Genetic management without pedigree: effectiveness of a breeding circle in a rare sheep breed

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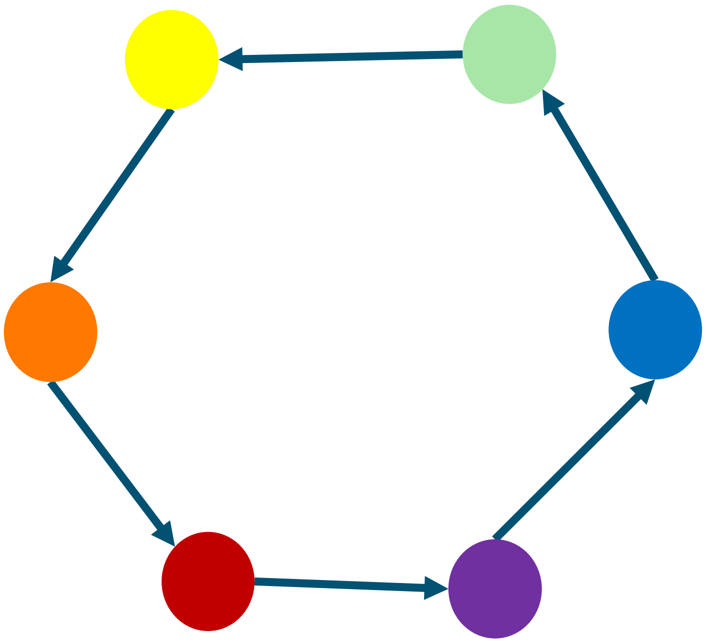
Rare breeds

- Numerically small (especially males)
  - High inbreeding rate
  - Loss of genetic diversity
  - Inbreeding depression and genetic defects
- Genetic management needed
  - Pedigree: management of relatedness and inbreeding
  - No pedigree: breeding circle

Breeding circle

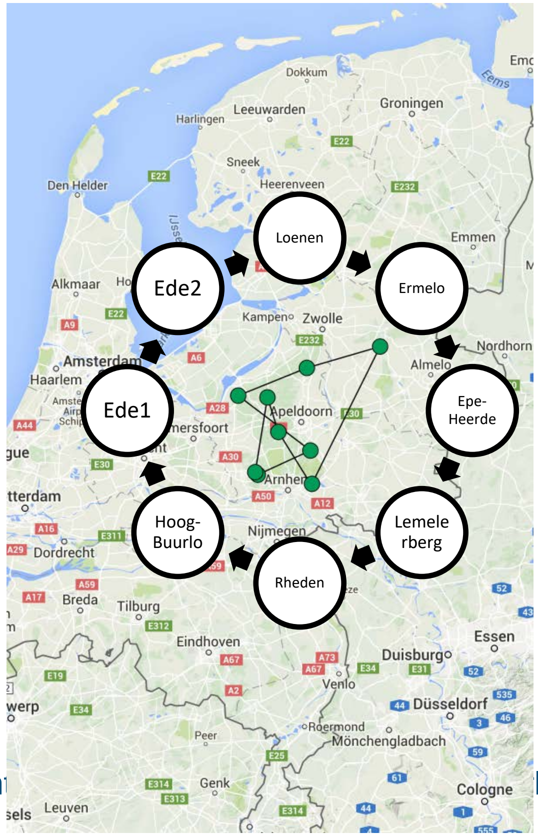
- Each herd receives rams from the previous herd in the circle
- Each herd provides rams to the next herd in the circle
- Ewes stay in own herd
- Pattern remains the same over the years
- Relatively simple
- Theoretically effective in reducing inbreeding rates
- Practically effectiveness not tested



Veluws Heideschaap

- Rare sheep breed
- Dates back to middle ages
- 8 large herds remain
- Used for heath conservation
- Inbreeding problems before
- Breeding circle since 1980’s

Unique case to test effectiveness of breeding circle in practice



Aim of study

- How effective is the breeding circle in the "Veluws Heideschaap"?
  - Mathematical
  - Computer simulation
  - DNA analysis

