The Importance of Animal Genetic Diversity in Disease Resistance: the FAO Perspective

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Workshop on “Resistenza genetica alle malattie negli animali da reddito: presente e futuro”
Turin, Italy
16 May 2013
Animal Genetic Resources

those animal species and the populations within each of them that are used, or may be used, for the production of food and agriculture
Animal Genetic Resources

• Essential part of biological basis for world food security
  – One billion people rely directly on livestock for major proportion of livelihood

• Diverse resource base critical to eradicate world hunger
  – adaptation
  – “raw material” for breeders

• International public good
  – role of FAO in global coordination
Why is genetic diversity important?

- Domestic animal diversity is important for
  - economic potential
    - genetic improvement
    - response to change
  - social and cultural reasons
  - environmental services
  - research and training
Why is genetic diversity important?

- Genetic diversity also contributes to decreased disease incidence and increased health.
- Benefits can be observed on multiple levels:
  - individual animal
  - within breeds
  - within species
  - across breeds
Diversity on the individual level

- Diploid nature of animal genomes means that individuals have 2 copies of chromosomes and genes
- Diversity is increased when copies differ
  - ↑ heterozygosity
- Increased diversity is associated with increased health and disease resistance
  - less “inbreeding depression”
  - wider capacity to deal with pathogens
Inbreeding Depression

• Inbreeding is mating of relatives
  – mates share common ancestor(s)
• Decreases heterozygosity because offspring may receive the same ancestral chromosomal segment from both parents
  – homozygosity
• Single superior gene variant is often sufficient to compensate for inferior variant
  \[ +/+ \approx +/- \gg -/- \]
• Inbred animals will have more inferior homozygous genes and thus poorer performance
  – inbreeding depression
Inbreeding Depression

- Inbreeding depression tends to be greater for health and fitness traits

Estimates of inbreeding depression in dairy cattle

<table>
<thead>
<tr>
<th>Trait</th>
<th>Change, 0 to 12.5% inbreeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastitis incidence(^1)</td>
<td>+6.25%</td>
</tr>
<tr>
<td>Pregnancy rate(^2)</td>
<td>-3.54%</td>
</tr>
<tr>
<td>Calving interval(^3)</td>
<td>+8.8 days</td>
</tr>
<tr>
<td>Survival to 2(^{nd}) lactation(^3)</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Calf survival(^4)</td>
<td>-6.25%</td>
</tr>
</tbody>
</table>

\(^1\)Sorensen et al. 2006; \(^2\)González-Recio et al. 2007; \(^3\)McParland et al. 2007; \(^4\)Fuerst-Waltl et al. 2012
MHC diversity

- Major histocompatibility complex is a genomic region associated with immunity
- Encodes cell-surface glycoproteins involved in recognition and elimination of pathogens
- ↑ diversity = response to wider range of pathogens
- Inbred animals may have suppressed immunity
- Evidence of disassortative mating to maintain diversity in wild species
  - also in humans
- Balancing selection in domestic species (Codner et al. 2011)
Diversity on the breed level

• When diversity is adequate at the breed level, avoiding the mating of relatives is sufficient to avoid problems

• There are situations where genetic diversity on the breed level may be reduced
  – small population size
    • fewer animals = fewer different alleles
    • allelic frequencies vary greatly from one generation to next
      – Genetic drift $\rightarrow$ loss of alleles
  – long-term intense selection
    • few animals with many offspring
    • small “effective” population size
Several mechanisms can contribute to decreased health as a result of reduced breed-level diversity:

1. Inbreeding depression
2. Reduced MHC function
3. Decreased selection potential
4. Genetic defects
Decreased selection potential

- Health and disease incidence are influenced by genetics
- Genetic selection can be used as a tool for disease management
  - mastitis in dairy cattle
  - general resistance and livability in chickens
- Selection response is proportional to genetic variation
- With intense selection for production, alleles with positive effects on disease resistance can be lost
  - especially when health and production are antagonistic
• Single genes/alleles can have severe detrimental effects on health and functionality
• Most individuals probably carry a few such defective alleles
  – but only a single copy
• No effect is seen if one allele is normal
• Decreased genetic variability increases the chances of homozygosity for defective alleles
  – most animals are effectively “related”
  – analogous to inbreeding
Genetic defects with classic inbreeding

