Managing small and isolated populations

Panagiota Koutsouli

Lecturer

Department of Animal Production and Aquaculture

Laboratory of Animal Breeding and Husbandry

Agricultural University of Athens, Iera odos 75, 11855 Athens, Greece

European seminar on Agrobiodiversity

" Unrecognised and Isolated Populations of Rare Breeds and Varieties"

Overview

- Small and isolated populations
  1. Genetic structure
  2. Inbreeding
     - Inbreeding depression
  3. Genetic drift
  4. Consequences of Inbreeding and genetic drift
  5. Estimation of Inbreeding
  6. Inbreeding and Effective Size Ne
  7. Inbreeding and Genetic gain
- Measures and good practices
  1. Minimize inbreeding
  2. Maximize effective size Ne
  3. What to do

Small and isolated populations
1.Genetic structure

- Protection and preservation
  - Maintaining the special traits
  - Preservation of existing genetic variability (no loss of alleles)
    - ensures the survival, sustainability of the population
    - satisfactory levels of genetic variation - more adaptive

Small and isolated populations

2. Inbreeding

Small herd :

- Few males - a larger set of females
- the same males for years
- a valued male - replaced by his son in the same herd

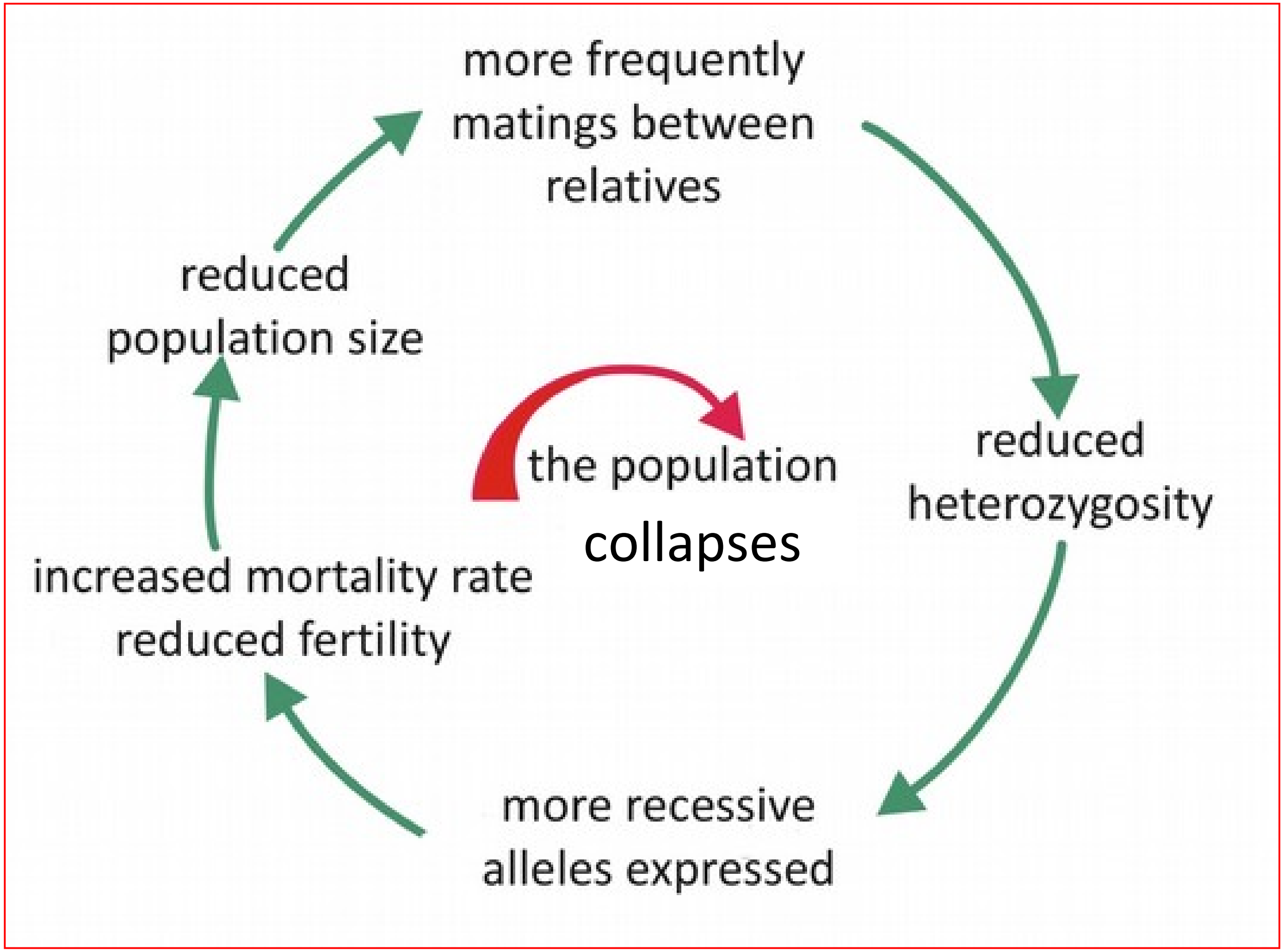
→ increased probability of mating between relatives

