Promoting diversity

Priority Setting for Conservation of Animal Genetic Resources

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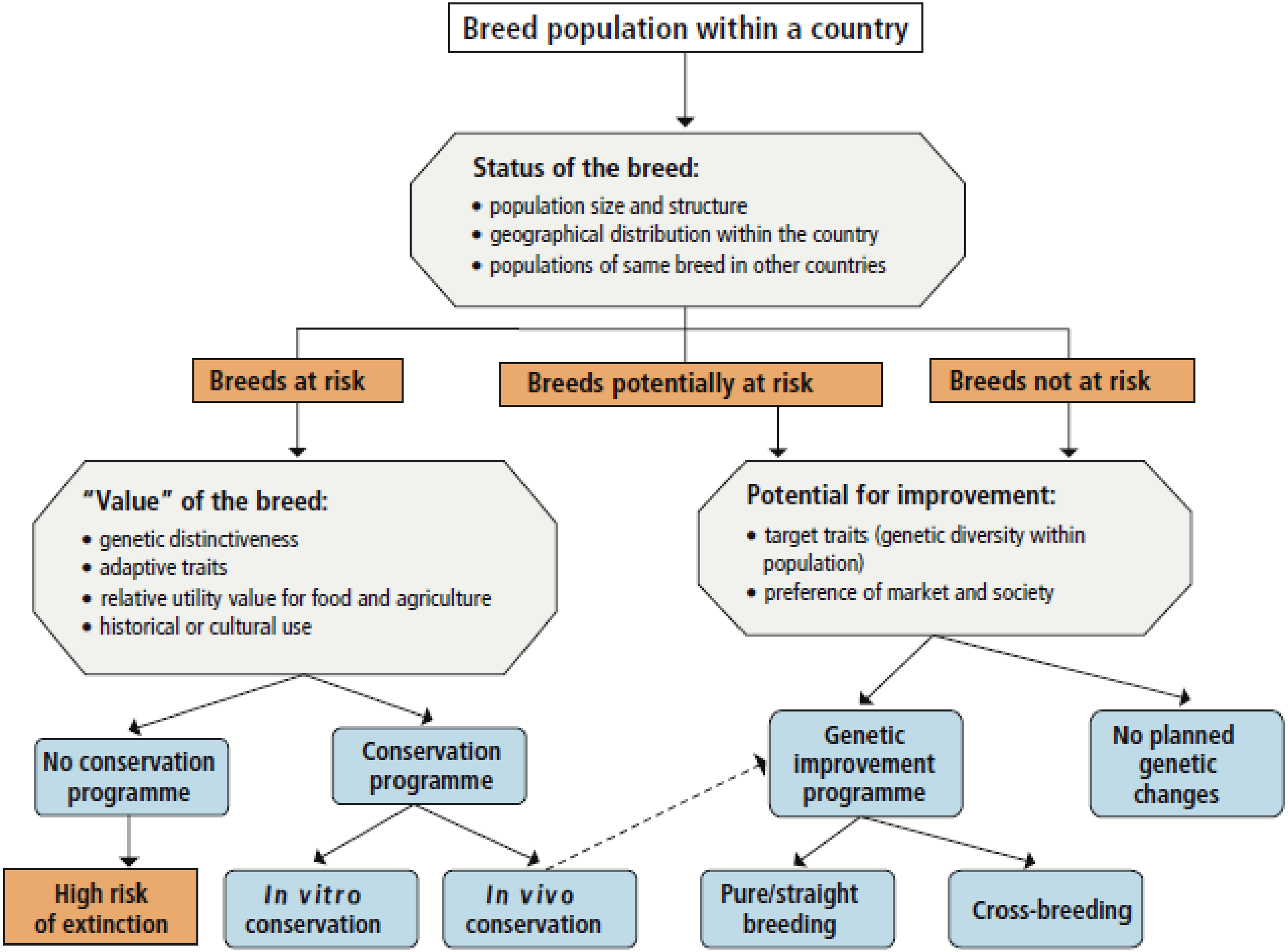
Conservation Planning

