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Annex: Presented Papers

Contents:

Status of animal genetic resources: time for action?

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Abstract

The FAO Domestic Animal Diversity Information Service (DAD-IS), which represents a global inventory of animal genetic resources, covers more than 30 species used for food and agriculture. National data has been recorded by more than 180 countries. National Coordinators for the Management of Animal Genetic Resources are responsible for reporting national data to FAO. Analysis of the databank was undertaken in 1993, 1995 and 2000 and published in the World Watch List for Domestic Animal Diversity. It is estimated that about 30% of livestock breeds are close to extinction. The figures for 2000 represent a 10% increase in the number of breeds recorded as being at risk since 1995, and a 13% increase since 1993. Erosion of animal genetic resources (AnGR) is alarming. Even though data has been collected over more than ten years, there is still a big gap as regards information on population sizes and structures. Consistent nationwide surveys and inventories have not been conducted by most developing countries. The same applies to regular monitoring of breeds. In particular, local breeds, notably those that have been developed in harsh environments in developing countries, have not been sufficiently characterized. In the case of their extinction, the value lost to humankind is not known. The lack of information hinders proper decision-making with respect to what to conserve and how to allocate the limited funds available for conservation. A certain loss of local breeds will be inevitable and acceptable given the current dynamics in production systems, and the limited availability of resources for conservation in the public sector. However, it is certainly time for action to strategically safeguard the genetic diversity represented in the world's animal genetic resources for food and agriculture. Animal genetic diversity is our common heritage and contributes to food security at present and will help to secure future food security by allowing a wide range of products to be produced under diverse environmental conditions. Guiding principles for decision-making on AnGR management based on deficient information are needed at national, regional and international level. The international community is asked to develop concerted action plans to support countries that lack capacity and resources, to maintain valuable animal genetic resources and to develop a fall-back strategy when *in vivo* conservation is not feasible and invaluable or unique resources are at stake.

Documentation of animal genetic resources

Genetic resources naturally ebb and flow within ecosystems and it can be expected that over long periods, certain livestock breeds or even species will emerge while others become extinct. However, the actions of human beings have an enormous effect on the speed with which the changes to genetic resources occur. Human development has created the breeds found today, but current trends in economic and social development have the potential to erode them very rapidly. Environmental changes or shifts in agro-ecosystems including the effects of global warming (Anderson 2004) can affect genetic resources. Genetic diversity may also be eroded as a result of wars, pest and disease outbreaks (animal and human) and other natural disasters (drought, floods, earthquakes, etc.), including through the effects of unsuitable restocking after disasters (Goe and Stranzinger 2002).

Within the animal species that are used, or may be used, for the production of food and agriculture, wild and feral populations, landraces and primary populations, standardized breeds, selected lines, varieties, strains (including conserved genetic material) may be found. All of these groupings are currently categorized as breeds[1] (FAO 2000). In the absence of direct measures of genetic diversity, breeds provide the best indication of total farm animal genetic diversity (FAO 1999). The term breed is often accepted as a cultural rather than a biological or technical term. Breeds are commonly classified as indigenous or exotic, where indigenous breeds are mainly kept in low-input–low-output production systems while exotic breeds are generally adapted to intensive, high-output systems and do often not flourish in low-external input production environments, particularly in the tropics.

Systematic documentation of animal genetic resources on supranational level commenced in Europe in the 1980s. In the early 1990s, FAO started building up the Global Databank for Farm Animal Genetic Resources. This databank builds the backbone of the Domestic Animal Diversity Information System (DAD-IS at http://www.fao.org/dad-is/), which was launched in 1995. National-level information is being actively entered into the system by, currently, 140 officially appointed National Coordinators for the Management of Animal Genetic Resources. FAO analyzed the information reported by countries in 1993, 1995 and 2000 in three consecutive editions of the World Watch List for Domestic Animal Diversity. It needs to be stressed that countries are committed, by their ratification of the Convention on Biological Diversity, to report information related to their animal genetic resources to FAO. FAO can only consider information that has been reported officially by countries. This requires that National Coordinators actively enter the information into DAD-IS. However, country reports, and particularly national action plans, stressed the fact that national inventories have not yet been conducted in all countries or are still incomplete.

In 2000, worldwide, over 6300 breeds of domesticated livestock had been reported to FAO. Of these, over 1300 are extinct or considered to be in danger of extinction. Many others have not been formally identified and may disappear before they are recorded or widely known. Europe records the highest percentage of extinct breeds or breeds at risk (55% for mammalian and 69% for avian breeds). Asia and Africa record only 14% and 18% respectively, but the data for developing countries are much less fully documented in the World Watch List for Domestic Animal Diversity than those for developed countries. When all breeds, including those that are maintained, are considered, 1687 breeds—or 40% of breeds with data on population size—are classified at risk. Extrapolating this figure to include all breeds (including those without population data) recorded in the Global Databank for Farm Animal Genetic Resources would mean that 2255 breeds are at risk. Overall, these figures represent a 10% increase in the number of breeds recorded at risk since 1995, and a 13% increase since 1993 (Scherf 2000).

[1] Breed: either a sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity. Breeds have been developed according to geographic and cultural differences, and to meet human food and agricultural requirements. In this sense, breed is not a technical term. The differences, both visual and otherwise, between breeds account for much of the diversity associated with each domestic animal species (FAO 2001).

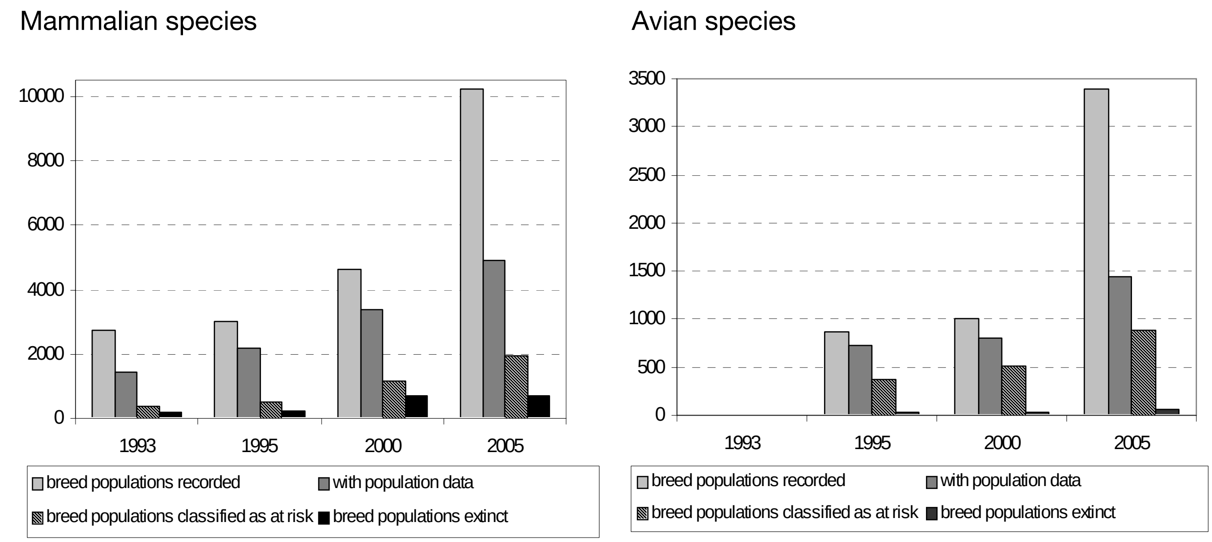

Figure 1. Status of information recorded in the Global Databank for Farm Animal Genetic Resources

Presently the databank is being updated and further developed and the number of recorded within-country breed populations has increased to nearly 14 000. Countries have now been encouraged to report not only on their local breeds but also on their imported genetic resources. It can be assumed that as a result of the massive effort undertaken by more than 170 countries in preparing reports on the state of their animal genetic resources, and FAO's effort to extract breed-related information from country reports and integrate it into the global databank, documentation of animal genetic resources is now much more complete than in the past. This is illustrated in Figure 1. However, the information needs to be further verified by National Coordinators. Particular effort is required by National Coordinators to report regularly, annually or bianually, data on population sizes and structures for each breed to DAD-IS, to enable better planning of action and communication of issues at national and international levels. It can be observed that the status of reporting of information on breeds of avian species is less complete than that for breeds of mammalian species.

Progress has also been made in achieving more complete geographical and species coverage. In 1993, the global databank contained information from 131 (out of 197) countries and seven species of domestic mammals, whereas in 2005, information from 181 countries and 35 species of birds and mammals was reported.

A first attempt to consolidate the database has been made by FAO by linking breed populations that may belong to a common gene pool and may therefore be considered the same breed. These breeds have been termed 'transboundary breeds'. The overall number of breeds developed worldwide including transboundary and local breeds might be around 9000. The table provides an overview of numbers of breeds that may be part of the same gene pool versus breeds that only appear in one country. National Coordinators will have to verify the proposed linkages based on their in-depth knowledge of the origins and development of breeds.

Table 1. Overview of number of transboundary and local breeds for some species

Mammals	transboundary	Local	Birds	transboundary	local
Cattle	208	1138	Chicken	160	1240
Sheep	232	1191	Goose	24	161
Horse	129	651	Duck	27	221
Goat	86	537	Turkey	26	79
Pig	62	778	Guinea fowl	5	49
Rabbit	59	184	Ostrich	3	14
Ass	15	141	Muscovy duck	1	23
Buffalo	15	122	Pigeon	1	67
Deer	13	13	Quail	1	49
Dromedary	5	65			
Bactrian Camel	2	10			
Alpaca	2	4			
Llama	2	3			
Guinea Pig	1	16			
Yak		27			

For example, Holstein Friesian cattle have been reported by 158 countries, followed by Brown Swiss, Jersey and Simmental reported by 76, 76 and 73 countries respectively. The broad definition of the term 'breed' leads to problems of comparability between entries in the global databank. Some developed countries, where birds are kept by hobby breeders, may enter colour varieties or bantam stocks as separate breed entries, whereas some developing countries may only be able to provide information at species level e.g. for muscovy ducks or asses. Specific characterization work is required for many populations to enable description of specific breeds.

Dilution of the genetic make-up of breeds by introgression of genes from other breeds or cross-breeding with other breeds is not yet documented and is difficult to capture in the global databank. Dilution is thought to be the major reason for the erosion of genetic resources.

Although countries have been reporting on the status of their animal genetic resources over more than ten years, it is not easy to estimate the rate of loss of the animal genetic resources. Besides

Examples from Country Reports submitted to FAO

Surveys in remote areas in **China** have resulted in the discovery of 79 previously unregistered breeds or populations being used by farmers.

In **El Salvador** there is a lack of even basic livestock statistics. The last national inventory was carried out in 1971 and an update of the livestock inventory is urgently needed.

Surveys have been conducted in **Botswana**, but they do not provide adequate information to assess the status of breeds within each animal species. There is no information on the distribution of breeds across the country or on herd structures.

Systems are in place in **Malaysia** to monitor the status and trends in breeds of each species, including monitoring breeds at risk. General surveys on all animal genetic resources important to food and agriculture are undertaken on an annual basis to determine population data and population trends.

knowledge gaps about the characteristics and the status of genetic resources, assessment is hindered because methodologies for breed surveys (ILRI 2003; Ayalew and Rowlands 2004; Lokhit Pashu-Palak Sansthan 2005) and for assessing the risk status of populations (Simon and Buchenauer, 1993; FAO 1998; Scherf 2000; Gandini et al. 2004; Drucker 2005) have not been standardized.

Need for monitoring and characterization

Routine monitoring and national and international reporting on the state of animal genetic resources is essential given the current threat to animal genetic resources, and the unknown state of many breeds. Data and information obtained from inventories, monitoring and characterization would enable farmers to make informed decisions on which breed should be chosen and managed under the prevailing production conditions. Completing the national inventories stating the main breed characteristics and the production environment they have been developed for are a basic requirement for effective management of AnGR. At the same time, routine inventories and monitoring have to be initiated in many countries. Otherwise, breeds could become endangered before farmers and local people, government officials and the international community are aware of their significant decline, and unique characteristics may be lost before their value is recognized and appreciated. A more in-depth understanding of breed characteristics and estimates of current performance levels is necessary to guide decision-making in livestock development and breeding programmes to achieve optimum production levels. Comparative analysis of the performance of indigenous and exotic breeds is also needed to guide decision-making. In the absence of such analysis local breed development may be ignored in favour of the introduction of exotic germplasm.

Trends in erosion in animal genetic resources

A recent study (IDL 2002) argues that the risk of losing indigenous breeds is currently low as they are mainly kept by poor people in rural areas, who will not immediately change their production system or abandon their breeds. However, this situation may be changing as the poor either integrate with global market chains or move out of livestock production. During the 20th century, research and development in the commercial livestock sector has concentrated on a very small number of exotic breeds, in which rapid increases in meat, milk or egg production were achieved. Only 14 of the approximately 30 domesticated mammalian and bird species provide 90% of human food supply from animals. While production increases have been remarkable with a reduced number of breeds, local breeds are threatened as erosion of local animal genetic resources and intensive use of highly productive breeds occur at the same time. Seré et al. (1996) noted that loss of breeds is expected to be high in the mixed rainfed systems in temperate zones or tropical highlands. Furthermore, pastoralism worldwide is deeply threatened as a livestock production system (Blench 2001) and as a livelihood, by interlinked pressures. These include inappropriate government policies on land tenure leading to the encroachment of cultivation onto rangelands, private ranching and protected areas, failure to develop appropriate livestock and human services, recurrent drought and armed conflict (Devendra et al. 2005). Thus, the breeds kept in this system are threatened. All over the world, loss of breeds or introgression of exotic genes in local breeds is occurring while it is still largely unknown which breeds contain significant genetic diversity or specific genes that should be targeted for conservation and/or incorporation into breeding programmes.

Some of the policies directly or indirectly affecting breed choice follow clear breed development strategies and are conscious of the implications. Others pursue more general social or economic objectives but distort the playing field on which different genetics compete. While the impacts of such policies are readily discernable in broad terms, little is known about their impact on animal genetic diversity. They may have helped to supply affordable and safe animal products to urban populations, but they have disadvantaged less intensive production systems and compromised household food security. Where livestock policy changes affect livestock genetic resources directly, the net costs and benefits of such policies have usually not been documented, and policy environments or strategies that promote conservation and appropriate utilization have not been defined. The challenge at national, regional and global level is to formulate policies which consider animal genetic resources and favour their sustainable management.

Implications for conservation

Despite the valuable efforts of individuals, governments and non-governmental organizations, animal genetic resources continue to be at risk (Figure 1). Strategic investments in the conservation of animal genetic resources at national and international level are critical. Appropriate conservation measures should ensure that farmers and researchers will continue to have access to a vast gene pool of breed diversity for further breeding. This genetic diversity serves as an essential insurance policy against future changes such as climate change, outbreaks of new pests and diseases, and changing consumer demands. Country reports indicated that many breeds at risk are in developing countries, which have limited resources for designing and implementing conservation programmes. This is a serious situation, as breeds used in developing countries often possess unique genetic traits which enable their survival in a diverse range of production environments with combinations of intense stresses, such as disease and drought. Despite large phenotypic differences, genetic differences between local breeds may be small, because adaptive traits may be common to many breeds due to a long history of natural selection in similar stress environments. However, research on functional traits needs to be further advanced.

Decisions related to conservation programmes at national, regional and international level have to be based on genetic and cultural value and the risk status of the breeds.

At the national level, conservation programmes need to be embedded into an overall development plan for livestock resources. This was underlined by many country reports. Such national programmes would encourage countries to study carefully the reasons for breeds becoming less popular with farmers and provide an opportunity to re-examine policies that promote exotic breeds that, in many instances, are contributing to the decline of indigenous breeds. The development of coherent management plans is hindered by a lack of successful breed improvement programmes for local breeds raised in low-input production systems, which could foster their genetic improvement when the production environment allows for higher productivities. The commercial livestock sector has concentrated on a very small number of exotic breeds in which rapid increases in meat, milk or egg production were achieved (IDL 2002), but breeding for low-input production systems will continue to remain a task for the public sector and can be supported by producer cooperatives or community-based breeding programmes.

The analysis of the country reports shows that conservation efforts vary significantly between countries, as does the capacity to implement conservation measures. Many developing countries and several developed countries are far from developing comprehensive national conservation programmes or policies for animal genetic resources. The gaps in capacity include a lack of financial resources, inadequate staff to establish and implement conservation measures, a lack of stakeholder involvement, and insufficient or no facilities for *ex situ* conservation. Funding for breeding research and training is also inadequate in many countries to support conservation efforts. However, there are also a number of countries that have established a comprehensive national programme for animal genetic resources and indicated their willingness to share their experiences.

Guiding principles for decision-making on AnGR management based on deficient information is needed at national, regional and international level. The international community is asked to develop concerted action plans to support countries that lack capacity and resources, in maintaining their valuable animal genetic resources. It is also time to develop a fall-back strategy when *in vivo* conservation is not feasible and (potentially) invaluable or unique resources are at stake. Research on methods to determine which genetic resources should be maintained is scarce in biological, economic and social sciences. The various levels of genetic diversity (breed diversity or genetic variability) and their different public goods character are expected to play a role in conservation decisions and the level of their conservation (national or international) (Hoffmann and Scherf 2005). Decisions on conservation measures will be taken at the policy level in all cases that involve public funding.

Conclusions

Erosion of animal genetic resources is ongoing as indicated by the trends. While the global inventory of breeds has much improved through the country-based State of the World reporting process, there is still a big gap as regards information on population size and structure for many breeds. Most developing countries lack capacity and resources to conduct consistent nationwide surveys and inventories.

Many local breeds, particularly those adapted to harsh environments of developing countries, have not yet been sufficiently characterized and in the case of their extinction the value lost to humankind is not known. The lack of information also hinders proper decision-making with regard to what to conserve and how to allocate limited funds available for conservation.

Given the current dynamics in livestock production systems and the limited availability of resources for conservation in the public sector, a certain loss of local breeds will be inevitable. However, further extinction should not be permitted to occur at random. Countries and the international community should be conscious of which losses are likely to happen, which losses they are prepared to accept and what investment is needed in maintaining/conserving animal genetic diversity. The international research community should provide the necessary scientific guidance for strategic decisions under imperfect information.

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Farm animal genetic resources: why and what do we need to conserve

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Abstract

Since the beginning of agriculture, livestock have played a major rule in human livelihood in both the developed and the developing world. Farm animal genetic resource (FAnGR) diversity has allowed both the development and the sustaining of livestock production in nearly all agro-ecological zones. The result has been the development of hundreds of breeds/populations adapted, through natural and human selection, to various human needs and market demands. Molecular markers are playing a major rule in our understanding of the origin and distribution of FAnGR diversity both at local and global level, and it is providing directions for prioritization of conservation. There is an urgent need for conservation of FAnGR to respond to the future needs of the livestock production systems and consumers. However, priorities for conservation will likely vary between production systems, the developed and the developing world. Our challenge is to identify rapidly what to conserve to maximize conservation of diversity and utility function of FAnGR at global level. Wild ancestral populations of domestic livestock species, breed-populations at livestock diversity hotspots, and breed-populations representative of all agro-ecosystems should be given priority for global action for conservation of FAnGR.

The origin of diversity

The history of today's livestock genetic resources started around 10 000–12 000 years ago during the agricultural revolution of the early Neolithic which occurred independently in several locations scattered all over inhabited continents except Australia. The control of food production by the early farmers led to major demographic, technological, political, and military changes that are at the roots of our modern societies (Diamond 2002). After the initial domestication events, a period of expansion of farmers' societies in nearly all terrestrial habitats followed rapidly. It led to the present livestock diversity, the legacy of hundreds of years of natural and human selection, genetic admixture, genetic drift and inbreeding. FAnGR diversity has both allowed the development, and the sustaining of livestock production in a variety of production systems and agro-ecological zones.

Typically, livestock diversity is described in terms of phenotypic diversity, the result of the interaction of the genotype with its environment. Its unit is the breed. It is often quantified in terms of numbers of breeds with threat, related to the loss of breeds or the level of endangerment. However, the advent of molecular genetics has and is changing the scene. Now, we can access and characterize the diversity of the genotypes, and sooner or later we may be able to infer the expected phenotype from the genotype given the environmental conditions in which the animal has been reared and/or is living in. A first breakthrough[1] has been the use and development of genetic markers, typically microsatellite and mitochondrial DNA sequences, which are now commonly applied for the study of genetic diversity of livestock at country-level (see Baumung et al. 2004 for a review) but also in a few cases at the level of an entire continent (e.g. Hanotte et al. 2002). Information from neutral genetic markers allows estimation of within- and between-breed diversity and these markers have been central to the application and development of prioritization approaches for breed conservation (e.g. Marti et al. 2003)[2].

Besides breed diversity information, the application of neutral molecular markers on a large geographic scale is providing new insights on livestock domestication and dispersal, highly relevant to our livestock diversity conservation strategies. Perhaps the most surprising result has been the discovery, through predominantly mitochondrial DNA studies, that several ancestral 'species', subspecies or maternal lineages have contributed to the current genetic pool of our major livestock species (Bruford et al. 2003; Hanotte and Jianlin in press). Multiple domestications and/or maternal introgression are the rule not the exception with several major and distinct geographic centres of livestock domestication. The situation might even be more complex as we could reasonably expect multiple male lineages at the time of domestication (Hanotte et al. 2000) or subsequently through male mediated introgression in our largely polygenous livestock domestic species. Molecular markers have also been shown to be extremely powerful in unravelling the pattern of ancient and more recent livestock movements (e.g. Hanotte et al. 2002), leading to the identification of areas of low or high genetic diversity (Freeman et al. 2005). Last but not least, they have confirmed that the developing world is the natural *in situ* reservoir of the largest diversity of FAnGR.

Why do we need to conserve

The 'traditional' economic argument underpinning conservation of diversity of FAnGR is to be able to respond to the present and, to some extent unpredictable, future needs of the livestock production systems, the consumers and the market[3]. In the intensive high-output livestock production systems which dominate livestock production in the developed world and which are expanding rapidly in the developing world, the primary rule of FAnGR is food supply and/or other commodities of high demands (e.g. wool). Typically, the intensive production system will rely on a small number of highly selected breeds for productivity traits (e.g. Holstein – Friesian cattle for milk, Merino sheep for wool production, commercial broilers and egg-layer lines for egg and meat, etc.). Within-breed selection is the rule today, with inbreeding a major threat to loss of diversity. The need for conservation of diversity is related largely to productivity, survival and reproductive traits, to which could be added disease resistances (e.g. scrapie susceptibility in sheep) and consumer preferences (Gibson et al. in press).

The developing world is largely characterized by extensive production systems, typically low-input–low-output systems, which rely mainly on indigenous livestock genetic resources. FAnGR

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[1] While molecular genetic information about FAnGR diversity has come predominantly from neutral markers, what we want to ultimately conserve and utilize is functional diversity. Up to now, information about functional diversity in FAnGR is rare. A good example is the study on milk protein genes by Beja-Pereira et al. (2003). However, with the ongoing and accelerating genomic revolution, the unravelling of functional livestock diversity (e.g. genetic adaptation) and its geographic distribution is becoming a realistic option for the near future.

[2] Louis Ollivier and Jean-Louis Foulley, "Tools available for setting conservation priorities of farm animal genetic resources", this workshop.

[3] Livestock diversity is also playing major 'cultural' roles in agropastoral societies and loss of diversity will undoubtedly impact the cultural identity of the communities owning it. Criteria for conservation should ideally include cultural value of FAnGR as well as genetic value.

provide not only food but also have important socio-economic (e.g. movements of goods and people, accumulation and storing of capita), socio-cultural (e.g. dowry, prestige status, religious ceremony) and agro-ecological (e.g. grazing, manure, nutrient recycling) roles. These indigenous livestock genetic resources are often kept by poor smallholder rural farmers[4] whose survival will depend on the ability of their indigenous, locally adapted livestock breeds and populations to cope with the impact of often harsh and highly variable and unpredictable production environments. Cross-breeding with 'exotic' breeds and/or breed replacement, often triggered by inadequate national breeding policies, increasing demands of livestock food products as well as rapid changes in production environment, are major threats to the livestock diversity of the developing world; it explains largely why today FAnGR of the developing world are the most at risk. Moreover, the often multifunctional rule of livestock to the poor rural farmers of the developing world, the complexity of the production systems, the time-scale as well as the cost associated with the development of breeding programmes and, last but not least, the dilemma between conservation diversity and improvement of farmer livelihoods represent major challenges for the design of conservation strategies for the developing world.

What do we need to conserve

With more than 10 000 domestic livestock breeds[5] recognized there is undoubtedly a need to prioritize breeds for conservation given the limits of any financial resources that are or might be available. Understanding the potential, limits and complementary of the options for conservation (*in situ*, *ex situ in vivo*, *ex situ in vitro*) are also central to the design of conservation strategies[6]. In an ideal world, a global strategy for AnGR conservation should rely on accurate and complete information on both the diversity of the phenotypes and genotypes of all livestock populations, and it should be supported by appropriated legal and policy frameworks (Gibson and Pullin 2005; Gibson et al. in press). The reality is, however, a lack of information on the characterization of livestock genetic resources, and the development of a comprehensive legal framework for the global conservation animal genetic resources is still lacking[7]. However, given the increasing threat affecting FAnGR, there is an urgent need to develop criteria for prioritization of FAnGR conservation, followed immediately by concrete conservation action. Applications of these criteria should lead to optimal conservation of the diversity and the utility functions of FAnGR, while conservation actions should have positive direct or indirect impact on human livelihood and should ensure long-term conservation of FAnGR as a global public good.

In such a situation, what do we conserve and what should be our strategy for a global approach of FAnGR conservation? There is an urgent need for further and more detailed characterization[8]. While this information is being accumulated, our current knowledge may already guide priority decisions. For example: (i) the wild relatives of FAnGR are the custodians of FAnGR diversity; they should be given the highest priority for conservation. Often threatened by extinction, they should benefit from *in situ* as well as *ex situ* (*in vivo*, *in vitro*) conservation strategies. Also, (ii) domestic livestock populations from centres of origin of domestication and/or at the crossroad of ancient trading routes and/or movements of pastoral people will likely be the depository of large diversity. They should also be given high priority. And, (iii) likely equally important will be the inclusion of livestock populations

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4 It is estimated that some 70% of the world's rural poor depend on livestock as a component of their livelihoods (Livestock in Development 1999).

5 In their paper, "Status of animal genetic resource: time for action?", presented at this workshop, Beate Scherf and colleagues report new figures reaching now nearly 14 000 breeds or populations.

6 David Notter, "Complementarity of conservation approaches", this workshop.

7 Daniele Manzella, Claudio Chiarolla, Irene Hoffmann, "The legal framework for the conservation of animal genetic resources", this workshop.

8 John P. Gibson, "Information needs for animal genetic resources conservation'', this workshop.

representative of all agro-ecological zones and production environments, in order to capture most of the adaptive traits. For (i) and (ii), molecular but also archaeological, historical and phenotypic information will guide the identification of these 'livestock diversity hotspots', while for (iii) the availability of detailed geographic information system (GIS) information (e.g. climatic, physical, vegetation parameters) including socio-economic ones (poverty maps) will be essential. In addition, (ii) and (iii) will often lead to priority geographic areas for conservation rather than the identification of specific breeds or population.

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The legal framework for the conservation of animal genetic resources

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Abstract

National laws and regulations about *in situ* and *ex situ* conservation exist in many countries. The regulations of the European Commission are presented as an example of a comprehensive regional framework. At the moment, there is not yet a global legal framework specifically dealing with animal genetic resources (AnGR) management. The impact of increasing patenting on conservation is difficult to predict.

Introduction

The Animal Production and Health Division (AGA) of FAO is leading and coordinating the development of the *Global Strategy for the Management of Farm Animal Genetic Resources*. In this context, it has been recognized that the legal and policy frameworks are important components for the sustainable management of AnGR. However, information about the regulatory frameworks for AnGR is scarce as compared to the wealth of information available on legal frameworks for plant genetic resources (Gibson and Pullin 2005).

A series of workshops have been conducted in the SADC region on various aspects of AnGR management, including on the development of policies, incentive measures and legal frameworks. These workshops identified the need for FAO to assess and analyze legal frameworks for the management of AnGR. As a result, a legislative study has been prepared by the FAO Legal Office, Development Law Service and the Animal Production Service and will soon be published (Ingrassia et al. 2005). The study highlights that there is not yet a global legal framework specifically dealing with AnGR management, but a variety of regulations at national and, to a lesser degree, regional levels. This note outlines some of the findings of the said study regarding national and regional legislation and adds further information on *ex situ* conservation and intellectual property rights (IPRs).