→ **inbreeding**

Conclusion: In a small population, the goal is to reduce the inbreeding growth rate

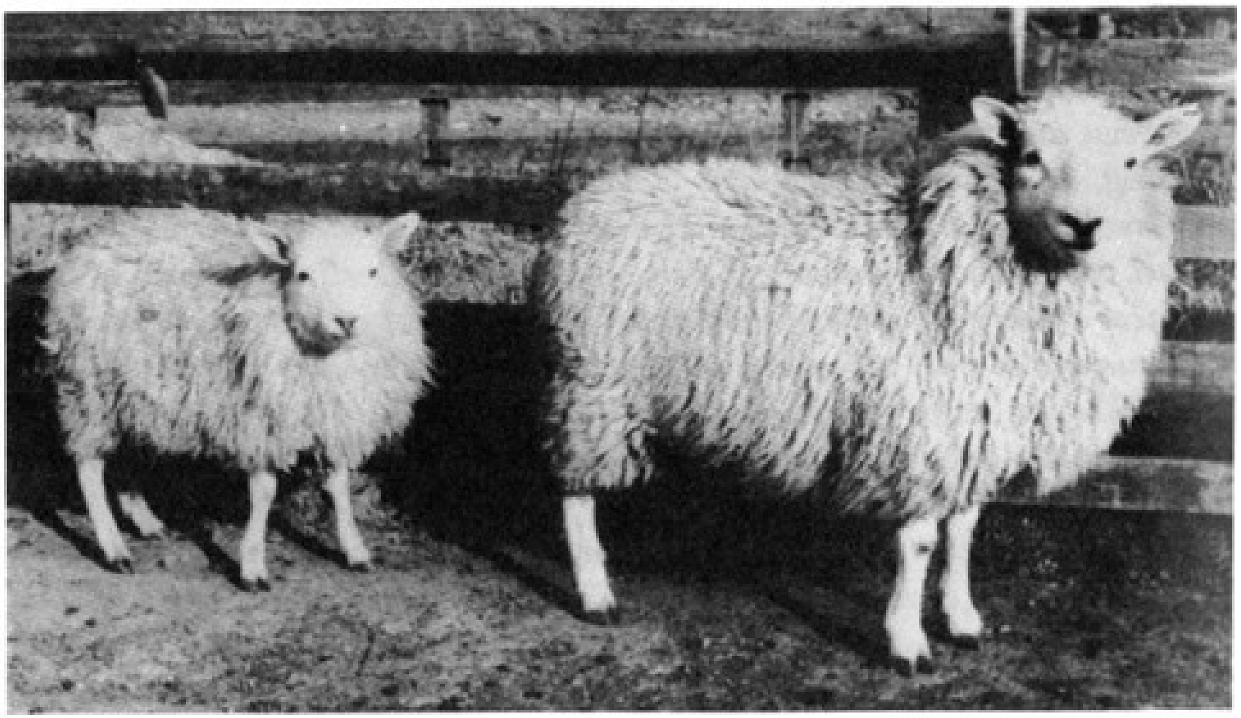
Small and isolated populations

2. Inbreeding - Inbreeding depression (i)



Small and isolated populations

2. Inbreeding - Inbreeding depression (ii)



Inbred ewe from mating between parent-offspring for successive generations (left) with F=50% and non-inbred ewe (right) with F=0

