CLASSIFICATION SYSTEMS AND INDICATORS TO EVALUATE BREED ENDANGEREMENT LEVEL – A CRITICAL REVIEW

Nina Sæther

NORWEGIAN UNIVERSITY OF LIFE SCIENCES MDCCCLIX

OUTLINE

- Introduction
  - Brief outline of different classification systems for evaluating breed endangerment level
- Today's risk status for animal genetic resources
- Seven examples of classification systems and their criteria for breed endangerment level
- The importance of genetic variation and self sustainability
- An attempt to harmonize the indicators
- Concluding remarks

Historical classification systems for evaluating the endangerment of farm animal breeds

Presented and reviewed by Gandini et al. (2004)

- European Union (Avon, 1992)
- The EEAP Genetic Data Bank (Simon & Buchenauer, 1993)
- FAO, the World Watch List for Domestic Animal Diversity (Lotus & Scherf, 1993)

Conclusion:

Incomparable systems ☹

Policy classification systems

- Guidelines for defining criteria for endangered and/or native breeds
- Based on the classification systems from the 1990s.

Examples:

- Governmental organisations

  EU FAO

- Non Governmental Organisations (NGO) i.a.
  - Rare Breeds Survival Trust (UK)
  - American Livestock Breeds Conservancy

- National classification systems, i.a.

  Denmark Slovenia Greece

  Norway Germany UK

More recent scientific studies on classification systems

- A Framework for Prioritizing Domestic Animal Breeds for Conservation Purpose at the National Level: a Norwegian Case Study (Ruane, 2000)
- An approach to the optimal allocation of conservation funds to minimize loss of genetic diversity between livestock breeds (Simianer et al., 2003)
- Domestic animal diversity conservation: a case study of rural development plans in the European Union. (Signorello & Pappalardo, 2003) (analysing the effect of EU's Rural Development Plans on endangered breeds)
- Criteria for the recognition and prioritisation of breeds of special genetic importance (Alderson, 2003)

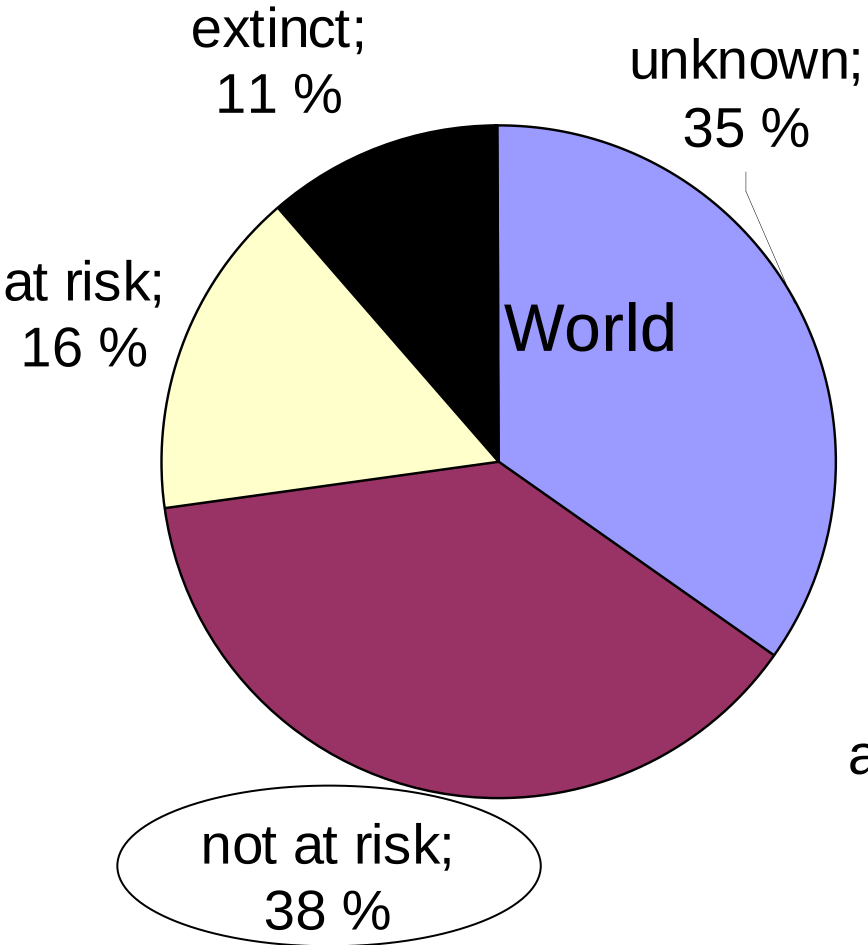
Harmonization is needed! (Gandini et al., 2004, Alderson, 2009)