- For national management of AnGR, comprehensive planning and organization are critical
  - Ensure most valuable AnGR are maintained
  - Increase efficiency
  - Consider interests of all stakeholders
- For conservation, critical step in this process is identifying breeds at risk
  - Based on survey and monitoring

Prioritization

- Once breeds are assigned to risk classes, *prioritization* of breeds should be undertaken
- Conservation of all breeds impossible
  - Many breeds and limited financial resources
    - Food security more important in developing countries
    - Short-term economic return more important in industrialized countries
- Wholesale conservation not scientifically justified
  - Breed may have no apparent short- or long-term value
  - Breeds may be effectively the same genetically


Breed population within a country
Status of the breed:
• population size and structure
• geographical distribution within the country
• populations of same breed in other countries
Breeds at risk
Breeds potentially at risk
Breeds not at risk
"Value" of the breed:
• genetic distinctiveness
• adaptive traits
• relative utility value for food and agriculture
• historical or cultural use
Potential for improvement:
• target traits (genetic diversity within population)
• preference of market and society
No conservation programme
Conservation programme
Genetic improvement programme
No planned genetic changes
High risk of extinction
In vitro conservation
In vivo conservation
Pure/straight breeding
Cross-breeding

Factors Influencing Conservation Priority

- Risk of extinction
  - Breed Demographics
    - number and distribution
- Genetic variability (seek to maximize)
  - between and within breeds
  - molecular and quantitative genetic
- Phenotypic performance
  - genetic merit for productivity

Factors Influencing Conservation Priority

- Unique traits
  - adaptive traits
  - interaction with environment
- Historical and cultural importance
- Practical considerations
  - species and ease of conservation
  - chance for success

Risk of Extinction

- In most cases, risk of extinction has been used as the primary criterion for conservation
  - Allows for immediate action
- Sometimes, simple qualifiers are used
  - Recognized as a local breed
  - Not available in other countries
- When circumstances (time) allows, consideration of other factors may be more efficient
  - Store the most valuable resources

Accounting for Non-Demographic Factors

- *Action 1. Assign responsibilities and agree on the conservation strategy*
  - National Advisory Committee on AnGR
    - FAO Guidelines on **Preparation of National Strategies and Action Plans for Animal Genetic Resources**
      - ftp://ftp.fao.org/docrep/fao/012/i0770e/i0770e.pdf
  - Expert task force
    - Involve key stakeholders

Assessing Conservation Value

- *Action 2. Determine the factors upon which the conservation value will be based*
  - Consider conservation objectives
    - Values of importance
      - direct use and option values most common
    - Factors affecting values
  - Propose strategy (Bennewitz et al., 2007)
    - Maximum risk
      - Extinction risk only
    - Maximum diversity
      - High weight on genetic diversity
    - Maximum utility
      - Multiple factors
  - Determine relative importance of factors
    - Ranking
    - Assign weights

Assessing Conservation Value

- *Action 3. Gather the information necessary to determine the conservation value*
  - Ideally, characterization will have already been completed
    - Undertake characterization
    - Consult stakeholders
  - Productivity, uniqueness, cultural value
  - Genetic variability
    - Molecular markers
    - Pedigree
    - Population history

Assessing Conservation Value

- *Action 4. Discuss and evaluate the advantages and disadvantages of the breeds*
  - National AnGR Advisory Committee
  - SWOT analysis
- *Action 5. Rank breeds for conservation value*
  - Subjective
  - Objective

Subjective Prioritization

- Following the gathering and discussion of information needed to determine the value of breeds, priority order may be determined in a simple approach
- Voting by committee
  - Determine highest priority
  - Continue down list until all breeds are ranked
- Ranking by committee members
  - Order based on average ranking

“Objective” Prioritization: Index

- Assign each breed a value for each factor
- Each value considered should be expressed numerically
  - Breed average for quantitative traits
  - 1/0 for absence presence of special trait
  - Ranking or score for cultural value
    - ↑ value = ↑ number
- Calculate mean and SD for each factor to perform standardization
  - For quantitative traits, mean and SD are species specific
- Suggestion: calculate means and SD across risk classes but prioritize within risk class
  - Or include risk as a factor in the index