(Wiener, Lee & Williams, 1992)

Small and isolated populations

2. Inbreeding - Inbreeding depression (iii)

In a sheep flock:

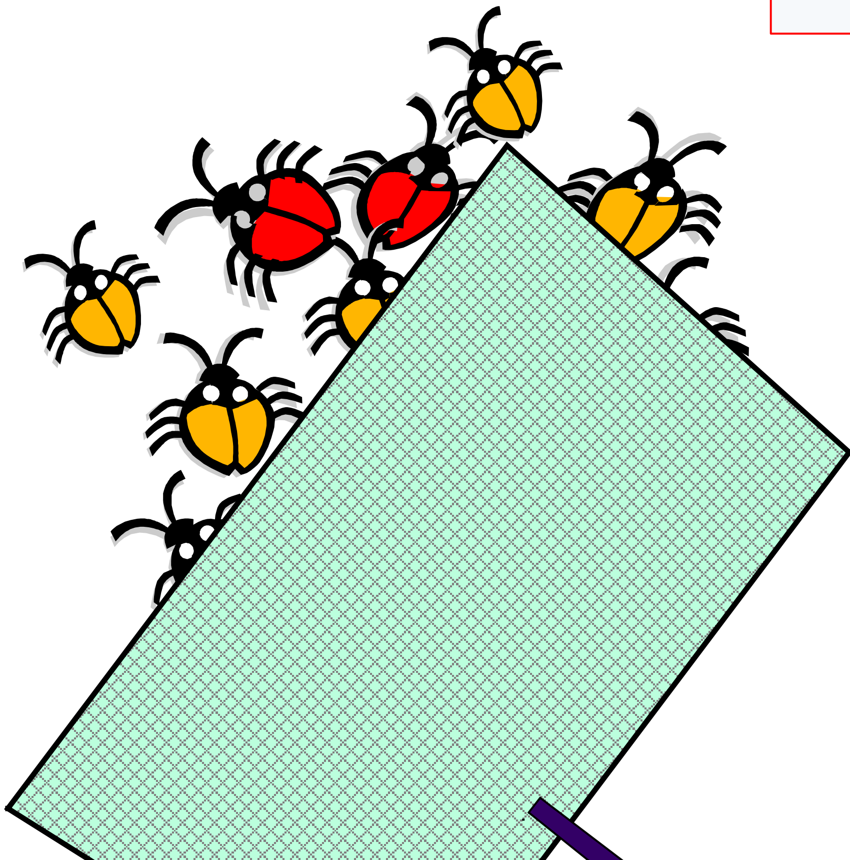
An increase 10 % of the inbreeding rate $\Delta F \longrightarrow$

- Ewes fertility decreases 14 %
- Lamb survival till weaning decreases 28 %
- Body weight of lambs till weaning decreases 1.1 kg