Legislation dealing with animal genetic resources encompasses various elements which may be grouped into four specific areas: a) institutional arrangements; b) genetic improvement; c) animal health; and d) genetic resources conservation. For the purpose of this paper, only the latter is considered. Conservation of animal genetic resources refers to all human activities, including strategies, plans, policies and actions undertaken to ensure that the diversity of animal genetic resources is being maintained to contribute to food and agricultural production and productivity. Conservation encompasses *in situ* and *ex situ* measures, including the management of genebanks. Information on national and regional legislation has been gathered through the country reports in the framework of the First Report on the State of the World's Animal Genetic Resources and through a questionnaire filled by National Coordinators as well as from publicly available sources such as the FAOLEX database. Available literature has been reviewed and on-line resources have been accessed.

Findings

In situ *conservation*

National legislation may deal with general objectives such as the conservation of agricultural ecosystems and associated wildlife, which may have a positive impact on animal genetic resources, as well as contain explicit provisions on conservation of animal genetic resources for food and agriculture.

With regard to the former category, conservation of agricultural ecosystems is implemented under nature conservation laws, rural development strategies and agro-environmental programmes. More than 40 countries have legislation that provides for nature conservation, including conservation of agricultural ecosystems.

General national laws for nature conservation cover mainly biodiversity and environmental management. Typical examples for the African region are the 'pastoralist charters'. The Law 01-004 on the Pastoralist Charter of Mali defines the fundamental and general principles framing pastoral activities in the country. It enunciates what are the pastoral resources as natural resources necessary for feeding animals (mainly water and grazing) and also the rights and obligations of the resource users, especially regarding the protection of the environment. Animal health and trade are excluded. Requirements of this Law refer to the mobility of animals (internal and international), preservation of the environment and the sustainable use of the natural resources, access rights to pastoral resources, and proper management of pastoral resources by the local authorities. Another example of this type in the Near East region is the Mauritanian Pastoral Code.

In Bolivia, the Law on the Environment constitutes a legal instrument for the conservation of the environment and the genetic patrimony of native species of Bolivia. It also lays down norms for genetic research activities, the protection of the environment in development projects, and the support of the local communities.

Specific provisions for the *in situ* conservation of animal genetic resources are reported to be in the legislation of 31 countries. In several countries, legislation on animal breeding contains separate chapters on conservation and sustainable use of animal genetic resources, and provides detailed descriptions of the scope and measures for conservation. In other countries, there are no specific laws but there are national conservation programmes in place that were endorsed and are financially supported by the Ministry of Agriculture.

At the regional level, it is worth looking at the current legal framework for *in situ* conservation in the European Union. The EU has built up a significant body of legislative texts relevant to genetic resources conservation programmes. At the regional level, the Biodiversity Action Plan for Agriculture was adopted in 2001[1]. Council Regulation (EC) No. 870/2004 implemented the Action Plan[2]. The main aims of the new programme are to:

- Finance measures to promote the conservation, characterization, collection and utilization of genetic resources in agriculture, allowing for a wider coverage of plant and animal diversity with particular emphasis on complementing the scope (as regards beneficiaries and/or eligible actions for funding) of the Regulation 1257/1999; and

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[1] The priorities of the Action Plan are: a) the promotion and support of environmentally-friendly farming practices and systems that benefit biodiversity directly or indirectly; b) the support of sustainable farming activities in biodiversity-rich areas; c) the maintenance and enhancement of good ecological infrastructures; and d) the promotion of actions to conserve local or threatened livestock breeds or plant varieties. Moreover, biodiversity conservation greatly depends on compensatory allowances for less favoured areas and agro-environmental measures, within the framework established by the Common Agricultural Policy.

[2] This Regulation repealed Council Regulation No. 1467/94 on the same subject.

- Promote the *in situ*/on-farm genetic resource conservation activities, which should be a means to promote the conservation of genetic material on a transnational basis but taking into account, if appropriate, bio-geographic regional aspects.

The new programme will function based on proposals for actions to be reviewed and selected by independent experts. Proposals may be submitted by a public-sector body or any natural or legal person who is a national of a Member State and established in the Community, including genebanks, non-governmental organizations (NGOs) and breeders' associations.

As regards *in situ* conservation, activities eligible for funding include: a) the development of European-wide standardized and comparable criteria to identify the national priorities for action and related requirements for international cooperation; b) the development of strategies which support the enhancement of profitability of local breeds in order to develop links between local breeds and their typical products, to identify and to promote the value of local breeds for their environmental services (e.g. landscape conservation, agro-ecosystems management) and for their contribution to the multifunctional character of agriculture (e.g. maintenance of rural cultural diversity, rural development and tourism, etc.); and c) the development of strategies which promote the utilization of underutilized animal genetic resources that could be of interest on a European level.

Targeted actions include a European network of national inventories of administrative aspects (origin and status of funding, state of breeds and their endangerment, location of herdbooks, etc.), which should be managed in conformity with the FAO Domestic Animal Diversity-Information System (DAD-IS), a database that monitors the status of animal genetic resources. Signorello and Pappalardo (2003) criticized the domestic animal biodiversity conservation programme reporting that many breeds at risk of extinction according to the FAO were not included in Rural Development Plans (RDPs) set up in European Countries. They also noted that the main conservation efforts were focused on local cattle and sheep breeds and that payments to farmers do not take into account the different breed extinction probabilities. Moreover, notwithstanding subsidy payments, the raising of local breeds remained unprofitable in most of the case studies. On the basis of these observations, Signorello and Pappalardo proposed a revision of the current EU agro-environmental measures to increase the profitability of local breed farming through higher payments and support for agricultural products and foodstuffs related to local breeds.

Ex situ *conservation*

Only a limited number of countries have legislation dealing with *ex situ* conservation of animal genetic resources, namely the establishment and management of genebanks, or cyropreserved genetic material. As in the case of *in situ* conservation, substantial efforts and activities on collection and storage of genetic material are carried out within national animal genetic resources conservation programmes.

For this reason, it is appropriate to look at the EU regulatory framework supporting *ex situ* conservation in the context of conservation programmes. Council Regulation (EC) No. 870/2004, which implemented the 2001 Biodiversity Action Plan for Agriculture, contributes to establishing the European framework for *ex situ* and *in vitro* conservation of animal genetic resources. This framework comprises research on methods, molecular genetic characterization, breeding, technology platforms (such as EFFAB[3]) and genebanks.

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[3] The European Forum for Farm Animal Breeders is preparing a vision paper on the developments in European farm animal breeding and reproduction. This initiative should result in the start-up of a Technology Platform on Animal Breeding and Reproduction.

Council Regulation (EC) No. 870/2004 lists a variety of *ex situ* and *in vitro* conservation activities eligible for funding[4]. With regard to *in vitro* conservation of animal genetic resources (semen, embryos), a web-based network of national inventories and a European search catalogue for minimum passport data should be developed. The inventory is to consist principally of the establishment, regular updating and regular publication of the facilities (storage and conservation) for genetic resources in agriculture collected in the Community, and the listing of current work on the conservation, characterization, evaluation, collection, documentation, development and utilization of those genetic resources. Minimum passport data of individual accessions may be included.

The European Regional Focal Point (ERFP) Guidelines (Hiemstra et al. 2004) provide a thorough analysis of the legal and technical issues that, at the national and at the international level, affect the storage and transfer of *in vitro* animal germplasm. These Guidelines set the following strategic targets for the establishment of cryopreservation programmes: a) avoiding irrecoverable loss of breeds and genes; b) re-establishing a breed to secure animal resources from sanitary accidents; c) breeding in small populations and conserving genetic variations in selected programmes. The ERFP Guidelines also underline the importance of veterinary requirements concerning the storage of genetic materials. In particular, collecting facilities should be able to certify that samples were properly collected from disease free animals.

The intake, use and access to genetic material stored in a cryobank are regulated by specific contractual arrangements, which usually contain provisions concerning the legal status of the material; obligations of the provider and user of the material; and the ownership regime applicable to research results. The agreement used for material collected for the cryobank is called Material Acquisition Agreement (MAA). Core elements relating to property rights, use restrictions, rights of subsequent donors, veterinary/sanitary aspects and benefit-sharing are dealt with in the MAA. The agreement used for material given from the cryobank is called a Material Transfer Agreement (MTA) and is enforceable between the cryobank and subsequent users. It contains the following elements: a) legal entity and affiliation of the applicant; b) type and quantity of genetic resources to which access is sought; c) accurate information regarding intended use; and d) kinds and types of benefits that may result from the accessed resources.

In addition to the elements mentioned for the MAA, the MTA should regulate:

- the receiver's property right to the natural offspring deriving from accessed material;
- the user's right to claim intellectual property rights on the material;
- the cryobank's right to get access to derived genetic material; and
- issues arising from the subsequent transfer of accessed material to third parties.

The impact of increasing patenting on conservation

Public-sector research institutions are dealing with the extension of Intellectual Property Rights (IPRs) protection over research tools, genetic resources, animals, animal varieties and materials. The first time the US Patent Office awarded a patent for an animal invention was in 1988. Since then roughly

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[4] Namely: a) the development of European-wide standardized and comparable criteria to identify the national priorities for action and related requirements for international cooperation; b) the establishment of European cryopreserves for animal genetic resources based upon national or institutional cryopreserves; c) the characterization and evaluation of animal genetic resources (species and breeds) used or potentially useful for food and agriculture; d) the establishment of a standardized European performance testing regime for animal genetic resources in agriculture, and documentation of characteristics of endangered farm animal breeds and populations; e) the establishment and coordination of an European-wide network of "Ark farms", rescue-stations and farm animal parks for endangered European farm animal breeds; and f) the development of common cross-national breeding programmes for endangered breeds and populations as well as the establishment of rules for the exchange of information, genetic material and breeding animals.

500 have been granted for higher animals. At the international level, also the European Union, Canada, Australia, New Zealand and Japan allow animal patenting. At present, approximately 75 animal patent applications are pending in EU patent offices[5].

The process of standardization and internationalization of IPR protection is going to allow IPR-owners to seek worldwide protection for their products and research tools. A recent example of this global trend is given by the international patent application filed by Monsanto under the Patent Cooperation Treaty for a method that uses the detection of a gene sequence, associated with daily feed intake, to identify animals from among pig populations to serve as breeding stock for enhanced pork production. The eventual awarding of over-broad patents for the products of modern animal biotechnology would have impressive implications not only for research and development, and economic development in those domestic markets in which the exclusive rights are granted, but also for international trade patterns in such goods. How this process will affect conservation strategies by public and private institutions as well as by local communities is difficult to predict. Ultimately, what is relevant is not so much how IPR legislation is designed but how it is interpreted by administrative institutions, enforced in national courts and utilized by title holders in order to affirm their monopoly rights.

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Avian influenza and its impacts on poultry diversity in Thailand

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Introduction

Indigenous chicken of Thailand have been part of the socio-economic and cultural lifestyle of Thai people since the Ayudhya era some 400 years ago. Their major roles in supplying animal protein for rural areas as well as for cockfighting have been well-documented. Since the introduction of exotic broiler and layer breeds from Europe in 1923 and successful industrial-scale production from 1963 onwards, the role of native chickens has been less significant as a protein source. Backyard production for cockfighting and additional income have kept indigenous local breeds/strains of chicken from extinction (Chansereewat et al. 1998)

Prior to the outbreak of Avian Influenza (AI), Thailand was one of the top exporters of chicken meat with several large integrated companies leading this market. The AI outbreaks occurred first in late 2003 with official confirmation in January 2004 and continued later with sporadic outbreaks. The early outbreaks caused an estimated loss of US$2.5 billion (Matishon Daily, January 2005 and Krung thep Business, January 2005). Industry has turned towards closed housing systems with strict biosecurity control. Export is now 100% cooked meat (Thai Broiler Processing Exporters Association 2005).

Poultry industry in Thailand

The poultry industry in Thailand is largely comprised of broilers and layers. There are far fewer ducks and geese. Thailand produces 900 million birds (0.9 million tonnes of meat) and is the eighth biggest exporter in the world (0.3 million tonnes of cooked meat). Thailand ranked fourth as world exporter in 2002–2003 before the AI outbreak.

All commercial broilers produced in Thailand are of imported breeds. They are imported as grandparent or parent stocks. The popular stocks are Arbor Acre, Ross, Cobb, Hubbard and Hybro.

Layer breeds are also imported: mainly Isec, AA Brown and Isa Brown Eggs being produced for domestic consumption and export of oversupplies.

Each year Thailand produces 5 million meat-type ducks in closed systems, 10 million laying and meat-type ducks mainly in extensive systems, and about 0.5 million in backyard production.

Thai indigenous chicken comprises approximately 100 million birds consumed per year. They may be truly native, or cross-bred with broiler/layer breeds (Kai Baan Thai).

Thai indigenous chicken

Thai indigenous chickens (TIC) are primarily classified by plumage and appearance. Plumage of males is mainly black but the dorsal plumage including neck, hackles, back, saddle and wings are different such as yellow, green, dark brown, reddish brown or white. Females are basically black except for the Kai Chee breed (Department of Livestock Development 2003). Essentially, the specific breeds (17 are considered as such) are classified by inspection but 'native' is normally used in the context of all local chickens, most of which have not been classified and are best described as 'non-descript'. However TIC is also used to cover all native poultry.

TIC are the most common chicken raised by farmers with approximately 5–6 million households throughout the country—about 80% in the northeast and the north, and the others in the central and southern region. The main purposes of the TIC are for food and additional income, hobby and recreation (cock fighting), the latter being about 3–5% of cockerels. TIC annual production is about 90–120 million chicks at market size with a value of US$125–175 million.

Nowadays, TIC is higher in demand than previously because of the better flavour and texture but less fat than broiler meat. However, they still have low production rates. The cross-breds of TIC (or Kai Baan Thai) which grow faster but with the same meat quality as TIC, are a new product for the high-end niche market.

There are two systems of production of TIC. One is backyard production, the traditional method by small farmers. The average eggs laid and hatched are 30–50 eggs and 25–40 chicks/hen per year respectively, of which approximately 10–15 chicks may grow to market size. It takes 15–18 weeks to grow to market size of 1.0–1.2 kg. Birds are free range and fed on natural produce such as vegetables, grass, grains, insects, depending on the season, plus household waste, rice, etc.

The other system is for cross-breds. These groups have certain percentages of male TIC genotypes. They fetch 40–50% higher prices than broiler. With broiler and layer compositions, they grow faster than TIC and reach market weight at 1.5–1.8 kg in 13–15 weeks. These groups are fed in the same manner as broilers.

Avian influenza outbreaks: impacts and control measures

There are three major periods of reported AI outbreaks in Thailand. The first wave started with confirmation of an outbreak in January 2004 and this spread throughout the central and lower northern part of the country. Laboratory results indicated that most outbreaks occurred in native chickens (58.4%) and fewer in commercial farms of broilers or layers (2.1% for each of them); species other than chicken accounted for 37.4% of outbreaks. The second wave of outbreaks was from July 2004 to April 2005 and again most outbreaks occurred in native chickens (57%) with ducks accounting for 37.4% of outbreaks (http://www.dld.go.th). The last small incidence started in July 2005 in native chickens and grazing ducks and sporadic cases are still occurring.

The Ministry of Public Health is responsible for the public safeguards (monitoring and control in humans) while the Department of Livestock Development (DLD) is responsible for animal health controls and eradication of AI. The DLD introduced a slaughter policy including depopulation in a 5-kilometre radius. A surveillance and control system was introduced covering movement of birds and the transportation, biosecurity measures and proposals for poultry and duck keeping in future. Industry has now tightened its closed housing and biosecurity measures for their units. The practicality and effects of the proposed measures have yet to be verified, but may hold serious consequences for smallholder farmers and traditional farming systems.

The overall impact of the first wave of outbreaks can be summarized as follows:

- Export of chicken meat—Thailand has moved from fourth in world rankings of exporters in 2003 to eighth in 2004. The export structure has moved from 94% frozen product in 2002 to 100% cooked meat in 2005.
- Per capita consumption has reduced from 14 kg/year in 2003 to an estimated 8 kg/year in 2005.
- The price of live birds dropped from US$ 0.75 per kg in 2002 to US$ 0.4 per kg in 2004.

The total estimated loss during 2004 was US$2500 million including US$311 million for the feed industry, US$100 million for hatching and breeder firms, US$700 for contract farmers, US$710 million for the processing and packaging industry and US$700 million for exports. This is equivalent to 0.32% of GDP (Bank Thai, Research and Planning Division, Jan. 2004). This estimated loss excludes small farmers and backyard poultry keepers, consequential losses and the costs to the ministry department involved.

Newspaper reports quote figures of the slaughtered/dead as 17 378 963 layers, 10 351 125 broilers and 18 037 997 native chickens. Figures for other AI-related deaths are not available. The figures suggest that 39.4% of those slaughtered were native birds, while 60.6% were commercial layers and broilers.

The monetary loss to backyard and smallholder farmers has not yet been estimated.

There has been no formal impact assessment on smallholder farmers except for a research project studying several districts in the central part of the country. This found that 82.7% of the 669 farmers interviewed raised native chickens (or fighting cocks) with an average of 12.7 chickens per family. The birds are reared in the open, free range for family consumption, additional income and as a hobby. After the AI outbreaks, 63% of birds died or were compulsorily slaughtered. More than half (57.7%) of farmers suffered loss of income and only 23.5% believed that they would keep poultry in the future given the new proposals for a closed flock system. It is argued that it is essential for commercial production that all farmers comply with the new regulations and have full biosecurity controls (Wongnagpheth 2005). As noted, the new regulations/recommendations are likely to add to the losses and to reduce the numbers keeping poultry but, in addition, may well have serious repercussions on the genetic resources of the country.

The effects of slaughter on the genetic resources are unknown since no records have been kept of the breed types slaughtered (either approved TIC or 'non-descript' native). It is impossible to know the repercussions on the genetic resource—a similar situation exists in Vietnam and in Indonesia (Steane, personal communication).

Conservation programme

TIC was first brought to general attention and, later, further developed by two distinguished animal breeders (Associate Professor Dr Kanok Palaraksa and Dr Sawat Thummabud, both now retired).

TIC development appeared in the fifth National Economic and Social Development plan in 1983. The aims were for protein supplement and additional income to smallholder farmers. Since then, research results indicated that:

- TIC is more suitable to smallholder farmers than broiler or TIC cross-breds due to their adaptability and survivability as well as thrift in a rural environment;
- Socio-economic situation is a major factor affecting rural TIC production;
- TIC meat is tasty and more palatable than broiler meat.;
- Cross-bred chicken, sired by TIC, has high potential for industrial-scale production of high-quality chicken meat.

The Thailand Research Fund (TRF) collaborated with the Department of Livestock Development (DLD) in establishing, in 2001, flocks representing four major breeds of TIC. There are about 17 known breeds/strains of TIC. The four major breeds are:

- Pradu Hangdum at Chiangmai Livestock Research Center;
- Luang Hangkhao at Kabinburi Poultry Research Center;
- Kai Dang at Suratthani Livestock Research Center;
- Kai Chee at Khon Kaen Livestock Research Center.

The flocks are each of about 70 males and 350 females and are selected for plumage colour of that breed. They are housed in deep-litter style houses but each flock has a section based on traditional management as well. The TRF also supports the research conducted at these four DLD sites in full cooperation and collaboration with scientists from universities and the private sector. The main objective of this programme is to supply the industry with improved and more uniform breeding stock of indigenous chicken.

Current strategies and options

DLD has a policy of distributing surplus chicken raised in these research centres to small farmers or groups of farmers at lower cost than market price. This practice enables the farmers to earn additional income as well as reproducing the more uniform breeding stock in the village. As a result, conservation takes place effortlessly.

However, the AI outbreaks and subsequent DLD measures requiring all chickens to be kept under strict biosecurity control are likely to disrupt the process since a large proportion of small farmers may not be able to afford the cost of netting, housing and fences. *In situ* conservation best takes effect only when it is incorporated into farmers' lifestyle. The disruption could have a huge impact, even unintentionally, on the decision-making of the farmers. In fact, if followed through as some wish, there will be no more natural chicken keeping within the country and the resources will be lost.

The TRF is considering supporting strain/inbred line formation in cooperation with certain establishments, universities and private sectors. The four breeds mentioned above are now in the fourth generation. Since they are under no direct selection for any traits except for colour uniformity as specified by breed standards, we expect that they contain a pool of genetic variation to be worked with. Establishing a new flock will also safeguard both the genetic diversity and the possibility of being depopulated by any disease outbreaks.

The AI outbreak has identified a major weakness in the *in situ* policy in that there is no *ex situ* programme for storing genomic material for the long term. It is clearly a matter for urgent discussion and action since the genotypes may well be lost totally either by the slaughter policy or by the amended management requirements destroying the normal environment of these resources.

Conclusions

The AI outbreak has had serious repercussions for the Thai poultry industry. The resulting measures imposed have assisted the control of AI but whether or not eradication can be achieved still remains unresolved. However, the large industrial concerns have been able to adjust their farming systems, biosecurity controls and their processing to meet the export requirements of the normal buyers.

The majority of outbreaks occurred on small farms but no detailed analysis of the effects has been undertaken and no estimates made of economic loss. The new regulations will have serious consequences on these farmers and many will stop keeping poultry. What effect this will have on family nutrition has not been evaluated. The loss in genetic resources is not known and other countries have a similar experience. All efforts in Thailand have been directed at disease elimination and the continuation of an export-lead industry, and no consideration to genetic resources has been given. Even if these had been assessed, it is not clear what funding would be available to protect the resources and to ensure *ex situ* storage of material is carried out.

The effect of the new regulations on the genetic resource has not been discussed, but loss of genetic diversity especially for traits involved in survival could take place.

The reports of ducks being carriers but not dying (Hulse-Post et al. 2005) raises questions about the mechanisms by which this is occurring and whether such birds can be of future advantage. It also raises questions regarding a similar possibility in chickens but present depopulation policies do not allow for any such birds to be seen.

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Effects of disease on diversity

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Introduction

The erosion of genetic diversity in farm animal genetic resources through animal disease can happen in a number of ways:

- The direct impact of an infectious disease outbreak where the disease itself can be fatal to the species e.g. Avian Influenza;
- The impact of infectious and notifiable disease control measures resulting from an outbreak involving a slaughter policy of infected animals, dangerous contacts and contiguous culls e.g. Foot and Mouth Disease (FMD);
- The impact of a selection policy to eradicate susceptible genotypes to a particular disease from a population e.g. Scrapie in sheep.

Scenario 1 will be covered in another paper presented at this workshop, entitled "Avian influenza and its impacts on poultry diversity in Thailand" (Chancharat Reodecha). This paper will focus on scenarios 2 and 3. The UK has had profound experience of both in the past five years and the impact on farm animal genetic diversity will be summarized briefly.

The impact on genetic diversity of the FMD outbreak in the UK in 2001

The scale of the outbreak

The FMD outbreak in 2001 was the largest ever recorded in the UK since reliable records began. There were 2030 cases between February and October 2001 in which a total of 6 million animals were culled (4.9 million sheep, 0.7 million cattle and 0.4 million pigs). Four million were culled to control and eradicate the disease (1.3 million in infected premises; 1.5 million as dangerous contacts; 1.2 million as contiguous premises). A further 2 million were culled under various animal welfare disposal schemes to relieve the suffering of animals which could not be moved off farm because of movement restrictions (Thompson et al. 2003).

The total cost of the outbreak was £3.1 billion, principally to the taxpayer although the direct cost to farmers was estimated at £355 million. The cost to tourism was over £2.7 billion although the impact of this on the overall economy was reduced as this money was displaced to other sectors of the economy. Therefore the overall impact on the economy was less than 0.2% of GDP in 2001 (The Royal Society 2002).

The effect on animal breeding populations

The outbreak was first identified in cull sows from a pig farm in the North East of England. However it had already spread very rapidly through the sheep population nationally through livestock markets where biosecurity was vulnerable. February is a time of year when store lambs are traded from the North and East to the South and West to find winter feeding for finishing. The threat to sheep and

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cattle breeding populations in particular was immediate and severe. Table 1 gives an indication of the reduction in a selection of purebred breed populations in the UK.

Table 1. Estimated reduction in purebred female breeding population 2001

Breed	Endangered status	Total no. of breeding females in 2002	Estimated % reduction of breeding females in 2001
Cattle			
Belted Galloway	Rare	1 400	30 approx
Galloway		3 500	25
Whitebred Shorthorn	Rare	120	21
Sheep			
British Milksheep	Rare	1 232	< 40
Cheviot (South Country)	Local	43 000	39
Herdwick	At risk	45 000	35
Hill Radnor	Rare	1 893	23
Rough Fell	At risk	12 000	31
Swaledale	Local	750 000	30
Whitefaced Woodland	Rare	656	23

Source: RBI, RBST 2002

Purebred breeding female populations in certain breeds caught in the epidemic were reduced by 20% to 40%. Fortunately no breeds were completely lost. However some breeds lost some very valuable male breeding animals and some very small populations were severely threatened because key herds were close to infected areas (e.g. Chillingham cattle—population 17; British Lop pig—population 162).

A number of actions were taken to protect genetic diversity during the outbreak:

- *Emergency cryopreservation*. A Heritage Gene Bank was set up under a new Trust—The Sheep Trust. Semen was collected under strict veterinary supervision from three sheep breeds (Herdick, Rough Fell and Portland breeds) which, although not numerically scarce, were threatened because they were geographically isolated and adapted to the local environment. Storage was confined to within the disease surveillance zones until the outbreak had passed. Further precautionary semen collections were taken from one critical, four endangered and one at-risk breed by the Rare Breeds Survival Trust (RBST).
- *Culling exemptions were established* for a number of rare and at risk breeds. A protocol was devised for sheep and goats and applied through Divisional Veterinary Managers within 2 months of the outbreak. Veterinarians were reluctant to exempt rare pig herds because of the higher risk of infectivity among pigs. However a protocol was eventually agreed based on very tight biosecurity precautions.

There were some very positive outcomes for conserving genetic diversity from the experience:

- Genetic conservation exemptions were incorporated into animal health legislation at EU and UK Government level e.g. FMD Directive. More recently discussions are continuing regarding similar exemptions for Newcastle Disease and Avian Influenza.
- The situation regarding the reduction of the Herdwick sheep population from about 70 000 to 45 000 in Cumbria increased public awareness over conservation management issues and led to a very successful campaign by the RBST to raise money for a national Rare Breeds Gene Bank.

- It raised the profile of the UK Country Report on FAnGR 2002 and has assisted in establishing the need for a co-ordinated National Action Plan for FAnGR.

The impact on genetic diversity of the National Scrapie Plan

Scrapie is a progressive and fatal neurological disease of sheep and goats and is the most widely distributed transmissible spongiform encephalopathy (TSE) of animals. It has been found in British flocks since 1732 and is reported in many other countries. It has been a notifiable disease since 1993.

Scrapie eradication via breeding for scrapie resistance is possible for sheep because of the unique resistance or susceptibility Prion protein (PrP) alleles which are inherited. Sheep carrying the ARR/ARR PrP genotype are considered the most resistant to scrapie and therefore the most desirable and the VRQ/VRQ genotype is considered the most susceptible and least desirable. In July 2001 the National Scrapie Plan was launched and by the end of 2004 1.3 million sheep had been genotyped. Currently around 29% of sheep in the Plan are of the most resistant ARR/ARR genotype but this is increasing annually as the susceptible genotype frequency is reduced (DEFRA 2005).

There is widespread concern about the impact on genetic diversity on two fronts:

- That by selecting against the VRQ and associated alleles in the national flock of mainstream commercial breeds some valuable genetic material may be lost. There may be some useful linked production and health traits which are inadvertently lost especially in those breeds where the incidence of VRQ alleles is high.
- That some rare breeds which have a very low incidence of ARR/ARR alleles may come under increasing threat of extinction or suffer severe inbreeding problems as a result of compulsorily selecting for scrapie resistance. Some very valuable genetic material could be lost in this way.

To counteract these threats two courses of action have been taken:

- A Semen Archive has been set up to conserve ARQ, ARH, AHQ and VRQ ram genotypes. So far 243 ARQ allele samples have been collected, 1 ARH, 72 AHQ and 48 VRQ from a total of 71 sheep breeds.
- A survey of Rare Breeds has been conducted to establish genotype frequencies and distribution levels in native rare breeds of sheep. The results indicated that the application of genotype breeding strategies may be appropriate for some rare breeds but not for others. In the light of this more work is being conducted on the data to assist in the development of longer term breeding strategies for rare breeds of sheep to conserve genetic diversity and at the same time reduce susceptibility to scrapie. A consultation document has just been released on these various strategies.

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Overview of the genetic variability in French selected livestock populations and management approaches

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Abstract

Some results from pedigree analyses of French livestock breeds are reported. Results on both probabilities of gene origin and rates of inbreeding show that 'large' breeds may be small populations from a genetical point of view. Different management methods for selected populations are presented and the efficiency of optimized procedures is illustrated on cases of dairy cattle and pigs breeds. The easiness of application of such methods is discussed.