Conservation Value Index

$CV_i = w_{F1} \times (F1_i - \mu_1)/\sigma_{F1} + wF_2 \times (F2_i - \mu_{F2})/\sigma_{F2} + \ldots + w_{Fn} \times (Fn_i - \mu_{Fn})/\sigma_{Fn}$

- where, for

$$w_{F1} \times (F1_i - \mu_{F1})/\sigma_{F1}$$

  - w_{F1} = is the weight (i.e. relative importance) of Factor 1 (e.g. milk yield)
  - $F1_i$ = is the value for Factor 1 for Breed i
  - μ_{F1} = is the average of all breeds for Factor 1
  - σ_{F1} = is the standard deviation of all breeds for Factor 1

Conservation Value Index

Hypothetical: Factors considered important for conservation and data per breed

	Effective population size	Genetic uniqueness	Milk yield (kg/yr)	Cultural importance
Breed 1	60	2	1000	0
Breed 2	100	3	700	0
Breed 3	50	1	500	1
Overall mean	70	2	733.33	0.33
Standard deviation	26.46	1	251.66	0.58
Weight in index	3	1	2	1

Promoting diversity

Conservation Value Index

Two measures of genetic variability

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Measured variables

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subjective variables

Conservation Value Index

	Breed 1	Breed 2	Breed 3
Standardized values			
Effective Pop'n Size	-0.38	1.13	-0.76
Genetic uniqueness	0	1	-1
Milk yield	1.06	-0.13	-0.93
Cultural importance	-0.58	-0.58	1.15
Weighted values			
Effective Pop'n Size	-1.13	3.40	-2.27
Genetic uniqueness	0	1	-1
Milk yield	2.12	-0.26	-1.85
Cultural importance	-0.58	-0.58	1.15
Conservation value	0.41	3.56	-3.97
Rank	2	1	3

Formal Prioritization

- Various methods have been proposed to consider extinction risk, genetic diversity and possibly other factors together in prioritization
  - "Weitzman" Method (Weitzman, 1992 and 1993)
  - Reviewed by Boettcher et al. (2010)
- Yield a single numerical value as the criterion for prioritization
- Generally consider molecular-based measures of diversity
- Technically sound, but complicated
  - To now, primarily used in research

Formal Prioritization with Molecular Diversity

- Objective
  - Prioritize breeds objectively by considering all factors simultaneously
  - Use molecular data to account for genetic diversity in conservation
- Inputs
  - Conservation objectives to be addressed
  - List of breeds at risk
  - Information about factors that affect conservation value
  - Molecular genetic information
- Outputs
  - Analysis of the genetic diversity of breeds
  - List of breeds prioritized for conservation

Prioritization according to Total Utility

$$U_i = 4 \times (risk_i \times D_i) + SCV_i$$ (Simianer et al., 2003)

where,

- **U_i** is the total utility for breed *I*
  - *Criterion for prioritization*
- **4** depends on importance of conservation value
- **$risk_i$** is the risk of extinction for breed i
- **D_i** is the contribution of breed i to the overall genetic diversity of the collection of breeds
- **SCV_i** is the standardized conservation value of breed i
  - *based on conservation index*
  - *without genetic diversity factors*

Accounting for Extinction Risk

- Option 1: Prioritize within risk category and use an arbitrary constant for risk for all breeds
  - Risk becomes first criterion
  - No refinement within risk category
    - risk with 50 breeding females = risk with 100
- Option 2: Assume risk is equal within risk category and assign reasonable values to each
  - Critical $\leftarrow$ 0.50
  - Endangered $\leftarrow$ 0.25
  - Vulnerable $\leftarrow$ 0.10
- Option 3: Estimate numerically the extinction risk for each breed

Estimation of Extinction Risk

Three Options:

- Base estimates on breed status for various factors related to risk
- Predict extinction based on past data and modeling
- Estimate loss of genetic variation over time

The final two methods require past time-series data

- More difficult in developing countries

Estimating Extinction Risk (Reist-Marti et al. 2003)

