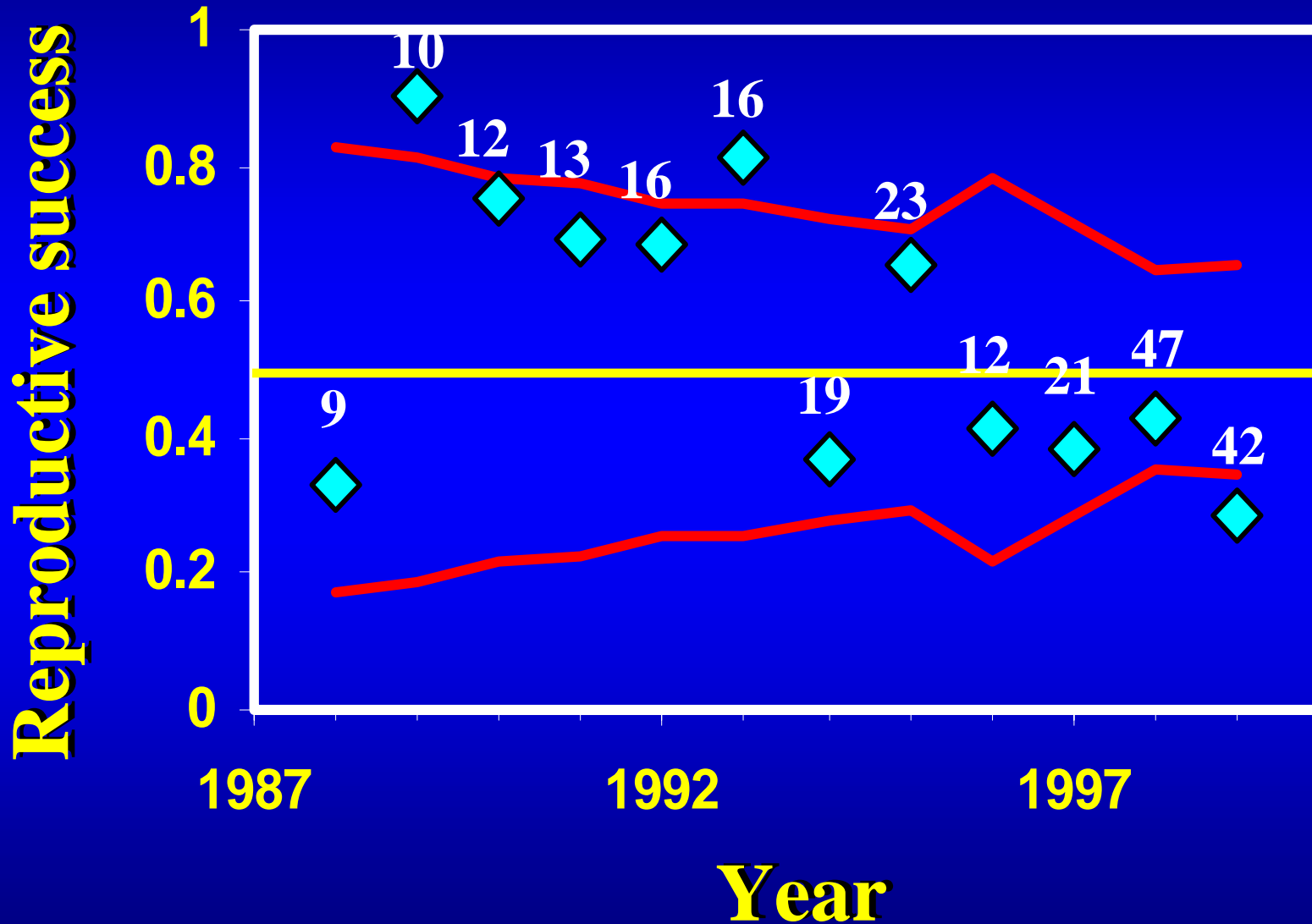
# Parameterization of the model

- 1. Parameterize for reproductive success.**
- 2. Parameterize survival.**

# Reproductive success by year



# Reproductive success by year



# The Beta distribution

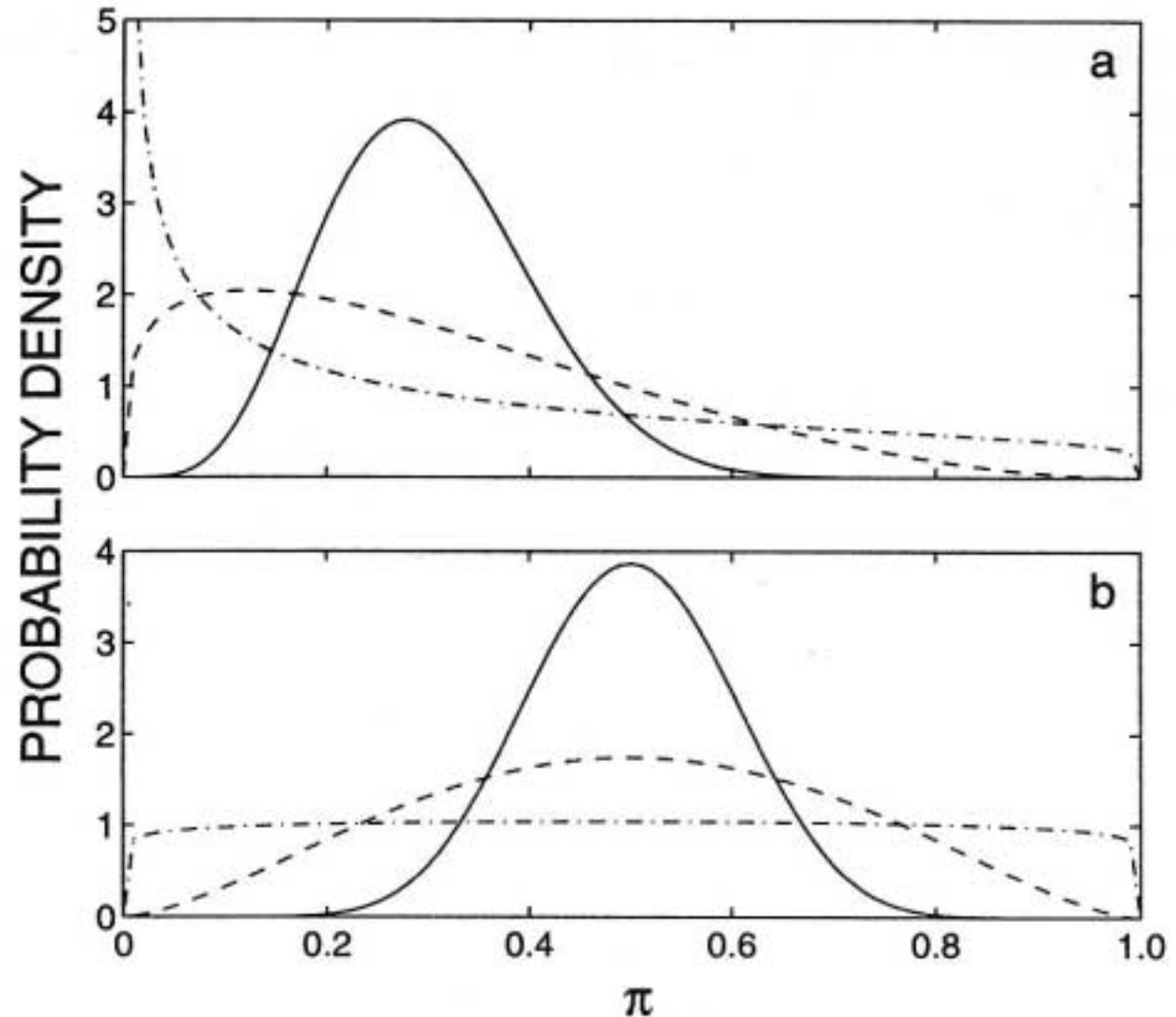
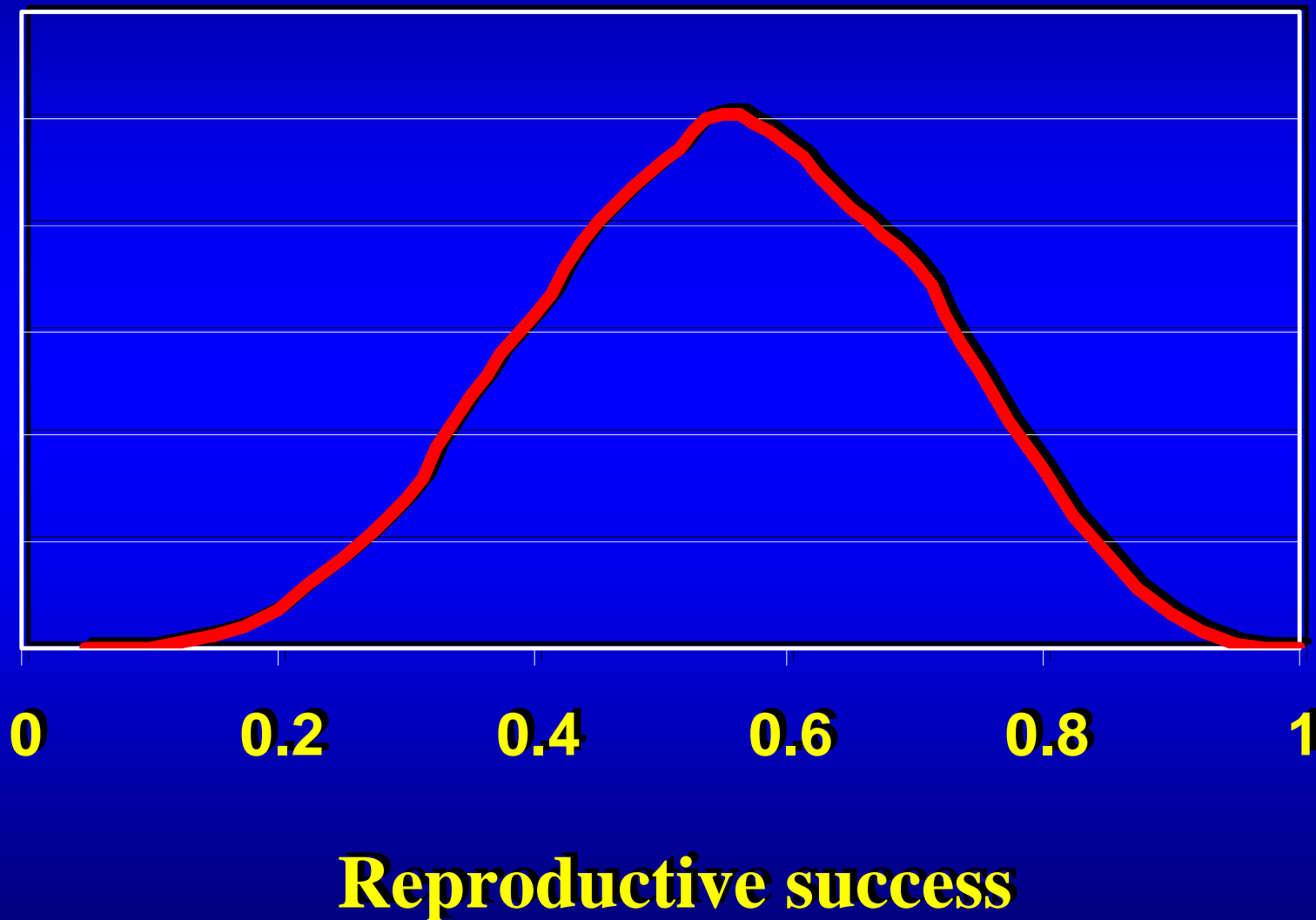