Mathematical

Based on Nomura and Yonezawa (1996)
GSE 28:141

- Keep track of average kinship (f) within and between herds
- f between herds depends on kinship between parental herds in previous generation

$$f_{x,y(t)} = \frac{1}{4}\left(f_{x,y} + f_{x,y-1} + f_{x-1,y} + f_{x-1,y-1}\right)_{t-1}$$

- f within herds on effective population size + kinship between parental herds

$$\frac{1}{N_e} = \frac{1}{4n_m} + \frac{1}{4n_f}$$

$$f_{x(t)} = \frac{1}{N_{e,x}}\left(1 - F_{x(t-1)}\right) + \left(\frac{1}{2}\right) f_{x(t-1)} + \frac{1}{2} f_{x,x-1(t-1)}$$

- F on kinship in parental herds

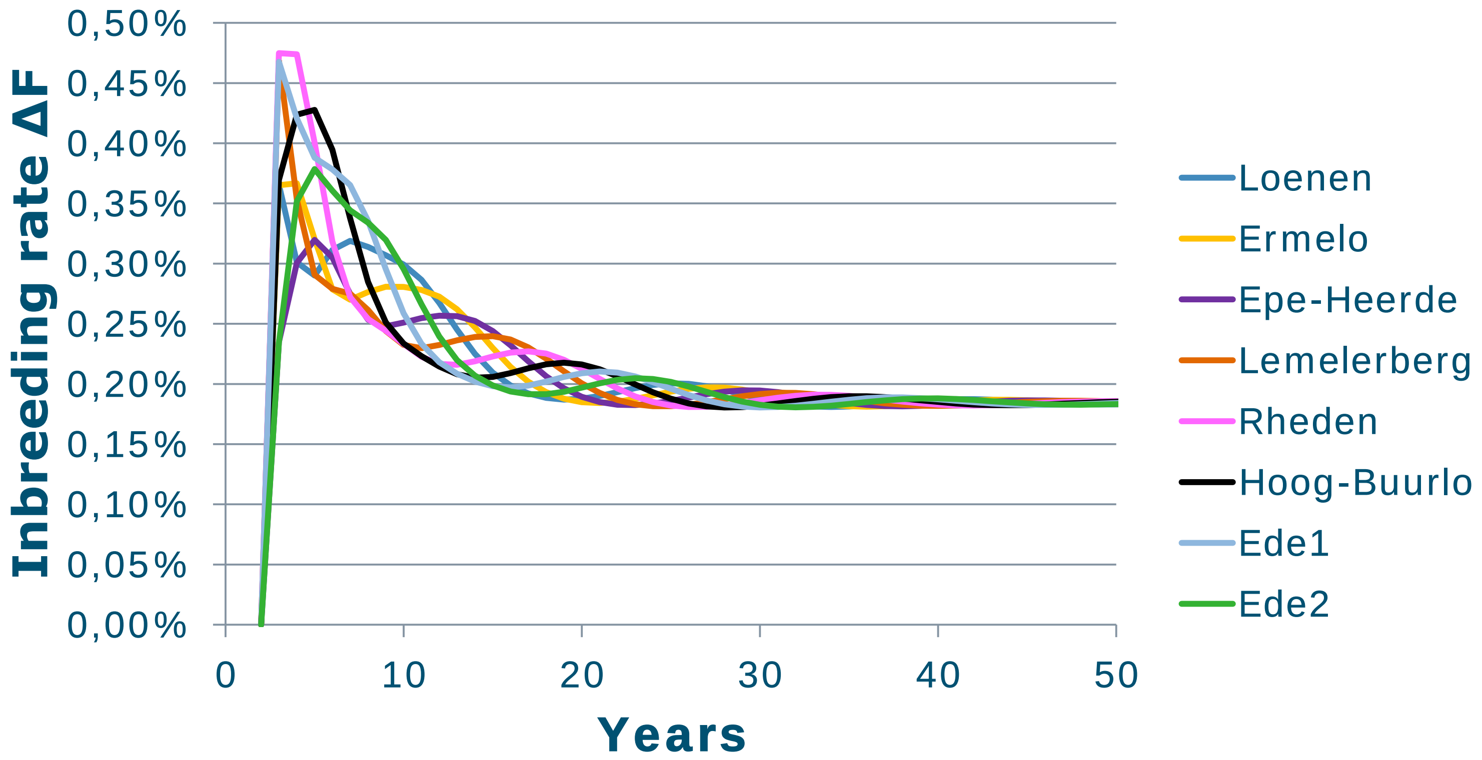
$$F_{x(t)} = f_{x,x-1(t-1)}$$

Mathematical 2

- Kinship matrix in excel based on formulas
- For 8 herds with herd sizes equal to Veluws Heideschaap in 2015
- Inbreeding rates calculated from inbreeding levels