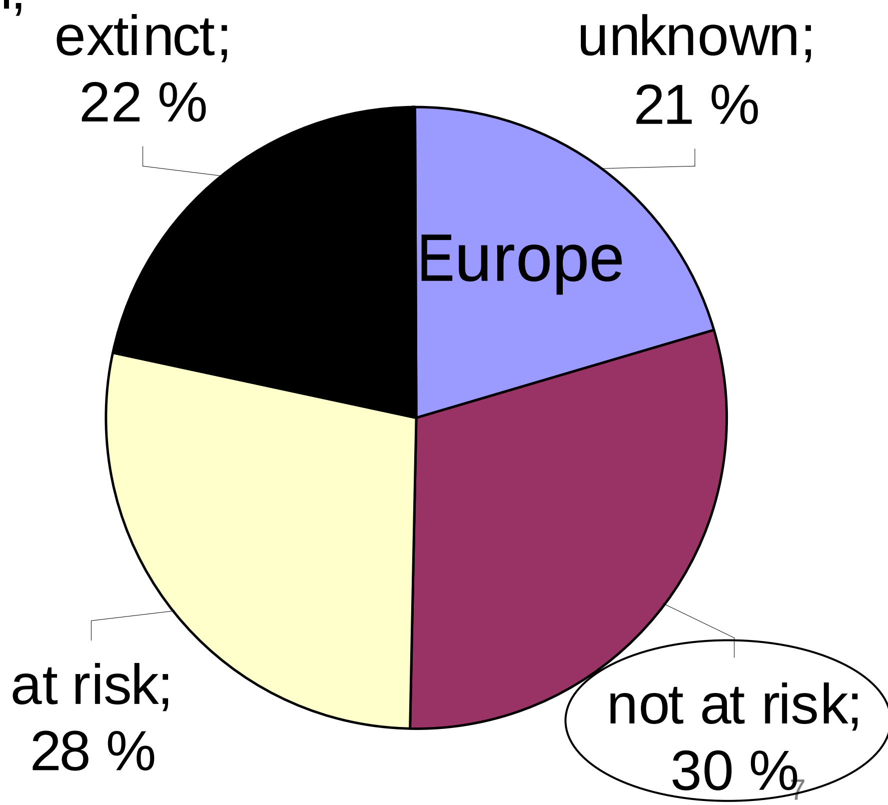
OUTLINE

- Introduction
  - Brief outline of different classification systems for evaluating breed endangerment level
- **Today's risk status for animal genetic resources**
- Seven examples of classification systems and their criteria for breed endangerment level
- The importance of genetic variation and self sustainability
- An attempt to harmonize the indicators
- Concluding remarks