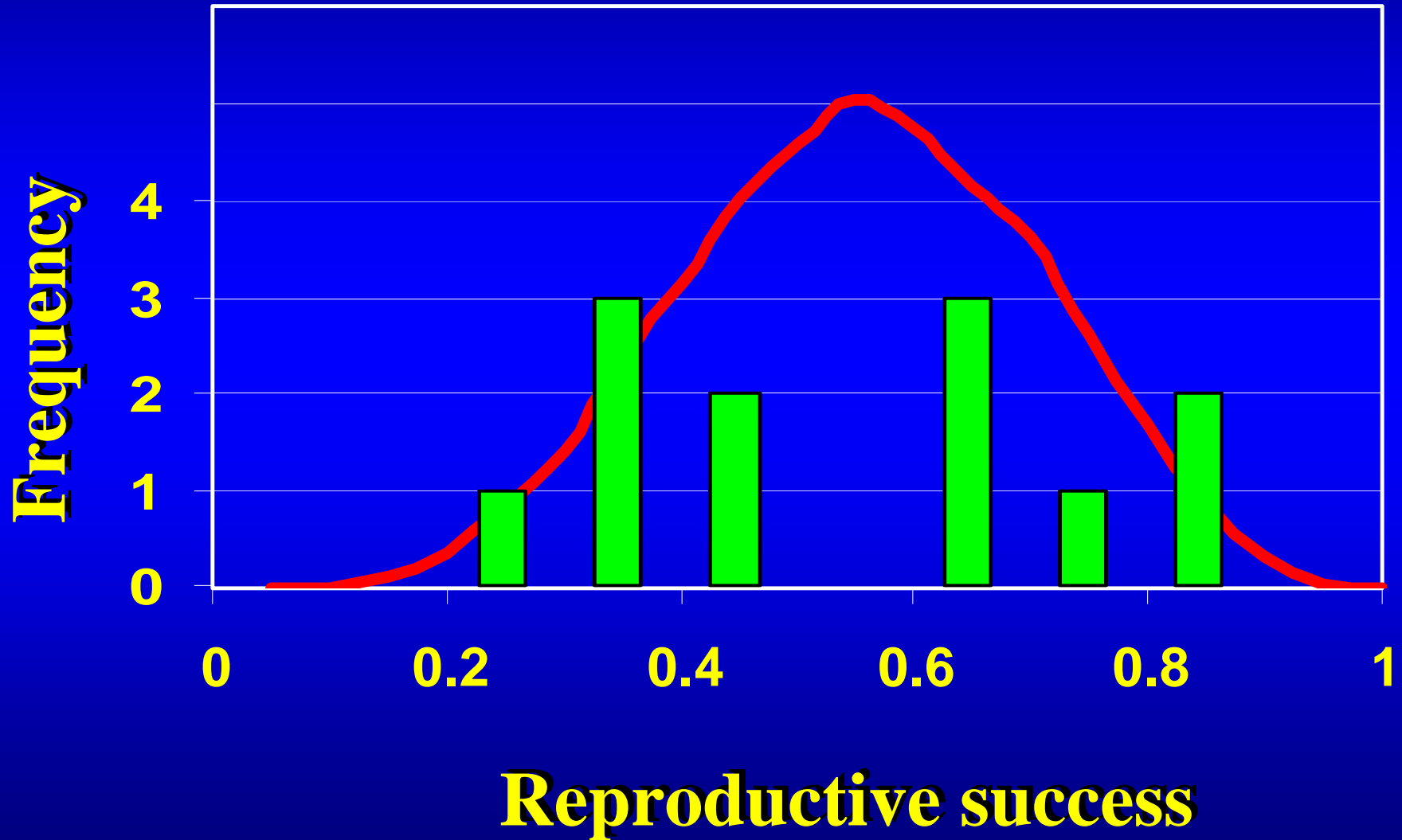
FIG. 1. Beta-distributed probability densities of survival probability ( $\pi$ ), showing variances of 0.01 (solid line), 0.04 (dashed line), and 0.08 (dash-dotted line). Means are (a) 0.3 and (b) 0.5. (From Kendall 1998)

# Fitting the Beta to the annual reproductive success

Probability Density Function



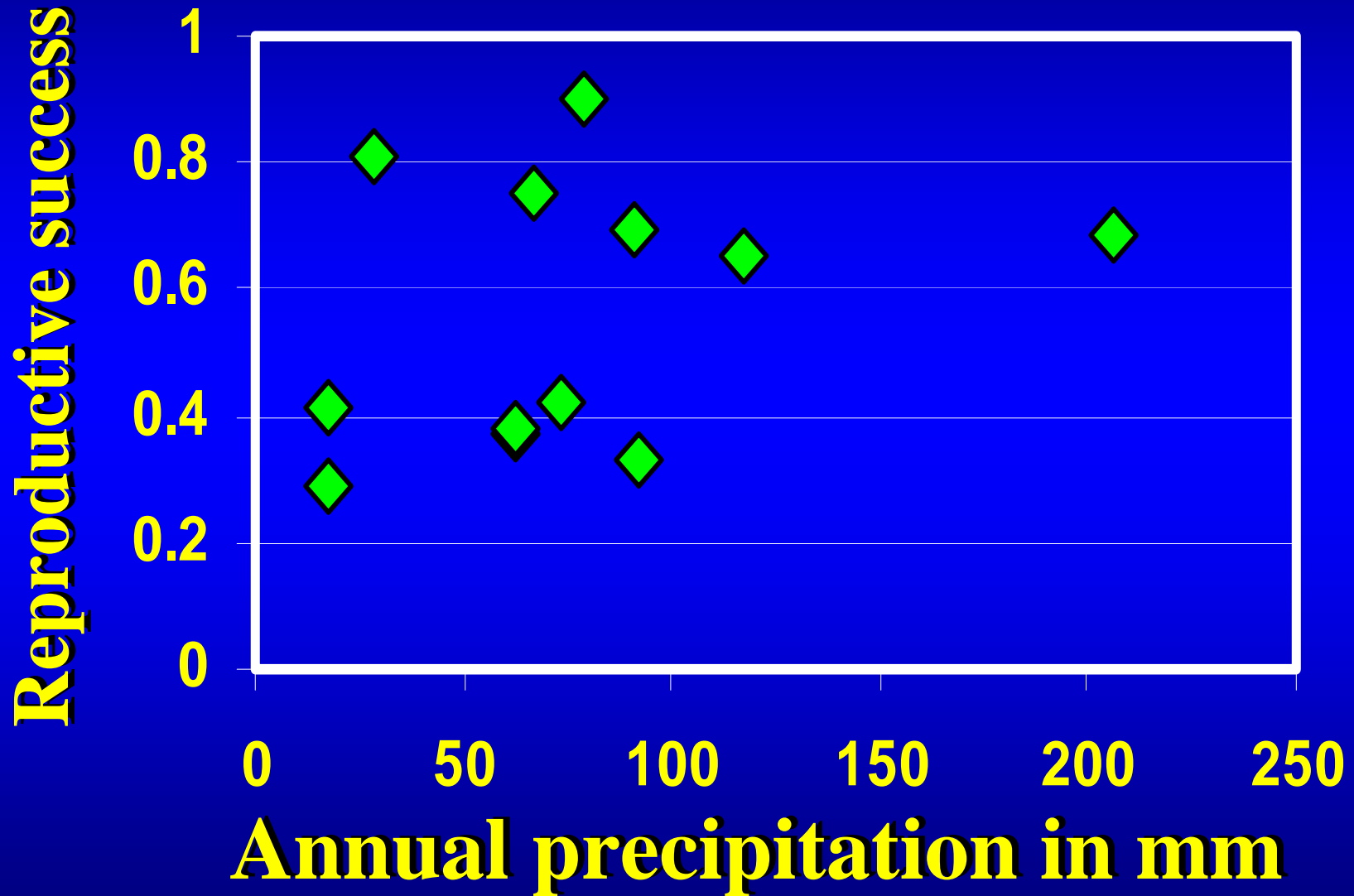
# Fitting the Beta to the annual reproductive success