Introduction

In the last decades selection pressures have increased on all livestock species and selection methods have been improved, leading to more and more efficient programmes. However, due to an intense and accurate selection and to a small number of breeding animals in the selection nuclei, it is expected that within-population genetic variance of the selected traits will decrease and that inbreeding will increase faster than under pure drift (for a review, see Verrier et al. 1991). Preserving the within-population variability and monitoring the rate of inbreeding are necessary for both short- and long-term considerations. The purpose of this paper is two-fold: (i) to demonstrate, using some examples of French livestock populations, how the theoretical predictions are verified; and (ii) to discuss the possible ways and methods to manage selected populations.

What can we learn from the analysis of large selected populations of farm animals?

Information and methods available for analyzing the within-population genetic variability

Three kinds of information are available: (i) phenotypes, giving a global view of the variability of the genes (generally unknown) governing the observed traits; (ii) genotypes at genetic markers, giving a detailed view of the variability of the observed loci; and (iii) pedigrees, giving the view of the variability for an anonymous locus (theoretically, a neutral locus with no mutation) anywhere in the genome. Pedigree information is mainly used due to several advantages: easiness and low cost of recording, possibility to trace the history of populations for long periods, and easiness of interpretation. With such information, the genetic variability is assessed in terms of probabilities of gene identity (coefficients of kinship and of inbreeding) and probabilities of gene origin (for example, see Boichard et al. 1997 and Caballero and Toro 2000).

Two case studies: the main French dairy cattle and pig breeds

Pedigree of the main French dairy cattle and pig breeds were recently analysed (Moureaux et al. 2001; Maignel and Labroue 2001; Delaunay and Mérour 2006). The probabilities of gene origin of the most recent cohort of animals known at the time of the study were analyzed (Table 1). The major ancestors of each cohort were identified by the iterative method proposed by Boichard et al. (1997) and were ranked by decreasing expected genetic contribution. Half of the gene pool was found to originate from a very few ancestors (Table 1). The effective number of ancestors is defined as the reciprocal of the probability that two genes drawn at random in the cohort originate from the same major ancestor (Boichard et al. 1997*)*. In a given locus, the genetic variability of the studied cohort is equivalent to the variability that would originate from the balanced contributions of a number of ancestors equal to the effective number. These results highlight the narrow genetic basis of such populations, due to strong bottlenecks in the pedigrees. In addition, the annual rate of inbreeding was found to be about 0.2% in dairy cattle and between 0.1% and 0.5% in pigs, according to the breed (Delaunay and Mérour 2006). In both species, the changes in the slope of the observed curves have been interpreted as consequences of previous changes in the management of the breeds (Moureaux et al. 2001; Maignel and Labroue 2001; Delaunay and Mérour 2006).

Table 1. Analysis of the probabilities of gene origin in the main French dairy cattle and pig breeds.

	Dairy cattle†			**Pigs**‡		
	Holstein	**Montbéliarde**	**Normandy**	**LW**§ **Line Nr 1**	**LW**§ **Line Nr 2**	**French Landrace**
No. of animals in the cohort	2 141 261	341 512	326 699	70 551	10 888	40 037
No. of ancestors for a cumulated contribution of 50%	16	12	12	18	28	12
Effective no. of ancestors	33	30	33	31	75	32

† Recorded cows born in 1993–1996

‡ Recorded sows born in 1999

§ Large-White is the main maternal pig breed used in France. It is divided into two lines differing by the traits on which the most emphasis is given in the breeding goal: litter size in Line Nr 1, growth rate in line Nr 2.

Other cases and conclusions from these studies

In the last decade, extensive pedigree analyses were carried out on French breeds in race or riding horses (Moureaux et al. 1996), draught horses (Vu Tien et al. 1998; Verrier et al. 2005), dairy cattle (Moureaux et al. 2001), sheep (Palhière et al. 2000), beef cattle (Vu Tien et al. 1998), meat sheep (Huby et al. 2003), pigs (Maignel and Labroue 2001; Delaunay and Mérour 2006), rabbit (Kerdiles and de Rochambeau 2002) and dogs (Leroy et al. 2006). From the observed values of the generation length and of the annual rate of inbreeding, the rate of inbreeding per generation and the realised effective size were computed (Table 2). The realised effective size does not depend on the actual population size nor on the status of the breed. On the contrary, there is a strong effect of the management strategy applied by breeders, as revealed by the detailed comparison between national breeds with large population sizes (Moureaux et al. 2001), between separate lines of the same national breed (Palhière et al. 2000) or between rare breeds (Huby et al. 2003). An extreme case is represented by the Holstein dairy cattle breed, which is simultaneously the largest French cattle breed and the breed with almost the smallest realised effective size, mainly due to a very unbalanced use of artificial insemination bulls, both on the sire–sire and the sire–dam paths (Moureaux et al. 2001). All these studies indicate that 'large' breeds, i.e. those that are widely raised for commercial purposes, may be small populations from a genetic point of view.

Table 2. Realised effective population sizes estimated in some French livestock breeds.

Species and production	Breed	Status†	Realised effective size	Period analyzed (birth years)	Reference
Horse	Thoroughbred	S I	181	1974–1992	Moureaux et al. (1996)
	Boulonnais	C R	44	1965–2000	Verrier et al. (2005)
Dairy cattle	Holstein	S I	52	1980–1996	Moureaux et al. (2001)
	Montbéliarde	S N	81		
	Normandy	S N	59		
	Abondance	S L	60		
Dairy sheep	Lacaune Line Nr 1‡	S N	278	1970–1999	Palhière et al. (2000)
	Lacaune Line Nr 2‡	S N	167		
Meat sheep	Berrichon-du-Cher	S N	120	1980–2000	Huby et al. (2003)
	Solognot	C R	223		
Pigs	LW Line Nr 1	S N	84	1985–1999	Maignel and Labroue (2001)
	French Landrace	S N	60		

† Programme: S = selection, C = conservation; Extent: I = international, N = national, L = local, R = rare.

‡ The Lacaune dairy sheep breed is divided into two lines, with a few exchanges between lines.

Methods for limiting the increase of inbreeding and the decrease of within-population genetic variability due to selection

Simple demographic rules

From well-known population genetics principles, an effective way to preserve genetic variability is to breed the largest number of males possible and to equalize their progeny sizes. Males are considered here rather than females due to their smaller number and the easier ability to obtain large differences in their progeny sizes. Due to extra costs and penalties on genetic progress, these rules are rarely strictly applied, except in poultry breeding on the sire–sire path. However, these rules should be kept in mind in order to avoid excess on the selection and the use of breeding males.

Splitting the population into groups

As for the management of some rare breeds (de Rochambeau and Chevalet 1985), the population is split into reproduction groups and the selection works within groups. Such a method has been applied with success in the selection of some rabbit lines (Kerdiles and de Rochambeau 2002). Both lines of the Lacaune dairy sheep breed are managed with rams' groups. By retrospective analyses, it has been shown than these two lines have achieved the same genetic progress for dairy traits but that they differ for realised effective size (see Table 2) due to differences in both the management of the groups during a round of selection and the stability of the groups from one round of selection to the next (Palhière et al. 2000).

Use of modified EBVs

Many authors have suggested using Estimated Breeding Values (EBVs) different from those deduced from the index theory. Two types of modification have been proposed: (i) reducing the weight given to familial information, either by simple algebra after the EBV has been calculated computation or by inflating the value of genetic parameters; and (ii) including penalties based on the candidate's degree of inbreeding or its kinship with other animals. For a recent list of references, see Colleau et al. 2004b). An example of the possible construction of such EBVs with penalties in pigs is given by Delaunay and Mérour (2006).

Optimization methods

The methods currently considered as methods of choice, from a theoretical point of view, consist of choosing breeding animals and determining their relative contribution to the next generation by optimizing a decision function combining genetic values and inbreeding coefficients, e.g. Toro and Perez-Enciso 1990, Brisbane and Gibson 1995, Meuwissen 1997, Caballero and Toro 2000, Woolliams et al. 2002, Colleau et al. 2004a, Colleau et al. 2005b. In the method proposed by Meuwissen (1997), the genetic progress in one generation of selection is maximized under a constraint on the increase of inbreeding, with no attention paid to the mating plan. Considering that breeders are more familiar with genetic gains than with levels of inbreeding, Colleau et al. (2004a; 2004b) proposed to minimize the increase of inbreeding for a given expected genetic gain, looking also for the optimal mating design between males and females. This method was tested on real data from selection programmes on dairy cattle (Colleau et al. 2005b) and pigs (Colleau and Tribout 2006) and also goat breeding (unpublished results). In each case, the major selection steps were identified and optimized retrospectively. Optimization would have led to kinship and inbreeding coefficients decreased by about 20% at each of the selection steps considered (see Table 3).

Table 3. Relative decrease of inbreeding rates (ΔF) and coefficients (F) from using optimized procedures.

Species	Selection step	ΔF	F
Dairy cattle (3 breeds)	Mating for young bulls	15–18%	22–29%
	Young bull selection for sampling	7–20%	
	Use of AI bulls	19–29%	
Pig (1 breed)	Use of boars	19%	17%
	Replacement + use of boars	30%	32%

Sources: Colleau et al. 2005b, Colleau and Tribout 2006.

From theory to practice: towards sustainable breeding

The first step towards sustainable breeding is to regularly provide information to the breeders and their selection organizations de Rochambeau et al. (2003). For instance, from January 2005 in France, each pig breeding organization receives, several times per year, the results for some parameters (probabilities of gene origin, inbreeding, kinship, …) computed on both its own population and the whole breed considered (Delaunay and Mérour 2006). In dairy cattle, the average coefficients of kinship between the young AI bulls and the old AI bulls are provided yearly.

Optimization methods indicate that at any given time, candidates for selection differ as to their recommended contribution to future generations. Then, corresponding calculations might be achieved with a pre-determined time schedule. Indeed, this new parameter is the most informative one to be transmitted to breeders as guidelines for selection and use decisions. It would not involve any operational complexity for users, exactly the same way as EBVs are just information, not dictating everyday behaviour. Optimal rankings are also useful and these rankings can be predicted by penalized EBVs, although imperfectly, as shown by the experience of dairy cattle and pig breeding schemes. An utmost important topic is to make breeders, at farm level, not departing too much from recommended rates, when using AI males. This might be the objective of renewing the current methodology of the mating plans proposed to them by AI organizations, by integrating the most efficient concepts of population and quantitative genetics.

Conclusions

Management of animal genetic resources should not only focus on the between-population diversity but also consider the evolution of the within-population variability over time. From that point of view, the situation of some 'large' breeds seems to be more critical than the situation of some rare breeds. Several efficient management methods are available, their use depending on their ease of application and their acceptance by breeders.

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Characterization of small ruminant genetic resources in Central Asia, the Caucasus, West Asia and North Africa

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Introduction

Small ruminants are an integral part of farming systems in the dry areas, where they make a substantial contribution to the livelihood of resource-poor farmers. In remote and isolated areas, such as in the mountains and on high altitude ranges, these species may be the only option farmers can use to secure an income and gain access to meat and dairy products.

The total small ruminant population of the region stands at about 245 million head (FAO 2004): 196 million head of sheep and goats in Mediterranean West Asia and North Africa (WANA), including Jordan, Iraq and Iran, and 49 million in Central Asia and the Caucasus (CAC). These animals contribute to the livelihoods of an estimated 5.5–12 million families. This underlines their importance within the farming systems of the region, and explains why small ruminant production has been part of ICARDA's research agenda from the organization's inception.

A rich and large diversity of adapted breeds is available in the CAC and WANA (CWANA) regions. These breeds are adapted to a range of dry, often marginal, environments which suffer from intense droughts, water scarcity, and to a vast range area. Known adaptations (such as the fat tail) allow these breeds to thrive in such harsh environments, benefiting local farmers who are able to use them to produce meat, milk, fibres and skins.

In 1998, ICARDA began to implement an animal genetic resource research strategy. This aimed (1) to assess current levels of genetic diversity and any threats to it; (2) to synthesize all the information available on the phenotypic and production characteristics of the breeds of CWANA; and (3) to characterize selected breeds under current production scenarios in order to identify the main factors affecting genetic diversity. This summary reports the results of this task, focusing on key issues of management and the conservation of small ruminant genetic diversity in the region.

Types of breeds according to origin

A total of 155 different breeds have been catalogued in the whole region; of these breeds 122 breeds were identified in WANA and 43 breeds were identified in CAC.

Not all breeds are indigenous to the region, as some consist of genotypes which were introduced as purebreds, while others are synthetics which were developed by crossing native breeds with introduced germplasm. Most (73 out of 75 or 97%) of the sheep breeds kept in WANA are indigenous; only a small fraction (2 out of 75 or 3%) are non-native. By contrast, most (23 out of 37 or 62%) of the breeds kept in the CAC region are non-indigenous synthetics while only 14 out of 37 (38%) of the breeds are indigenous (Iñiguez 2005a; 2005b; 2006). In goats all 32 breeds found in WANA are indigenous and two out of the 11 breeds of CAC are synthetics.

The synthetic breeds kept in the CAC region consist of a range of specialized wool producing breeds. These produce either fine wool or coarse wool, the latter of which has little, if any, value in current markets. The development of these breeds began with either the single or multiple crossing of a native breed and a given, introduced, improved European breed or breeds (such as the Merino, Lincoln or Romanov). The cross-bred populations produced were then allowed either to interbreed following selection or underwent different degrees of absorption to a European breed before selection. At a given point, the selected or upgraded populations were again crossed with a new breed in order to introduce specific characteristics. Once some degree of homogeneity was displayed by the selected groups during the selection process, they were declared to be breeds by Soviet standards. Thus, in the formation of a synthetic, three to four breeds could be involved in a continuous cycle of cross-breeding followed by selection.

Cross-breeding, facilitated by the massive use of artificial insemination (AI), was apparently so popular that, almost until the breakdown of the Soviet Union, the procedure was further applied to some synthetics even if they had already been declared to be breeds. This information is key when considering the potential for conserving the breeds. For those synthetics under the threat of extinction, the genetic pool of native and European breeds from which they were derived is still available, and could act as a natural gene reservoir in the context of their preservation.

Types of sheep breeds as defined by tail type

It is expected that the adaptation traits of all breeds of sheep and goats will vary, though such adaptation is often not apparent. However, the tail type is an interesting feature which does display considerable variability. The ability to store fat in the tail is a trait which allows animals to thrive despite fluctuations in feed availability. All breeds native to the CAC region are fat-tailed, and so are most of the breeds found in Continental West Asia (Jordan, Iraq and Iran) (Iñiguez 2005a) with the exception of only one thin-tailed breed in Iran. Native thin-tailed breeds do occur, particularly in Turkey, Egypt and North Africa, and are most frequent in Morocco, as all the seven breeds native to that country are thin-tailed. An explanation for this, other than the possibility that they were more influenced by the European breeds found in the Mediterranean region, is not available at present. ICARDA is planning to genetically characterize the breeds of West Asia and CAC, in order to assess the genetic relationships which exist along the Silk Road—a route which linked China and Europe and which may have resulted in important germplasm exchanges in the past.

Potential for dairy production

Not all the sheep and goat breeds of Central Asia are milked for commercial purposes; most are reared only for the purposes of meat, fibre and pelt production. By contrast, however, even though their levels of production are not necessarily high, most sheep and goat breeds in the Caucasus are milked, in order to produce dairy products which can be sold in local markets.

Highly productive dairy sheep only occur in West Asia; particular good examples of such are the Middle Eastern Awassi sheep and the Chios sheep from Cyprus and Turkey. The tradition of consuming dairy products is well-developed in Turkey, Syria, Jordan, Lebanon and the Caucasus, and this results in farmers milking all the breeds available to them in order to allow them to benefit from the high demand for small ruminant dairy products exerted by local markets (Iñiguez 2005a). In North Africa, the only breed milked for commercial purposes is the Tunisian Sicilo-Sarde, which is not indigenous to that region (Iñiguez 2005b).

In general, goats are milked because they have a prolonged lactation period; their milk is mainly consumed by the producer's family. The only highly productive breeds milked for commercial purposes are the Megrel, from Georgia, and the Shami, or Damascus, from the Middle East. Interest in improving the productivity of herds is increasing, due to a rapid rise in the demand for milk (particularly goat milk) in these countries. This has resulted in local goats being crossed with other breeds, often with Shami goats but also with European breeds (Iñiguez 2004).

The potential for rapid lamb/kid growth and meat production

All breeds of sheep in CWANA are exploited to produce meat, which is usually sold to satisfy the demand set by local markets. Most countries have breeds which exhibit good potentials both for growth and for the production of lambs which would be able to reach adequate weights shortly after weaning if managed appropriately. In WANA, market demand for lamb is leading to sophisticated production systems designed to produce fattened lambs. Fattening systems are particularly intensive in the Middle East, because of the excellent prices paid in the Gulf; lambs are therefore fattened and sold to satisfy this affluent market.

Some breeds, such as the Awassi, produce lambs with the potential to grow at rates of 250–300 g/d, responding well to intensive fattening. In the CAC region, adequate use of rangeland during the summer could allow producers to pre-fatten lambs ready for the process to be finished in the fall; and, this could be done at a lower cost than would be the case in WANA. However, several of the breeds which occur in the region only have the potential for low growth rates. Farmers are resorting to crossing these breeds with native breeds which display the potential for better growth. Research is needed to assess any specific attributes that these breeds might have (i.e. special flavour, leanness, the ability to be raised entirely on the ranges, etc.). Such work should be coupled with an exploration of the marketing strategies which could be used to capitalize on the peculiar characteristics found. This would, in turn, help to prevent threats to the integrity of what is an undervalued genetic resource.

With regard to its size, the largest native breed in the whole CWANA region is the Jissar, which is found in the mountainous areas of Uzbekistan and Tajikistan. Other large breeds which produce lambs that display excellent growth rates under range conditions were also developed as coarse-mutton synthetics prior to the dissolution of the Soviet Union.

Very limited information exists about the meat producing ability of goats in CWANA.

Potential for wool/fibre production

Almost all CWANA native sheep breeds produce a coarse to semi-coarse wool, which has little market value. Other than in the case of some breeds used to produce the special wool needed for carpet manufacturing, particularly in Turkey, Iran and Turkmenistan, little attention is paid to this trait because wool contributes relatively little to an animal's value. Synthetic wool producing breeds were developed in Central Asia through crosses involving highly productive animals such as the Merino. Apparently, the breeding programmes either placed more emphasis on quantity than on quality or did not take into account international market trends. As a result, in order to allow producers in the region to compete with other traditional producers, such as Australia, important work needs to be undertaken. This should encompass breeding, as well as production and marketing improvement. However, in general, researchers in Central Asia tend to ignore this fact, and assume that the quality of the wool is high and that the value of the wool will increase automatically once the market prices improve.

The only specialized fibre-producing goat from WANA is the Angora, which is native to Turkey. However, the population numbers of this goat have declined dramatically, falling from 3.7 million in 1980 to 0.5 million in 1995. This is the result of the low prices commanded by mohair, coupled with the breed's low productive capacity (in terms of its growth rates and milk production), which means that it is unable to compensate for the stagnation in the fibre production industry. Another contributing factor is the reduction which has occurred in the area of rangeland available (Iñiguez 2005a).

Central Asia has considerable potential with regard to cashmere and mohair production, as use could be made of two specialized synthetics developed during the Soviet Union: the Cashmere goat and the Mohair goat.

Current trends and farmer claims that have a bearing on small ruminant genetic resources

Population growth is causing markets to expand. This is particularly true in WANA, where such market expansion has increased the demand for small ruminant products.

Farmers are attempting to capture the opportunities offered by this by intensifying their production systems. Specifically, they are doing this by reducing the effects of the critical feed fluctuations which occur during the year. Such intensification brings concomitant changes in the genotype x environment (GxE) interactions which occur. Farmers claim that the productivity of unimproved breeds under the new GxE interactions does not match the often costly investments they have to make to stabilize the environment, particularly the feed fluctuations which occur. As a result, improved animals are needed. This is why, in recently conducted constraint assessments, breeding issues have received the same amount of attention as feeding issues. In addition, and of relevance in this context, farmers also claim that they lack access to improved genotypes, because breeding programmes remain centralized and are not managed by the farmers themselves.

Many native breeds are undervalued and their potential is not being fully capitalized upon through the use of appropriate marketing strategies. This is causing farmers to begin to consider the possibility of taking advantage of the options offered by other native breeds with better performance, an action which could lead to undervalued breeds being absorbed and eventually lost. As indicated above, market and consumer preferences are also factors likely to determine further changes in breeds that are well-valued.

The conditions described above are, in some cases, leading to indiscriminate cross-breeding between native breeds and breeds that better fit with market demand.

In addition, wars in the region have severely impacted upon whatever breeding systems were available and, very probably, upon the genetic resources available. This said, however, the actual impact of such conflict has not been assessed in this regard.

The current status of small ruminant genetic diversity in WANA

With few exceptions (4–5 breeds out of a total of 112), the sheep and goat breeds of WANA are under no real threat and in many cases their population numbers are increasing. The few exceptions involve minor breeds, usually those which have little opportunity to compete with those other more productive breeds that have attained greater popularity in relation to market demand. Research, including breed descriptions, suggests that it is likely that the threatened breeds are closely related to other more productive breeds kept in nearby areas. Thus, careful genetic characterization is justified, prior to and to ensure the conservation of these minor breeds.

Information on the production characteristics of goats is far more scarce than that available for sheep. Only a few of the goat breeds available in CWANA have been characterized; and, most have been given only a generic name (e.g. 'Tunisian native goat') to distinguish them from the goats found in other countries. This has been done without attempts being made to discriminate between each breed's natures, and without their characteristics and production potentials being appropriately assessed.

Small ruminant genetic diversity is being affected by changes which are occurring in the production environment, particularly by increases in market demand. For instance, intensive and often indiscriminate cross-breeding of local goats with other more productive genotypes (i.e. the Damascus goat or European dairy breeds) is occurring in several of those countries in which local demand for goat milk products has increased. This is particularly the case in the mountainous regions of WANA. In another example, changes in consumer preference are also resulting in changes in diversity. This is true in the case of the massive amount of cross-breeding which has occurred between two Tunisian indigenous sheep breeds: the Barbarine fat-tailed sheep and the Tunisian thin-tailed sheep—a response to the fact that consumers prefer carcasses without a fat tail. This case is currently being studied by ICARDA and INAT in Tunisia.

Current status of the small ruminant genetic diversity in CAC

Native sheep and goat genetic resources in the CAC region (with the exception of 2–3 breeds in the Caucasus) are not under threat, and population numbers are increasing. However most of the Synthetic breeds, particularly those producing coarse wool, are vanishing, as a result of their indiscriminate absorption by native breeds.

The indiscriminate crossing which is occurring is mainly market driven; however, it is also in part due to the collapse of the breeding programmes which were maintained during the Soviet Union and a lack of technology transfer services (Iñiguez et al. 2004). Farmers claim that their products stagnate and that, under the current conditions, they would prefer to keep a more sturdy animal able to produce meat and fat, both of which are preferred by consumers, such as those found among the indigenous fat-tailed sheep.

Within the CAC region, goat diversity is even more poorly characterized than it has been in WANA, and the associated information is thus also scanty.

The changes that occurred in the political and economic environment of the region after the collapse of the Soviet Union, particularly the collapse of markets and the fragmentation of large production systems into numerous systems containing only a handful of animals, has severely impacted upon the animal genetic resources of the region. During the transition period that moved the region towards an open market economy, sheep populations declined. This was particularly true in countries such as Kazakhstan and Kyrgyzstan, where more substantial economic reforms were applied. Kazakhstan alone lost nearly 28 million sheep, which resulted in the country’s sheep population declining from 36 million head in 1992 to just under 8 million head in 2000 (Iñiguez et al. 2004). In those countries which applied the reforms more conservatively (e.g. Uzbekistan and Turkmenistan) the impact was less pronounced.

Conclusions

Most native genetic resources are stable in the region. The exceptions to this are a few of the native breeds in the whole region and many of the non-native, synthetic breeds found in CAC. In the case of threatened native breeds, potential gene reservoirs apparently exist in the form of breeds kept in neighboring areas, a fact which justifies genetic characterization prior to direct conservation measures being taken.

Most synthetics have undergone continuous cycles of cross-breeding with several European breeds. These breeds were developed under a specific market context which has now changed substantially. However, most of the parental breeds, European and indigenous, are available. Thus, the steps that should be taken for their conservation, if such steps are needed, should be carefully assessed.

It is important to make the efforts needed to help farmers to reorient their production systems, in order to allow them to better utilize the genetic resources available. Steps must also be taken to develop community-based, decentralized and participatory breeding strategies owned by farmers, as this will help to provide them with access to sources of improved animals.

Market issues and opportunities should be monitored to assess and eventually anticipate changes in genetic resources, as well as to capitalize upon the possibilities available to increase the value of undervalued breeds by capitalizing upon their adaptations, specific attributes and the quality of their products.

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Information needs for animal genetic resources conservation

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Abstract

The combination of high costs to characterize and improve livestock genetic resources coupled with the difficulties and costs of *in vitro* conservation require that decision-making on conservation and utilization of livestock genetic resources should be taken together. The accuracy and value of all decision-making is dependant on the quality of the information available. There is far from sufficient information for effective decision-making on the majority of livestock breeds of the developing world. Most of the information that does exist is scattered across diverse literature and is difficult to locate and access. Only a proportion of this information has been collected in comparative trials that allow reliable comparison of information between breeds. Three substantive animal genetic resources (AnGR) information systems (DAD-IS, DAGRIS and EFARBIS) collect complementary information and provide useful baseline data, but all capture only a small proportion of the information available. There is urgent need to characterize the majority of the world's AnGR in designed studies that will allow comparisons across breeds. Better information is required on how to collect such information efficiently. Such information will take time to amass and in the meantime information such as molecular genetic assessments of diversity and GIS referencing of breed origins and use will assist inferences about where useful diversity exists. The AnGR information systems need to capture the information that already exists along with all new information as it is generated. These information systems need to add greater functionality to allow users to search and analyse the information they contain, and deliver decision aids for conservation of, access to, utilization of and improvement of AnGR, particularly in low input settings where information on how to effect sustainable action remains poor.

Background

In the developed world, change in nature and use of AnGR in recent times has fallen into three broad phases: in phase I, as agriculture intensified in the 19th century, breeds were recognized and managed as formal entities and breeds better adapted to improved agriculture began to replace other breeds; in phase II in the early through middle 20th century, breed replacement continued and cross-breeding became widespread in many species; in phase III, from the middle 20th century, the remaining breeds and cross-breed composite populations were subject to within-breed genetic improvement as opportunities for breed replacement were exhausted.

Intensification of animal agriculture is now widespread, though still highly variable across the developing world. Intensification is used here in its broadest sense and ranges from introduction of simple drugs or vaccines to improve health of animals in otherwise unchanged production systems, through to systems in which all aspects of nutrition and environment and disease challenge to animals are effectively removed (as in many intensive animal systems in the developed temperate world). Even a single change, such as the introduction of low-cost disease treatment provides opportunities for livestock keepers to change genotype; for example to use an otherwise well-adapted and somewhat more productive breed that was previously excluded from the area because of disease susceptibility. At various levels, therefore, the developed world is already repeating, but much more rapidly, the process of breed replacement, cross-breeding and within-breed selection that happened over the past 200 years in the developed world. These changes are likely also to create rapidly accelerating threats to existing livestock genetic diversity as breed substitution and crossing proceeds.

Livestock are relatively costly and time-consuming to characterize and improve. *In vitro* conservation is possible for some species, but is much more costly than with plants, with greater costs to extract, reconstitute and test stored material. This favours live animal conservation through use as the preferred conservation method. Livestock are not static entities, but undergo constant improvement and need to undergo such improvement to remain a viable livelihood option for their farmer owners. All the above factors argue that for livestock, conservation, utilization and improvement are all highly interrelated and cannot be safely dealt with separately. To manage all of these changes effectively, in the best interest of both the farmers involved and society at large, will require access to high-quality information. More detailed descriptions about the value and use of information in livestock genetic conservation and utilization can be found in Gibson, Ayalew and Hanotte (2006) and Gibson and Bishop (2005).

Information requirements for effective decision-making

Decision-making in conservation, breed replacement, cross-breeding and within-breed genetic improvement all require access to high-quality information, some of which is unique to each action but much of which is required for all actions. Examples include, *inter alia,* accurate and comprehensive characterization of each breed, preferably in multiple environments; prediction of breed characteristics in a new environment; prediction of cross-breed performance (based on phenotype and molecular diversity data); estimates of socio-economic and livelihood value of AnGR, globally and locally, between and within breeds, short- and long-term; information on availability on how to access germplasm, including biosafety and regulatory requirements; continuously updated estimates of degree of risk faced by each breed; proof of performance of breeds or cross-breeds newly introduced into an area or production system; estimates of genetic parameters coupled with socio-economic values to optimize directions for genetic change.