RISK STATUS FOR MAMMALIAN BREEDS

Only 30-40 % of the breeds are not at risk

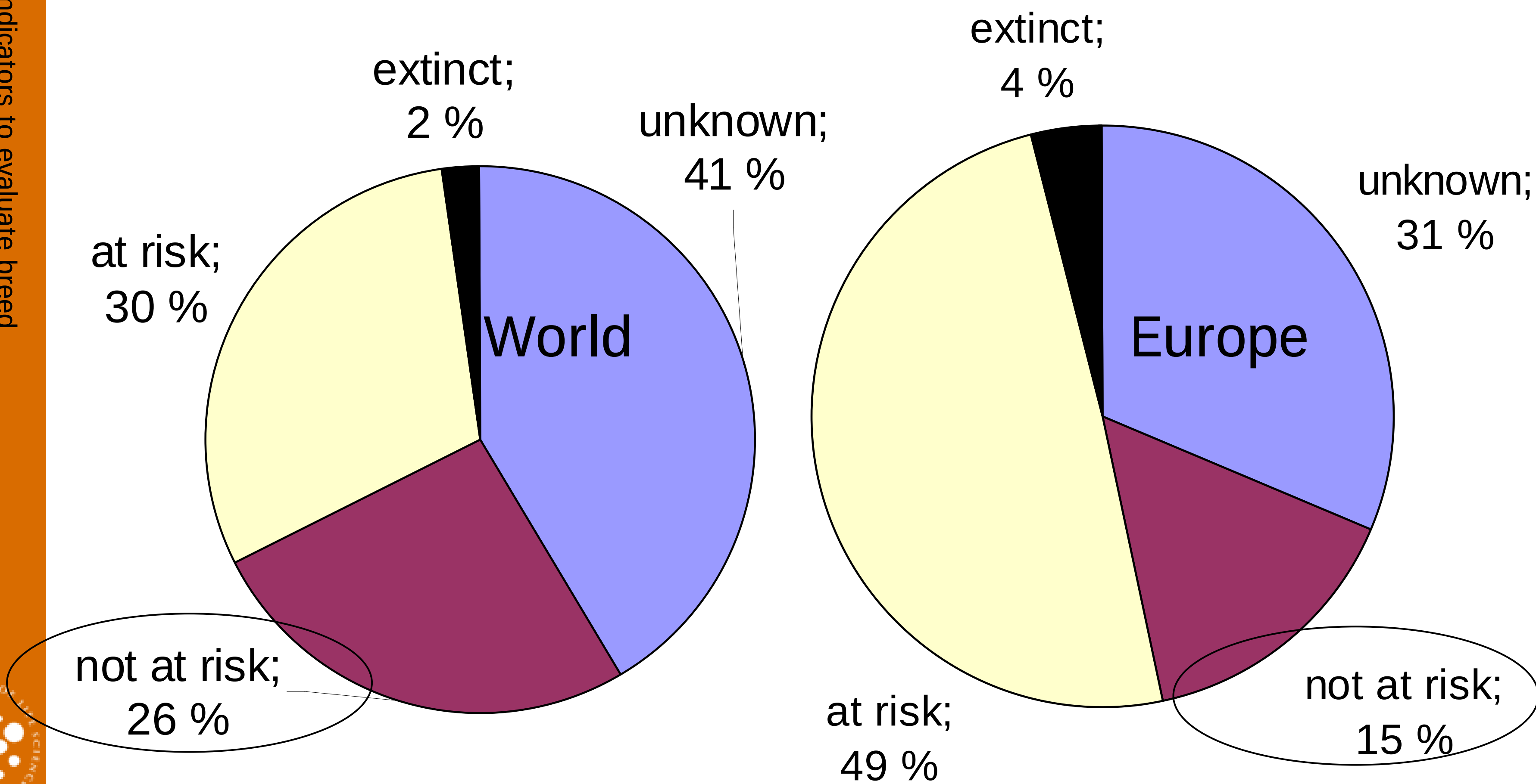




FAO 2007

RISK STATUS FOR AVIAN BREEDS

Only 15-26 % of the breeds are not at risk!



FAO 2007

The extinction of native commercial poultry breeds, Norwegian example

- 1960s:
  - 23 breeding stations for poultry with 26 different lines
- 1973
  - One national breeding program established, reduced number of breeding lines.
- 1994
  - The European Economic Area opens for import of commercial poultry to Norway.
- 1995
  - The commercial Norwegian poultry breeding closes down.
- Today:
  - All commercial egg and broiler production is based on genetic material imported from international breeding companies.

WORLD WIDE GENETIC VARIATION WITHIN POULTRY

- 74 % of the world's **egg and broiler** production is based on four breeding lines (Gura, 2007)
- Commercial White Leghorn compared to Red Jungle Fowl (Hillel et al, 2003)
  - 50 % lower gene diversity across 22 genetic markers (0.33 and 0.62, respectively)
  - 55 % fewer alleles/locus (2.7 and 4.8 respectively)

The importance of breeds

Reviewed by Woolliams & Toro (2007):

"In conclusion the range of values for breed variation remains poorly documented but provide justification for the broad statement that ***breed variation accounts for approximately half of the genetic variation***."