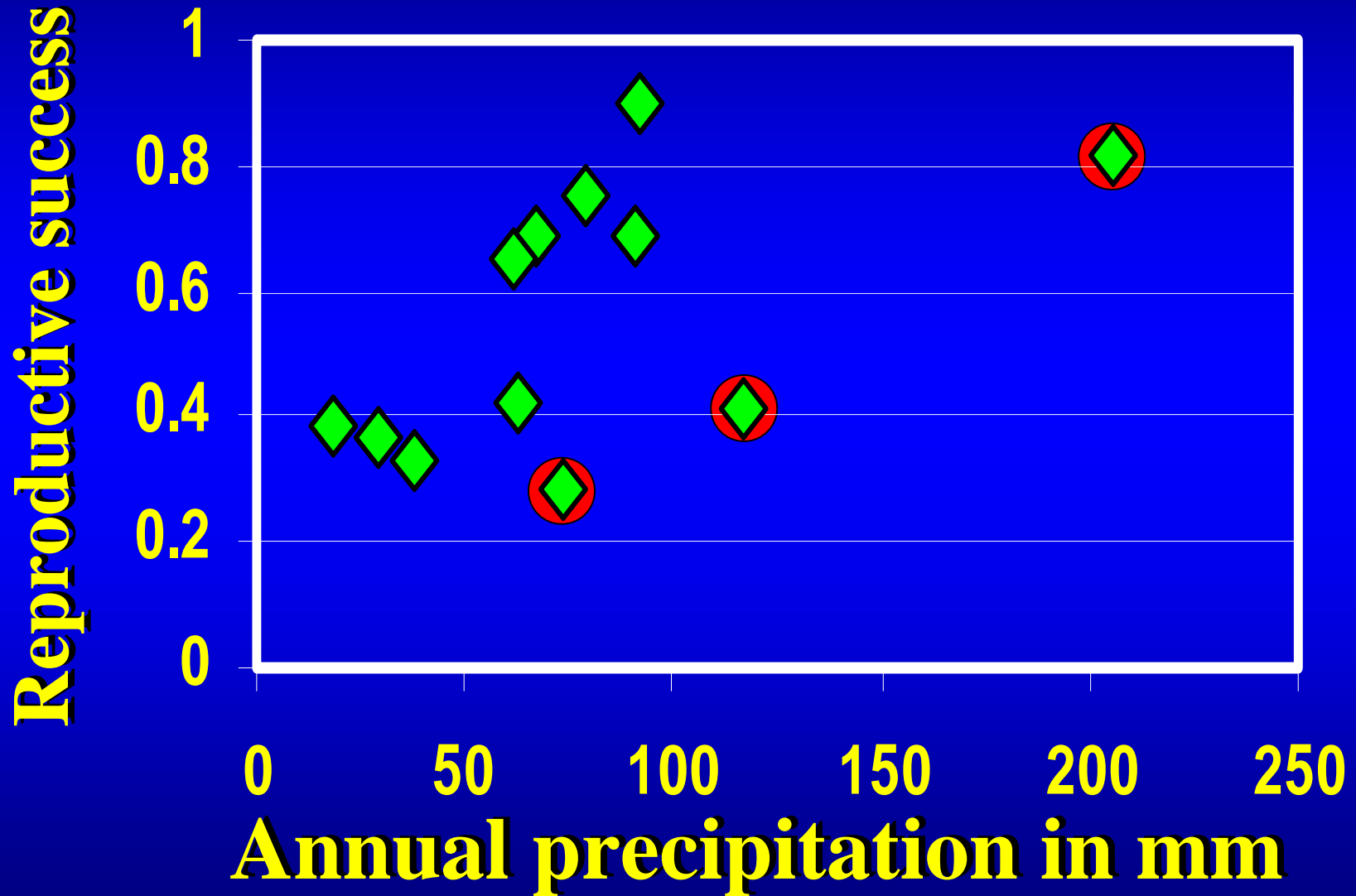
**Try and correlate reproductive success to some environmental factor.**

**In deserts, rain would be a good candidate.**

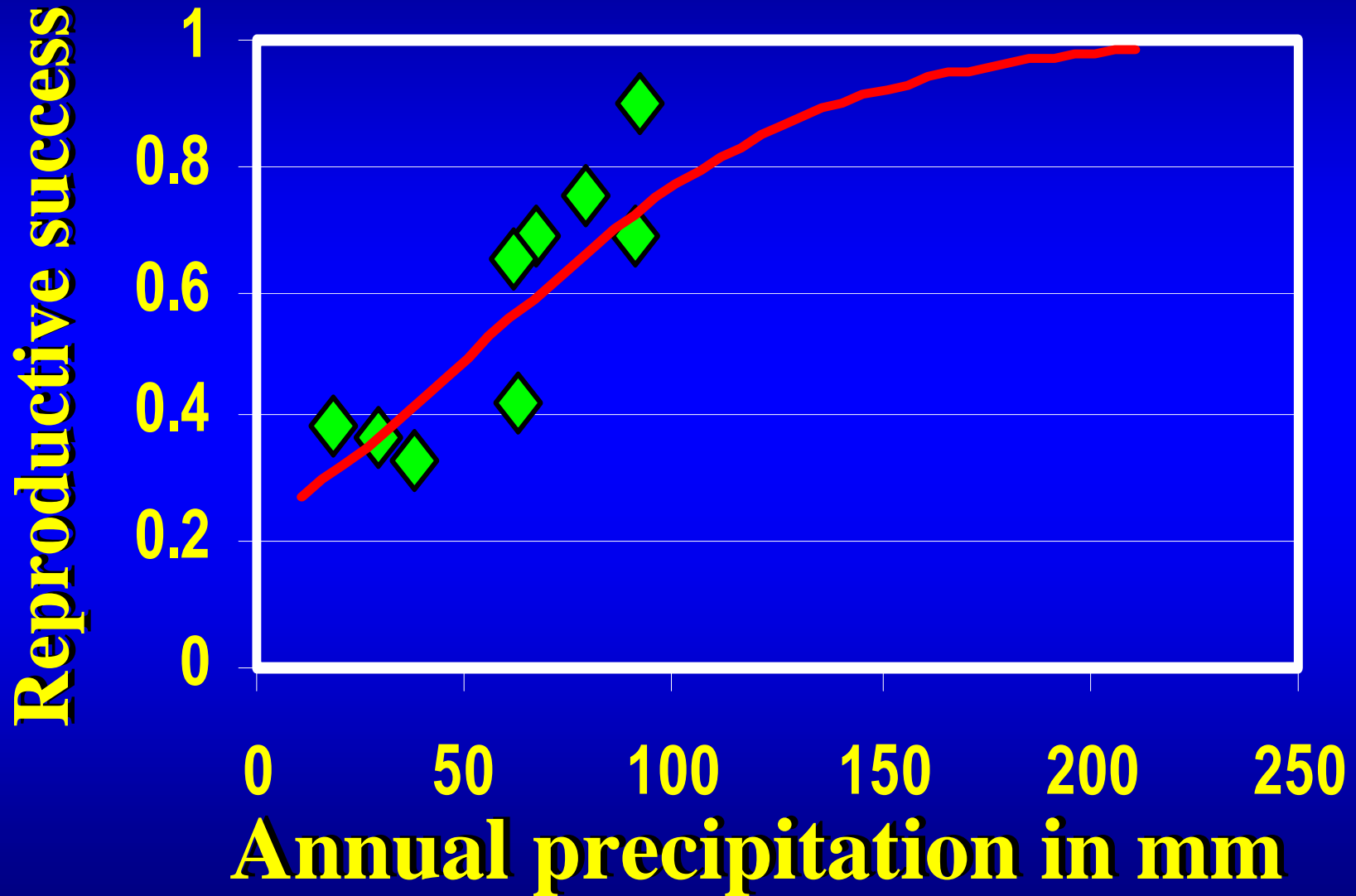
# The relationship between reproductive success and precipitation during the year before parturition.