Small and isolated populations

3. <u>Genetic drift</u>

- a mechanism of evolution
- affects the genetic structure of the population through an entirely random process



before

8 RR → 0,50 R

8 rr → 0,50 r

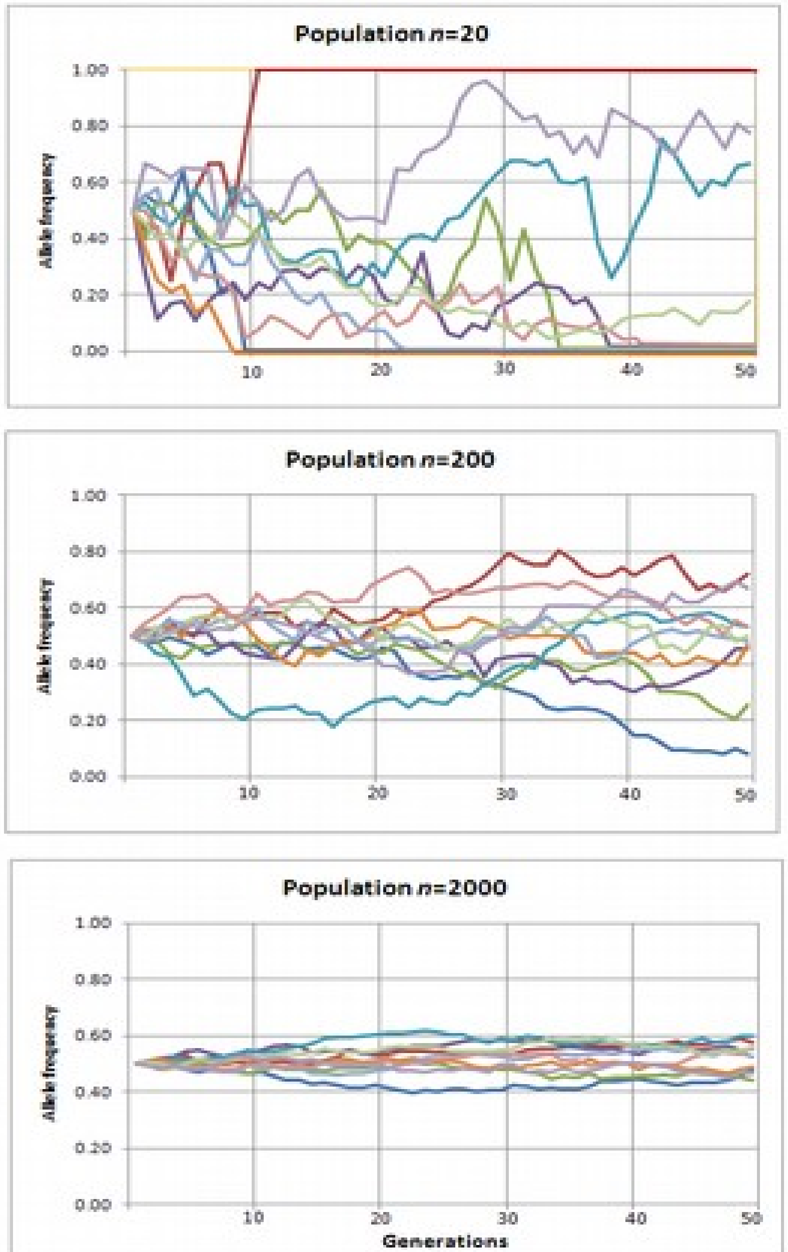
after

2 RR → 0,25 R

6 rr → 0,75 r

Small and isolated populations

3. Genetic drift



Consequences:

- Increase of homozygosity
- Some alleles are lost and others are fixed
- Among populations greater genetic differentiation
- Within populations greater homogeneity

Small and isolated populations

4. Consequences of Inbreeding & genetic drift

- Change the genetic structure of the population
- Genetic variability declines
- Smaller the size, sharper action
- Reduction of animals fitness and lower productivity
- Increased risk of extinction in future

Small and isolated populations

5. Estimation of Inbreeding (i)

Inbreeding coefficient F

- F_x = the probability that the individual X brings alleles identical by descent, exact copies of an ancestral allele
- Genealogical data - reference to the common ancestor
- F between 0 and 1

Small populations (rare breeds)