- Choose factors affecting risk:
  1) population size = p
  2) change in population size = c
  3) geographic distribution = g
  4) presence of breeding programmes = b
  5) farmer satisfaction = f

Estimating Extinction Risk (Reist-Marti et al. 2003)

Establish ordered categories for each factor and assign values to breeds according to effect on risk

- p ~ population size
  - s = 0.0 if population size is $\geq$ 100,000
  - s = 0.1 if population size is between 10001 and 100 000
  - s = 0.2 if population size is between 1001 and 10000
  - s = 0.3 if population size is $<$ 1 000
- g ~ geographical distribution
  - g = 0.0 if the breed is found in locations across the country
  - g = 0.1 if animals tend to be found in a single specific area of the country

Estimating Extinction Risk (Reist-Marti et al. 2003)

- Sum values across factors to determine risk for a given breed

$$risk_i = p_i + c_i + g_i + b_i + f_i + 0.05$$

- Values should be chosen to not exceed 1.00
- 0.05 is to ensure non-zero results

Genetic Diversity

- Different countries may have different objectives for maintenance of genetic diversity
  - Maintain distinct breeds
    - Emphasize distinctiveness
      - Preserve allelic combinations
  - Conserve specific alleles
    - Avoid loss of rare variants
  - Capture maximum diversity
    - Emphasize within-breed genetic variation

Genetic Diversity

- Optimal method to measure diversity will depend on the objective
  - Maintain distinct breeds → genetic distance
  - Conserve specific alleles → allelic diversity
  - Capture maximum diversity → kinships
- Decision can be simplified as a trade-off between within- and across-breed diversity
- In most cases, an intermediate method may be the best choice
  - Piyasatian and Kinghorn (2003) – 5 to 1 ratio
  - Bennewitz and Meuwissen (2005) – 2 to 1 ratio

Genetic Diversity

- "Maximum-Variance-Total" approach to diversity
- Calculate marker-based kinship → matrix **K**
- vector (c) of contributions to a "core set"

$$\mathbf{c} = \frac{1}{4}\left(\mathbf{K}^{-1}\mathbf{F} - \frac{\mathbf{1}'_N\mathbf{K}^{-1}\mathbf{F} - 4}{\mathbf{1}'_N\mathbf{K}^{-1}\mathbf{1}_N} \cdot \mathbf{K}^{-1}\mathbf{1}_N\right)$$

(Bennewitz and Meuwissen 2005)

Four-Breed Example

$$c = [\ 0.58 \quad 0.13 \quad 0.00 \quad 0.29\ ]$$

- Breed 1 is the most important for genetic diversity
- Breed 3 is not important
  - given that 1, 2 and 4 are present
- In the total utility equation, insert c_i as D_i
  - e.g. for breed 1, $c_1 = D_1 = 0.58$

Assign Conservation Value

- Use Conservation Value Index described earlier
- Standardize to fall between 0.1 and 0.9

$$SCV_i = 0.1 + [0.8 * (CV_i - CV_{min}) / (CV_{max} - CV_{min})]$$

- Cv_i = conservation value of breed I
- CV_{min} = value of breed with smallest CV
- CV_{max} = value of breed with largest CV

Prioritization according to Total Utility

$$U_i = 4 \times (risk_i \times D_i) + SCV_i$$ (Simianer et al., 2003)

where,

- **U_i** is the total utility for breed *i*
  - *Criterion for prioritization*

- Breeds are ranked according to total utility and those ranking highest are targeted for conservation

The Final Step: Use the information

- *Action 1. Prepare a report on breed prioritization*
  - Draw up “red list” of endangered breeds
    - Increase public awareness
- *Action 2. Hold meetings with stakeholders*
  - Pass results on to stakeholders
    - government and donors = provide support
    - farmers = design and implement conservation measures
- Implement conservation programmes

Thank You

Current Status of Prioritization

- Extinction risk most often used
- Objective prioritization methods applied to most livestock species on research basis
- Little application in practice
  - Austria
  - ALBC in USA
- Reasons?
  - lack of molecular characterization
  - no clear consensus on optimal approach
  - no simple comprehensive computational tools