Availability of information

Comprehensive, high-quality information on production, adaptation and disease resistance characteristics is available for a small number of intensively studied breeds of pigs, sheep, cattle and poultry, most of which are predominantly used for livestock production in the developed world. A substantial number of other breeds have reasonable information on easy to measure production characteristics, but substantially less information on more difficult to record productivity characteristics, adaptation or disease resistance. The majority of the world's breeds have been poorly characterized. The inadequacy of the extent of characterization of livestock breeds notwithstanding, the total amount of information available is substantial. A problem in accessing that information is that much of it has been published in the 'grey literature' such as national journals, ministry and institutional reports that are not readily accessible outside their country of publication (and often also difficult to access within the country of publication) and predate or are still not captured by current electronic bibliographic databases.

In order to make comparisons among breeds, breeds have to be evaluated under identical conditions, requiring well-designed trials on several breeds simultaneously, with sufficient animals, sampled appropriately from each breed to obtain reasonably accurate estimates of each breed's performance. Ideally, information would be available for each breed in a variety of production and disease challenge environments. In practice, much of the information available has been collected from small trials, often involving only one or two breeds, often in only one environment and often with limited information on the environment in which the animals were evaluated.

In the absence of comprehensive evaluation of breed characteristics, molecular genetic markers have been used to assess the genetic diversity within and between breeds of livestock. Molecular genetic diversity information can be useful in setting priorities for conservation, for assessing likely sources of novel genetic variation useful for genetic improvement. Molecular genetic markers can also be used to test hypotheses about the existence of novel genetic variation in certain breeds and also utilized in genetic improvement. Extensive regional surveys of genetic diversity have been undertaken for a few species in Europe and Africa, but comprehensive global surveys of genetic diversity are still lacking. Information that has already been collected is widely scattered and there are technical difficulties in combining the data that has been collected.

Information systems

A number of Web sites contain some information on developing world AnGR but only two provide sufficient coverage to be useful in decision-making. FAO has developed and maintains the DAD-IS database (Domestic Animal Diversity Information Service, http://www.fao.org/dad-is/), while ILRI (the International Livestock Research Institute) has developed and maintains the DAGRIS database (Domestic Animal Genetic Resources Information System, http://dagris.ilri.cgiar.org/dagris/).

DAD-IS is maintained as an information resource on conservation and management of FAnGR. In addition to extensive lists of guidelines and reports of intergovernmental processes related to FAnGR, it includes a database into which countries can enter their own data on a limited number of breed characteristics and status that they choose to make available publicly. Typically, neither the environment in which production data was collected nor the source of the information is listed. The database provides a useful starting place to identify the existence of AnGR in a given country and provides a snapshot of breed characteristics, though breed lists remain incomplete for some countries. A limitation is that many breeds have different names in different countries and the list of synonyms is not always complete. The low level of information on physical and production environments and the highly variable quality and extent of characterization data mean that DAD-IS is of limited value for identifying germplasm that might prove useful in another location. A European consortium is developing a substantially updated and extended form of DAD-IS for European countries to use, and DAD-ISI will migrate to an EFARBIS format once it is completed. DAD-IS and DAGRIS (see below) are cross-linked to each other but otherwise managed and developed independently.

DAGRIS is maintained by ILRI as a database into which data is transcribed and edited from a wide range of publications, ranging from institute and ministry reports, and national, regional and international journals. Each breed in each country has descriptions of breed origin, production system, geographical distribution and status. These descriptions are either prepared by ILRI staff or commissioned from experts familiar with the breed. Users can search the database at a variety of levels. Within a breed, users can access summaries of performance data taken from all the publications that have been entered, and from each data entry, the user can go to the abstract of the paper from which the data was taken. At present the database includes a relatively comprehensive collation of data for African cattle, and substantial collations for sheep and goats, also mostly in Africa. A start is being made on chicken breeds, with plans to extend some information collation into Asia (subject to funding). DAGRIS has provided a major step forward in availability of existing information on AnGR for the small number of species and limited geographical regions it covers.

Future priorities for information collection and provision

An urgent priority is to place into the existing electronic information systems all information that currently exists on breed characterization so that it is universally accessible. This is perfectly achievable, but will require a dispersed global effort that will require new interfaces to existing databases and new ways of operating compared to the current methods for adding and curating such information. The information systems will also require new tools for accessing, collating and analysing the information they hold. Examples include ability to undertake regional or global searches for multiple breeds and/or trait ranges and/or environments, and ability to pull data together to perform multiple breed analyses. Ideally the information systems will contain analysis options, but at very least should have options to export data compiled to user specifications in multiple format options for import into external databases or statistical analysis packages. The information systems will require facilities for capture and storage, search, access to and analysis of genetic diversity data of various forms, including molecular marker data, along with all descriptors necessary for analysis and interpretation of such data.

Given the lack of information on disease resistance and adaptation traits for most breeds, it may be possible to infer the characteristics of many breeds from the environments in which they evolved and are currently used. A high definition GIS system onto which past and present breed distribution data is layered would provide many insights in potential breed characteristics and allow targeting of breed characterization studies. Such GIS systems should include the diverse features, such as livestock production system mapping, climate, physical, vegetation and disease and/or disease vector maps. Such maps are currently being developed in several independent projects and this argues strongly for bringing together all livestock (and in indeed agricultural) mapping projects and information systems into one single information system working on a common platform, into which AnGR information is added.

High-quality characterization data is urgently required for many breeds, and this will require better information being available on how to conduct such characterization studies in a cost-effective manner that generates accurate data. Molecular genetic assay of genetic diversity needs to be extended to provide global coverage and methods need to be developed to collate and analyse the data that already exists across many independent studies.

Most decisions on conservation and utilization will ultimately be based on assessments of socio-economic value of alternative AnGR. This requires better methodologies for estimating such value and methods to capture and access such estimates of value once they have been generated. Decision-makers and executive agents need access to guidelines and tools for determining and then executing optimum strategies for *in vivo* and *in vitro* conservation and for utilization of AnGR. Such guidelines and tools still need to be developed for low input systems of the developing world and once developed should be made accessible through AnGR information systems.

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Tools available for setting conservation priorities of farm animal genetic resources

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Abstract

Conserving farm animal genetic resources (FAnGR) presents analogies with the more general question of preserving biodiversity. A methodology for defining optimal conservation strategies among endangered breeds under a limited budget constraint is presented. The four fundamental ingredients needed for each breed are utility, distinctiveness, present and future survivability and cost of improving survivability. Breeds may be ranked on a criterion combining these four variables. Various situations regarding the diversity considered and the costs of conservation are discussed. The difficulties for quantifying the information needed with sufficient precision are also underlined.

Introduction

Conserving FAnGR presents analogies with the more general question of preserving biological diversity. In both cases, owing to the limited resources which can be devoted to conservation, the central question is 'what to protect' (see Vane-Wright et al. 1991). The choices are difficult and an operational framework is needed. An economic theory for guiding actual conservation policy in a diversity-improving direction has been provided in a series of papers by Weitzman (1992; 1993; 1998), who has formalized the problem of optimum diversity preservation under a budget constraint as the Noah's Ark Problem. Essentially, boarding the Ark is a metaphor for investing in a conservation project to improve survivability of a set S of n elements (e. g. species or breeds) subject to an overall budget constraint. This provides a convenient framework for setting priorities of FAnGR conservation (Ollivier 2005).

The ingredients of an optimum policy

The four fundamental ingredients of an optimum policy are *utility*, *distinctiveness*, *probability of survival* and *cost* to improve survivability. These quantities are defined for each breed k as U_k, D_k, P_k and C_k, respectively.

Utility of genetic resources can be measured through evaluation of the benefits derived from their conservation. The methods available for the economic valuation of FAnGR have been reviewed by Drucker et al. (2001), and in a special issue of *Ecological Economics* (see Drucker and Scarpa 2003). In addition to genetic variation, many other benefits can be seen from breed conservation, such as landscape/environment benefits, cultural value and existence value (Mendelsohn 2003).

The approach to *distinctiveness* advocated by Weitzman is based on the concept of distance, or dissimilarity. The idea of distance between two elements can be extended to distance between a set of elements and an element outside this set, defined as the distance between the latter and its closest neighbour in the set considered. The diversity function V of Weitzman is then defined as "the maximum, over all members of the set, of the distance of that member from its closest relative in the set plus the diversity of the set without that member" (Weitzman 1993). This theory, applied by Weitzman to an example of species conservation, may be extended to livestock breeds diversity, as advocated by Thaon d'Arnoldi et al. (1998). The V function allows evaluating the loss of diversity V_k

which would result from the extinction of any given breed *k*. V_k is the breed contribution to diversity and can thus be seen as a measure of the genetic uniqueness of each breed in a given set *S*. The approach may easily be extended to measuring the contribution to diversity of any subset of breeds. It thus allows partitioning diversity among groups of breeds defined either by category, country or region of the world. The method has already been widely used, particularly in several farm animal species (see Ollivier et al 2005, and references therein). A software is available for deriving the breed contributions from any distance matrix (Derban et al. 2002).

Breed diversity in those studies was based on genetic distances. As to the genetic diversity to consider, however, we should keep in mind that both between-breed and within-breed components of diversity are to be considered. An *aggregate diversity* combining the two components linearly may be defined, and breed contributions to aggregate diversities are then easy to derive (Ollivier and Foulley 2005) The method is in fact quite general, and could be applied to other types of genetic diversity, such as *allelic richness* diversity (Foulley and Ollivier 2006), as well as to any type of diversity, such as the *cultural diversity* considered by Gandini and Villa (2003).

More generality may be given to distinctiveness by taking into account *probability of survival* or degree of endangerment. Based on the survival probability P_k of each breed over a given period of time, various extinction-survival patterns may occur with given probabilities, and an expected diversity can be defined. The *distinctiveness* D_k of a breed *k*, which may also be called its *marginal diversity*, is then obtained as the partial derivative of expected diversity with respect to P_k. D_k so expresses the increase in expected diversity with respect to the increase in survival probability of breed *k* (Weitzman 1993). Other approaches to genetic diversity have been proposed (as reviewed by Ollivier and Foulley 2005). It should be noted that these alternative methods are based on variances and may consequently yield negative contributions to breed diversity (Thaon d'Arnoldi et al. 1998). In contrast, the *V* function has the intuitively appealing property of "monotonicity in species (or breeds)", meaning that diversity cannot increase when a breed is removed.

The *costs* to improve survivability will in general depend on the desired increase in survival probability of each breed, P_k, and vary according to the situation of each breed and to the various techniques of conservation, *in situ*, *ex situ* or by management, as we shall see below.

A formal solution of the Noah's Ark problem

Given the utility (U_k), distinctiveness (D_k), desired increase in survivability (ΔP_k) and corresponding costs (C_k) for each breed *k*, the formal solution of the Noah's Ark Problem, as demonstrated by Weitzman (1998), is an "extreme policy", meaning that each breed should be made either totally safe or left to become extinct, within the budget allowed. Ranking the breeds is a linear programming problem and the breed projects should be ranked by the following criterion:

$$R_k = (U_k + D_k)\, P_k / C_k \qquad (1)$$

Two particularly simple situations are worth considering. If the costs C_k are proportional to the survivability improvements achieved P_k, one can see from equation (1) that P_k/C_k is a constant and the diversity ranking should then be based on the breeds' distinctiveness and utility. In some cases the more endangered breed may appear as less distinctive, as the crowned-crane paradox of Weitzman (1993) shows. It will then be optimal to make the safe breed even safer at the expense of making the endangered one even more endangered. On the other hand, if C_k is assumed to be the same for all breeds, and if P_k is taken at its maximum value, i. e. equal to the breed extinction probability E_k, the optimal diversity ranking should be based on the product D_kE_k, named *conservation potential* (Weitzman 1993). This parameter, considered by Weitzman as the single most useful indicator in the absence of specific knowledge about preservation costs, would apply to livestock species conservation, where cryopreservation is available and can be assumed to make a breed safe. In line with equation (1), and assuming cryogenic preservation costs to be equal over different breeds of the same species, breed cryopreservation priorities could then be based on a *cryopreservation potential* equivalent to the conservation potential defined above.

The logic underlying equation (1) implies that different priorities will be defined according to the cost situation assumed. Under systems of live animal conservation, for example, it will usually be difficult to link expenditures and survival improvement. The possibility to apply iterative algorithms for ranking breeds on the basis of conservation costs is then an alternative to consider, as shown for breeds of cattle in Africa by Simianer et al. (2003).

Discussion

As we have seen, a cost-effectiveness methodology exists for defining optimal conservation strategies, so that economically sound priorities of conservation can, at least in theory, be established. It should be emphasized that equation (1) is a general framework, and may not be easy to apply in the real world, due to the difficulty to evaluate the four necessary ingredients with sufficient precision. This is particularly the case for risk of extinction (or degree of endangerment) which is in general quite challenging to evaluate: see the African cattle situation analysed by Reist-Marti et al. (2003), or the European situation discussed by Gandini et al. (2004). The framework proposed may at least be seen as a point of departure even in a more complicated world. Equation (1) also implies that distinctiveness and utility should be properly weighted. Here again evaluation may be difficult. A method to balance genetic diversity, perceived merit and population viability has been proposed by Piyasatian and Kinghorn (2003). Depending on the emphasis on diversity, the solutions may give priority to the conservation of pure breeds or of crosses between closely related breeds more adapted to enhancing populations' viability.

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In situ conservation strategies for animal genetic resources: lessons learned from rural communities across the world

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Introduction

For many communities around the world, mainly in developing countries, domestic animals are the basis for their livelihood, offering food security, social coherence, a source of income and hopes for a better future. In collaboration with livestock communities, research centres, universities, governmental and non-governmental organizations, FAO identified and documented 13 case studies on community-based management of animal genetic resources. The selection of case studies was done in such a way as to raise awareness of the important interactions between human communities and animal populations. The case studies originally provided to FAO were written by authors from various countries with extremely different backgrounds. They have only been edited and therefore they reflect the perceptions and opinions of their authors and not necessarily those of FAO.

The main purpose of this study is to gain a better understanding of:

- how rural communities organize themselves to manage their animal populations;
- local knowledge and good practices;
- linkages between people, their animals and the environment;
- how communities cope with threats to their local animal genetic resources;
- how sustainable are strategies and what possible long-term solutions exist.

Most case studies involve local livestock breeds that are raised in traditional livestock farming systems, mostly in marginal areas, for the production of meat, milk products, eggs, fibre, fertilizer and manure or to provide draught power. In such systems, local knowledge is crucial in safeguarding the equilibrium between farmers, their animals and the environment. Indigenous knowledge is the actual knowledge of communities that reflects the local experiences based on traditions and incorporates more recent experiences with modern technologies. This knowledge is under a great deal of external pressures, some of which could be reduced through formal government involvement.

Therefore, a primary objective of this study is to make available to decision-makers examples of real life situations that show the importance of traditional livestock farming systems to the livelihoods of farming communities, and also their contribution to the conservation of domestic animal diversity. Livestock diversity represents future capacity to meet unforeseen needs and opportunities, besides offering a wide choice of products for a varied and nutritious diet to consumers in both developing and developed countries. The study draws specific attention to ways in which decision-makers can support these farming communities, hoping to encourage them to include incentives to active conservation of animal genetic resources (through sustainable use and improvement) in legal, regulatory and institutional planning.

What did the case studies tell us?

Livestock keepers in the areas of study primarily raise domestic animals to provide food for their families. Secondary products such as manure, hides and wool are used to meet other needs—fuel for cooking or clothing. Should there be a surplus of any of these products, farmers will generally try to sell them to supplement their income and, whenever possible, they will seek to increase their economic returns though other farming alternatives. Many farmers have for example recently developed activities in the ecotourism sector, in which their domestic animals play a key role.

Farmers select and keep animals that provide products best meeting their needs and they aim to maximize their production potential under the given circumstances, which may change over time. Therefore, these are dynamic processes. In each of the areas where the case studies originate, the climatic and environmental conditions are harsh and feed is often scarcely available and of low quality. However, the animals raised in these areas are physiologically adapted to the conditions of their habitat and, with appropriate management and based on local knowledge, they can survive and produce.

Besides markets, policies have been identified as drivers of change in livestock production systems, with implications on breeds. Livestock keepers, and especially nomadic pastoralists, are often marginalized by policies arising from their own governments. When developing livestock related policies, decision-makers often do not take into account the pastoralists' way of life nor acknowledge their contribution to the country's economy. Policies favouring exotic livestock breeds, those supporting foreign industrial investments such as mining, or those changing land tenure for the regeneration of forests or wildlife conservation are severely threatening the sustainability of the farming systems described. Such policies have shown to have far-reaching impacts on the daily lives of the rural communities in the study areas, such as the permanent loss of domestic animal diversity and local knowledge, social disruption, health problems and economic losses.

In some case studies, changing land tenure policies was one of the key drivers of change in livestock farming systems, especially those based on transhumance. Privatization of large areas of previously common land is an example of a policy that forces pastoralists to find new migration routes and to compete for the remaining commonly available grasslands. This often leads to conflict amongst livestock keepers and between livestock keepers and sedentary farmers. Moreover, the animal density on the accessible lands increases above sustainable levels resulting in the permanent loss of valuable feed resources and ultimately of local domestic animal breeds. In such a situation farmers are left with no choice but to either drastically adapt their management strategies or, when this is not an option, abandon livestock farming all together, which often leaves them with no other option but to move to urban centres to seek new job opportunities.

Main areas of attention

The authors of the various case studies proposed a number of ways to combat some of the above mentioned threats. In addition, they put forward various ideas to support farmers with the conservation and improvement of their animal genetic resources. When grouping and summarizing the most frequently mentioned proposals, five main areas of attention were identified, as given below.

Awareness raising and capacity building

Passing on lessons is considered essential to generate new ideas and solutions so that farmers can develop and conserve their animal genetic resources and ultimately improve their livelihoods. This can be achieved by connecting farmers with others who are addressing similar problems. Informal and formal networks can be developed to exchange information, techniques, methodologies and experience, some of which may require government support. Potential tools of communication could be newsletters and, if financially and technically viable, national or regional workshops could be organized and virtual interaction enhanced.

As part of a coordinated livestock improvement strategy, various authors consider training and coaching crucial, especially to increase farmers' knowledge about the sustainable utilization of local animal genetic resources. The development objectives of such a strategy should take into account all stress elements present in the production environment and the linkages between livestock, forests, rangelands and wildlife conservation should be highlighted. Farmer field schools could be a possible way to teach farmers about their production environment and the interaction between its various components. Field schools offer farmers an opportunity to learn by doing, by being involved in experimentation, discussion and decision-making. This strengthens their role in the researcher–extensionist–farmer chain and also improves the sense of ownership of rural communities in technological packages and new knowledge and skills.

Giving farming communities the opportunity to decide about their future

Governments should seek to involve indigenous and local communities more actively, understand their needs and incorporate their knowledge and technologies when developing national livestock programmes for the improvement, sustainable use and conservation of domestic animal diversity. They should also take into consideration that both these needs and knowledge continuously change according to the dynamics of the socio-economic and natural environment.

More specifically, many authors mentioned that governments need to include the participation of indigenous and local communities when developing policies for the conservation and sustainable use of animal genetic resources, the access to these resources, the sharing of benefits and the designation and management of protected areas. The experience and knowledge of these farming communities, and their respect towards their animals and the environment, are essential to developing sound policies. A first step to facilitate the participation of these communities in policy development is to translate livestock breeding policy and guidelines into understandable documents for farmers.

A number of governments have adopted specific laws and policies in national biodiversity action plans, strategies and programmes for protecting traditional knowledge. They have developed laws whereby the prior informed consent of knowledge-holders must be attained before their knowledge can be used by others. These activities are consistent with the fulfilment of obligations to the Convention on Biological Diversity.

Market opportunities

Most farmers will find it worthwhile to invest in the improvement and conservation of their local farm animal breeds if new market opportunities arise. Sometimes the temptation to change to high production breeds may be too large but many times with disastrous consequences due to high input requirements that are not available. This may sometimes be the result of official policies or government incentives. Identification of new markets and marketing strategies are particularly important to provide farmers with the necessary incentive to continue raising their indigenous breeds rather than changing to a greater input with high production breeds.

Niche markets for products of local breeds are seen as one possibility of keeping local breeds in the market. Local breeds are often raised in extensive and often organic livestock farming systems. The genetic characteristics of traditional breeds may contribute, for example, to a special taste and structure of the meat. Also the vegetation consumed in extensive production systems, or some special processing of meat or dairy products such as cheese may contribute to these special products. These aspects could be promoted among consumers through the media, publicity campaigns and the organization of farm animal fairs. In turn this would lead to a better appreciation of indigenous farm animal breeds and stimulate a greater market demand for products of local origin. The development of niche markets for products of local breeds in their traditional environments is seen as one possibility for active breed conservation.

Another reason to promote the improvement and conservation of local farm animals is to preserve the characteristics of their products, at a given technology level in the value chain. As an example, for local activities such as weaving, it is important that the quality of the wool sold on the market is stable. Also the farmers are used to working with a certain type of wool and if this is modified, it will disrupt local home industries. Through cross-breeding it would be possible to improve the fineness of the wool of some local sheep breeds, and this makes sense from a large-scale industrial point of view (finer wool is more valuable in the international market), but not from the perspective of these local communities. Local weavers have always worked with thick wool and do not have the equipment or the skills to process this 'new type' of wool of reputed higher quality.

In areas where tourism industry is rapidly developing, alternative income-generating activities such as handicrafts and ecotourism could be further explored. In countries like Lesotho and Bhutan local farm animals used for packing and means of transportation in remote areas are now also put to use for transporting the more adventurous type of tourists ('trekking').

Conservation

Without highly motivated livestock keepers *in situ* conservation efforts of local animal genetic resources are wasted. A precondition is for farmers to be convinced about the potential of their animals and the need for their products and services. Community-based management of animal genetic resources has two aspects: the community and the breed, which may disconnect over time. It can be assumed that social disruption may lead to the loss of local breeds; however, the case studies, which were selected to represent communities managing their animals, do not provide examples. One case study clearly shows that a functioning community of farmers changed their breed. In Nepal, farmers lost interest in their local animal breed and willingly and successfully replaced this breed with an exotic one. Due to the parcelling out of available land as a result of population growth rural households were forced to sell their local buffaloes. Accessible bank loans encouraged the purchase of high-yielding exotic buffaloes that do not depend on large parcels of land for grazing and can be stall-fed. In less than 30 years, more than 95% of farm households in the study area have replaced their local *Lime* swamp buffaloes with high-yielding exotic *Murraha* milk buffaloes from the Indian lowlands. Initial obstacles to managing the newly introduced breed have been overcome and farmers no longer wish to return to the past. Farmers have kept exotic buffaloes successfully on a prolonged basis, and have been rewarded with an improved standard of living. Their priority now is to further develop breeding strategies for the *Murraha* buffaloes to achieve even better productivity.

Farmers will not conserve a breed without targeted incentives. In developed countries this incentive might be of a sentimental nature (conserve the breed because of its beauty, its uniqueness), but this is hardly the case for farmers in developing countries. These farmers often strive for improvement and conservation at the same time. Through the use and further development of their local animal breeds farmers significantly contribute to the conservation of domestic animal diversity.

Several authors pointed out that strategies such as cryopreservation and associated reproductive technologies are necessary for the conservation of genetic livestock material. The costs of these types of technologies depend on local circumstances, availability of technology, labour and local facilities. Therefore, it is important for decision-makers to reconsider the balance regularly between objectives, costs and technical and practical feasibility in conservation programmes.[1]

Policy and legal framework

Raising awareness among government officials about the importance of maintaining genetic diversity, better coordination of institutional capacity and reviewing policies that may have had unintended negative effects on animal genetic resources, are considered a priority. Sustainable livestock

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[1] Hiemstra SJ, van der Lende T, Woelders H. 2005. The potential of cryopreservation and reproductive technologies for animal genetic resources conservation strategies. The role of biotechnology. Villa Gualino, Turin, Italy, 5–7 March 2005.

development projects may encourage the development of appropriate policies and regulations, promote participation and consensus, and develop new partnerships.

It should not be ignored that in some cases it is better to have no law or policy in place rather than adopting an inappropriate one; for example, instead of implementing a national breed development policy that promotes the indiscriminate introduction and use of exotic breeds, the authors considered it preferable to have no breed development policy at all.

Legal documents addressing farmers' rights and privileges with regard to animal genetic resources must be developed carefully in order to ensure that the people who maintain and depend upon these resources can continue to do so in the future.

Conclusions

All documented case studies are examples of *in vivo* and *in situ* conservation methods in marginal areas. Despite the large number of communalities between the various case studies each situation does require a unique approach. No overall recommendations can be made on how to guarantee the sustainable use, development and conservation of community-managed animal genetic resources in general.

Communities can learn from each other. Through the exchange of experiences and information new ideas can be generated, possibly leading to innovative livestock practices that can complement and improve traditional farming ways.

At present, the communities of the described case studies unfortunately do not have easy access to information or to communication networks. As previously mentioned, farmer field schools as well as specific radio programmes and extension work could offer farmers the opportunity to be better informed. Such initiatives can only work if fully supported by governments.

Community-based management of farm animal genetic resources: a donor's perspective

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Introduction

Let us start with a question: Why should we deal with farm animal genetic resources (FAnGR) when the Millennium Development Goals (MDGs) target reduction of poverty and hunger, improved health services and better access to clean drinking water?

Keeping animals is not only an activity to produce luxury food for overweight eaters of red meat. It is also an activity often being pursued by poor people to make a living. In many cases, keeping animals is a way to alleviate poverty or, at least, to prevent poor people from becoming absolutely destitute. So if we want to halve the number of poor people in this world by 2015, we should be giving high priority to enabling poor people to keep animals. And management of FAnGR or breeding is an important part of this.

Animals kept to alleviate poverty are not being kept on large farms, but by smallholders and pastoralists or in backyards in urban areas. Many of these animal keepers live in marginal areas, and—contrary to modern, 'Northern' animal production systems in which the environment, including disease and nutrition, is controlled—poor people's animals usually have to cope with adverse and highly variable environments. Therefore, rather than keeping uniform animals, it is important for the smallholders and pastoralists to keep animals that are adapted to these variable conditions, to disease pressures and often to low-quality feed.

In this paper, we want to discuss community-based management (CBM) of FAnGR from the perspective of a donor organization. We will start with definitions, explore different ways in which communities manage FAnGR, look at the framework conditions, indicate some support measures and specifically what donors can do, and end with some open questions to ponder.

Definitions

For this audience, it is hardly necessary to define FAnGR. We all know that fewer than 30 species have been used extensively in agriculture and fewer than 14 species account for over 90% of global livestock production (FAO 1999) and that a number of wild species (e.g. of fish) are now undergoing the process of domestication. For breeding management purposes, species are subdivided into breeds. The term 'breed' is not strictly defined (e.g. Rege 2003), but there is general agreement that a breed is a population of animals that are bred with each other and have common characteristics. Breeds can be defined geographically or primarily according to phenotypes. In industrialized countries, where scientific breeding started about 200 years ago, breeds are linked to herd-books and are registered, either by state authorities or by breed associations. In developing countries, breeds may be linked more to a particular area and/or a particular group of animal keepers. Often, the genealogy of the animals plays an important role in defining whether an animal belongs to a particular breed or not.

There is disagreement about ownership of FAnGR. Some people argue (e.g. Ott 2005) that FAnGRs are a public good, a national or even global inheritance. This means that nations, the global community and mankind have also obligations in maintaining this inheritance, and that subsidies may be justified on national and/or international level. It also means that, because FAnGR are a public good, individual breeders have the right to develop the breeds further but have only the immediate use value at their disposal. Others (e.g. Köhler-Rollefson et al. 2005) argue that breeds are owned by communities, who may have a more global vision in the sense that they do not regard themselves as owners of a breed but rather as mere custodians of the animals. For still other people, particularly those in breeding firms, breeds are regarded as private property, and this can mean that other breeders not only may have to pay for the livestock, but moreover they are either not allowed to breed further or they must pay a royalty if they want to breed further.

Support for CBM of FAnGR puts communities of animal keepers in the centre of attention. A 'community' is a group of people who share common interests in managing natural resources and who, in most cases, inhabit a particular territory. Of course, not only with respect to management of FAnGR, a community is not homogeneous. Whereas the majority of households may own chickens or goats, some (usually the very poor) will have no animals. And larger animals such as cattle or camels may be owned only by a minority of relatively well-off people. This should be kept in mind when support for CBM of FAnGR is being viewed as a means to alleviate poverty. There is also a difference between support for maintaining indigenous breeds, on the one hand, and CBM of FAnGR, on the other. The two may go together, but not necessarily. In this paper, however, we focus on CBM of indigenous animal breeds.

Finally, an attempt to define 'donors': These are government, international or private organizations with money that is made available as donations, grants or credit and can be allocated to particular projects or programmes. The donors set criteria and have administrative procedures for allocation of funds and they may or may not have a clear policy with respect to FAnGR. According to the analysis by Gibson and Pullin (2005), a clear and meaningful policy with respect to FAnGR is the exception rather than the rule, and only few donors give FAnGR a high priority. We can regret that, but can also see it as an opportunity.