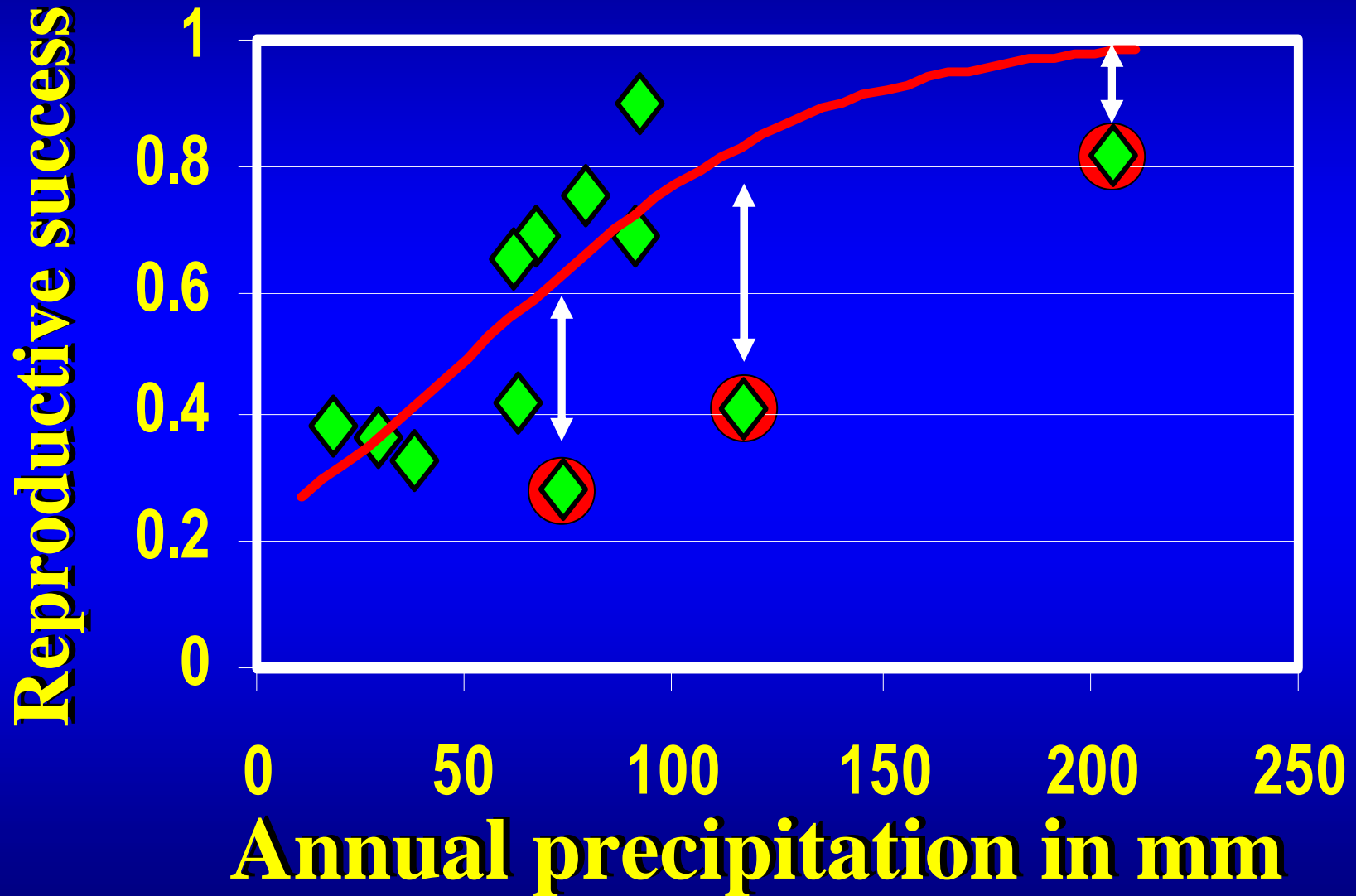
# The relationship between reproductive success and precipitation during the year before conception.



# The relationship between reproductive success and precipitation during the year before conception...



...and the effect of drought in the year before parturition.



# Selecting the best model using multiple logistic regression and Akaike's Information Criteria (AIC)

Model	Par.	AICc	delta-AICc	Akaike Weights
RP+DY	3	314.093	0.000	0.573632596
RP+DY+AF	4	315.933	1.840	0.228639439
MR+RP	3	317.673	3.580	0.095764219
MR+AF	3	317.77	3.677	0.091221363
MR+RP+RT	4	322.101	8.008	0.01046615
MR+RP+RT+AF+DY	6	329.37	15.277	0.000276233

RP=rain prev.; RT=rain this; MR=min. rain;  
 AF=Ad.fem; DY=drought year; MA=mother's age.

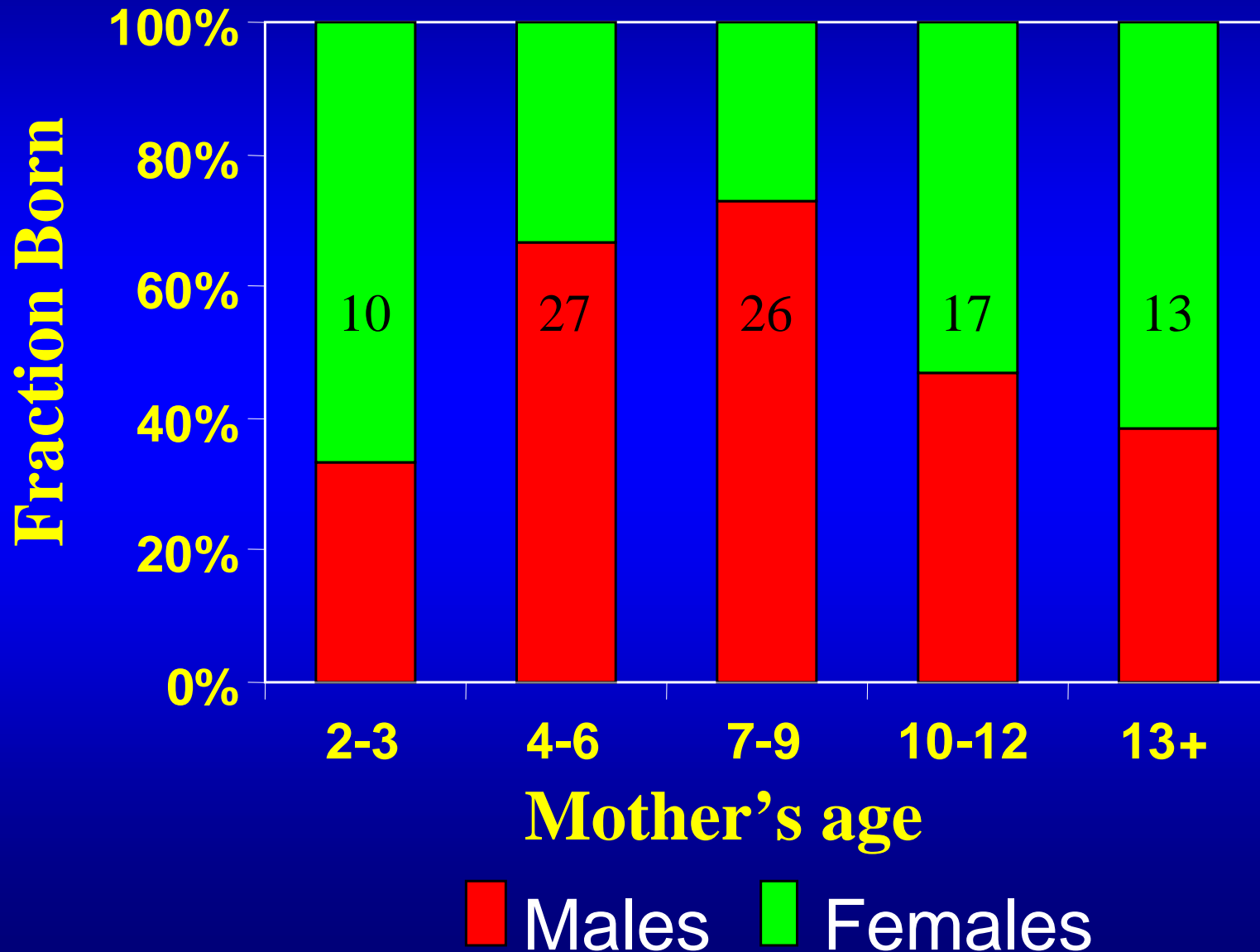
# Multiple logistic regression - best model

Parameter	DF	Estimate	Std Err	Chi Sq.	Pr>Chi
INTERCEPT	1	-1.0318	0.3008	11.765	0.0006
DROUGHT	1	-1.5025	0.3798	15.646	0.0001
RAIN-PREV	1	0.0203	0.0044	20.923	0.0001
SCALE	0	0.9983	.		

# Multiple logistic regression – next best

Parameter	DF	Estimate	Std Err	Chi Sq.	Pr>Chi
INTERCEPT	1	-0.4719	0.3891	1.471	0.2252
DROUGHT	1	-1.3149	0.3527	13.900	0.0002
RAIN-PREV	1	0.0182	0.0041	20.121	0.0001
AD. FEMAL	1	-0.0171	0.0088	3.760	0.0525
SCALE	0	0.8728	.		

# Progeny sex ratio in the reintroduced Asiatic wild ass herd.



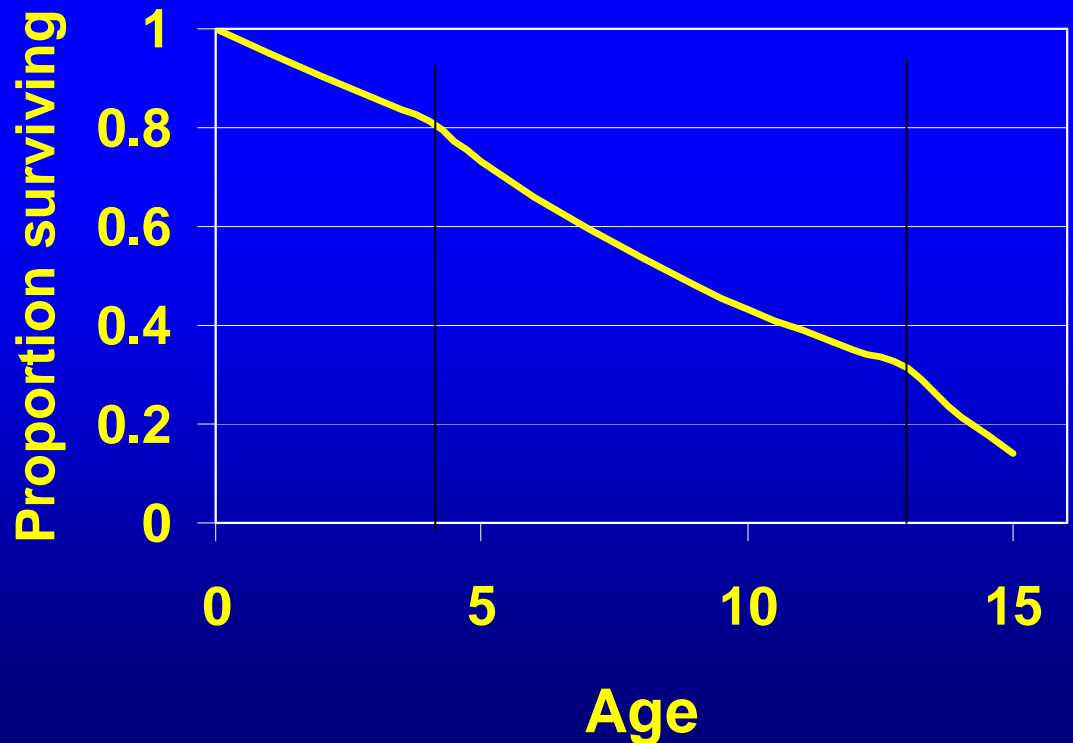
## The equation for reproductive success (RS)

$$RS = \frac{\exp^{(-.4719 - 1.3149 * drought + .0182 * rainlast - .0171 * adults)}}{1 + \exp^{(-.4719 - 1.3149 * drought + .0182 * rainlast - .0171 * adults)}}$$

**Multiplied by the expected proportion of females for each age group.**

# Survival

A survival curve was taken from zebra (*Equus burchelli* – Spinage 1972); with annual survival ranging from 0.9-0.95 to age 13 and 0.67 thereafter, maximum life expectancy = 16.