Photo: Geno

Photo: A. Rehnberg

OUTLINE

- Introduction
  - Brief outline of different classification systems for evaluating breed endangerment level
- Today's risk status for animal genetic resources
- **Seven examples of classification systems and their criteria for breed endangerment level**
- The importance of genetic variation and self sustainability
- An attempt to harmonize the indicators
- Concluding remarks

Seven examples of classification systems 1

- Governmental organisations
  - FAO
  - EU
- Non Governmental Organisation
  - American Livestock Breeds Conservancy
- National classification systems
  - Begemann 2009 (Germany)
- Published scientific studies
  - Ruane (2000)
  - Gandini et al (2004)
  - Alderson (2009)

FAO's classification system from 1999

Food and Agriculture Organization of the United Nations' (FAO)

Used as

- Guidelines for nations
- Criteria for reporting to FAO

	Breeding females	Breeding males	Population size	Percent pure breeding females
Extinct	0	0	0	0
Critical	< 100	< 5	100	80
Endangered	100-1000	< 20	1 000	80
Critical-maintained	Active conservation programme			
Not at risk	> 1 000	>20	> 1 000	100

EU's classification system for incentives

- Incentive criteria
  - Population defined as breeding females
  - Threshold vary between species

Species	*Thresholds under which a local breed is considered as being in danger of being lost to farming*
Cattle	7 500
Sheep	10 000
Goat	10 000
Horses	5 000
Pigs	15 000
Poultry	25 000

Seven examples of classification systems 4

- Governmental organisations
  - FAO
  - EU
- Non Governmental Organisation
  - American Livestock Breeds Conservancy
- National classification systems
  - Begemann 2009 (Germany)
- Published scientific studies
  - Ruane (2000)
  - Gandini et al (2004)
  - Alderson (2009)

American Livestock Breeds Conservancy (ALBC)

An NGO working to protect breeds of livestock and poultry from extinction

Criteria to population sizes to be a breed prioritized by the ALBC:

	Registrations in the US	Estimated global population
Critical	< 50	< 500
Threatened	< 100	< 1 000
Watch	< 200	< 2 000 “or have a limited geographical distribution”

Begemann 2009 (Germany)

- *Country-based early warning and response system in Germany*
- Political instrument for national actions for breeds at risk of extinction
- Numerical criteria, N_e, *effective population size*

Risk status classification system based on risk status categories:

	N_e
Phenotypic Conservation Population	50
Conservation population	< 200
Monitoring population	200 - 1 000
Non-Endangered Population	> 1 000

Seven examples of classification systems

- Governmental organisations
  - FAO
  - EU
- Non Governmental Organisation
  - American Livestock Breeds Conservancy
- National classification systems
  - Begemann 2009 (Germany)
- Published scientific studies
  - Ruane (2000)
  - Gandini et al (2004)
  - Alderson (2009)

Ruane (2000)

Presents and discusses six different criteria

Table 1. **Comparison of domestic-animal genetic resources in Norway according to criteria that could be used to prioritize breeds for conservation.**

Species and breed	*Degree of endangerment*[a]	*Traits of current economic value*[b]	*Special landscape value*[b]	*Traits of current scientific value*[b]	*Cultural-historical value*[a]	*Genetic uniqueness within species*[c]
Cattle (*Bos taurus*)						
Norsk rødt fe	VL	Y	Y	Y	MD	L
Telemarksfe	H	N	Y	N	H	?
Sidet trønderfe og nordlandsfe	MD	N	Y	N	H	?
Dølefe	VH	N	Y	N	MD	?
Østlandsrødkolle	VH	N	Y	N	L	L
Vestlandsk raudkolle	H	N	Y	N	MD	?
Vestlandsk fjordfe	H	N	Y	N	MD	?
Sheep (*Ovis aries*)						
Dala	VL	Y	Y	N	L	L
Steigar	VL	Y	Y	N	L	L