Legal framework

The legal framework for CBM of FAnGR includes the international treaties and conventions and the national laws, both not free from contradictions.

The international treaties and conventions that touch upon CBM of FAnGR include the Convention on Biological Diversity (CBD), which supports the more global vision that FAnGR are an international or at least national inheritance (Ott 2005) that need to be conserved, whereas the World Trade Organization (WTO) tends more towards protection of individual intellectual property rights (IPRs). National laws are also, in some cases, contradictory, which is not surprising if the predominant paradigms in development are taken into account. Here, concepts of increases in production and 'progress' predominate, and local breeds are often regarded as 'non-descript' and needing to be replaced by more productive, 'modern' breeds. An example is the situation in India, where state governments heavily subsidize artificial insemination, particularly in cattle, and where cross-breeding of local animals with Jersey and Holstein Friesian is advocated. (Data on the success of cross-breeding are rare and, where investigated, cross-breds were often found to perform below expectations, simply because farmers could not afford to feed the animals better so that they could realise their potential). On the other hand, India also wants to maintain agrobiodiversity, including that of livestock.

However, there are also some hopeful signs. The African Union (Ekpere 2001) has proposed 'model laws' to conserve animal biodiversity and has recommended that member countries adopt these laws. Declarations such as the Karen Commitment (League for Pastoral Peoples and ITDG 2003) or the Sadri Declaration (Köhler-Rollefson 2003) bring voices mainly from the NGO sector. The CBD has endorsed a multi-year work programme on agricultural biodiversity, including FAnGR. Similarly, the Commission on Sustainable Development endorsed the need to develop a Strategy for the Management of Farm Animal Genetic Resources (Martyniuk 2003). FAO is presently preparing the

First Report on the State of the World's Animal Genetic Resources, and has already published several editions of the World Watch List for Domestic Animal Diversity. These international activities may do little for CBM of FAnGR at the grassroots level, but they do draw attention to problems and give—hopefully—more breathing space for activities on the ground.

Particularly in industrialized countries, there are an increasing number of small non-governmental organizations (NGOs) who support the conservation of particular breeds. This may be the prime purpose of the NGO, or breed conservation is part of a wider rural development concept.

The emphasis of WTO on IPRs and the elaboration of the International Treaty on Plant Genetic Resources (ITPGR-FAO) led to calls for a treaty on livestock keepers' rights, including benefit sharing, if commercial enterprises make financial gains out of further developing or marketing indigenous breeds. It is, however, an open question whether local farmers or communities can really benefit from that. Experiences with plant genetic resources are not really encouraging in this respect.

How is CBM of FAnGR being organized?

Developing countries greatly differ in their social organization and in their institutional and economic development. Therefore, CBM of FAnGR will also differ between countries and regions. We also should not forget that pastoralists and farmers have managed animals – and have bred them—for more than 12 000 years (Martyniuk 2003), whereas scientific animal breeding has a history of little more than 200 years (Rege 2003). Moreover, breeding objectives and methods also changed—somewhat—over time.

In a broad sense, two major types of CBM of FAnGR can be differentiated:

- *Pastoral settings.* Households and groups keep relatively large herds, and still practise mobile forms of animal husbandry. Groups of pastoralists have large enough herds to develop their own breeding strategies and their own types of animals.
- *Smallholder settings*, where households tend to keep few animals, and maintenance of particular types of animals depends either on cooperation among a large group of smallholders or on support from outsiders, e.g. pastoralists, or—where they do exist and function well—on breed societies.

It should be noted that both pastoralists and smallholders keep and breed animals and normally would not refer to these activities as management of FAnGR.

Pastoral breeding practices

In recent years, breeding practices among pastoralists have received considerable attention, first of all by anthropologists and rural sociologists but more recently also by animal scientists. We should be careful not to sanctify pastoralists, but their achievements are considerable. For example, they select animals for:

- Hardiness;
- Disease resistance;
- Ability to walk;
- Colour;
- Milk and meat production under non-optimal feeding conditions;
- Temperament and character;
- Tendency to stick together in a herd (and to walk long distances to find the home herd again, if contact with the herd is lost);
- Ability to defend the herd and calves against predators (quite successful) and thieves (less successful);
- Horn shape and size.

This was done without selection indices and computers. In the studies, the main emphasis has been on the keeping and breeding of large animals (camels, cattle, buffaloes, yaks), but pastoralists also managed to produce sheep and goats, horses and donkeys that are well-adapted to the local environments.

Selection may be along male lines but, because the mother can be determined more easily and more accurately, pastoralists may also select animals along female lines—i.e. the character and the performance of the mother is more important than the (assumed) father for selecting a bull or ram.

Contrary to modern animal breeding, where one breed has one ideal type of animal, pastoralists do not always follow this ideal. It was found in northern Kenya, for example, that camel pastoralists tend to keep a range of different types of animals, some of which may be particularly drought resistant (but don't grow fast and don't produce much milk under good conditions) and some of which may be more susceptible to drought, but benefit more from better—non drought—conditions, that is, they grow faster and/or give more milk if feed is plentiful (Adams et al. 2002).

The practices of castration or early sales of male animals not selected for breeding ensure that breeding is targeted and that desirable traits are maintained.

Pastoralists' livestock is not static, however. When circumstances change, the preferred types of animals may change. This can be a change from one species to another. For example, with bush encroachment in northern Kenya and southern Ethiopia, some Borana pastoralists increased their camel holdings and reduced their cattle holdings. As another example: when market opportunities improve, such as for sheep, it was observed in both Somalia and Senegal that pastoralists reduced their holdings of large animals and concentrated on sheep. It can also involve a change in breed. For example, when Borana pastoralists in southern Ethiopia suffered from drought and their cattle herds were greatly reduced, they had to change from a purely pastoral way of life to an agropastoral livelihood. They began to keep more of a smaller type of cattle that were more resistant to disease and could cope better with low quality and low quantity of feed than could the traditional large white animals that could walk long distances (Homann 2005).

An exchange of breeding animals between herds often takes place through marriage contracts (when the family of the groom has to give animals to the family of the bride) or through loans from richer to poorer people. In some areas, livestock raiding also has the effect of gene flow between communities—although this would not be a mechanism to be encouraged.

Smallholders and agropastoralists

In contrast to pastoralists, smallholders and agropastoralists are rarely autonomous breeders. In animal breeding, they depend on cooperation in some form with fellow smallholders and agropastoralists or on interactions with pastoralists or, where they exist, with commercial farmers and breed societies. In fact, smallholders may not always keep animals of a particular species year-round. They may operate special fattening schemes, speculating just before important festivals, or they may keep dairy animals but buy in replacement stock rather than raising it themselves.

In many cases, breeding of small ruminants by smallholders or agropastoralists can be fairly straightforward. In West Africa, goats are kept in small groups, with rarely more than ten head per household, yet very few entire males are 12 months or older. Males are slaughtered young (mostly at 6–9 months of age), and fast-growing males are slaughtered first. As the young males can act as sires, this practice is in fact a selection for early maturity, and as small, slow-growing males are slaughtered last, for small size. Inbreeding does not appear to be a problem, because goats are frequently sold, bought or exchanged (Bayer et al. 2003).

In other cases, specific breeding institutions developed. In northern India, some landless people specialize in keeping buffalo bulls and gain a living by charging farmers for the services of their bulls. In some parts of the country, the buffalo bull keepers have privileges in using communal forage resources. In parts of northern Pakistan and in the former centrally planned economies of Eastern Europe and the former Soviet Union, smallholders bring their animals together to form village herds.

The village herder may only look after the animals of the villagers but, in some cases, he may also have a responsibility to keep breeding males.

A common practice is to acquire livestock from larger transhumant herds that move through a particular area. These can be breeding stock (e.g. in northern India, buffalo bull keepers often buy their bulls from buffalo nomads), animals for fattening (agropastoralists in central Nigeria buy animals from more mobile pastoralists) or draught animals. Small ruminants kept in towns, e.g. in Africa or the Middle East, are also often acquired from nomads, either directly or through traders who buy up animals in rural areas and bring them to cities, where they are usually slaughtered soon afterwards but may be kept for a while and even reproduce. Livestock being kept in cities are usually rather mixed with respect to breed.

Where communal and commercial farms are located side by side, commercial farms and breed associations can have an important role in maintaining a particular breed. An example comes from South Africa, where white extension staff and agricultural policymakers initially regarded the indigenous breeds of livestock as 'scrub' that needed to be replaced. At one stage, a law (which was fortunately not enacted) called for the castration of all bulls of indigenous cattle. Gradually, animal scientists and later commercial farmers began to realise the potential of one indigenous type of animal, the Nguni cattle, as a low-input but nevertheless productive breed. However, communal animal keepers, after having been told for decades that their animals were worthless, had started to believe this tale and had begun to cross-breed their cattle with bigger, European breeds (the South African cattle marketing system seems to favour XL or XXL breeds) that indeed grow faster than Ngunis if very well-fed. Programmes and projects are now underway to convince communal farmers that the original animals can, in many instances, be better than the large commercial breeds. Resistance to ticks and disease and better adaptation to low-quality feed are some of the positive characteristics (Bester et al. 2003).

How can CBM of AnGR be supported?

The loss of adapted animal breeds through cross-breeding is a concern not only for NGOs or farmers associations, but increasingly also for governments. So the question is: How can CBM of AnGR be supported? Communities of livestock keepers do not always want to stick to their original animals, if keeping exotic animals appears to be more profitable. In Eastern Morocco, for example, the predominant sheep breed was the small and hardy Beni Guil. Low prices for grain and high prices for mutton made fattening of larger sheep breeds profitable, so farmers started to cross-breed or replace the Beni Guil with larger Oueled Djellal from neighbouring Algeria. The Moroccan Government responded with an import ban and with efforts to limit cross-breeding, but neither of these efforts seems to work (Khalil 1997).

In industrialized countries, it is argued that old breeds are part of the culture and national or even international inheritance. Keepers of endangered breeds therefore receive subsidies, in the EU from EU programmes, but also from national and provincial programmes. The justification for the subsidies is that extensive breeds yield less than breeds that can be intensively kept and that farmers should therefore be given some incentive to keep the less productive animals suitable for extensive management. Together with other subsidies (e.g. for maintaining agricultural landscapes, for grazing that enhances flora biodiversity in natural pastures), the subsidies can be a more important source of income for a farmer than is the sale of the animals and animal products. These subsidies are crucial for maintaining endangered breeds. Ott (2005) found that less than half of the keepers of an endangered pig breed would be willing to continue to keep the breed, if the subsidies would be removed. If financial support is given to encourage maintenance of a particular breed of livestock, it usually has to be on a long-term basis, and not a government or EU programme that is limited to—say—five years or so. Otherwise, it would be doubtful whether farmers would continue to keep the breed—seeing as there is otherwise no economic advantage in doing so.

This approach to maintaining animal biodiversity is possible because a rich majority of non-farmers in industrialized countries supports a small minority of farmers. In most developing countries, however, farmers (smallholders and pastoralists) make up the majority of the people.

Another approach is to promote indigenous breeds into 'officially' recognized breeds. In southern Africa, there a number of examples where indigenous breeds were taken up by commercial farmers and became officially recognized by breed societies. In South Africa, such breeds include the above-mentioned Nguni cattle, the Tulli cattle from neighbouring Zambia and the Damara sheep. Some more examples from other areas are the Boran cattle in Kenya or various Indian cattle breeds that became popular only after being exported to Brazil or the United States and undergoing some transformation.

Yet another way to promote indigenous breeds would be through ecotourism. Visits to herds, villages and particular focal points (e.g. where animals are watered) could be part of the tours. This would require that three major stakeholders cooperate: the state administration, the tourist operators and the livestock-keeping communities. In such a private–public partnership, the animals would need to be attractive to tourists, e.g. dark reddish-brown cattle with long horns, or multicoloured—such as the goats in Afar—or spectacularly white and occurring in large flocks, such as the goats in pastoral northern Kenya or Somalia. Special events, such as the seasonal movement of herds to a new grazing area, could also be a tourist attraction. This is, however, a niche market, which could work as an additional attraction in traditional tourist countries, such as Kenya or South Africa. As a niche market, it cannot be expected that this could be a 'solution' that could bring benefits to the majority of animal keepers.

Another example for public–private partnerships that could promote maintenance of indigenous breeds is the use of Nguni cattle leather from communal areas in South Africa in luxury cars built in Germany.

In efforts to promote endangered breeds of livestock in industrialized countries, local and special markets for the animal products (meat, cheese, wool, hides) play an important role. The question is whether, also in developing countries, high-priced niche markets could be exploited for the benefit of traditional livestock keepers. This may work in countries with a relatively rich urban population, but hopes should not be set too high. Specialized niche markets have a limited capacity—as the term itself implies—and, if the consumers pay more, they want to be sure that they get what they pay for. In rural areas, consumers may know the producer and her or his farm personally; in urban areas, the producer–consumer relationship is anonymous and this makes certification and labelling necessary. The control mechanism needed for this are costly, and experience in organic agriculture suggests that smallholders may have to spend up to 25% of their turnover simply to be certified. Group certification can reduce these costs per farmer, but communities have to be organized in an efficient way to be able to handle group certification. There are, however, exceptions. Local chicken often fetch a higher price (and are sold out earlier) than factory chickens. The reasons given by customers are that the local birds taste better and give more to chew than fast-growing commercial broilers.

As already indicated, breed associations or clubs and commercial farmers, where they exist, can support smallholder and agropastoral communities in their efforts to maintain a particular breed. One precondition is that local communities keep the same breed of animals as do the respective commercial farmers. Because of the larger herds and record–keeping involved, the breeding schemes can benefit smallholders, provided that commercial farmers select for adaptive traits important to the smallholders and not for fast growth and large size. Breed societies seem to concentrate on large animals and, only in exceptional cases, on poor people's animals like goats or chickens.

What else can be done to promote indigenous FAnGR? Information on particular breeds or types of animals could be more widely disseminated, in a variety of ways. A booklet on indigenous and locally developed breeds in South Africa raised considerable interest among livestock farmers, as did visits to stud farms and discussions with commercial farmers. Discussions of adaptive traits such as tick resistance between a consultant and farmers was first met with disbelief by the farmers and later looked at with growing interest. An illustrated book on Nguni cattle colour patterns is selling quite well and is raising awareness and the status of Nguni cattle among the wider society in South Africa. Such actions are relatively inexpensive and, once farmers are convinced, promotion in this form does not have to go on forever.

The invitation to this workshop indicates that both *in situ* and *ex situ* methods of conservation need to be considered. In CBM, the emphasis is clearly on *in situ* methods. *Ex situ* means that communities lose control. Furthermore, the widespread use of *ex situ* methods would create a genetic bottleneck, since only part of the genetic diversity could be conserved. The genetic description of indigenous breeds in developing countries is not detailed enough to say whether 5, 10 or 15 sire lines exist; consequently, it is also not possible to say how many samples need to be deep-frozen to conserve the diversity.

What can donors do?

Some activities, such as support for DAD-IS (Domestic Animal Diversity Information Service) may be more long-term, if it is based on core funding of an international organization such as FAO or ILRI, but beyond data collection and analysis, donors usually fund only short-term programmes and projects related to FAnGR. This has consequences as to what donors can do and what they cannot do, even if programmes can be bundled or phased and can last effectively for 15 or 20 years.

It would make sense for donors to provide subsidies for keeping a particular breed only if either a sustainable transfer of money can be guaranteed—as done for some national parks in Africa—or if the government of the respective country is prepared to and capable of taking over payment of the subsidies within the project period of, say, 3–5 years.

Donors can help to promote a breed via workshops and conferences, via support for organizing marketing chains, and via publications at various levels. The publications from our project "People and Biodiversity in Rural Areas" are efforts in this direction. It is important that publications are done in a way that reaches non-specialists and a broader public. The Nguni book by Poland et al. (2003) is an example of how such a publication can look. Efforts should also be made to reach news media (journals, magazines, newspapers, radio, television).

Donor agencies should integrate support to maintaining animal genetic diversity into their development policies. This means that support to CBM of FAnGR should be considered when implementing activities in the fields of rural development, biodiversity, nature conservation, land-use planning, development of food supply chains, etc. It should also be considered in connection with activities concerning cultural diversity, as the knowledge linked to AnGR is part of the indigenous knowledge of the communities, especially among minorities and indigenous peoples.

Donor agencies can also exert some influence on framework conditions. They can commission studies on the effects of proposed trade regulations and international treaties, and representatives of donors may be part of delegations when treaties are negotiated. NGOs (which can also be donors) can also be active in lobbying for increased public and political attention to agricultural biodiversity. However, the influence of donors in this respect should not be overestimated.

Open questions

With respect to promoting CBM of FAnGR, there are a number of open questions, some of which are quite fundamental.

Some of the simpler questions are: If the WTO negotiations produce what we fear, how can local animal-keepers' rights be defended? If a breed becomes commercially successful, how can benefit sharing be assured? The experience in trying to strengthen farmers' rights in plant genetic resources shows us that it may take years to develop something similar to this international instrument—and this without yet knowing whether the instrument with respect to plant genetic resource is indeed effective. Can we afford so much time to develop the concept of livestock-keepers' rights? Will the development of biotechnology in the field of livestock not overtake these activities and make them obsolete?

Conserving breeds can also be quite an expensive process (Ott 2005; Reist-Marti et al. 2005). Who decides on what basis which breed will be given special support and which breed will not? New methods of genetic analysis offer new possibilities of analysing breeds, but the question of participation in decision-making to set priorities still remains.

Finally, a more fundamental question: Are we on the right track? Are breeds, as loosely defined as they are, the right units to be promoted? Breeds are often based more on genealogy than on characteristics, such as tick resistance. Breeds develop and are based on phenotypes. They can be regarded as a kind of envelope for a set of characteristics. However, selection for growth, milk yield or number of eggs can change the content of the envelope. With a view to management of animal genetic resource to decrease hunger and poverty, would it not be better to concentrate on characteristics that are important so that poor people can keep animals—characteristics such as tolerance of low-quality feed, for which blood urea levels in times of nutritional stress could be an indicator?

An example, again from South Africa: In a breed comparison, 50% of Nguni cattle could be classed as highly tick resistant, compared with slightly less than 30% of Bonsmara and 10% of Hereford, yet 30% of Nguni cattle showed low tick resistance (compared to over 50% of Bonsmara and Hereford). On average, the Nguni are clearly better, but farmers keep individual animals, not uniformly average ones. Would promotion of selection for tick resistance not be better than promotion of a particular breed? We know that this would require different data than presently collected, but it may be worthwhile to change the data collection and analysis if it is found that such an approach is to the greater benefit of the poor.

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Private and public roles in conservation

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Abstract

States are responsible for the sustainable use of their biological resources, as is clear from many of the contributions to this workshop. In this paper, we focus on the possible contribution of breeding organizations to conservation of animal genetic resources, and the (un)likelihood of commercial exploitation of exotic genotypes in western animal production. Breeds and strains[1] that currently play no significant role in breeding[2] carry alleles that may become of interest if production conditions change and other traits become important. Such changes are likely but difficult to predict, and breeding organizations have a clear long-term interest in conserving a wide array of such alleles[3]. We discuss here the possibilities of, and the prerequisites for, conservation of animal genetic resources by the breeding industry, and provide a case study from pig breeding.

Possibilities: conservation scenarios

It is useful to distinguish between *in situ* versus *ex situ* conservation and, in another dimension, between conservation of alleles versus conservation of populations.

Ex situ conservation excludes genetic change in the conserved genotype. Cryopreservation provides an illustration: embryos, semen or DNA can be frozen and stored until the genotype becomes of interest. Many farm animal breeding organizations routinely store germplasm as a genetic contingency backup, often as part of national genebank initiatives. This also allows for straightforward estimation of genetic improvement (e.g. Oksbjerg et al. 2000; Tribout et al. 2004), a direct measurement of the effectiveness of the breeding programme. *Ex situ* conservation of genetic resources could be usefully outsourced to breeding organizations, because they have the required facilities available and therefore can cut down on overhead costs. By contrast, *in situ* conservation works with live populations which are subject to genetic change. In order to remain competitive, breeding organizations have to push for genetic improvement of production traits. This constrains the conservation of genotypes that under-perform in any of those traits: there will be a continuous drive to reduce that 'lag', unless the maintenance of the exotic population is funded externally[4].

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1 We will further use the term 'genotype' to refer to breeds, strains etc. Note that this differs from what the term represents in molecular genetics: the allele status of one or more particular genes in a particular individual.

2 We will further refer to such genotypes as 'exotic'. Hence this term does not imply any kind of geographic origin.

3 See the "Code of good practice for European farm animal breeding organisations": http://www.code-efabar.org/.

4 Government partnerships will often be indispensable; see http://www.ars-grin.gov/animal/index.html for USA examples.

Conservation of whole populations

When an exotic resource is to be maintained as a population in its own right, two issues must be dealt with: (i) loss of genetic diversity due to small population size and inbreeding, and (ii) breeding goals. Breeding organizations should be able to deal with issue (i) as a matter of course: maintaining closed populations of limited size is a routine activity in most species. The breeding goal (ii) is more likely to be controversial. The inherent drive towards improvement of genetic production potential may be in conflict with the maintenance of the exotic genotype's defining (and possibly long-term interesting) features. This raises the question regarding which of those features must be conserved.

It is useful to recognize that farm animal genotypes have evolved as part of particular production systems. When a production system disappears (a very common event in the long term) its genotypes will disappear as well unless a new function can be found for them, in terms of (i) products, (ii) traits or (iii) cultural heritage.

Examples of genotype-specific products are *jamón iberico* (pigs, Spain), *poulet de Bresse* (poultry, France) and *formaggio di Razza Bruna* (cattle, Italy). These products rely on a particular genotype and guard their authenticity through a centrally controlled labelling system ('appellation d'origine controlée' etc.). As long as the system can sustain the demand for its (often high-priced) product, the future of the associated genotype is safe (it has a market) and breeding organizations should have an interest in maintaining it.

As implied in our introduction, exotic genotypes may be of future interest for the breeding industry because they excel in particular traits that have received little focus in conventional breeding—up to the point where an unforeseen change in the production system occurs and 'new' traits become important. These are most often traits that are difficult to improve because of low heritabilities (fertility, resistance) and/or because of difficult measurement (longevity, product quality). As long as an exotic genotype's particular alleles outperform quantitative selection for such traits in the established genotypes, it has a competitive advantage and therefore a future. The trade-off is usually in a distinct disadvantage for production performance. This may be difficult to overcome without loss of the novel advantage; for that reason, this scenario is more commonly dealt with by introgression (see next section).

Farm animals as a cultural heritage element are often valued for landscape maintenance (grazing grasslands or heather) or because of their exterior. In both cases, there is little incentive for animal breeding organizations to get involved unless there is external funding or a certain amount of hobbyism among the relevant staff.

Introgression

Introgression of an exotic genotype into established commercial ones starts with a cross between the exotic line and an established one, often followed by one or more backcrosses to either of them. After that, the resulting synthetic/composite is maintained as a pure line for use in the breeding organization's cross-breeding schemes. As in the previous section, this maintenance involves: (i) control of inbreeding; and (ii) selection for a particular breeding goal. The breeding goal for the new synthetic will logically focus on the traits that the exotic excels in, e.g. fertility, resistance, longevity or product quality traits as above. The associated exotic alleles will be selected for and will therefore be conserved. By contrast, many other of the exotic's alleles are likely to be selected against, particularly those which cause a lag in production potential[5]. Whether this is a problem or not depends on the

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[5] Reduction of an allele's frequency is different from it becoming extinct—animal breeding usually maintains genetic variation.

broad conservation goal for the exotic genotype. The most desirable scenario may involve ongoing cryopreservation until a new round of introgression becomes relevant.

Prerequisites for interest in exotic genotypes

For a commercial animal breeding organization to become interested in an exotic genotype, two prerequisites must be met.

First, the genotype must be commercially interesting. It should excel in some of the low-heritability or hard-to-measure traits mentioned above, while its performance lag for production traits is sufficiently small to be largely removed by a few rounds of directional selection. Only in very exceptional circumstances will the animal production sector accept an advantage in fertility, resistance, longevity, or product quality at the expense of basic production performance. Examples of such exceptions are the labelled, certified and highly-priced products mentioned in the *Conservation of whole populations* section above.

Second, access to the population must be organizationally feasible. The most important barrier here is veterinary restrictions to the movement of animals (or semen). Closely linked to that is the breeding organization's risk of introducing pathogens into its units, particularly novel viral diseases that cannot be serotested for.

Another important aspect is the maintenance cost of the new population, which can easily grow prohibitively high, especially when the exotic's production levels are low—the inherent cost of by-products (e.g. surplus males) of low slaughter value is a key factor to be considered when budgeting the breeding programme.

Case study

We illustrate the above by describing the impact made on western pig production by the Taihu breeds of the Shanghai area (China). Some of these pig breeds (Meishan, Jiaxing) were imported into France, the UK and the USA in the 1980s. The interest is in reproductive traits: low age at puberty, high ovulation rate and embryo survival resulting in high litter size, and high teat numbers. The disadvantage is in high body fat levels and slow growth rates.

These imported Taihu populations have triggered much scientific study into the physiological mechanisms behind their high reproductive capacity, culminating in the still ongoing identification of genes responsible for these features and for body fatness. These imports have led to a considerable increase of our knowledge of the regulation of such processes in the pig.

At the same time, several commercial breeding organizations in France, UK and Canada have invested in the introgression of Jiaxing and particularly Meishan pigs into their damlines[6], the only recent example of introgression of a non-western exotic pig or poultry genotype that we are aware of. This was accompanied by studies into the trade-off between improved fertility and reduced leanness (e.g. Bidanel 1989). These suggested that the feasible way to commercially exploit these genotypes would be “as composite lines at the grandparental level after six to eight generations of selection for growth and body composition traits” (Legault 1998, our translation). In accordance with this, several introgressions were made, leading to commercial parent sows mostly holding 12.5% Taihu genes.

Selection for improved growth rate and carcass leanness was reported to be successful, for example by Zhang et al. (2000) for one of the French genotypes. Two of the French public commercial product evaluations[7] have compared a Taihu-based genotype with six conventional ones. The progeny of these

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6 See http://www.asp.asso.fr/HY/HY_j.htm, http://www.acmc.co.uk/hybrid_female.asp, and http://www.hypor.com/canada/ for more details.

7 See www.asp.asso.fr/autres%20pages/tests/tests_j.htm for the detailed results.

sows performed at rank 3 (1997–98) and 4 (2001–02) out of 7 for growth rate (1 is best), at rank 1 and 4 out of 7 for feed efficiency, and at rank 5 and 6 out of 7 for lean yield. Note that these results are confounded with the effect of the terminal boar genotype used in combination with each sow product.

One of these introgression cases led Webb (1998) to the conclusion that the carcass lean content of 12.5% Meishan pigs is "about 3% lower than current commercial slaughter generation. Females containing Meishan genetics appear to be very docile and, for markets with a low investment in buildings and less concern over lean yield, Meishan crosses may well find acceptance within 5 years". However, up to 2005 this breeding organization has not succeeded in establishing that acceptance (GA Walling, pers. comm. 2005).

Likewise a regional French study concluded "we can only imagine a traditional (that is to say extensive) exploitation of the Meishan, trusting its prolificacy to compensate for the loss in production traits. A preliminary economic analysis leads us to believe that the improved prolificacy is more than sufficient here, taking into account that the Meishan sow has other interesting features such as a low feed consumption and a very satisfactory maternal ability" (Franck et al. 1995, our translation).

By contrast, after several generations of intense selection for production traits, a UK breeding organization[6] is now advertising its Meishan-based product with "Rigorous testing means no compromise on efficient growth or carcass quality" and says to have developed its composite to the production levels of a conventional western dam line, suitable for both extensive and intensive production systems (MJ Curtis, pers.comm. 2005).

In summary, the trade-off between enhanced fertility and reduced leanness of Taihu-based genotypes seems a serious obstacle towards large-scale commercial exploitation, although persistent genetic improvement in the latter trait obviously solves the problem. A complicating factor here is that a few years after the Taihu imports, improved statistical methods allowed for a much faster genetic change of reproductive traits in pigs than ever before, while genetic improvement of leanness continued at the same rate as before (Figure 1).