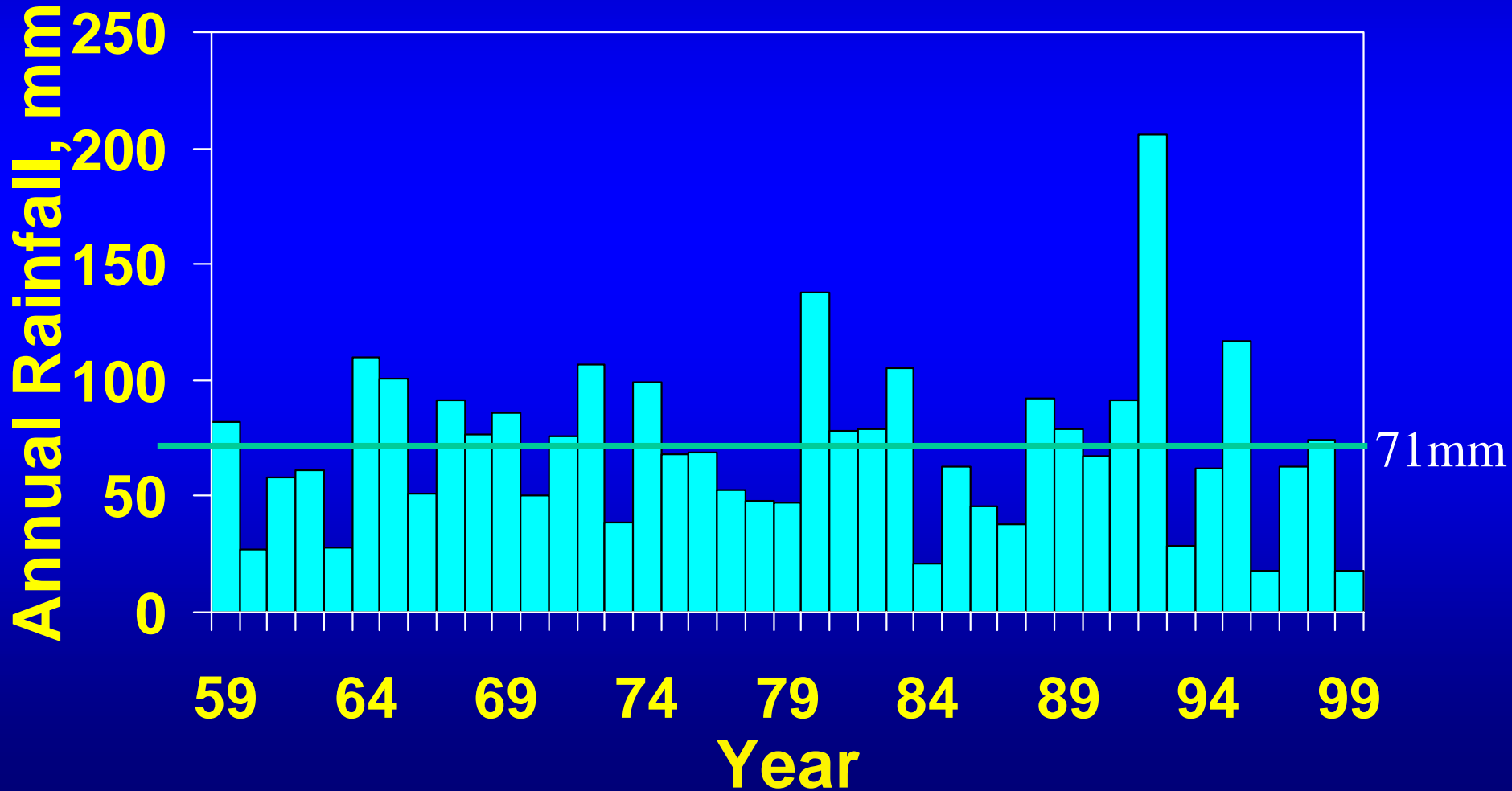


# Stochasticity

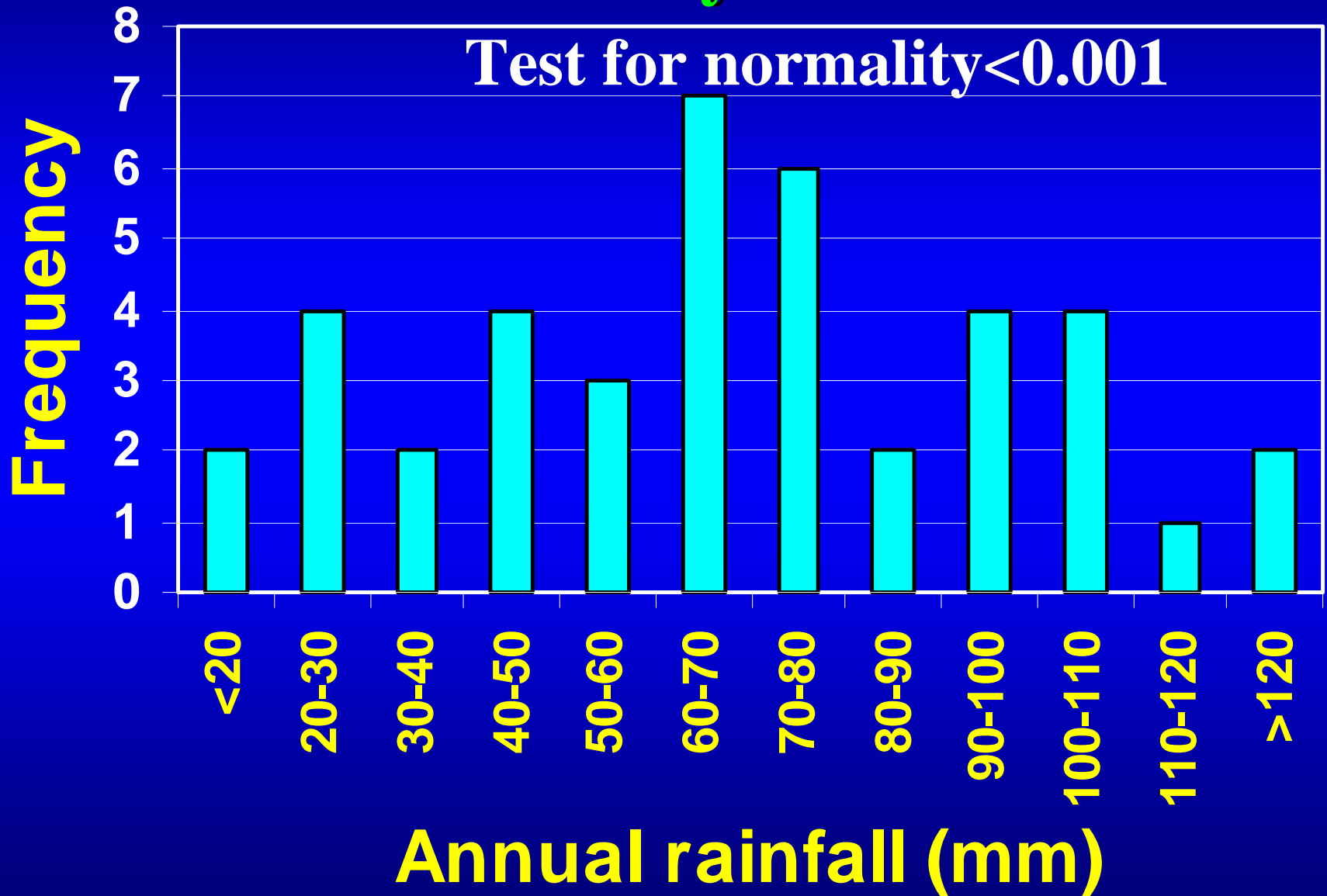
**Demographic stochasticity**– a simple binomial  $(n,p)$  where  $n$  = number of adult females, and  $p$  = expected reproductive success (based on logistic regression parameters multiplied by the proportion of female offspring according to mothers age) or survival (age dependent).