- Three genetic criteria and three use value criteria
- No distinct ranking between or within the different criteria
- Conclusion:

“Breed prioritization involves applying ***subjective measurements*** *to a range of widely different criteria.”*

Gandini et al., 2004

- et al = members of The European Federation of Animal Science (EAAP) Working Group on Animal Genetic Resources
- Stresses the need for harmonizing classification systems.
- Analyses different criteria, i.a.
  - Population growth rate (based on breeding females)
  - Rate of inbreeding
  - Self-sustainability – In-situ conservation in practise!
    - *"...preventing the loss of self-sustainability can be much more effective and less costly than therapy..."*
- Conclusion
  - *"course of the paper is to introduce uniformity among European classification systems"*

Alderson 2009

- Bases for the 2009 Watchlist categories for Rare Breeds Survival Trust (NGO), United Kingdom
- "need to harmonise and implement an agreed classification system"

Category	Numerical	Geographical	Inbreeding
	Breeding females[a]	Concentration[b], km^2	Predicted in 25 yrs
Critical	100 - 300	12.5	30
Endangered	165 - 500	15	25
Vulnerable	300 - 900	17.5	20
At risk	500 - 1 500	20	15
Transitional	1 000 - 3 000	25	10

[a] breeding females, [b] area containing 75 % of the population

Presents distinct classification system! ☺

Seven examples of classification systems

- Governmental organisations
  - FAO
  - EU
- Non Governmental Organisation
  - American Livestock Breeds Conservancy
- National classification systems
  - Begemann 2009 (Germany)
- Published scientific studies
  - Ruane (2000)
  - Gandini et al (2004)
  - Alderson (2009)

Extracting the indicators from the seven examples of classifications systems

Indicators on genetic variation

- Different varieties of population sizes (all)
- Rate of inbreeding (Gandini et al 2004)
- Level of inbreeding (Alderson 2009)
- Genetic uniqueness within species (Ruane 2000)

Indicators on self sustainability

- Traits of current economic value (Ruane 2000)
- Special landscape value (Ruane 2000)
- Cultural-historical value (Ruane 2000)
- Self sustainability (Gandini et al 2004)
- Geographical distribution (Alderson 2004)

OUTLINE

- Introduction
  – Brief outline of different classification systems for evaluating breed endangerment level
- Today's risk status for animal genetic resources
- Seven examples of classification systems and their criteria for breed endangerment level
- **The importance of genetic variation and self sustainability**
- An attempt to harmonize the indicators
- Concluding remarks

The importance of genetic variation

- Genetic variation is the bases for all selection
- High genetic variation is crucial
  - increasing the potential to respond to selection
    - Present selection as well as future selection
    - Man-made selection as well as natural selection
  - avoidance of inbreeding depression

Inbreeding depression

- reduced fitness due to inbreeding
- associated with high rate of inbreeding (*△F)*
- Rate of inbreeding is connected

  to effective population size by $\triangle F = ½(N_e)$

Examples on effect of inbreeding depression on production traits:

per 10 % increase of △F

- Milk yield, cattle: 135 kg
- Fleece and body weight at 1 yr, sheep: 0.29 kg & 1.32 kg, resp.

Inbreeding

- Inbreeding
  - is the mating of two individuals that are related to each other by ancestry
  - increases homozygosity – ***decreases genetic variation***
  - occurs more frequently in a small population than in a large population

What gives a large effective population size

- Random mating
- 1:1 sex ratio
- No variation of family size
- Discrete generations

What is typical in a breeding population

- Selected mating
- Males have more offspring
- Variation in family size (The best selected animals get more offspring)
- Overlapping generations

Typical breeding populations get often small effective population sizes

How small can the effective population size be without losing too much genetic variation???

- 50-100 (Meuwissen & Wooliams, 1994)
- 50 (Wooliams et al., 2005)
- 100 (Meuwissen, 2009)

So low numbers should not be a problem for large commercial breeds?