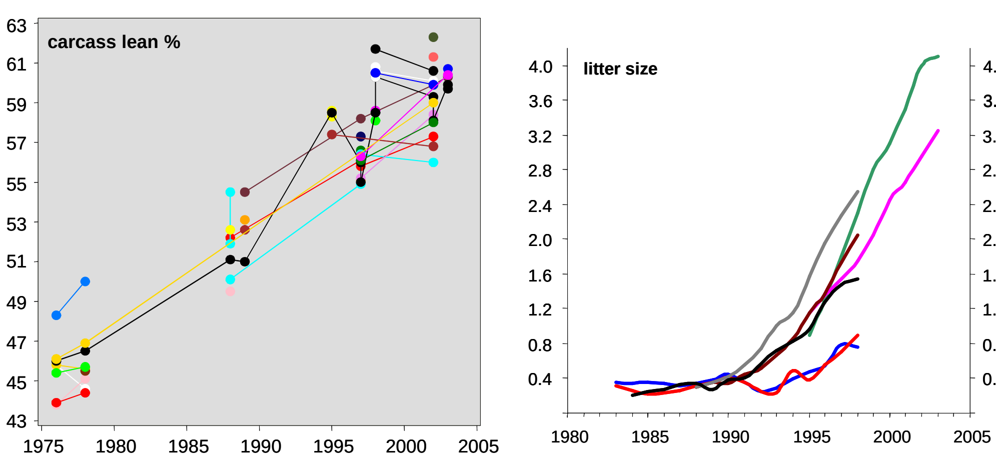

Figure 1. Genetic trends of carcass lean content (left, from Knap 2005) and litter size at farrowing (right; data from Knap et al. 1993; Merks 2000; Gueblez 2001; Danavl 2004) in commercial European pig genotypes.

This has reduced the initial advantage of the Taihu genotypes: the contrast in reproductive performance with the established genotypes has gradually decreased. This is illustrated in Figure 2 which shows the modelled litter size performance of sows of four types of genetic make-up. A: the conventional Large White × Landrace cross (LW×LR); B: a cross between crosses of both LW and LR with Meishan, (MS×LW) × (MS×LR); C: a (LW×LR) cross after hyperprolific selection in both lines (hyperLW×hyperLR), which has led to genetic trends in litter size such as in Figure 1; and D: the 12.5% Meishan composite product hyperLW × [(MS×LW) × hyperLR] that was eventually settled for in practice.

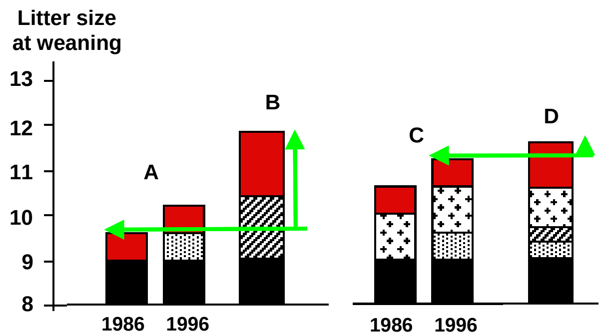

Figure 2. Modelled litter size at weaning in four parent sow breeding scenarios. Adapted from Legault (1998). See the text for the codes; the bar colours indicate genetic elements such as heterosis, response to selection etc.

The relevant comparisons are indicated by the arrows in Figure 2: the initial schemes were focusing on the simple two-way cross 'B' which indeed shows a strong advantage over the conventional product 'A', especially in the mid-eighties.

But after a decade of hyperprolific selection in the LW and LR breeds, and after having arrived at the more feasible 12.5% MS product on the other hand, the advantage is much reduced. In fact, scenarios 'C' and 'D' represent alternative ways to arrive at the same type of product; the initial hope was that this way would be much shorter with the Taihu introgression, but lengthy selection for increased leanness slowed this down.

Western commercialization of the Taihu breeds has been successful to the extent that somewhat less than 100 000 Taihu-based parent gilts are currently sold per year in Europe and North America[8], about three quarters of these in France. Although this should be more than sufficient to conserve the introgressed genotype (it clearly has a market), it represents less than 1.5% of the total market volume in this area, illustrating the difficulty of large-scale commercialization of exotic animal genotypes.

Conclusions

- Farm animal breeding organizations can play an important role in the conservation of genetic resources, either as partners in public schemes or by developing commercial applications. The latter option requires a sound strategy for the breeding goals of these genotypes.
- A crucial element is that the resulting population can be commercialized, either through distinct consumer products or through a distinct advantage in terms of relevant traits. This often involves trade-offs with other traits which may require lengthy selection processes to overcome. External funding may be required.
- Successful introgression of exotic genotypes into western animal breeding is very rare.

[8] Based on data supplied by A. Lacoste, M.J. Curtis, G.A. Walling and G. Gosselin. Pers. comms., 2005.

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In vivo approaches: state of the art

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Abstract

This paper discusses some issues related to *in vivo* conservation of animal genetic resources (AnGR). It reviews options available for the genetic management of local breeds, and identifies the limits of their application in different farming contexts. It discusses strategies for having self-sustainable local breeds, and it analyzes their potential, limits, constraints and areas for development. Finally a worldwide panorama of current approaches to *in vivo* conservation of AnGR is presented.

A polyhedric picture

A discussion on live conservation of AnGR must take into account its polyhedric character. First, in terms of materials and contexts involved, considering the different areas of the world, species and breeds, the diversity of farming, economic and social environments. Second, in terms of the objectives that the society may have in conserving breed diversity, from maintenance of genetic variation for future animal production development, to conservation of their environmental, cultural or socio-economic values. This diversity implies that various opportunities for *in vivo* conservation are opened and that there are no recipes for successful live conservation programmes. In the last 20 years many *in vivo* conservation activities have been undertaken, but limited data are available in the official literature for the analysis of successes and failures. In this respect it is strongly advisable in the future to report all experiences in a form that can be assimilated and understood.

This paper proposes for discussion some major aspects related to live conservation. A first issue is that populations are often small and this can lead to erosion of their genetic variation. A second issue is how to reach breed self-sustainability. A worldwide panorama of current approaches to live conservation of AnGR is also presented.

Genetic management of populations

A well-known fact in population genetics is that the presence of small numbers of individuals leads to loss of allelic diversity and inbreeding increment. The number of animals, measured as effective population size (Ne), is a crucial parameter in determining the amount of genetic variation that can be conserved in a population. Thus, maintaining sufficient effective population sizes and genetic variation is a central theme of long-term management of breeds of conservation interest. Techniques to increase effective population size (e.g. Meuwissen 1999) include balancing sex ratio among parents, minimizing the variance of progeny size, minimizing average relationship among parents and average mating relationship. The utilization of cryopreserved genetic material in order to increase effective population size and the combined use of molecular and pedigree information have also been proposed, although these techniques require appropriate technology and can be costly. Most theoretical and implementation models refer to pedigree populations with a rather high control over herds and animals, as it can be found for some species in a limited number of countries. Thus there is a need to develop management rules that can be effectively implemented in populations with limited genealogical information, in contexts with poor control over herds and funds availability. Local knowledge of animal breeding should be taken into account.

Genetic improvement in populations of small size requires specific considerations. Selection programmes may increase the genetic ability for productivity and consequently the profitability of local breeds. However, two major considerations must be borne in mind. Selection schemes should take into account the maintenance of genetic variation within the breed and risks associated with high inbreeding increments. Secondly, traits proposed for selection should be accurately identified. With selection, inbreeding rates 1.5 to 4 times higher than with random selection can be observed, but a theoretical framework has been developed in the last years to design breeding schemes which maximize genetic gain while limiting the rate of inbreeding. Nevertheless, these investigations generally refer to intensively selected nuclei. The application of these methods to local breeds has been poorly investigated and their implementation, even in the most developed countries, needs further research. Traits proposed for selection should be evaluated for their genetic correlation with those traits that determine the conservation value of the breed, in order to avoid their deterioration.

Strategies for self-sustaining local breeds

The dynamics of erosion of AnGR are poorly known and, considering the variety of possible situations, are probably complex. They may involve cultural, social and food-demand changes, transformations of the food production chain, importation policies, GNP, country regulations and technological changes affecting breed decline and extinction in various ways. In most cases it is likely that these factors result in lack of economic profitability. *In situ* conservation should aim to identify and implement strategies to halt the decline of the breed (Gandini and Oldenbroek 1999). In this respect *in situ* conservation should be triggered when potentialities for breed recovery are still present, and should integrate with the sustainable use of the resource. Then the following questions arise: which options are available to halt and reverse the process of breed decline? Which past experiences can guide us?

The large differences among areas of the world, in particular on the basis of GNP and technology availability, would suggest treating groups of countries separately. However, considering the rapid changes we observe in some areas of the world, the presence of a continuum of situations rather than separated groups, and trends in institutional support, we can analyze the different options for self-sustaining breeds worldwide, with remarks on opportunities of transfer across countries/areas of the world.

Market development of quality of breed productions and products

Many local breeds show produce of higher quality with respect to those of commercial breeds that were highly selected for quantitative production. In addition, sometimes, these produce are linked to high-quality products. In those countries where the market is ready to recognize this quality, the traditional relationship between local breeds and products has been used to diversify typical products and sell them at higher prices in order to improve the profitability of local breeds. In the areas of the world where food security is given greater consideration, such as most African regions, this approach can rarely be considered. However this the potential of this option should be kept in mind.

Identification and development of cultural and environmental breed products

Local breeds have often played a central role for relatively long periods in the social life of rural populations; they can therefore, in principle, be considered the point of reference and custodian of local traditions including religious and civic traditions, typical products of animal origin, handicrafts, agro-ecosystems and rural landscapes historically connected to their farming (Gandini and Villa 2003). The cultural value of local breeds has generally been associated with conservation of AnGR in Europe, where the traditional relationship between local breeds and products has been used to diversify typical products and sell them at higher prices, or where it has been utilized to promote cultural tourism. In the developing world the cultural value of breeds and its potential role for self-sustaining breeds has been less considered, but its role in maintaining the cultural identity of rural populations cannot be neglected. It is likely that at later times cultural aspects may become significant also in these areas of the world. For example, cultural tourism has been expanding rapidly over the past two decades and further growth is expected in the future, and could likely intersect with AnGR conservation efforts in some developing areas of the world.

We mentioned above that local breeds sometimes co-evolved with specific agro-ecosystems whose conservation can only be guaranteed through maintenance of their farming systems. In addition, the role of grazing of local breeds to control fire and risk of avalanches has been underlined. The challenge is to have these breed services recognized by the market and by society.

Economic incentives

Incentive payments to compensate farmers for the lower profitability of the local breeds compared to substituting these breeds with more profitable exotic breeds have been adopted by the European Union since 1992. Economic incentives have sometimes been effective in halting the decline of local breeds, however they cannot last forever. In addition, in many cases, in spite of the EU's support to farmers, rearing local breeds still remains unprofitable (Signorello and Pappalardo 2003). Both in Europe and in other parts of the world it seems worthwhile to investigate the use of incentive measures more specific to the particular situations. Within Europe, for example, the elimination of milk production quotas for endangered breeds could effectively promote their farming. More generally, economic incentives should be used to accelerate the process toward breed self-sustainability rather than to provide a general temporary economic support.

Improving technical assistance, optimization of production systems

Increasing economic performance of local breeds might imply some re-organization of their production systems, including seasonal planning of production, changing age/weight at slaughter. Introducing some cross-breeding could be also considered, however attention should be given to the conservation of the local breed. Most often local breeds, both in more and less developed countries, are producing in areas with low socio-economic development where lack of infrastructure and technical assistance might impair their economic performance. The development of networks for milk collection and processing, slaughterhouses, networks for products development and commercialization must be considered.

Finally, we should underline that the options discussed above for self-sustaining breeds need adequate policy and legal frameworks.

Approaches to live conservation of AnGR

Rural communities and farm animal resources are interdependent and cannot be separated. This is particularly true in many developing countries with pastoral and smallholder communities. In 2001 an international workshop in Swaziland underlined the importance of developing community-based management of animal genetic resources. This approach relies on AnGR and ecosystem management in which the community is responsible for decisions on defining, prioritizing and implementing actions for conservation and sustainable use of AnGR (Kohler-Rollefson 2004). Some projects are adopting and testing the community-based approach. Focusing on rural communities allows promoting at the same time the development of rural communities and the conservation of AnGR.

Live-animal management in reproducing herds is the most frequently adopted conservation method in Europe (Simon 1999). It allows the evolution of the breed to changing production and environmental conditions, and the maintenance of its environmental and cultural values, where applicable. By adopting strategies that increase the market value of local breed farming, such as developing links with typical products or recognizing their environmental and cultural values, maintenance of herds in their farming areas becomes a tool for the socio-economic development of rural communities, as advocated by EU agricultural policies. This approach requires the participation of most of farmers and possibly local enterprises dealing with food transformation. In Europe conservation of endangered breeds is generally performed *in situ* on farms. However, in some cases animals are kept in farm parks and, in a fewer cases in zoos. Thirty-five farm-parks with conservation of endangered breeds were counted in 1999 in Europe, with 25 farm-parks alone in the United Kingdom and nine in Germany. In the United Kingdom farm-parks are visited by an average of 100 000 people each year. Thus, a specific value of farm-parks is that they contribute to awareness of the need for conservation. Farm-parks are also present in North America. NGOs, such as rare Breed Survival Trust in the UK, developed schemes for farm-parks in order to ensure given standards and some coordination. In particular for some species, like poultry, enthusiastic hobby breeders' organizations play a certain role in conserving local breeds. The first example of natural protected areas, such as national or regional parks, including rare domestic breeds was in Hungary where native breeds are conserved on the Puszta, but now are also found in other parts of Europe as well as outside Europe.

To conclude, it should be underlined that whenever endangered breeds are maintained *in situ* or *ex situ* live, by farmers or hobbyists, within the traditional production system or in natural areas, they should be managed in such a way as to guarantee conservation of their genetic variation in the long term.

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In situ conservation strategies: a quick scan of SoW-AnGR country reports

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Abstract

Based on a quick scan of 148 country reports for the First Report of the State of the World's Animal Genetic Resources (SoW-AnGR) (under preparation by the Food and Agriculture Organization of the United Nations [FAO]), strategies for *in situ* conservation of animal genetic resources are discussed. Four global regions are distinguished: Europe, Asia, Africa and the New World. The scan covers six domesticated farm animal species: cattle, pig, sheep, goat, horse and chicken. In all continents, livestock systems are changing with significant consequences for the use and conservation of farm animal genetic resources. In poultry, pigs and cattle, multinational companies develop and maintain a limited number of breeds and lines. Based in West Europe and North America, they extend their activities towards East Europe, Africa and Asia. *In situ* conservation programmes are reported by 73 countries and *ex situ in vivo* conservation by 31 countries. Especially in East Europe, West Asia and South East Asia conservation plans have to be developed. Nature management, organic farming, participatory breeding, niche markets and hobbyists create opportunities to conserve native breeds which are not developed by multinational breeding companies. Education in genetic management of populations should be given a high priority in many countries.

Introduction

The perspective of a breed depends, to a great extent, on its present and future function in livestock systems. A change in livestock systems may have great impact on the use of breeds. Livestock system development is driven by many external and internal factors such as: the presence of ecosystems that are suitable for animal production, the country's policies for the use of animals, the prevalence or outbreak of diseases, the political (in)stability, the possibilities for introduction of exotic breeds, the growth of the human population, the growth of the country's economy and export possibilities. Therefore in the country reports submitted by national governments for the First Report of the State of the World's Animal Genetic Resources (SoW-AnGR), much attention is paid to changes in livestock systems. These changes indicate which genetic diversity will be used in the (near) future and which must be conserved. Conservation of the genetic diversity between (and within breeds) can be realized using methods ranging from *in situ*—via *ex situ in vivo*—to *ex situ* conservation.

In situ conservation is defined as conservation of livestock through continued use by livestock keepers in the agro-ecosystem in which the livestock evolved or are now normally found (includes breeding programmes). *Ex situ in vivo* conservation is defined as conservation through maintenance of live populations not kept under normal farm conditions and or outside of the area in which they evolved or are now normally found. In this paper *ex situ* conservation will not be considered.

The SoW-AnGR country reports were scanned for changes in livestock systems and for the applied and required conservation methods in the range from *in situ* conservation to *ex situ in vivo* conservation. The results will be discussed for six species distinguishing four global regions and opportunities for these conservation methods will be indicated briefly.

The choice of the global regions and the species

In the 148 country reports analyzed, 73 (50%) mention the existence of *in situ* conservation programmes and 31 of *ex situ in vivo* programmes. Realising that FAO distinguishes 15 regions, in this paper for the presentation of the results of a quick scan four (combinations of) regions will be used: Europe, Africa, Asia and the New World. The latter consists of the Americas and the South West Pacific. In this quick scan the number of species is restricted to the six species prevailing in all regions with an important role in food production (cattle, pig, sheep, goat and chicken) or in draught and leisure activities (horse).

Trends in livestock systems

In all four regions the main reported drivers for changes in livestock systems are: extreme bad weather conditions, the prevalence and outbreaks of infectious diseases, international trade regulations, liberalization of markets and types of political instability. These drivers have different effects on livestock systems. For example: highly infectious diseases cause unexpected drops in food production and loss of markets in developing countries and also results in changes in consumption patterns in developed countries. International trade regulations (e.g. WTO) facilitate breeding companies, which highly invested in breeding programmes for high-input–high-output systems, to extend their market to the other regions. Political instability, varying from the dispersion of dominions (e.g. Russia) to wars (e.g. Rwanda, Yugoslavia), results in the destruction of animal production research institutes and universities, a severe long-lasting drop in number of animals (up to 70% in eastern Europe) and a new start of animal production, often in small-scale farming systems.

In addition to these global drivers, in Europe the introduction of environmental and production restrictions induced changes in livestock systems, resulting in more sustainable systems like organic farming and resulting in large amounts of land no longer used for agriculture. At the same time, the number of part-time farmers and hobbyists keeping farm animals in rural areas increase. In Africa and Asia the strong population growth requires a 200% increase in food production within 15 years and many countries report a strong pressure on land. This requires intensification of all agricultural systems and a strong improvement of the quality of the animals used. In general, in Asia this process goes much faster than in Africa. In many African countries chronic poverty and the high incidence of AIDS hamper economic development. In the New World economic growth and export possibilities stimulate the intensification of animal production and require a high protection of the health status in all parts of the production chains. Industrialized animal production dominates in the New World, but in the less developed countries in this region subsistence farming is still important. In this 'new' part of the world nearly all breeds used for food production are imported from other continents.

At the global level livestock systems are variable and dynamic. In many parts of the world intensification and industrialization of food production is emphasized to reach a better level of food security. Additionally, sustainability and food safety are driving future developments. All together, massive movements and developments in livestock systems have a severe impact on the use of animal genetic resources, since they are an integral part of livestock systems.

Trends in species with consequences for *in situ* conservation

Cattle

In low input systems cattle is a multi-purpose species and is not only used for milk and beef production but also for draught. The draught function of cattle becomes less important, because of mechanization. In Africa and Asia this species also has social functions like dowry, savings, gifts and ceremonies. In the past 50 years in many countries dual-purpose breeds were developed for milk and beef production. But nowadays, for high input systems specialized breeds for dairy or beef are developed. At a global level, this will be the main system to produce milk and beef. In the dairy sector the Holstein Friesian breed dominates and in the beef sector the French beef breeds will get that position. In many countries these specialized breeds are used for cross-breeding to improve performance of the native breeds. Only in a few situations stable cross-breeding systems are developed in which also populations of the native breeds are used and conserved. The value of the dual-purpose breeds is not always clear. In some countries these cattle breeds are used for organic farming or for new functions like landscape and nature management or are kept as suckler cows by hobbyists. Conservation programmes have to be discussed for the native cattle breeds and the dual-purpose breeds that will not be used anymore for milk and beef production.

Pigs

This species is primarily kept for its meat: pork. In some religions it is forbidden eat pig meat. In small-scale farming systems in Asia and Africa pigs eat left-over human food and food-processing waste. In Asia, industrialization of pig production is taking place and exotics from Europe and North America are imported. In Europe and the New World, pork production is highly industrialized and a few multinational breeding companies dominate in the pork production chains. These companies develop a few lines of a limited number of breeds and these lines are used globally. In the concentration of the breeding industry many breeds and lines are taken out of production. Sometimes these lines and breeds are conserved *ex situ.* In Europe, Africa and the New World relatively few native pig breeds exist. Many native pig breeds can be found in East Asia.

Sheep

In the past the main function of this species, often kept in harsh environments, was to provide wool for human clothes. In addition, its meat was and is eaten. In small-scale farming systems this species is still important for meat production and it plays a role in ceremonies. But in countries with high-input livestock systems, such as in Europe and the New World, the number of sheep decreases drastically. There, sheep are no longer used for wool and meat production because other species appear to be more efficient. The future use of this species in these countries seems to be nature management.

Goat

The goat is a very important species for meat production in small-scale farming and is often productive in harsh conditions in mountainous areas. In Africa and Asia its milk is important for children. In more developed countries the milk is considered to improve health and is used for cheese production. Around the world many native breeds exist. Only a few breeds, e.g. Saanen, Toggenburger, Boer and Anglo-Nubian, have been improved by breeding.

Chicken

On the one hand, the chicken is (like the goat) a very important species in small-scale farming systems, producing eggs and meat for local consumption. On the other hand, breeding and production of this species is the most specialized and industrialized of all animal species, showing similarities with plant breeding and production. At a global level only three multinationals are active, selling highly specialized hybrid layers and broilers. The number of chickens is increasing rapidly at the global level, mainly due to active marketing by the layer and poultry industry. Many universities and research institutes try to conserve the locally developed (dual-purpose) breeds, which are no longer used by the industry. In eastern Europe many highly selected lines, bred in the period of the Cold War, are still available. In some European countries some small companies produce layers and broilers, but their number is declining quickly. In Europe and in the New World many people keep chickens as a hobby. These hobbyists can play an important role in the conservation of native breeds.

Horse

In the past horses were mainly used for draught and transport. In Asia and Africa also other species, such as camels, buffaloes, donkeys and cattle, still have these functions. Very heavy muscular types were used for draught purposes, which could also be used for meat production. This is still the case in eastern Europe. After the onset of the mechanization in transportation and later in agriculture horses were bred for a variety of leisure purposes and are mainly kept by hobbyists. Many breeds are used across countries but no international breeding management is reported. The only exceptions are the Icelandic Horse and the Friesian Horse, where respectively the Icelandic and the Dutch herdbooks coordinate the breeding activities.

Methods for *in situ* conservation, objectives and opportunities

Many stakeholders are reported to be active in conservation: breeding companies, national governments, non-governmental organizations (NGOs), institutes for research and education including universities, part-time farmers and hobbyists.

Breeding companies, in pig and poultry breeding, have the top animals in the breeding pyramid in ownership. In the genetic improvement of pure lines, they pay a lot of attention to the effective population size to avoid inbreeding and they try not to limit their selection possibilities in the future. In these programmes they conserve the genetic diversity within the breeds. Nucleus breeding has started in dairy cattle, but in general the widely used multinational cattle populations are not managed by a central organization. Additionally, many dairy farmers still participate in the breeding activities of these populations. On a global level an intense selection for a few production traits and a large exchange of semen of the best bulls lead to low effective population sizes in the most popular dairy breeds with a real risk of losing genetic diversity. Such problems can be avoided by the composition and use of a breeding goal with a lot of objectives as is found in some Nordic dairy cattle populations. In sheep, goat and horse species (with an exception for the Icelandic and Friesian horse) only a few international breeding activities are reported.

In some African and Asian countries, which are not self-sufficient for food of animal origin, national governments are involved in breeding activities. In most cases they own nucleus farms, with native or exotic cattle. These nucleus farms sell breeding stock (males) to improve populations owned by (small) farmers. This system of participatory breeding plays an important role in the conservation of these breeds. Farms of universities and research institutes often play a role in animal breeding by selling breeding animals or by conserving native breeds. They combine this with their primary tasks to educate students and to perform research.

In several European countries arable land is abandoned by farmers. Governments or NGOs take the responsibility for nature development in these regions. Grazing animals (sheep, cattle and horses) can play an important role in the development and management of natural areas. At a global level, food of animal origin will to a large extent be produced in high-input–high-output systems with highly specialized breeds or cross-breds. In many countries farmers or farmers' organizations started organic farming with a variety of breeds. Other countries (East Europe) recognize the opportunities to export organic products. In Europe and in the New World farmers try to use niche markets to sell special products from native breeds. The native breeds are an integral part of the brand for these special products.

In some parts of Europe, the governments are initiating farms for socio-economic or cultural historic purposes (prison farms, health care farms, demonstration farms, farm-parks, museums) where native breeds are kept. This can be characterized as *ex situ in vivo* conservation and 31 countries report this type of conservation. In many developed countries NGOs conserve and stimulate breeding native breeds by hobbyists. These hobbyists play an important role in the conservation of native chicken, horse, sheep, goat and cattle. Not many hobbyists are involved in the conservation of pigs!

Discussion on the effectiveness of *in situ* conservation strategies

The effectiveness of the conservation of genetic diversity can be measured with criteria such as effective population sizes, number of sires and dams used in each generation and mating schemes practised. However, none of the country reports gives these parameters. Thus, only some qualitative remarks can be made for the conservation activities of the different stakeholders.

In the modern breeding schemes of breeding organizations conservation of genetic diversity is often taken into account. When, for example in cattle breeding, these techniques are introduced in mating schemes used by farmers, inbreeding problems at production level can be minimized. These optimization techniques are well-developed and effective. For some breeds it might be wise to use breeding stock from related populations to enlarge the effective population size or to select semen in the genebanks of 'lost' founders and to use these sires again.

Nature management offers a great possibility for conservation of genetic resources. It is true that the animals are kept outside their original environment and are used for another type of production (*in vivo* instead of *in situ* conservation). But in nature management large populations of animals are required and, if managed properly, that gives a great opportunity to conserve the genetic variation within the breed for future uses.

Organic farming offers an opportunity for the conservation of the recently developed dual purpose breeds. These breeds fit better in the production goals of organic farming than highly specialized breeds or cross-breds, but require (cooperative) management of the populations used for these purposes. Multinational breeding organizations are often not interested in these relatively small markets for breeding material.

The development and production of special products for niche markets in natural environments offer the possibility to use native breeds and to make them profitable again.

Conservation on a small scale in special farms often leads to a loss of genetic variation within the population. Sometimes this is also the case in small populations of hobby breeds, when inbreeding is not properly avoided. But hobbyists play a very important role in the conservation of the between breed variation in chicken, horse, sheep, goat and cattle.

In many countries the knowledge on breeding and conservation (genetic management of populations) is limited to breeding companies and a decreasing number of research institutes and universities. Education programmes on genetic management should have a high priority.

Conclusions

- In all regions livestock systems are changing quickly with important consequences for the use (and conservation) of farm animal genetic resources.
- In many countries in East Europe and West and South East Asia (*in situ*) conservation programmes must be developed.
- In poultry, pigs and (beef and dairy) cattle multinational companies develop only a limited number of breeds and lines and are starting activities in East Europe, Africa and Asia. Many recently developed (dual-purpose) and native breeds must be considered for conservation.
- Production and breeding objectives have changed radically in sheep (wool > meat > nature management) and in horses (draught > meat > leisure activities), with consequences for the use and conservation of genetic diversity.
- Many opportunities for *in situ* conservation should be further explored: nature management, organic farming, participatory breeding, niche markets and hobbyists.

- Education programmes on genetic management should have a high priority.

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Cryopreservation strategies for farm animals

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Abstract

There is growing interest in development of (*ex situ)* cryopreservation strategies for farm animal genetic resources. Although *in situ* strategies have several advantages compared to *ex situ* strategies, national stakeholders and the international community should anticipate a continued global decline in domestic animal diversity and implement a combination of *in situ* and *ex situ* conservation strategies. Substantial progress in cryopreservation and reproductive technology during the last decades show that cost-efficient and effective cryopreservation strategies become reality for all farm animal species. On the other hand, besides progress in technology development, practical circumstances and policy, institutional and regulatory aspects affect the feasibility of cryopreservation programmes.

Introduction

There is worldwide consensus about the global decline in domestic animal diversity and the need to conserve genetic diversity. In addition to *in situ* conservation, methods or techniques to maintain live animals outside their production or natural environment (*ex situ 'in vivo')* or through cryopreservation of germplasm (*ex situ 'in vitro'*) are set up to preserve rare breeds and to safeguard genetic diversity in the more widely used commercial breeds.

There is a growing interest in development of *ex situ* conservation programmes, serving a variety of objectives (ERFP 2003). In several countries *ex situ* conservation represents an integral component of conservation strategies (Blackburn 2004). Some strategies focus primarily on preservation of germplasm of rare breeds, but in general there is consensus that *ex situ* collections should be established for all breeds with the aim to capture as much allelic or genetic diversity in conservation programmes as possible.

In situ conservation or use of animal genetic resources is not necessarily dependent on high-tech approaches or facilities, In contrast, the efficiency and efficacy of *ex situ* conservation strategies will certainly benefit from advances in cryopreservation and reproductive technology. In this paper, the overall feasibility of cryopreservation strategies will be discussed, taking into account technical, financial, practical and institutional aspects.

State of the art in cryopreservation and reproductive technology

It is expected that cryopreservation allows virtually indefinite storage of biological material without deterioration over a time scale of at least several thousands of years, but probably much longer. A general perception about feasibility of cryopreservation strategies is that only few animal species can be cryopreserved at present. However, important progress in cryobiology was achieved in the second half of the previous century. In this section, the state of the art in cryopreservation and associated reproductive technology will be summarized for different species and type of genetic material. For more details and references, see Hiemstra et al. (2005).