# Environmental stochasticity -

## Annual rainfall recorded in the study area (1959 - 1999)



# Distribution of annual rainfall based on 41 years of data

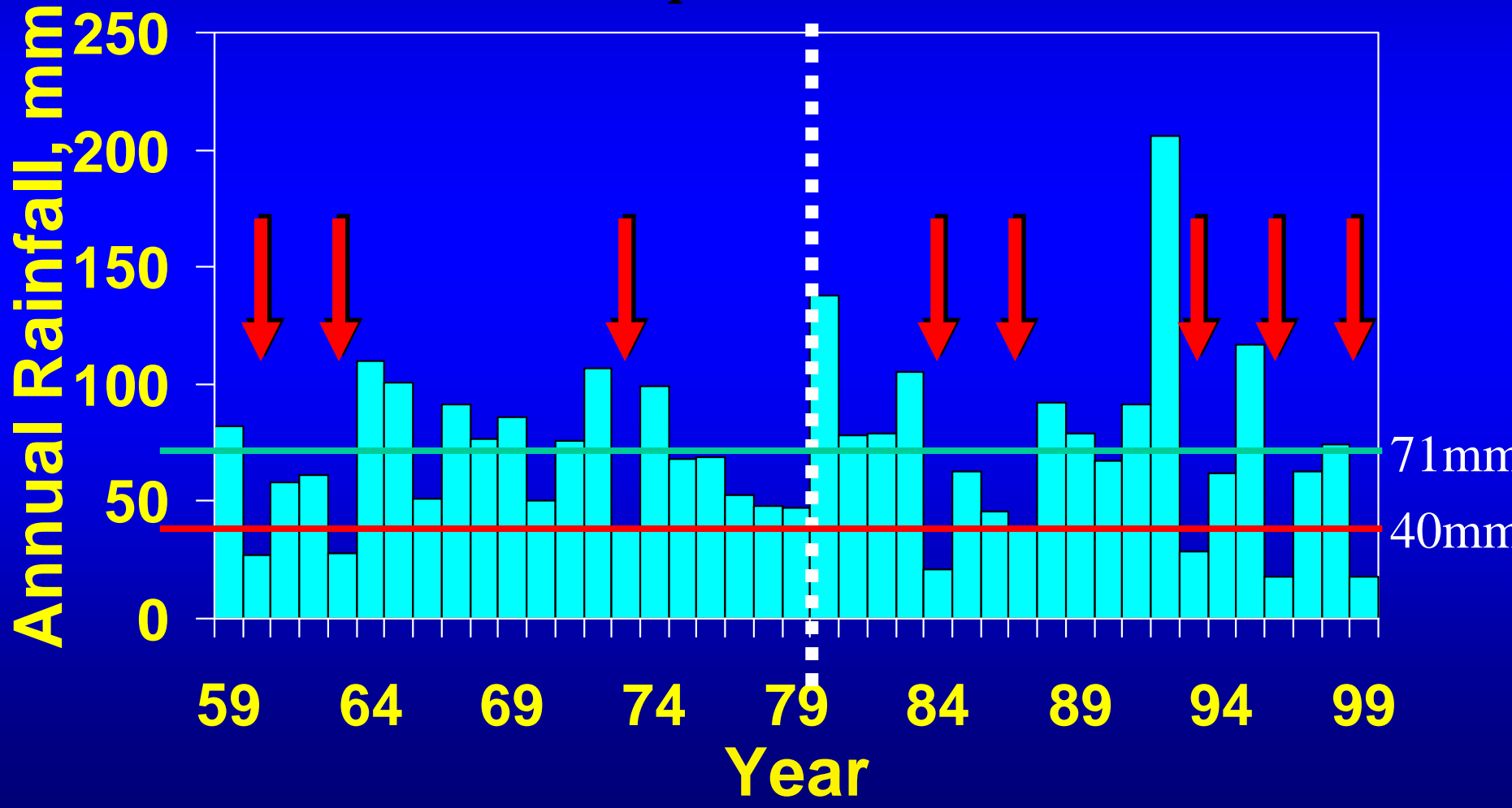


**Environmental stochasticity - Rainfall data generated by bootstrapping from a 41 year data bank of Makhtesh Ramon rain with drought years defined as those with  $<40$  mm.**

# Annual rainfall recorded in the study area (1959 - 1999)

$\bar{X} = 68 \text{ mm}, \text{SD} = 25$        $\bar{X} = 74 \text{ mm}, \text{SD} = 45$

Prob. Eq. Var. = 0.0117



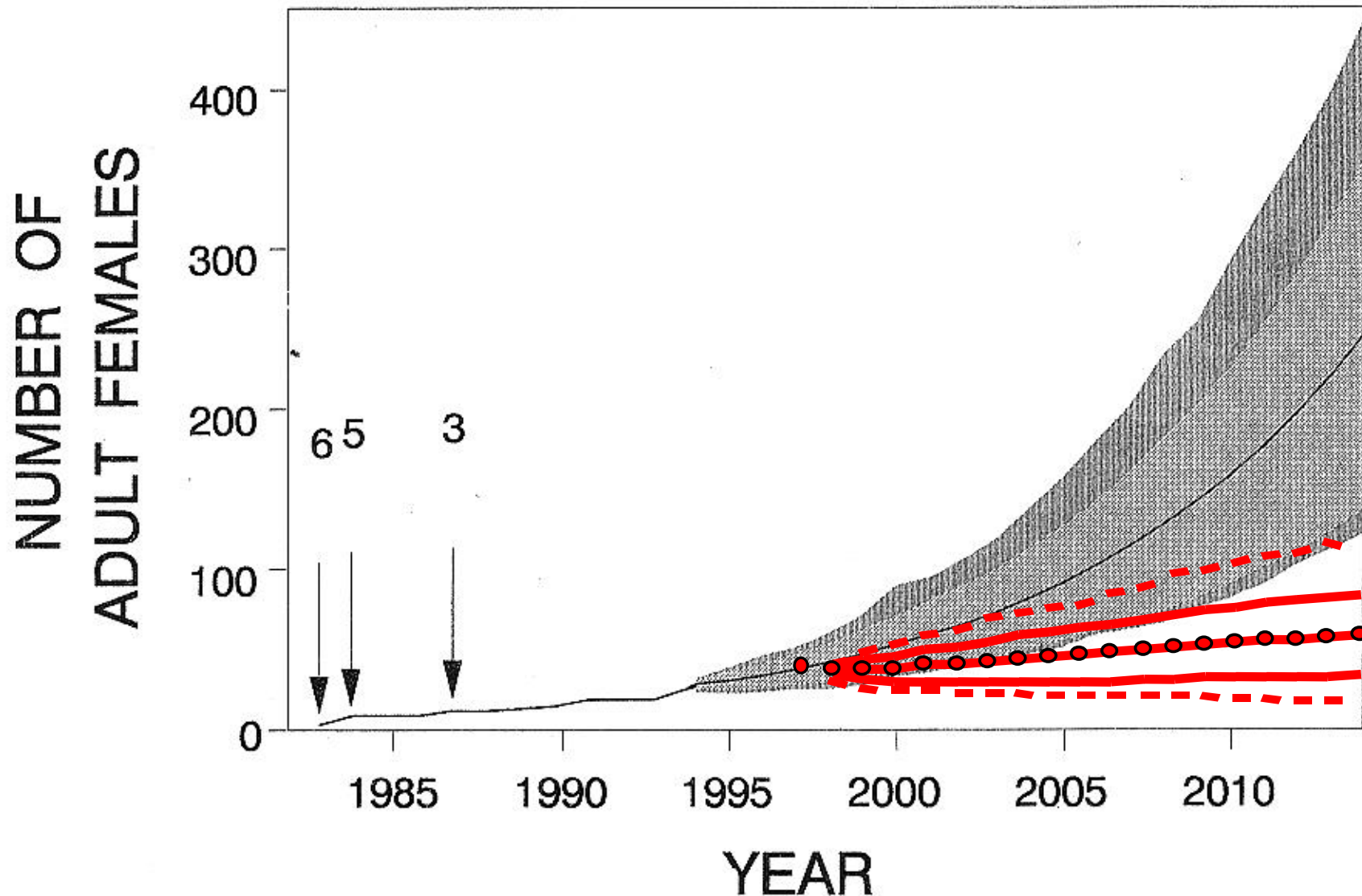
# Scenarios

- 1. Global change, i.e. pattern observed reflects or emulates directional atmospheric changes – bootstrap first 21 and last 20 years separately to simulate performance before and after change.**
- 2. What if adults survival is impacted by droughts?**
- 3. There is no change, i.e. pattern observed is random – bootstrap from all 41 years.**