Herd	Nm	Nf	Ne	ΔF
Loenen	9	175	34	1.47%
Ermelo	14	271	53	0.94%
Epe-Heerde	7	141	27	1.85%
Lemelerberg	7	110	26	1.92%
Rheden	9	140	34	1.47%
Hoog Buurlo	7	147	27	1.85%
Ede I	14	279	53	0.94%
Ede II	9	170	34	1.47%
total	76	1433	289	0.17%

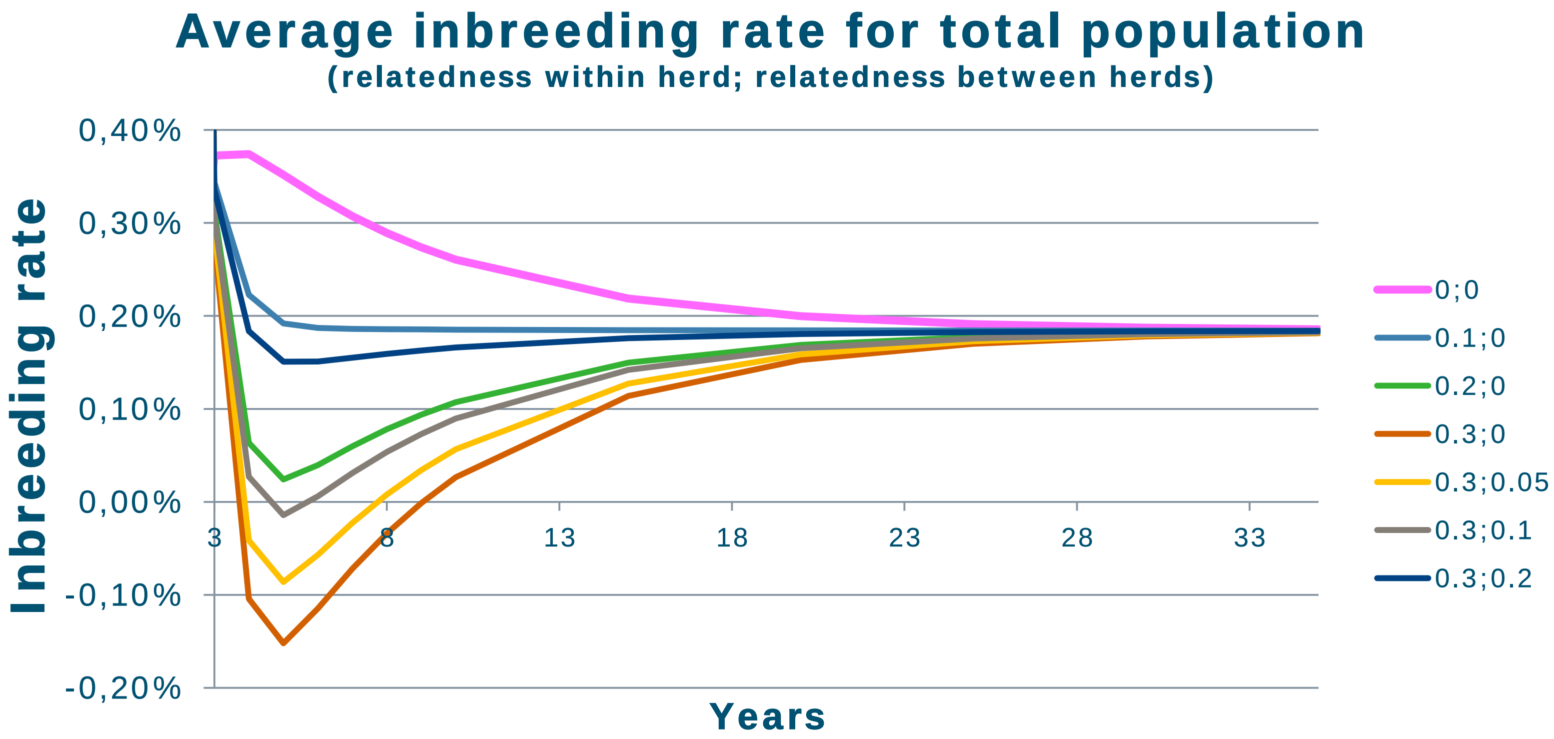
Result Mathematical inbreeding rates



- Initially divergent inbreeding rates between herds up to 0.47%
- After 40 years all rates 0.18%