5. Estimation of Inbreeding (ii)

$$F_X = \sum \left(\frac{1}{2}\right)^n \left(1 + F_{A_i}\right)$$

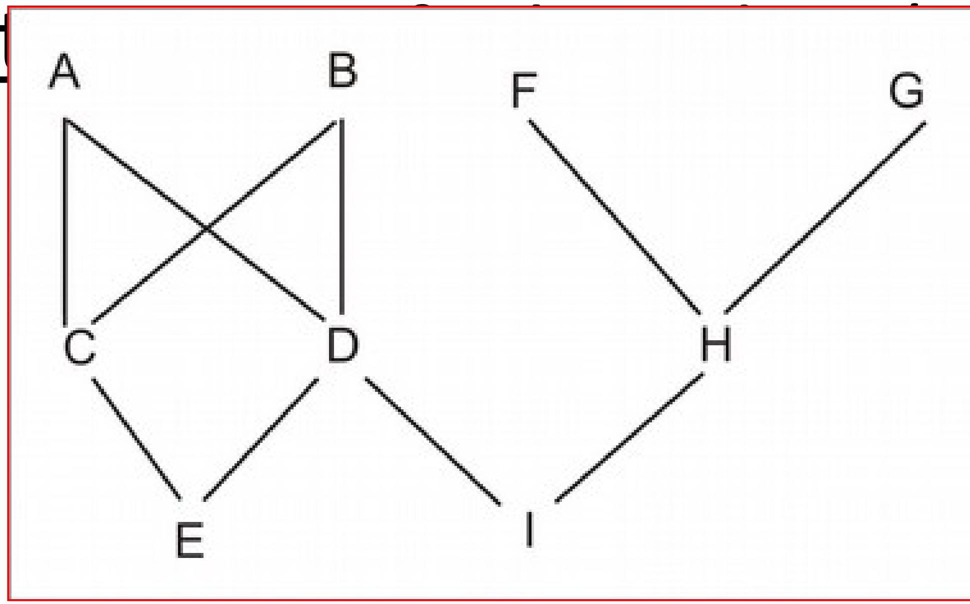
where:

n = the number of individuals in each route that connects parents with a common ancestor (measured parents, common ancestor of every person within the route)

$F_{A(i)}$ = coefficient of inbreeding i of the common ancestor

Small populations (rare breeds)

5. Est … i)



$$F_E = pathEC\overline{A}DE : \left(\frac{1}{2}\right)^3 (1+F_A) + pathEC\overline{B}DE : \left(\frac{1}{1}\right)^3 (1+F_B)$$

$$F_E = \left(\frac{1}{2}\right)^3 + \left(\frac{1}{2}\right)^3 = \frac{2}{8} = 0.25$$

$$F_I = 0$$

individual E is inbred (the parents C & D are full-sibs)

Individual I is not inbred (the parents D & H are not relatives)

Small and isolated populations

5. Estimation of Inbreeding (iv)

Relationship between parents	F *
Full - sibs	25 %
Parent - offspring	25 %
Half - sibs	12.5 %
2 common grandparents	6.25 %
1 common grandparent	3.13 %

* : F of the common ancestor =0

Small and isolated populations
6. Inbreeding and effective size Ne (i)

- Effective size N_e << actual size N
- Effective size N_e: is the part of population which gives the gametes in the next generation

$$N_e = \frac{4 \times Males \times Females}{Males + Females}$$

&

$$\Delta F = \frac{1}{2N_e}$$

- Goal: Ne as large as possible

Small and isolated populations

6. Inbreeding and effective size Ne (ii)

Example: Estimation of effective size Ne

In a herd with 5 bulls and 100 calves

- The actual population size is N=105

$$N_e = \frac{4 \times bulls \times calves}{bulls + calves} = \frac{4 \times 5 \times 100}{5 + 100} = 19$$

- the effective size Ne is: 19

- The inbreeding rate is $\Delta F = \frac{1}{2N_e} = \frac{1}{2 \times 19} = 2.6\%$

Small and isolated populations

6. Inbreeding and effective size Ne (iii)

Sex proportion and Ne in a population of fixed size (N=100)				
females	**males**	**N**	**Ne**	**ΔF (%)**
50	**50**	**100**	**100**	**0.5**
90	**10**	**100**	**36**	**1.4**
95	**5**	**100**	**19**	**2.6**
99	**1**	**100**	**4**	**12.5**

As the number of males from the number of females deviates from 50:50 proportion, the effective size Ne reduces and the inbreeding rate ΔF becomes higher.