Semen cryopreservation

Semen of most livestock species can be frozen adequately. Also, for a large number of avian and mammalian livestock species, dedicated freezing media and equipment for collecting, packing, freezing and inseminating semen have been developed and are available commercially.

Freezing and thawing leads to a significant reduction of the percentage of motile sperm or membrane-intact sperm. In addition, the surviving sperm may have reduced fertilizing ability and longevity. Hence, the fertility of frozen–thawed semen is generally lower compared to the fresh semen. However, in some cases, e.g. in cattle, the same level of fertility can be attained provided that the sperm dose is adequately increased to make up for the lower fertility of frozen–thawed semen. In some species, the fertility of frozen–thawed semen may be too low for commercial procreation, but will still be adequate for the purpose of genebanking.

Artificial insemination (AI)

Although AI techniques have been improved for many species, there are large differences between species in insemination techniques and pregnancy rates using fresh or frozen semen. Only in cattle the use of frozen semen replaced the use of fresh semen.

Cryopreservation of oocytes

In the last ten years, considerable progress has been made with cryopreservation of oocytes. Viable oocytes have been recovered after freezing and thawing and successes have been reported as to post-thaw oocyte maturation, fertilization, and embryo development in a number of species. Live-born young from embryos produced from cryopreserved oocytes have been reported in cattle and horses. However, the present efficiency and reliability of using frozen–thawed oocytes for generating offspring is still much lower compared to cryopreserved embryos. Freezing oocytes of avian species is not successful.

Cryopreservation of embryos or embryonic cells

In cattle, cryopreservation of embryos is highly successful. Cryopreservation of embryos resulting in live offspring has been reported for the important (mammalian) livestock species. Embryo cryopreservation is not viable in birds, but cryopreservation of isolated embryonic cells is an option.

Embryo transfer

Surgical embryo transfer is, in principle, possible in all mammalian livestock species. In contrast, non-surgical embryo transfer is possible only in cattle (routinely performed), horses and also pigs, although it is still not as efficient in pigs as in cattle and horses.

For embryo transfer purposes, embryos can either be flushed from donors or can be produced *in vitro*. Surgical embryo collection is, in principle, possible in all mammalian livestock species. In contrast, non-surgical embryo collection is only possible in cattle and horses. *In vitro* production of embryos by *in vitro* maturation and fertilization of oocytes is possible for major livestock breeds, although the efficiency varies between species.

Cryopreservation of somatic cells

Cryopreservation of somatic cells with simple procedures proved to be possible for a number of cell types.

Reproductive cloning

In mammals, live offspring have been obtained from embryos generated from somatic cells in a number of species, i.e. sheep, cattle, pigs, goats, horse and rabbits. However, it must be emphasized that current techniques are inadequate to be used safely and efficiently for procreation. In all published research, only a small proportion of embryos produced by using somatic cells developed into live offspring, i.e. typically less than 4%. Many pregnancies are terminated by abortion, and full term pregnancies not seldom result in abnormal offspring. Ethical issues associated with cloning are eminent in many countries.

Further progress in cryopreservation and emerging technologies

Continuation of research on fundamental aspects of cryobiology should enable further progress in cryopreservation methods. Emerging technologies with potential for future use in conservation programmes include transplantation of ovarian tissue and germ cells.

Choice of type of material

The choice of type of material to be preserved and sampling strategies depend, amongst others, on the objectives of cryopreservation programmes. Genebank collections may be established for various reasons, e.g. to prevent the loss of endangered breeds, to support the (*in situ*) breeding programme of small populations, or to 'archive' current genetic diversity in commercial lines or more widely used breeds.

Semen cryopreservation is a safe and feasible strategy for domestic animal species but there is considerable variation between species and within species in efficiency and efficacy. In order to support breeding programmes of small populations today, or to archive genetic diversity in commercial populations, semen cryopreservation is in general the best strategy. However, taking into account the loss of mitochondrial DNA and the time lag to re-establish a lost breed by repeated backcrossing, semen cryopreservation only may not be the optimum strategy. If the aim is to conserve (rare) breeds and to be able to re-establish those breeds, collection and cryopreservation of embryos could be a better option. Semen cryopreservation has the limitation that the original genome of the lost breed can never be fully restored.

In this context, cryopreservation of somatic cells does not seem to be a good alternative for cryopreservation of embryos, even if the efficiency of cloning is largely improved. Upfront costs of freezing somatic cells may be low, but mitochondrial DNA is not conserved and the efficiency of subsequent steps in reproductive cloning can probably never compete with the efficiency of cryopreservation and implantation of embryos.

Storage of both oocytes and semen may also be efficient in terms of sampling and freezing costs and offers more flexibility in mating. However, high costs are associated with *in vitro* fertilization (IVF) and ovum pick-up (OPU). It is expected that overall costs will certainly not be lower than when using embryos instead of semen plus oocytes.

Differences in generation interval and reproductive rates between species may also influence conservation strategies. In some species it is possible to regenerate a breed very quickly through repeated backcrossing. On the other hand, for species with long generation intervals and low reproductive rates, cryobanking of embryos rather than sperm is preferable.

Sampling strategies

In farm animals, both within-breed diversity and between-breed diversity are important. Therefore, sampling strategies for cryopreservation purposes require decision-making between breeds as well as within breeds. Several methods and software have been developed to estimate the contribution of a breed to the total genetic diversity in species. In order to be able to re-establish a breed at any time in the future, well-selected samples of semen, embryos, oocytes and/or somatic cells should be cryopreserved. Studies on sample collection strategies from a genetic point of view have mainly focussed on cryopreservation of semen and less on strategies which include embryos or oocytes.

Boettcher et al. (2005) reviewed the literature on estimates for the number of semen doses to be stored or, alternatively, the number of embryos, and carried out a simulation study on the combined use of embryos and semen for cryogenic conservation of mammalian livestock genetic resources. They concluded that in order to ensure that reconstruction goals will be reached, embryo percentages (equal to a percentage of embryos needed to reconstruct a breed using only embryos) should be >30% for 'single offspring' species and >20% for other species. In addition to increasing the risk of failure in reconstruction, decreasing the embryo percentage also tends to increase the level of relationships among members of the reconstructed population.

Cost efficiency

In general, cryopreservation and associated reproductive technologies are costly and the main limitations for extensive development of *ex situ* collections are high costs of collection and freezing and limited expected future use of preserved material. On the other hand, costs of implementing *in situ* conservation plans may be relatively low on the short term, long-term *in situ* support may become relatively expensive, and long-term storage of cryopreserved genetic material is relatively cheap. Furthermore, to rely on *in situ* conservation only is risky as illustrated by recent outbreaks of infectious animal diseases. Increasingly it is advocated that there is a need for an integrated conservation approach, which combines a range of available *ex situ* and *in situ* options.

Costs of sampling, collection, freezing, storage and use of genetic material differ between species and optimum strategies depend on local circumstances, availability of technology and costs of labour and facilities. Gandini and Pizzi (2003) reviewed the literature on conservation costs (*in situ* and *ex situ*) and concluded that published information on *ex situ* conservation costs was very limited and not very timely. Drucker et al. (2005) also indicated that economic research addressing livestock genetic diversity has concentrated largely on *in situ* conservation. In this study the authors stated however, that under the assumption that technical feasibility brings cryopreservation of livestock species within the same level of magnitude as that of conservation of plant genetic material, extensive conservation efforts would be justified on economic grounds.

Many conservation programmes focus on freezing of semen only. Costs of collecting and freezing of semen varies due to differences in handling, training, collection and freezing costs. Costs of embryo collection and freezing are in general much higher than those for semen collection and freezing. However, regeneration costs using embryos are much lower compared to those for semen (repeated backcrossing).

When survival of material after freezing/thawing will improve and the chance of pregnancy will increase, costs of sampling and freezing of genebank material will drop, because less genetic material is needed in the genebank to generate a sufficient number of live offspring. Sampling costs can also drop if new collection methods are explored. Furthermore, if freezability of semen of genetically important males can be improved substantially (especially in the case of 'bad freezers'), sampling costs will drop even more.

Practical circumstances

The state of the art in cryopreservation and reproductive technologies and sophisticated (theoretical) sampling strategies show that efficient cryopreservation programmes are possible. However, practical circumstances are often much more unmanageable. Often existing infrastructure, equipment and capacity is not sufficient to carry out cryopreservation programmes and to guarantee long-term storage of cryopreserved material.

Policy, institutional and regulatory aspects

Technical and economic feasibility of optimum conservation strategies are often hampered by (lack of) policies, institutional frameworks or regulatory aspects. *In situ* or *ex situ* conservation programmes will never be sustainable without long-term policy support from governments or other stakeholders. According to Drucker et al. (2005) institutional analysis related to the management of animal genetic resources is generally lacking. When there are no policies, institutional or regulatory frameworks in place, cryopreservation programmes will not be developed, will not be effective or efficient or will not be sustainable.

Specific but important issues related to cryopreservation of animal genetic resources are sanitary or veterinary aspects. In general, the (future) use and exchange of cryopreserved genetic material have to comply with existing regulations or laws. In many countries there are very strict regulations to minimize disease risks, but these regulations often do not take into account the value of conservation of animal genetic diversity.

ERFP (2003) presents guidelines to be used for the constitution of national cryopreservation programmes in Europe. With these guidelines the authors attempted to cover genetic, cryobiological, organizational, legal and sanitary aspects of cryopreservation programmes but the guidelines could be developed further in order to support (new) initiatives within or outside Europe.

Conclusions

- For all domestic animal species, cryopreservation of genetic material is technically feasible, but there are important differences between species. For all species, cryopreservation of semen is feasible. If the aim is to conserve breeds, collection and cryopreservation of embryos should be considered.
- Advances in cryopreservation and reproductive technology have contributed and will continue to contribute to the (cost) efficiency and effectiveness of conservation programmes.
- Sampling strategies for cryopreservation programmes should always take into account both between- and within-breed diversity.
- Decision-makers in conservation programmes should regularly reconsider the balance between objectives, costs, technical feasibility, practical circumstances and policy, institutional and regulatory aspects.

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Complementarity of conservation approaches

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Abstract
Complementary approaches to conservation of farm animal genetic resources that combine *in situ* conservation of live animals in traditional production systems, *ex situ in vivo* maintenance of live animals in artificial environments such as research farms or zoos, and *ex situ in vitro* storage of cryopreserved gametes and embryos are required to optimally manage global farm animal genetic diversity. *In situ* conservation is most desirable for many reasons, but maintenance of an active role in agricultural livelihoods and adequate animal numbers to prevent losses in genetic diversity is not possible for all breeds. In these situations, *ex situ in vitro* collections of semen and embryos can bolster *in situ* conservation programmes by providing access to genetically more diverse material collected from founder animals when the breed was more secure and can make important contributions to managing inbreeding and avoiding unintended selection in small herds or artificial production environments. Similarly, *ex situ in vivo* approaches can support *in situ* conservation programmes by retaining samples of animals for educational, promotional, and research purposes and allowing more rapid multiplication of conserved breeds in responses to new opportunities for utilization.

Introduction
Complementarity among conservation approaches is not only possible, but is essential for better management of global farm animal genetic resources. Integration of the various approaches provides for stronger programmes, reduces risks of breed loss, and facilitates future use of endangered breeds.

Strengths and weaknesses of alternative approaches to conservation
Other presentations in this workshop will address individual conservation alternatives. However, some discussion of strengths and weaknesses of the various approaches is warranted to provide perspective on potential for complementarity.

In situ *conservation*

In situ conservation requires continued use of a breed by livestock keepers in the agro-ecosystem in which the breed evolved or is now normally found. *In situ* conservation has been recommended as the preferred approach to conservation of farm animal genetic diversity. Continued maintenance of breeding animals under commercial conditions maximizes opportunity for utilization and study of the breeds involved and facilitates comparison of traditional breeds with newly introduced exotic and exotic cross-bred animals. In many cases, traditional breeds are strongly associated with the cultural identity of their owners. Maintenance of these breeds can contribute to maintenance of community identity and stability. Innovative uses of traditional breeds to produce specialty or regionally branded products likewise can only emerge when animals continue to be available. Removal of endangered breeds from the production environment tends to validate the forces that led to their endangerment and effectively precludes objective assessment of their potential contributions to food and agriculture. *In situ* conservation is likewise required for most species of poultry, where practical cryopreservation of embryos is not possible and cryopreservation of semen is difficult.

Ex situ, in vitro *conservation*

Ex situ techniques involve maintenance of endangered breeds outside the traditional production environment. *Ex situ*, *in vitro* techniques specifically involve cryopreservation of gametes, embryos, or somatic cells that have the potential to reconstitute live animals. Properly constructed *ex situ*, *in vitro* collections can maintain much of the genetic diversity present within a breed and permit regeneration of the breed even if living animals no longer exist. Semen and embryos are the most common tissues used in animal cryopreservation. Embryo storage is encouraged for breeds with a high risk of extinction, because embryos can be used to regenerate animals of the breed in a single generation. In contrast, semen provides only a sample half of the genetic material of the breed and requires either access to purebred females or a long period of grading up from unrelated females to regenerate a breed. However, costs of collecting and using frozen semen are much less than those involved in collection and use of frozen embryos. Cryopreservation of somatic tissues for future use in somatic cloning has also been recommended. The generation of live animals from somatic cell cultures has proven possible for all mammalian species that have been tested, but it is not clear if frozen tissues alone (e.g. ear punches) are appropriate sources of material for cloning. Establishment of tissue cultures before cryopreservation of cells is likely a more reliable strategy, but would substantially increase costs of sample preparation. For the moment, the technology required for somatic cloning is difficult and costs of regeneration remain too high for use in any practical breeding programme or to regenerate a population. Storage of DNA or tissues that can be processed to yield DNA is likewise often recommended to allow future screening of DNA from extinct or endangered breeds, but DNA cannot be used to regenerate a breed.

The contrast between plants and animals in emphasis on *ex situ* and *in situ* conservation is striking. *Ex situ*, *in vitro* conservation of seeds has been strongly favoured for long-term conservation of plant genetic resources. This situation reflects in part the much lower costs of collection and storage of seeds compared to frozen gametes and embryos. Seeds of most annual plants can be stored under conditions of controlled temperature and humidity that are not particularly demanding whereas uninterrupted storage in liquid nitrogen is required for animal gametes and embryos. In addition, genetic resource utilization and variety development in plants occurs mainly in a highly centralized seed production sector, and generally involves relatively rapid replacement of current varieties, often with active introgression of genes from diverse parent lines to create new commercial varieties and hybrids. Access to plant material from *ex situ* collections is relatively easy, at least for the annual plants that dominate global crop production; recovery and preliminary evaluation of relatively large numbers of plants can occur in a single growing season with little, if any, greater cost than that associated with production from *in situ* varieties. In contrast, lower reproductive rates and longer generation intervals limit opportunities for new breed development in animals, and genetic improvement programmes are more focused on gradual improvement of existing breeds. Also, institutional capacity for farm animal genetic resource development is far more limited than that in plants. The cumulative effect of these differences is to make regeneration of an extinct or severely endangered livestock breed from material stored in *ex situ in vitro* collections much more difficult and expensive than it would be in plants. In addition, *ex situ in vitro* approaches cannot provide the cultural and historical connections that can motivate future *in situ* conservation and use, and are often viewed as approaches of last resort in animal genetic resource conservation.

Ex situ, in vivo *conservation*

Ex situ, *in vivo* conservation involves maintenance of living animals under something other than normal farm conditions (e.g. research or governmental stations or zoos) or outside of the area in which they evolved or are now normally found. Animals in these programmes are often no longer subject to the same adaptive forces that would be active under typical farming conditions with owners who rely on the animals for their livelihoods. However, the extent of the departures from typical production conditions can vary widely, as would, therefore, the risk of loss in adaptation.

Complementarity of *in situ* and *ex situ, in vivo* approaches

In situ conservation is generally preferred for farm animals for reasons discussed above, but maintenance of live animals outside the traditional production environment may be extremely important for breeds that are no longer actively used by farmers or as a complement to *in situ* conservation activities. In most cases, long-term *ex situ*, *in vivo* conservation of breeds that are no longer actively used by farmers is challenging in terms of how to best maintain the potential of those breeds to make future contributions to food and agriculture. Therefore, if *ex situ in vivo* approaches are to effectively support *in situ* conservation, these programmes must retain linkages to, and interactions with, *in situ* production. For example, a state breeding farm can serve as a source of breeding stock for small farmers or others who find it difficult to obtain breeding stock from declining breeds. Likewise, private farmers with an interest in conservation of rare breeds and the financial resources to maintain them can serve as sources of breeding animals for more commercially oriented but less affluent farmers.

If *ex situ*, *in vivo* conservation is to effectively complement *in situ* approaches, these programmes must retain commercial relevance. This is often not the case. Hobbyists, fanciers, and exhibitors often are mainly interested in maintaining, or in some cases accentuating via show ring criteria, unique phenotypes, with little or no corresponding concern for maintaining the production potential or genetic diversity of the breed. Breeders of fancy poultry are a case in point, where emphasis all-too-often is focused on accentuation of a few plumage or colour mutants, often by relatively intense inbreeding. The record of state breeding farms is only marginally better. In many cases, these farms attempt to impose 'improved' production practices that are inconsistent with those of surrounding farmers. The state breeding farms likewise often view their animals and breeding programmes as innately superior to those of private farmers, but fail to objectively evaluate and document if this is really the case under normal farm conditions. Successful complementarity of *in situ* and *ex situ*, *in vivo* approaches is thus best achieved when close collaboration, preferably with bidirectional exchange of animals, exists between private sector farmers and conservation herds and flocks. Maintenance of typical production conditions is essential, as is the application of sound genetic management principles.

Ex situ in vivo approaches are generally short-term in nature and care must be exercised to monitor the status and trends in animal numbers for conserved breeds to determine if combined *in situ* and *ex situ in vivo* approaches are successfully maintaining diversity. If *in situ* conservation programmes continue to weaken, implementation of *ex situ*, *in vitro* approaches should be considered.

Complementarity of *in situ* and *ex situ, in vitro* approaches

Reliance on *in situ* conservation alone carries significant risks. If programmes to re-establish or reinvigorate a breed are not successful or if government policies supporting continued use of a breed are withdrawn, animal numbers can decline rapidly, and in such emergency situations, timely collection of semen and/or embryos to establish *ex situ*, *in vitro* collections or rescue of animals in *ex situ in vivo* programmes may not be possible. Reliance on only *ex situ in vitro* conservation also carries the aforementioned risks associated with removing living animals from the production environment and thereby preventing their active characterization, improvement, and use. While a breed may be 'secured' by *ex situ in vitro* conservation, with current technology its regeneration and future use is likely only in response to a 'doomsday' event such as radical climate change or global pandemic.

Complementary use of these two techniques, however, has great potential to support conservation. *In situ* populations of the most endangered breeds are often found in isolated rural areas or owned by hobbyists and fanciers. Uncontrolled (or actively promoted) cross-breeding, selection for characteristics not consistent with traditional roles, or losses in fitness from inbreeding and limited population size can seriously compromise the prospects for such breeds. However, if semen from a representative sample of males can be cryopreserved before the breed is seriously endangered, this reservoir of material can be used when needed to reintroduce depleted genetic variation and return the breed to its ancestral state in a relatively short time (two to three generations). Maintenance of *in situ* herds or flocks provides access to animals for characterization and study while frozen semen provides capacity to rapidly introduce genes from the conserved breed into existing populations.

Emphasis on frozen semen is appropriate because frozen semen is much easier and cheaper to collect, process, and use than frozen embryos. Frozen semen is adequate to support both *in situ* conservation (because females of the conserved breed are still available), and the introgression of material from conserved breeds into commercial breeds to form new genetic combinations or composite lines. *Ex situ* embryo storage is desired when adequate resources are available but can be deferred until *in situ* populations are seriously endangered, since embryos for cryopreservation can then be generated by use of frozen semen (collected when the breed was more secure) on remaining females. Strong complementarity also exists between use of frozen semen and embryos for conservation and for improvement and development programmes. Widespread use of artificial insemination (AI) and embryo transfer (ET) is often blamed for losses in genetic diversity, but access to these technologies provides significant opportunities for their use in conservation.

Complementarity of *ex situ, in vitro* and *ex situ, in vivo* approaches

Neither of these approaches involves maintenance of live animals in traditional production environments and so they are generally adopted only for the most endangered breeds. In such cases, *ex situ* storage of both semen and embryos is ideal as a method to secure the genetic resource for future use, but maintenance of living animals, even under *ex situ* conditions, can aid in generating interest and facilitating preliminary study of the breed. Frozen semen can be used to avoid negative effects of inbreeding and, to some extent, defer unintended effects of selection in animals maintained in *ex situ* conditions. The amount of semen required for this use is modest (since *ex situ* herds and flocks are usually small) relative to that required for future regeneration of a breed. Inability to maintain a breed *in situ* effectively stops selection for commercial performance, so these techniques are mainly valuable to conserve genes for known or unknown special breed characteristics. Successful reintroduction into the original production environment may be difficult for breeds maintained for long periods through *ex situ* means.

Conservation of farmed fish genetic resources: broad options, strategies, availability of methods, and comparisons with those for conservation of the genetic resources of other farmed animals

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Introduction

Aquaculture, the farming of privately owned aquatic plants and animals, is part of agriculture. Farmed fish (finfish, crustaceans, molluscs and other aquatic invertebrates) are part of agrobiodiversity and the ecosystems from which they are produced are agro-ecosystems. Capture fisheries, apart from a small minority that are enhanced with hatchery-reared fish from aquaculture, are the hunting of aquatic wildlife, usually as common property. The Consultative Group on International Agricultural Research (CGIAR) refers to the genetic resources of all exploited fish species, including farmed fish, as fish genetic resources (FiGR) and to the genetic resources of other farmed animals—mainly buffalos, camels, cattle, goats, pigs, poultry and sheep—as farm animal genetic resources (FAnGR). The genetic resources of farmed insects, land snails, amphibians, reptiles, other birds and mammals are also regarded as FAnGR.

This paper is a review of broad options, strategies and availability of methods for conservation of the genetic resources of farmed food fish. It does not address conservation of the genetic resources of ornamental fish, which currently comprise about 5000 species for finfish alone. However, the strategies and methods described here for food fish would also apply to many of these. The focus here is on farmed and potentially farmable fish species, but many other species contribute to their production. Capture fisheries supply trash fish, fishmeal and fish oil for farmed fish feeds. Plankton in fish farm waters provide some farmed fish with food and/or oxygen and aquatic microorganisms provide waste processing services. The genetic resources of all these other species are, in a broad sense, genetic resources for aquaculture.

The increasing importance of aquaculture and types of fish farming are summarized, followed by overviews of domestication in farmed food fish and their genetic resources. Issues and concerns for the conservation of FiGR for aquaculture are then considered: information, threats, *in situ* conservation in open water ecosystems, *in situ* conservation on-farm, *ex situ* conservation, biotechnology, ownership and access, and networks and partnerships. Broad options, strategies, availability of methods, and some similarities and differences between FiGR and FAnGR are noted for all of these. The collective term livestock is used here for farmed animals other than fish. A final summary targets greater collaboration for conservation of FiGR and FAnGR. This paper draws upon and supplements, a recent review on the same topic, prepared for the CGIAR Science Council (Gibson and Pullin 2005).

The increasing importance of aquaculture

Aquaculture is expanding rapidly, while about two-thirds of the world's capture fisheries are fully exploited, declining or collapsed. According to FAO statistics, the contributions of farmed fish to world food fish supply grew from 3.9% in 1970 to 29.9% in 2002: an average growth rate of 8.9%/year and an increase in global per caput supply of farmed fish from 0.7 to 6.4 kg/year. Aquaculture production statistics are dominated by Asia, especially the People's Republic of China (Table 1).

Table 1. Production of farmed aquatic animals in 2002 for the top ten producer countries and the rest of the world.

Producer		Production ('000 mt) (position by value)
1.	People's Republic of China	27 767(1)
2.	India	2 192 (3)
3.	Indonesia	914 (6)
4.	Japan	828 (2)
5.	Bangladesh	787 (9)
6.	Thailand	645 (5)
7.	Norway	554 (7)
8.	Chile	546 (4)
9.	Vietnam	519 (8)
10.	USA	497 (<10)[†]
Rest of the world		4 550
Total		**39 799**

[†] Brazil ranked tenth by value

Source: FAO statistics.

Many developing-country governments now view aquaculture as the most feasible means by which to increase fish supply and are framing policies accordingly. Asian dominance of aquaculture will continue but other developing regions, especially sub-Saharan Africa and Latin America, face the same difficulties as Asia in sustaining and increasing fish supply from capture fisheries, and are planning substantial expansion of aquaculture. Brugère and Ridler (2004) listed the following national forecasts for future average annual growth of aquaculture: Bangladesh (2001–2020), 3.5%; Brazil (2003–2010), 25.3%; China (2002–2010) 2.0 to 3.5%; Egypt (2000–2017), 5.5%; India (freshwater; 1995–2005), 8.2%; Indonesia (2003–2009), 11.1%; Thailand (1996–2010), freshwater 2.0%, coastal 1.6%; Vietnam (2001–2010), 10.0%.

Farmed fish are therefore becoming increasingly important contributors to human intake of animal protein, healthy lipids and micronutrients, and concerns over some of the disease risks associated with livestock could further increase their contributions. Farmed fish can be very efficient converters of feeds. Unlike livestock, they do not use food energy to maintain constant body temperatures that differ from ambient. The farming of freshwater herbivorous/omnivorous fish already provides substantial nutritional and livelihood benefits to the poor (ADB 2005a) and has high scope for growth, especially in Asia. The extent to which this could be replicated in other developing regions, including sub-Saharan Africa, merits much fuller exploration. Inland aquaculture appears to be generally less risky than many forms of coastal aquaculture and can add value to freshwater resources by contributing to their multipurpose use.

Types of fish farming

Fish farms vary from the simple delineation of coastal areas where naturally settled, wild molluscs feed themselves by filtering seawater, through ponds and pens where fish graze on naturally occurring aquatic plants and microorganisms, to cage, pond, raceway and tank farms where fish are given supplemental or nutritionally complete feeds. Integrated crop–livestock–fish farming systems have a long history, especially in Asia (e.g. Edwards et al. 1988). In integrated farming, the crop, livestock and fish enterprises are interdependent and the genetic resources for all contribute to overall farm productivity, profitability and risk management. Another variant is capture-based aquaculture, where juveniles or young adults of species that cannot be bred in captivity (e.g. tunas) are harvested by capture fisheries and then fattened to market size in cages (Ottolenghi et al. 2004).

Mass production of fish seed (eggs, larvae, fry and fingerlings) in hatcheries and their growout to marketable size in fish farms are usually under different management. Livestock breeding and production also tend to be separate enterprises, though more livestock farmers than fish farmers breed and produce their own young animals. Hatchery production of fish seed for culture-based fisheries (CBF) (otherwise called enhanced fisheries or fish ranching) is considered by FAO and other agencies as part of aquaculture. CBF have been attempted with over 100 species. Their success, however, has been largely limited to enhancement of freshwater fisheries (especially for Asian carps in lakes and reservoirs), coastal fisheries for invertebrates and finfish that remain at or near release sites, and fisheries for salmon and other migratory species (e.g. Lorenzen et al. 2001; Leber et al. 2004).

Fish and livestock are therefore produced by similar types of farming methods: from ranching, through grazing to supplemental or intensive feeding in various forms of containment. However, there is no equivalent for livestock of the capture-based aquaculture of wild fish, and livestock ranching uses known domesticated breeds whereas most CBF use wild or relatively undomesticated fish.

Domestication of farmed fish

Even the oldest species of farmed fish have histories of domestication that are shorter by at least 10 000 years than those for livestock (Balon 2004). Routine captive breeding of some of the world's important and widely farmed fish, such as the Chinese and Indian major carps and penaeid shrimps, has been possible for only a few decades. Much of the fish seed produced for aquaculture still comes from broodstock populations that are poorly characterized, and the use of pedigreed fish is rare. Since the 1980s, however, there has been a large expansion of aquaculture genetics research, especially on the characterization and evaluation of carp and tilapia genetic resources for aquaculture (e.g. Pullin 1988; Penman et al. 2005). Over the same period, fish breeding programmes have begun to benefit large numbers of fish farmers and consumers; for example, the dissemination of genetically improved farmed tilapia (GIFT) and application to other farmed fish species of the methods used in their development (ADB 2005b).

The different histories of domestication of livestock and most farmed fish are reflected in the different current uses of the terms *in situ* and *ex situ* for FAnGR and FiGR. FAnGR, held *in vivo* on-farm, are called *in situ*, whereas FiGR held *in vivo* on-farm or in other forms of captivity are called *ex situ*, because they are away from their natural habitats. For FiGR, *in situ* usually means living freely in open waters, and *ex situ* means held *in vivo* on-farm or in any other form of captivity, or held *in vitro*. All FiGR and FAnGR held *in vitro* as cryopreserved genetic material are called *ex situ*.