EFFECTIVE POPULATION SIZE, N_e, INTERNATIONAL DAIRY CATTLE POPULATIONS

Breed	*Year*	N_e
[1]US Holstein	2001	39
[1]US Ayrshire	2001	161
[1]US Jersey	2001	30
[2]Danish Holstein	1983-1992	68
[2]Danish Holstein	1993-20031	49
[2]Danish Jersey	1977-1991	87
[2]Danish Jersey	1993-2003	53
[2]Red Danish (RDM)	1977-1998	157
[2]Red Danish (RDM)	2001-2003	47
[3]Norwegian Red (NRF)	2005	167
[4]NRF	2007	208

[1]Weigel 2001
[2]Sørensen et al 2005
[3]Sehested 2005
[4]Sehested 2007

Other measures of effective population size, N_e

- Allelic variation
  - Genetic markers
    - often neutral to production traits
    - how relevant are neutral markers for genetic variation in production traits? (Ruane 1999)

PROTEIN ALLELE FREQUENCIES (Lien et al 1999)

Protein/Breed	Døla	Fjord	Tele	WRP	ERP	STN	NRF
α_{s1} –casein							
B	1,0	0,7	1,0	1,0	0,9	0,9	0,9
C	0,0	0,3	0,0	0,0	0,1	0,1	0,1
β–χasein							
A1	0,4	0,3	0,7	0,4	0,4	0,3	0,5
A2	0,6	0,7	0,3	0,6	0,6	0,6*	0,5
κ–casein							
A	0,8	0,6	0,7	0,6	0,8	0,7	0,8
B	0,2	0,4	0,3	0,4	0,2	0,3	0,1*
β–lactalbumin							
A	0,4	0,2	0,1	0,5	0,4	0,3	0,3
B	0,6	0,8	0,9	0,5	0,6	0,7	0,8

Other measures of effective population size, Ne

- Allelic variation
  - Genetic markers
    - often neutral to production traits
    - how relevant are neutral markers for genetic variation in production traits? (Ruane 1999)

Example:

- High-density single nucleotide polymorphism (SNP) chip genotyping
  - New and advanced genotyping technique
  - Could be used for (Meuwissen, 2009)
    - *"Estimating relationship more accurate than pedigree-based estimates of relationship"*
    - *"estimates relationship per chromosome segment "* = breed-fingerprint

The indicators from the seven examples of classification systems

Indicators on genetic variation

- Different varieties of population size (all)
- Rate of inbreeding (Gandini et al 2004)
- Level of inbreeding (Alderson 2009)
- Genetic uniqueness within species (Ruane 2000)

Indicators on self sustainability

- Traits of current economic value (Ruane 2000)
- Special landscape value (Ruane 2000)
- Cultural-historical value (Ruane 2000)
- Self sustainability (Gandini et al 2004)
- Geographical distribution (Alderson 2004)

GEOGRAPHICAL DISTRIBUTION OF IMPORTANCE FOR

- Outbreaks of epidemic diseases
  - Mass culling or death from the disease
    - Foot and Mouth Disease in UK
      - 1967 Blue Albion extinct (Alderson 2009)
      - 2001 no breeds extinct (Alderson 2009)

- Extreme environments:
  - Local adaptation; sheep and goats eating seaweeds

Compensations

- Disperse geographical distribution
- Cryopreservation (frozen semen/embryos)

Indicators on self sustainability

- Traits of current economic value (Ruane 2000)
- Special landscape value (Ruane 2000)
- Cultural-historical value (Ruane 2000)
- Self sustainability (Gandini et al 2004)

Important indicators but generally poorly defined and ranked

Concluding remark on the presented classification systems

Gandini and his colleagues, 2004

"Incomparable systems!"

Still – is it possible to harmonize them?