- Blue square = identical carrier
- White square = normal family members
- White circle = normal family members
- Red circle = affected offspring
- Red square = affected offspring
Defects in intensely selected population

= heavily-used carrier

= descendant with defect
Bovine Leukocyte Adhesion Deficiency (BLAD)

• simple recessive condition that leads to impaired neutrophil function
  – recurrent bacterial infections
  – delayed wound healing

• Holstein bull *Osborndale Ivanhoe* was a carrier
  – AI allowed him to have many descendants
    • *Carlin-M Ivanhoe Bell*

• Gene spread quickly throughout the breed
  – 15% of bulls were carriers in early 1990s

• DNA test has resulted in near elimination
  – but costly in terms of animal losses
Diversity on the species level

- Livestock breeds have been developed over the millennia through a multi-step process:
  - Domestication
  - Migration
  - Isolation
    - Geographic
    - Genetic
  - Admixture
  - Selection
Diversity on the species level

This process has resulted in great genetic diversity
Diversity on the species level

- Geographic and genetic isolation have allowed populations to diverge genetically
- Interactions with the natural environment have resulted in adaptation
  - Increased frequencies of ancestral alleles improving survival under local conditions
  - Maintenance of new mutations with favorable effects
Diversity on the species level

- Adaptation includes factors related to animal health
  - Resistance and tolerance to specific diseases
    - against endemic pathogens
    - against local disease vectors
  - Resilience in harsh environmental conditions
    - less stress
    - increased general immunity
- Adaptive traits may become more valuable with climate change
  - “Natural” zones of endemic diseases change with climate
Domestic Animal Diversity Information System

- FAO maintains a database on animal genetic diversity
- DAD-IS
  - http://dad.fao.org
- 182 countries
- 38 species
- 8,000+ breeds
- 14,000+ national breed populations
Domestic Animal Diversity Information System

- What type of information is in DAD-IS?
  - common and local breed names
  - description and photos
  - origin and history
  - current distribution
  - population data
  - common uses
  - trait averages
  - breeding and conservation programmes
  - special traits
    - adaptation and health
## Disease resistance

### Examples of resistance reported in DAD-IS

<table>
<thead>
<tr>
<th>Species</th>
<th>Diseases and vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>Blood parasites, brucellosis, <em>Dermatobia hominis</em>, ECF, FMD, general parasites, TB, ticks, trypanosomes and general disease resistance</td>
</tr>
<tr>
<td>Chickens</td>
<td>Coccidiosis, Eimeria, fowl pox, IBD, Marek’s, Newcastle, Oncorna, respiratory disease and general disease resistance</td>
</tr>
<tr>
<td>Goats</td>
<td>Filariosis, trypanosomes and general resistance</td>
</tr>
<tr>
<td>Pigs</td>
<td>African and classical swine fever, kidney worm, fasciola, general parasites, trypanosomes and general disease resistance</td>
</tr>
<tr>
<td>Sheep</td>
<td>Blow fly, brucelosis, fasciola, fleece and foot rot, general parasites, heartwater, scapie, screw worm, trypanosomes, ticks, TB and general disease resistance</td>
</tr>
</tbody>
</table>
### General adaptation and resilience

#### Examples of adaptation reported in DAD-IS

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<tr>
<th>Species</th>
<th>Environmental conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>Desert, extensive production, forests, harsh conditions, hills and mountains, lowlands, marginal areas and wetlands</td>
</tr>
<tr>
<td>Chickens</td>
<td>Extensive production, lowlands and marginal areas</td>
</tr>
<tr>
<td>Goats</td>
<td>Desert, forests, harsh conditions, highlands, lowlands, marginal areas and rough terrain</td>
</tr>
<tr>
<td>Pigs</td>
<td>Desert, extensive production, forests, harsh conditions, lowlands, marginal areas, mountains and wetlands</td>
</tr>
<tr>
<td>Sheep</td>
<td>Desert, extensive production, forests, harsh conditions, hills and mountains, lowlands, marginal areas, rough terrain, saline conditions, steppe and wetlands</td>
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</tbody>
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Genetic diversity and FAO Work

• Livestock genetic diversity has been found to be decreasing globally
• Developing countries in particular lack capacity in animal genetic resource management
• FAO member countries have developed and approved the *Global Plan of Action for Animal Genetic Resources*
• FAO provides technical assistance in implementation
• FAO also monitors breed diversity and national management capacity
Thank you