Very effective!

Result Mathematical inbreeding rates



- Initially decrease in inbreeding rates
- After 30 years all rates 0.18%

Computer simulation

- Simulation tool that calculates inbreeding (Windig & Oldenbroek, 2015)
- Takes into account overlapping generations and variation due to chance
- Input
  - Population structure (population size, number of herds, number of sires and dams, litter size, age breeding animals, exchange of rams between herds etc.)
- Rams 1 year old, Ewes up to 6 years
- 25 runs, 100 years
- Output: Inbreeding level and rate

Results Computer simulation

	ΔF	Min.	Max.
Mathematical	0.18%		
Simulation	0.10%	0.09%	0.12%
Ewes 2 year	0.15%	0.013%	0.16%
No overlapping generations	0.17%	0.16%	0.19%

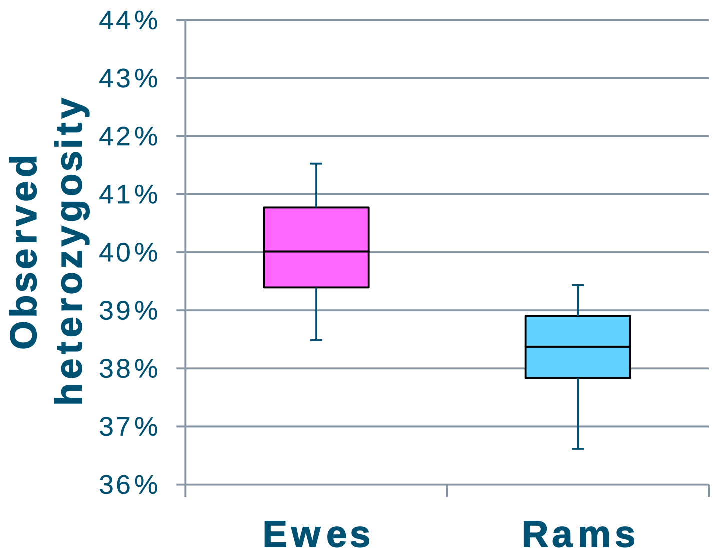
- Use of older ewes reduces inbreeding rate
- Computer simulations and mathematical calculations agree

Very effective!

Real inbreeding rates: DNA analysis

- 12 DNA samples per herd, 8 herds
  - Rams 1 year old
  - Ewes 6 years old
- 10k SNP-chip
- DNA edit: 96 samples → 90 samples
  12,785 SNPS → 11,432 SNPs
- Level of heterozygosity → inbreeding rate per generation
  - $\Delta F = \left(1 - \frac{H(t)}{H(t-x)}^{1/x}\right) * L$; $\Delta F = \left(1 - \frac{H(rams)}{H(ewes)}^{1/6}\right) * L$

Results – DNA analysis



- ANOVA:
  - Significant difference between sexes
  - No significant difference between herds
- Estimated ΔF
  - 1.35%

Not effective!

Possible reasons

- Sampling
  - Sampling simulated - ΔF: 0.07 -0.17
- Dominant rams: not all rams equal chance siring offspring
  - Simulated 2 dominant rams siring 90% offspring
  - ΔF: 0.38
- Selection
  - Strong selection on scrapie resistance in past 10 years
  - Old simulations: ΔF from 0.09 -> 0.36 with scrapie selection

Conclusions

- Theory does not always match practice
- Breeding circles theoretically effective
- High inbreeding rate in practise
- Caused by selection and dominant rams (?)

Acknowledgements
Rare breeds trust
Myrthe Maurice
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SZH VOOR LEVEND ERFGOED

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