# Results



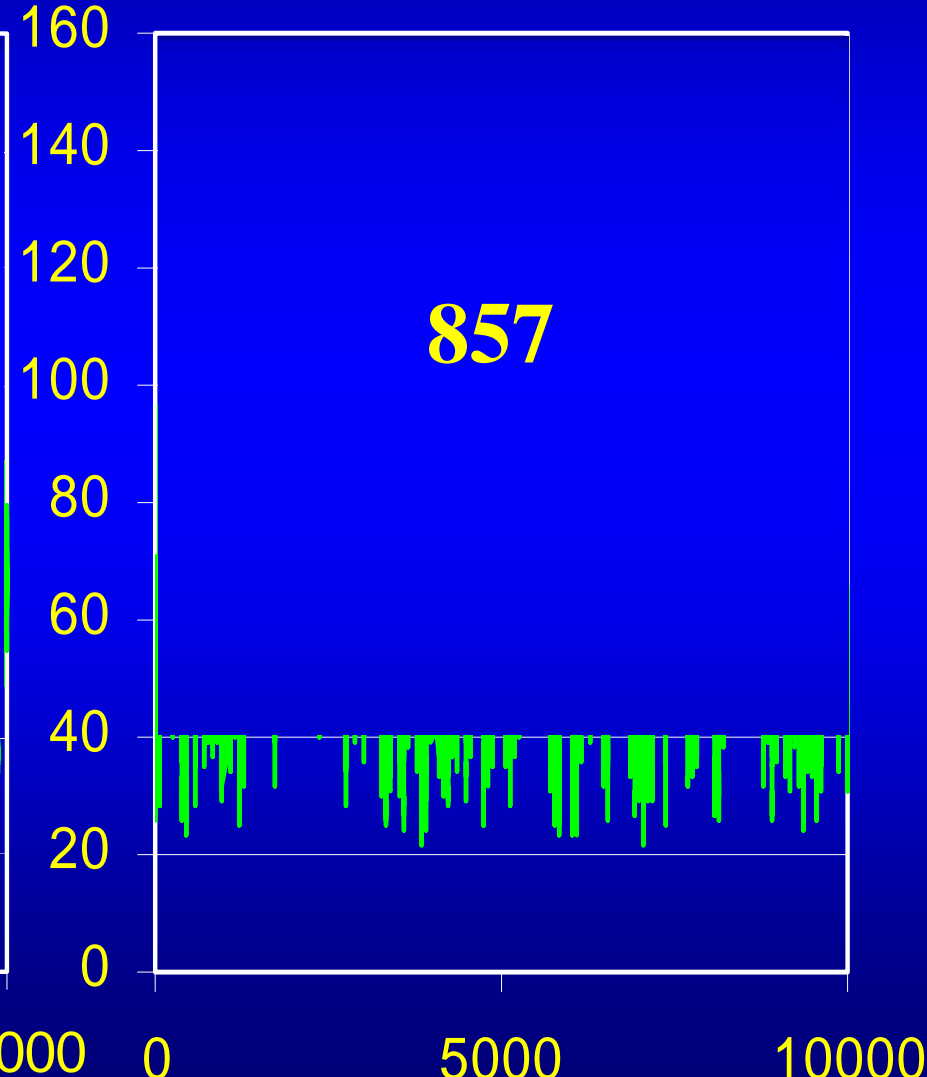
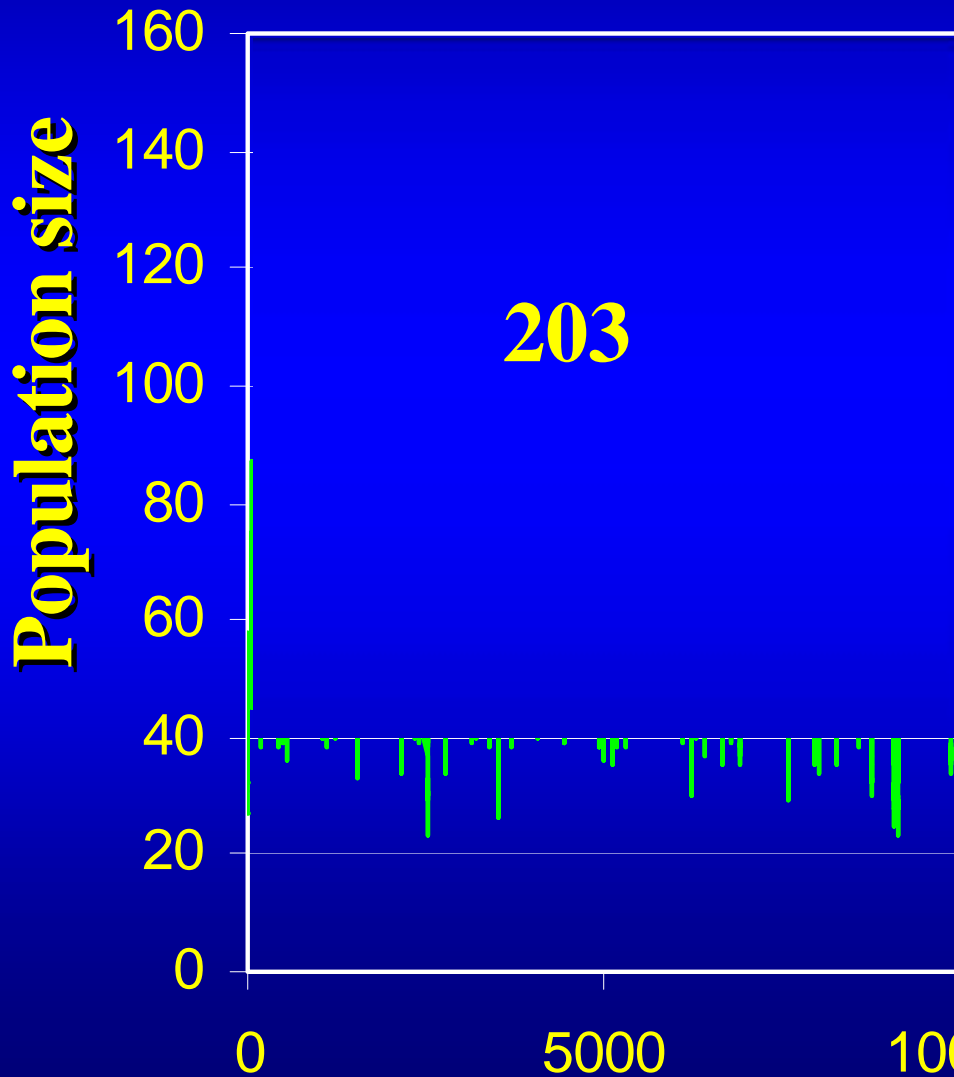
# Current projection compared with Saltz and Rubenstein (1995)



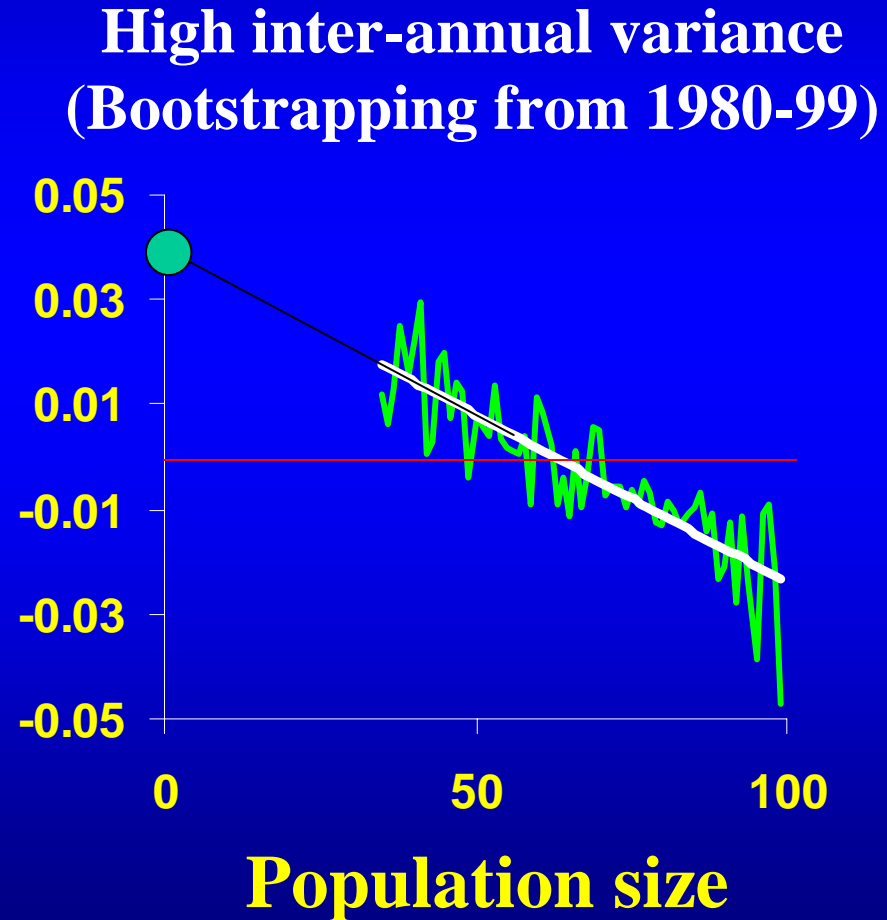
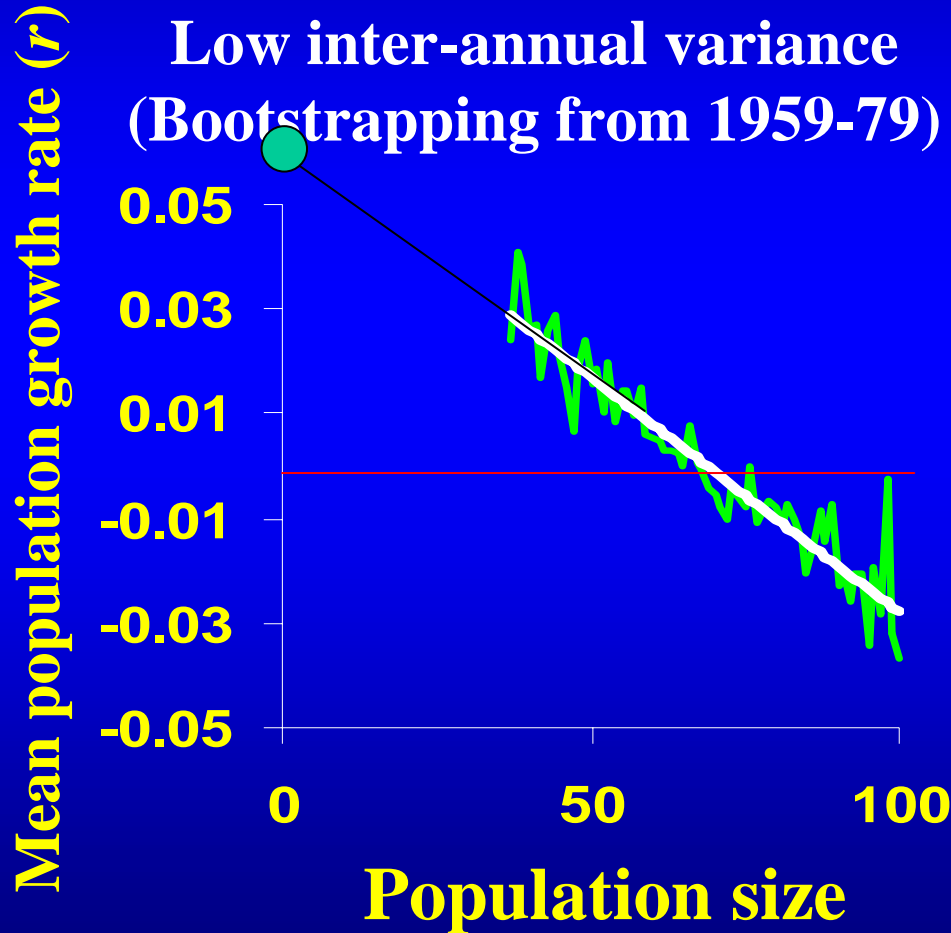
# Simulating the population over 10000 years

Low inter-annual variance  
(Bootstrapping from 1959-79)

High inter-annual variance  
(Bootstrapping from 1980-99)



# Comparing mean growth rate ( $r$ ) as a function of population size under global change scenario, before and after change.