OUTLINE

- Introduction
  - Brief outline of different classification systems for evaluating breed endangerment level
- Today's risk status for animal genetic resources
- Seven examples of classification systems and their criteria for breed endangerment level
- The importance of genetic variation and self sustainability
- **An attempt to harmonize the indicators**
- Concluding remarks

An attempt to harmonize the indicators

Indicators on genetic variation

- Different varieties of population size (all)
- Rate of inbreeding (Gandini et al 2004)
- Level of inbreeding (Alderson 2009)
- Genetic uniqueness within species (Ruane 2000)

Indicators on self sustainability

- Traits of current economic value (Ruane 2000)
- Special landscape value (Ruane 2000)
- Cultural-historical value (Ruane 2000)
- Self sustainability (Gandini et al 2004)
- Geographical distribution (Alderson 2004)

Harmonizing tools by considering

- Simplify – be more general for some of the indicators.
- Base the classification system on
  - indicators that are clearly defined.
  - available data.
- If an indicator is poorly defined, could it, at least to some extent, be covered by others?
- If there is lacking documentation on and data about the indicator, is it possible to redefine it without loosing too much of the intention?

An attempt to harmonize the indicators on genetic variation

- Different varieties of population size – **use only N_e**
- Rate of inbreeding = **N_e**
- Level of inbreeding within 25 yrs **= N_e**
- Genetic uniqueness within species
  - **genetic marker studies**

An attempt to harmonize the indicators on self sustainability

- Traits of current economic value (Ruane 2000)
- Special landscape value (Ruane 2000)
- Cultural-historical value (Ruane 2000)
- Self sustainability (Gandini et al 2004)
- (Geographical distribution (Alderson 2004))

Important indicators but generally poorly defined and ranked

Defining indicators on self sustainability based on existing data

Self sustainability – indicators on making money on the breed

1. Niche production
2. Traditional production systems

- Indicator on making money on niche production
  - Volume sold by a breed branded product

- Indicator on: **in what production system** do we find the breed?
  - Link national databases for incentives/subsidies to reveal where the breed is being utilized/used.
  - Norwegian example:

PRODUCTION SYSTEMS WERE ENDANGERED BREEDS ARE FOUND, NORWEGIAN EXAMPLE

- 450 farms have endangered cattle breeds per yr (2000-2008)
  - 327 : less than half of the herd are endangered breeds (A)
  - 69 : more than half of the herd are endangered breeds (B)
  - 53 : only endangered breeds in the herd (C)

Additionally entitled for these subsidies:	Group A	Group B	Group C	National mean
Organic farming	15 %	20 %	25 %	2 %
Grazing outlying land	75 %	80 %	75 %	50 %
Milk production	90 %	80 %	40 %	85 %

WHAT TO LEARN ABOUT THE NORWEGIAN FARMING WITH NATIVE ENDANGERED CATTLE BREEDS?

- Higher frequency of organic farms than the national average
- Higher frequency of farms utilizing outlying land than the national average
- Most farms have less than 50 % of their herd with a native endangered cattle breed
- Milk production is far least important for the farms with 100 % native endangered cattle breeds
  - And these breeds are traditionally dairy breeds...?

How are the discussed self-sustainable indicators covered in the Norwegian example?

- Traits of current economic value
  - Volume sold by a breed branded product
- Special landscape value
  - Grazing outlying land is important landscape management
- Cultural-historical value
  - Grazing outlying land is part of Norway's cultural history
- Geographical distribution
  - Not covered

Summarizing the attempt to harmonize the indicators

- Indicators on genetic variation – **Focus on estimating N_e**
  - Evaluate endangerment level based on status and trends in N_e
- Indicators on self sustainability – **Create relevant indicators based on existing databases**
  - Breed and rural development subsidies/incentives
  - Turnover rate of breed branded products

OUTLINE

- Introduction
  - Brief outline of different classification systems for evaluating breed endangerment level
- Today's risk status for animal genetic resources
- Seven examples of classification systems and their criteria for breed endangerment level
- The importance of genetic variation and self sustainability
- An attempt to harmonize the indicators
- **Concluding remarks**

Concluding remarks

- All classification systems focus on maintaining genetic variation, based on population size
- Several authors ask for harmonization of the classification systems
- Indicators on self sustainability are often difficult to define and rank
- Indicators on genetic variation is easier to define and rank

- An attempt to harmonize the indicators has been presented.
- Indicators on genetic variation
  - **Focus on estimating N_e**
- Indicators on self sustainability
  - **Create relevant indicators based on existing databases**

No complete harmonization, but maybe a step closer...

Thank you!

Photo: A. Rehnberg