Small and isolated populations

6. Inbreeding and effective size Ne (iv)

- **Changes in the size of population**
  - **Diseases**
  - **weather conditions**
  - **special financial needs of farmers etc..**
  - **Variations in the family size (the farmer keep different numbers of offspring from every family)**

→ **increase of inbreeding rate (ΔF)**

- **Ne : the harmonic mean of the values of several Ne.**

Small and isolated populations

6. Inbreeding and effective size Ne (v)

Population	generations				
	1	2	3	mean Ne	F (%)
1	100	50	100	75	0.67
2	100	20	100	43	1.2
3	100	10	100	25	12.5

population bottleneck :

- effective size Ne
- additive genetic variance
- heterozygosity

} decrease

- inbreeding depression increases

Small and isolated populations

6. Inbreeding and effective size Ne (vi)

Family size

- The variance of families' size high,→ the smaller the effective size Ne with respect to the actual size N and ΔF increases.
- The variance of families' size small,→ the effective size Ne is higher for a given size N and ΔF decreases.

Small and isolated populations

6. Inbreeding and genetic gain

- Selection of few animals → high genetic gain BUT low effective size Ne & high inbreeding rate F
- Selection of many animals → low genetic gain BUT high effective size Ne & low inbreeding rate F

Measures and good practices

1. Minimize inbreeding (i)

What is the value of Inbreeding rate ΔF for appearance of inbreeding depression?

If ΔF=1% ewe's fertility is reduced to 1.4%

If this F value is a limit for 10 generations (approx. 35 years) then ΔF= 0.01/10=0.001

$$\Delta F = \frac{1}{2N_e}$$

$$N_e = \frac{1}{2\Delta F} = \frac{1}{2 \times 0.001} = 500$$

Measures and good practices

1. Minimize inbreeding (ii)

preserving ΔF under 1%, 5% and 10% for a specific number of generations			
generation	Ne		
	F=1%	F=5%	F=10%
1	50	10	5
2	100	20	10
3	150	30	15
4	200	40	20
5	250	50	25
6	300	60	30
7	350	70	35
8	400	80	40
9	450	90	45
10	500	100	50

Measures and good practices

2. Maximize effective size Ne (i)

The maximum effective size Ne ensures a lower inbreeding rate ΔF

females	males	N	Ne	ΔF (%)
50	50	100	100	0.5
80	20	100	64	0.8
90	10	100	36	1.4
95	5	100	19	2.6
99	1	100	4	12.5

Measures and good practices

2. Maximize effective size Ne (ii)

Ne values for the conservation of an allele with 5% propability in a small population relative to frequency q		
generations	frequency of rare allele	
	q=0.05	q=0.01
1	30	150
5	45	229
10	52	263
15	56	283
20	59	297
25	61	308

Measures and good practices

3. What to do (i)

- Keep pedigree data
- avoid mating between relatives
- avoid buying animals which are relatives
- don’t mate the males with their daughters
- avoid to substitute a male with its son or a very close relative

Measures and good practices

3. What to do (ii)

- number of used males as greater as possible
- keep stable number of offspring from each family
- Keep stable size of the herd from generation to generation
- signs of inbreeding ? assisted migration, gene flow then use males from another flock (rotating male schemes)
  - hybridization of two small & isolated populations
- inbred animals should be mated with unrelated animals

Managing small and isolated populations - Summary

- Inbreeding F
- Genetic drift
- Effective size Ne
  - Sex ratio
  - Family size
  - fluctuations across generations
- Genetic structure for genes controlling many traits
- Deviations from equilibrium
- Tools from automated molecular methods many polymorphic loci

Thank you!