# **Time To Extinction - Using Belovsky's (1989) recursive form of Goodman's equation**

**Low inter-annual variance  
(Bootstrapping from 1959-79)**

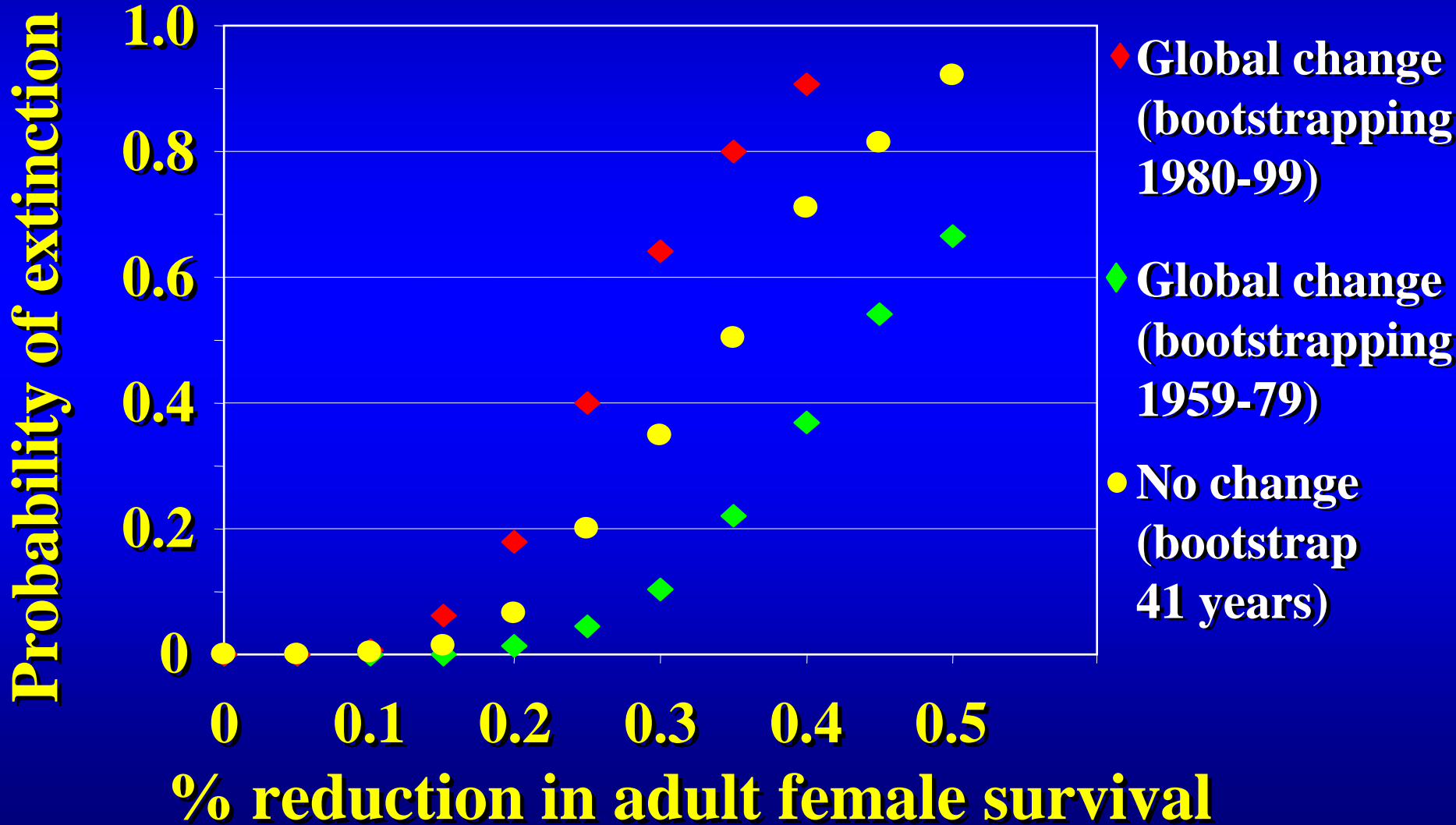
**3890 years**

**High inter-annual variance  
(Bootstrapping from 1980-99)**

**15826 years**

Treat with caution....

# Probability of extinction over 100 years based on 5000 simulations as a function of % reduction in survival during droughts.



# Conclusions

**Environmental stochasticity has and will have a profound impact on the dynamics of Asiatic wild ass.**

**If precipitation patterns in the future will reflect those of the period 1980-1999, minor reductions in survival during drought years will place the population at serious risk.**

**Long-term habitat changes and  $N_e$  not considered...**

# Acknowledgements:

**My collaborators: D. Rubenstein, M. Rowen, and G. White.**

**Funding: Nature and Parks Authority, Israel Ministry of Science, Opel Zoo (Germany).**



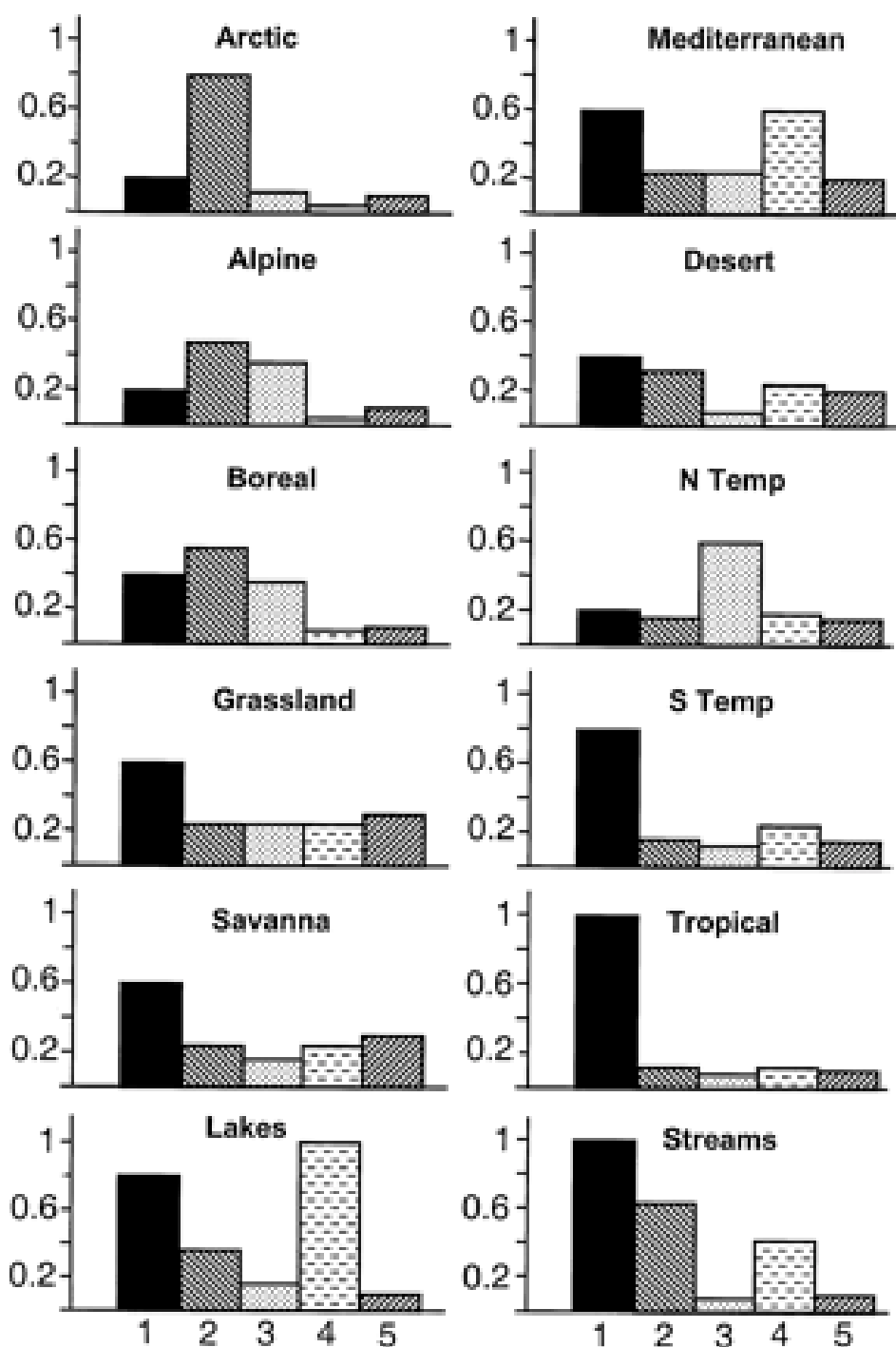


The  
End



**Thank you**

Relative biodiversity change



**Effect of each driver on biodiversity change for each terrestrial biome and freshwater ecosystem type calculated as the product of the expected change of each driver times its impact for each terrestrial biome or freshwater ecosystem. Values are relative to the maximum possible value. Bars: 1, land use; 2, climate; 3, nitrogen deposition; 4, biotic exchange; 5, atmospheric CO<sub>2</sub>.**