Based upon the definitions of the Convention on Biological Diversity (CBD 1994), using the term *ex situ* for substantially domesticated fish on farms is incorrect. The CBD defines *in situ* conditions as: "where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties"; and *ex situ* conservation as "conservation of components of biological diversity outside their natural habitats". For domesticated farmed fish that have distinctive properties, genetic resources held *in vivo* on-farm, should therefore be called *in situ*. The term *in situ* must also be retained for wild and feral FiGR in open waters.

Balon (2004) holds that only the obviously distinct farm breeds of one food fish species—the common carp (*Cyprinus carpio*)—and the distinct variants (such as albinos) of a few other species can be called true 'domesticates', and regards other widely farmed fish, including other carps, catfish, salmonids, sturgeons and tilapias as 'exploited captives'. A broader view is that most farmed populations of these species can also be called domesticated.

Most farmed fish are highly fecund, producing from thousands to millions of progeny per mating, and many have shorter generation times than livestock; for example, about 6 months for tilapias. Some fish seed producers and many farmers who raise their own seed have limited knowledge about how to manage the genetics of captive broodstock. This, together with the ease of obtaining large numbers of seed from few parents, can lead to reduced performance of farmed fish; e.g. from founder effects and inbreeding depression. For example, during the development of genetically improved farmed tilapia (GIFT) in the Philippines, wild type Nile tilapia from Africa outperformed long-established Asian farmed Nile tilapia populations (Eknath et al. 1993) and there is evidence of similarly reduced performance of farmed tilapia in Africa itself (Brummett and Ponzoni 2004).

Natural selection on the huge numbers of fish seed in hatchery and farm environments often involves very high mortalities, while still leaving enough survivors for further breeding and/or production. This takes place with or without any artificial selection. The main consequence is that so-called "domestication selection in aquaculture" (Doyle 1983) can be rapid, beginning with even one generation of captive breeding from wild fish. This means that some CBF can compromise the conservation of wild fish populations when hatchery-reared seed interbreed with and/or compete with them for food and breeding sites.

Genetic resources of farmed fish

FiGR for aquaculture comprise wild and feral populations, captive-bred populations that differ from wild types to various extents, substantially domesticated strains, hybrids and other genetically altered forms. Conservation of FiGR for aquaculture must therefore operate at species level and at all of these intraspecific and other levels.

FishBase (http://www.fishbase.org) lists 344 species of farmed finfish. The total for all farmed fish species is probably about 500. According to FAO statistics, the majority of farmed fish production derives from 29 species. For comparison, 14 species of livestock account for 82% of world livestock production, all completely domesticated and comprising over 6000 known breeds. The numbers of distinct, domesticated farmed fish strains are not known. The author's best guess—in terms of the CBD descriptors 'domesticated or cultivated' and 'distinctive properties', and regarding the location at which a farmed fish has developed these properties as 'origin'—is that there might presently be hundreds of these. This could be an underestimate and the number is sure to grow, possibly becoming comparable with that for livestock breeds.

The fish species that currently account for most of world aquaculture production will probably continue to do so, but there will also undoubtedly be some adoption of new species in aquaculture, especially herbivorous/omnivorous freshwater finfish. Conversely, the farming of some carnivorous marine fish is unlikely to remain profitable or sustainable because of their feed requirements.

Fish farmers, like livestock farmers, seek to farm the most viable and profitable species, strains, hybrids etc., for their particular farm environments and markets. This often means farming alien species, and decisions to change species, including changes from indigenous to alien species, can be rapid. Within the last decade, Asian farmers of penaeid shrimp in Asia have largely switched from farming indigenous species to farming the Pacific white shrimp (*Litopenaeus vannamei*), which probably now accounts for about 80% of their production. The Chinese silver carp (*Hypophthalmichthys molitrix*) has recently become the single species contributing most to production of farmed carps in South Asia. The Nile tilapia (*Oreochromis niloticus*) is farmed in all tropical regions outside its native Africa.

The farming of alien fish species, as well as the farming of genetically altered fish, whether of alien or indigenous species, can have large environmental impacts. When farmed fish escape, they can interbreed with and/or displace wild fish and they cannot be recaptured or culled, as is usually possible with escaped livestock. For example, robust feral tilapia populations have developed from fish that have escaped from farms or been released for CBF (e.g. Pullin et al. 1997; Costa-Pierce 2003). International introductions of alien fish species for aquaculture and genetically altered farmed fish, as well as their transfers across ecological boundaries within States, therefore require high precaution and prior appraisal of possible adverse environmental impacts. This would not apply to the same extent to most livestock, apart from invertebrates, amphibians and reptiles. Effective arrangements for quarantine and disease control are of course essential for all farmed fish and livestock.

Issues and concerns

Information

Accurate and up-to-date information on the status, location and use of FiGR for aquaculture is the foundation for their conservation. However, aquaculture production statistics are collected by national authorities and reported to FAO almost exclusively at species level. There are few easily accessible records of the contributions of strains, hybrids and other genetically altered fish. FAO has recognized this (e.g. Bartley et al. 1997). Information other than at species level is most extensive for widely farmed species; e.g. common carp in Europe and some carps and tilapias in Asia.

Options

The main options are to continue the *status quo* or to begin progressive documentation of the production of farmed fish hybrids, distinct strains and other genetically altered forms.

Strategies

The main strategy for change is higher investment, at national, regional and international levels in thorough documentation of the types of fish seed supplied to farmers and of the contributions of different types of fish seed to aquaculture production. Aquaculture statistics could then be progressively restructured to account for contributions not only of fish species but also of hybrids and distinct strains, etc. This would contribute much to FiGR conservation, because it would be evidence of their use. Correct, authoritative and standardized nomenclature will be essential.

Methods

FishBase (http://www.fishbase.org), a consortium comprising FAO, the WorldFish Center, and national institutes in Belgium, Canada, France, Germany, Greece and Sweden, provides correct nomenclature at species level for finfish and limited data on finfish cytogenetics, DNA markers and population genetics. FishBase allows user entry not only through the scientific names of fish but also through their common names in over 200 languages. FishBase has linkages, among many others, to the Global Biodiversity Information Facility (GBIF), Genbank, the World Conservation Union (IUCN), and the CGIAR's System-wide Information Network for Genetic Resources (SINGER). A new project, "All Fish", supported by the Oak Foundation and hosted by the WorldFish Center, commencing December 2005, will provide for aquatic invertebrates, including farmed crustaceans and molluscs, correct nomenclature and ultimately biological information comparable to those available for finfish in Fishbase.

Fish population genetics data is now largely derived from DNA analyses, in contrast the large body of historical data from electrophoretic studies of protein variation (e.g. Verspoor et al. 2005). DNA barcodes are being catalogued for 20 000 marine and 8000 freshwater species of finfish (http://barcoding.si.edu/AllFish.htm). FAO has made initial studies on possible approaches to information systems for FiGR (FAO 1999; Pettman 2002; Pullin 2002). The GBIF (http://www.gbif.org) is becoming the main system linking databases that provide information for conservation and use of genetic resources.

Similarities and differences between FiGR and FAnGR

As more fish breeding programmes develop, the farming of fish hybrids, distinct strains and genetically altered forms will undoubtedly increase and information about them will be increasingly needed, as has long been the case for livestock. Development of information sources for conservation of the genetic resources of farmed fish strains, hybrids and other genetically altered forms can benefit greatly from the experiences learned with FAnGR during development of DAD-IS (FAO Domestic Animal Diversity Information Service available at http://www.fao.org/dad-is/) and DAGRIS (Domestic Animal Genetic Resources Information System, available at http://dagris.ilri.cgiar.org/dagris/).

Threats

Wild fish, particularly freshwater finfish and molluscs, are the world's most threatened animals exploited by humans, mainly because of damage to or loss of their habitats and/or overfishing. Aquaculture can be both a contributor to and a victim of these threats and losses: a contributor by occupying and changing aquatic ecosystems and a victim from the loss of potentially valuable FiGR for research and breeding programmes. There is an ongoing debate about the inevitability of conflicts between economic growth and conservation of wild FiGR (e.g. Lackey 2005; Reed and Czech 2005).

According to IUCN Red List entries, the total number of threatened finfish species grew from 1128 in 1996 to 1249 in 2000 (Froese and Torres 1999; FishBase 2000 data). According to IUCN and FishBase data, about 24 species of farmed finfish are currently threatened. However, genetic resources of many more farmed and potentially farmable fish species, especially their wild populations in Asia, Africa and Latin America, are also under serious threat.

Some FiGR on farms are also threatened because fish seed suppliers' and farmers' commercial choices dictate and limit their contributions to conservation of farmed fish diversity. Some of the fish that they choose not to farm will still have potential to contribute to future breeding programmes for production in changed environments and/or markets.

Options

For wild FiGR, the main options are to accept the worsening threats and losses, taking no effective action, or to take countermeasures, as far as these are politically and socially possible. Options for the conservation of threatened fish strains, hybrids or other genetically altered forms must normally be sought in the public sector.

Strategies

Countering threats to FiGR must encompass *in situ* conservation in natural habitats, *in situ* conservation of domesticated fish on farms, and complementary *ex situ* conservation. Strategies for all must be based primarily on education, to heighten the awareness of policy-makers and the public to the seriousness of threats to FiGR and to the consequences for food security, livelihoods and quality of life if threats are not addressed. The highest priorities among threatened wild FiGR for aquaculture include tilapia and other African freshwater fish (e.g. Lévêque 1997; Agnèse 1998; Piers 2002), Asian carps and catfishes (e.g. Dehadrai et al. 1994) and South American freshwater and migratory fish (e.g. Carolsfeld et al. 2003). Conservation of threatened wild FiGR can benefit increasingly from the generation, sharing and understanding of molecular genetic information (e.g. Hendrik 2004), but this will require higher investments in education in this field. For distinct farmed fish strains, hybrids etc., there is little information presently available on threatened taxa. However, the most likely strategy for their conservation, as information emerges, is *ex situ* genebanking.

Methods

Methods are widely available for education that is targeted at conservation of wild genetic resources and agrobiodiversity, including FiGR. Non-governmental organizations, such as the World Fisheries Trust (http://www.worldfish.org), have been among the most successful developers and providers of educational material.

Similarities and differences between FiGR and FAnGR

Threats to FiGR are documented almost entirely for wild fish, usually at species level. For a few groups (especially salmonids) there is detailed information at intraspecific levels (subspecies, riverine and lacustrine races or other types of local population). There is some comparable documentation on threatened wild relatives of livestock, though on a more limited scale than for the wild relatives of farmed fish. There is no documentation for threatened fish strains comparable to that developed for threatened livestock breeds and no comparable development for threatened fish strains of the rare breeds trusts established for livestock. Estimates of the proportion of livestock breeds at risk of extinction vary from 22.5% to 32% (Drucker et al. 2001; FAO data).

In situ *conservation in open water ecosystems*

Many of the FiGR upon which the future of aquaculture will depend are wild types, living freely in open water ecosystems: coastal waters, floodplain water bodies, lagoons, lakes, reservoirs, rivers, seas, wetlands, etc. For the freshwater fish species that presently contribute to aquaculture production there are likely to be thousands of distinct wild populations with potential to provide important genetic material for fish breeding programmes and related research. Local populations of marine fish can also exhibit high genetic diversity, with cryptic speciation among invertebrates (Thorpe et al. 2000). Moreover, there are many fish species, particularly freshwater finfish and marine invertebrates, yet to be screened for aquaculture potential. Ryman et al. (1995) reviewed issues and strategies for the conservation of wild fish and large research efforts and conservation programmes are ongoing, especially for freshwater finfish (e.g. see contributions in Miller and Craig 2001; Collares-Pereira et al. 2002).

Options

The main options are to make adequate investments to ensure the conservation of valuable or potentially valuable wild FiGR in open water ecosystems or to accept their progressive loss, principally by change to and occupation of their habitats for other purposes.

Strategies

Strategies for conservation of FiGR in open water ecosystems are essentially the same as those for conservation of other forms of wildlife. The strong case for conservation of wild FiGR can help to catalyze conservation of aquatic habitats in general and more responsible use of aquatic ecosystems. One of the main requirements will be the establishment and upkeep of more aquatic protected areas of adequate size and diversity. For some aquatic protected areas, it is acceptable and a means for financing them to permit continued use for well-managed fisheries, ecotourism etc. However, for the conservation of important pure and undisturbed wild FiGR, aquatic protected areas should ideally be kept completely off-limits to and isolated from aquaculture, fishing and other human activities. This will often be precluded by political and social factors and/or by the lack of suitable sites. Where such isolated FiGR reserves are possible, co-financing their establishment and upkeep with the costs for development and management of responsible aquaculture, fisheries and other uses of aquatic ecosystems elsewhere, is a new strategy to be explored.

Methods

Guidelines for the conservation of FiGR as an integral part of their management have been proposed by Pullin (2000) and many examples of conservation of wild FiGR have been published (e.g. see Harvey et al. 1998). Methods are also available for the establishment and upkeep of aquatic protected areas, though results are often unpredictable. All sites have some unique features and the main method is still learning by doing. The primary goal of most published examples of aquatic protected areas has been either to improve the management of capture fisheries and/or to conserve fish biodiversity as part of nature conservation in general, with conservation of FiGR *per se* seldom emphasized (see examples in Shipley 2003). Marine protected areas have generally received more attention and publicity than inland aquatic protected areas. With respect to co-financing of isolated aquatic protected areas with responsible use of other parts of aquatic ecosystems, the starting point in most cases would be information from local studies. This is already extensive, though more so at the species level than at intraspecific levels (see examples in Palomares et al. 2003).

Similarities and differences between FiGR and FAnGR

Conservation of FAnGR in natural ecosystems has less importance for livestock breeding than conservation of wild FiGR in open waters has for fish breeding. Some nature reserves and national parks conserve wild relatives of farmed fish and of livestock, but for livestock in general there are few equivalents of the aquatic protected areas that are so vital for the conservation of wild FiGR.

In situ *conservation on farms*

In situ, on-farm conservation of FiGR of domesticated and distinct fish strains, hybrids and their parental stocks, and other genetically altered forms of fish, is mainly accomplished by commercial fish seed producers and farmers, as *in vivo* broodstock populations. These must be replaced at fairly frequent intervals; e.g. for tilapias, usually after a maximum of two years of seed production. The main conservation objective is to keep different populations separate and to maintain adequate effective breeding numbers. Commercial fish seed producers and farmers must produce and farm the best available and affordable fish strains, hybrids etc., unless adequately compensated to keep other less profitable fish. This means that market shares of different fish strains can change rapidly; for example, newly developed GIFT and GIFT-derived Nile tilapia strains accounted for 68% of tilapia seed production in the Philippines and 46% in Thailand within a decade of becoming available from government and private hatcheries (ADB 2005b).

Options

Fish seed producers and farmers have few options with respect to their choices of farmed fish species, strains, hybrids or other types. They must opt for fish of proven viability and profitability.

Strategies

Conservation of a wider diversity of FiGR than is possible *in situ* on commercial fish farms must be done mostly by public sector research and breeding centres, universities and aquaria. Farmers can contribute to this only if adequately compensated. Public–private partnerships have high potential for building bridges between on-farm *in situ* and institutional *ex situ* conservation of FiGR.

Methods

Methods for good management of fish broodstocks and for selection and breeding programmes in aquaculture are widely available (e.g. Tave 1986; WorldFish Center 2004a; Gjedrem 2005). Public–private partnerships in fish breeding, seed supply and farmed fish production are common, but methods have not yet been well-documented. Those associated with the genetic improvement of tilapia in the Philippines have led to a published declaration and workshop proceedings (Tilapia Science Center–WorldFish Center 2003; WorldFish Center 2004b).

Similarities and differences between FiGR and FAnGR

The motivations of fish and livestock farmers are the same with respect to their choices of which animals to farm, and therefore conservation of FiGR and conservation of FAnGR *in situ* on farms face the same limitations. Public–private partnerships are common in fish and livestock breeding, but for livestock there are far fewer equivalents of the large public sector (government and some NGO) fish hatcheries that typically supply large proportions of the fish seed used by farmers, especially in developing countries.

Ex situ *conservation*

Broodstocks of domesticated fish, held by research institutes, universities and other public sector organizations, are at present the world's main *ex situ, in vivo* fish genebanks, and are often called live fish genebanks. They are of immense national and international importance for *ex situ* conservation of FiGR. For example, the Fish Culture Research Institute of Hungary maintains a genebank of over 30 wild and farmed strains of common carp (Bakos and Gorda 2001). FiGR held as live fish genebanks are subject to change because of natural selection to broodstock and hatchery environments. Stable and indefinite *ex situ, in vitro* genebanking of cryopreserved sperm has been proven feasible for about 100 fish species. Tiersch and Mazik (2000) put the total at 83 for finfish, and further successes continue to be reported, mostly targeted at conservation of wild fish (e.g. Cruz-Casallas et al. 2004). However, fish sperm cryopreservation is still used mostly by advanced research institutes and fish breeding centres and only to a very limited extent by private fish seed producers and farmers.

Options

The main options for *ex situ* conservation of FiGR are to continue major or sole reliance on live fish genebanks or to develop progressively more complementary, *ex situ, in vitro* genebanking, principally as cryopreserved fish sperm.

Strategies

The main overall strategies are decentralization, spreading the responsibility and costs of fish genebanking among many service providers and end-users, and replication of collections as an insurance against accidental loss or loss of viability. Strategies for *ex situ* conservation of particular FiGR will vary according to the circumstances of those who must take responsibility for keeping them, often indefinitely, and with the needs and circumstances of end-users.

Methods

Methods for maintaining live fish genebanks are essentially the same as those described above for *in situ* conservation of FiGR on-farm. Methods for cryopreservation of sperm are available for some widely farmed finfish; e.g. carps and salmonids. Embryos of some farmed aquatic invertebrates, such as bivalve molluscs and sea urchins, have been successfully cryopreserved, but cryopreservation of finfish eggs and embryos is not possible because of their large size, hydrated contents and delicate structure. The World Fisheries Trust, among others, advises and trains on *ex situ* conservation of cryopreserved fish sperm, complementary to *in situ* conservation of wild fish in natural ecosystems and of broodstocks on farms.

Similarities and differences between FiGR and FAnGR

The principles involved in maintenance of live fish genebanks are similar to those for livestock breeding nuclei. The cryopreservation of fish sperm requires essentially the same techniques and facilities as are found in establishments for holding collections of livestock semen for artificial insemination. There are no equivalents for fish of embryo cryopreservation as has been established for breeding livestock, especially cattle. For both fish and livestock, there has been limited adoption of cryopreservation technology in developing countries. *Ex situ* genebank standards and certification for the identity and provenance of fish strains have yet to be established. Public aquaria could play a wider role and more active role in *ex situ* conservation of FiGR for aquaculture similar to that of some public zoos and private collections of livestock for conservation of FAnGR. In a World Zoo Conservation Strategy (IUDZG–CBSG/IUCN/SSC 1993), it was estimated that world's public aquaria were holding about 300 000 fish. Public and private aquaria now hold many more, including populations of some farmed species.

Biotechnology

According to its CBD definition, biotechnology is: "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". Genetic modification (often understood as pertaining only to that achieved through transgenesis) and other forms of genetic alteration are the probably the most important current and likely future applications of biotechnology in aquaculture. Transgenic fish have been produced by researchers for at least ten species of farmed food fish, with marked success, at research level, in improving growth performance and environmental tolerance (Beardmore and Porter 2003). Their commercial use is not yet officially permitted but it is highly likely that some will be farmed, given adequate safeguards and public acceptance. Other types of genetically altered farmed fish are already widely farmed, as indigenous and alien species, including: selected strains, hybrids, polyploids, and monosex populations (Dunham 2004). Sequencing of the Nile tilapia genome is being proposed, as a model perciform fish and a globally important farmed food fish (http://hcgs.unh.edu/cichlid/).

Options

There are numerous options for applications of biotechnology in aquaculture: in genetic improvement; for disease prevention and control, including development of vaccines; and in feed formulation to reduce reliance on fishmeal and fish oil as fish feed ingredients, etc. All have potentially large consequences for the conservation of FiGR—directly, through influencing farmers' choices of which fish to farm, or indirectly by their possible environmental consequences.

Strategies

The main strategies with respect to biotechnology in aquaculture must be high precaution and thorough appraisals of long-term costs, benefits and impacts. As applications of biotechnology in aquaculture increase in scale and complexity, strategies for FiGR conservation will have to include not only conservation of the products of biotechnology *per se* but also their potential impacts on other FiGR and on other biodiversity. Biosafety regulations should be applied to all such products, not only to transgenic fish. The characteristics of a genetically altered organism and its possible impacts on any recipient environments and biota, on-farm and off-farm, are the most important considerations with respect to biosafety, *not* the techniques by which it was produced (ICLARM–FAO Bellagio Conference 1999; WorldFish Center 2003).

Methods

Development of new biotechnology for aquaculture is a large and dynamic research field that is generating new methods. Although classical selective breeding is likely to remain the mainstay of genetic improvement in aquaculture, this is likely to be accompanied and to some extent supplanted in future by application of other technologies; e.g. combinations of chromosome set manipulation, hybridization and transgenesis have been proposed (Colombo et al. 1998). Methods are becoming available for these and other applications of biotechnology to an increasing diversity of farmed fish (e.g. see Beaumont and Hoare 2003; Dunham 2004).

Similarities between FiGR and FAnGR

Cunningham (1999) reviewed the potentials and limitations for applications of biotechnology in livestock genetics. There are many similarities here between FiGR and FAnGR including, for the most part, the main objectives of biotechnology; e.g. improved yields, disease resistance and wider environmental tolerance. Moreover, for both farmed fish and livestock, there is likely to be extensive application of the results of genome sequencing: already underway for the cow (*Bos taurus*) and chicken (*Gallus gallus*) genomes but still awaited for any farmed fish. From a purely practical perspective, transgenesis and other forms of genetic manipulation probably have better prospects for further development and use with farmed fish than with livestock. This is largely because of the huge numbers of fish eggs and embryos that are available from fish, the ease and low costs of working with such material, and the fact that large mortalities can be accepted. However, environmental safeguards for use of such technologies with farmed fish will be much more difficult to ensure for fish than for livestock.

Ownership and access

Intellectual property rights (IPR) or other forms of exclusive ownership or access have rarely been sought or enforced to date for farmed fish, especially in developing countries, largely because of the difficulties of proving the distinctiveness and provenance of most farmed fish away from their points of origin. National sovereignty over wild fish populations is provided by the CBD, and arguments can also be made for recognition of new countries of origin for strains, hybrids or other forms of alien fish species that have acquired distinctive properties by being farmed outside their native ranges. All tilapias are native only to Africa and the Levant, but the Philippines could probably now claim to be the country of origin of GIFT. Similarly, common carp is an alien species in Indonesia, but Indonesia could probably claim to be the country of origin of some of its distinctive farmed strains.

Where indigenous peoples are by rights the owners of unique wild populations of fish and related knowledge that bring benefits mainly or exclusively to others through their contributions to aquaculture development elsewhere, there are sensitivities that can be detrimental to development and to the conservation of FiGR. This also applies more generally where introductions of any alien species have led to highly lucrative aquaculture development other than in their native ranges, Wild Nile tilapia germplasm, collected openly in African countries, before the entry into force of the CBD and with the cooperation of national institutes and farmers, led to the successful development and use of GIFT in Asia. Meanwhile, tilapia farming and genetic improvement in Africa remained poorly developed. Understandably, the idea arose to introduce GIFT and other Asian farmed tilapias, including red tilapia hybrids, to Africa for aquaculture development. However, this would add to the threats to some wild tilapia populations. African aquaculture has much more to gain by application to its own diverse native tilapias of the freely published and simple methods that were used to develop GIFT in Asia, than by seeking to introduce GIFT and Asian hybrids from Asia to Africa (Pullin et al. 2001). In 2002, FAO, IUCN, WorldFish Center, national programme representatives and others discussing this issue recognized that "while improved strains and introduced species have potential to increase production there is clear risk of escape into the wild, and possible negative impacts on biodiversity" (WorldFish Center 2002).

Options

Genetic marking of morphologically similar but genetically distinct fish strains, hybrids and other genetically altered forms is an option for moving towards assigning IPR to benefit their developers and stewards, but the extents to which this would be legally enforceable are not clear. For conservation and equitable sharing of benefits from the use and potential use of wild FiGR, the obligations of parties to the CBD and to other relevant conventions, such as CITES[1] and Ramsar[2], theoretically dictate options and actions that must be taken. In reality, however, poor countries cannot afford to be the stewards of wild FiGR unless provided with adequate resources to do so.

Strategies

The private sector in aquaculture will increasingly explore opportunities for exercising intellectual property rights to particular FiGR, through material transfer agreements, restrictive use, royalty payments. etc., though these have had limited success so far. The collection and use of wild FiGR will be increasingly subject to the provisions of the CBD: prior informed consent, mutually agreed terms and sharing of benefits. Effective conservation of wild FiGR and related knowledge that are by rights owned by indigenous peoples and local communities, will be achieved only if they are beneficiaries from this, along with actual and potential beneficiaries elsewhere who contribute adequately to the costs of conservation. Provisions for this are made in Article 8j of the CBD and in instruments for protection of the rights of indigenous peoples (e.g. Posey 1999) but progress towards equitable sharing of benefits from conservation and use of FiGR remains slow (Greer and Harvey 2004).

Methods

At present there are no standard mechanisms and responsible institutions for acquiring and enforcing IPR on FiGR in aquaculture. Some commercial sellers of particular types of fish seed or broodstock make agreements with buyers that include restrictions on sharing this genetic material with third parties, but such agreements are difficult to monitor and to enforce. There are as yet no wholly convincing examples of benefit-sharing between stewards of specific wild FiGR and related aquaculture development. However, there have been many exchanges of fish germplasm (including GIFT) in the public domain, often with provision of related information and training, and these continue. Those organized through the International Network on Genetics in Aquaculture (INGA) (http://www.worldfishcenter.org/inga) are good examples of responsible sharing of FiGR and therefore, ultimately of benefits from their use.

Similarities between FiGR and FAnGR

Similar difficulties apply to the assignment and enforcement of IPR and other exclusive rights on FiGR in aquaculture and on FAnGR in livestock farming. Most livestock breeds have no clear owners. There is a lesson here for would-be holders of IPR on allegedly distinct farmed fish strains, many of which are not visually distinguishable or stable to the same extents as livestock breeds. Such fish genetic material is probably unprotectable. Companies that produce elite livestock lines and hybrids tend to distribute their products to farmers through special commercial agreements such as contract growing. This applies particularly to broiler chickens and feedlot pigs (Hamilton 1999). Large-scale, intensive aquaculture is becoming similar in many respects, with vertically integrated companies supplying contract fish farmers with a given strain or hybrid, bred exclusively by the company, together with feed from its feed mills, in-house veterinary services etc.

Exchanges of FiGR and FAnGR in the public domain also have some similarities; e.g. with respect to the need for quarantine arrangements. However, verifiable documentation of the identity and provenance of FiGR has been poorly developed so far in comparison with that for FAnGR. This is a root cause of the poor state of documentation on the use of different fish strains, hybrids and other genetically altered forms in aquaculture. Many buyers of fish seed or broodstock do not even bother to verify their identity at species level.

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1 Convention on International Trade in Endangered Species of Wild Flora and Fauna.

2 Convention on Wetlands, signed in Ramsar, Iran, in 1971.

Networks and partnerships

The ongoing global transition towards responsible aquaculture, following the provisions of the FAO Code of Conduct for Responsible Fisheries (FAO 1995), together with a growing number of national, regional and international guidelines for best practices and certification schemes, are encouraging signs for the conservation of FiGR. Networking and partnerships are essential for their further development and successful implementation.

Options

Options for networking and partnerships for conservation of FiGR are numerous at all levels: from international collaborative work programmes (such as those of the CBD and IUCN) to national and local arrangements, including public–private partnerships.

Strategies

Networking and partnerships for conservation of FiGR succeed when there are clear benefits for all participants and secure provision of adequate human and financial resources. It is important to avoid duplication of efforts and to minimize transaction costs. Conservation of wild FiGR could be given greater emphasis in more general networking and partnerships for nature conservation. Networks and partnerships for conservation of FiGR on farms and *ex situ* would benefit from linkages with those for FAnGR.

Methods

Networking and partnerships are the main bases for FiGR conservation efforts undertaken through the CBD (http://www.biodiversity.org) and the Ramsar Convention on Wetlands (http://www.ramsar.org). The World Conservation Union (IUCN) (http://www.iucn.org) has Specialist Groups for the conservation of threatened fish (e.g. coral reef fish, freshwater fish, groupers and wrasse). The Network of Aquaculture Centres in Asia-Pacific (NACA; http://www.enaca.org) and INGA are prominent examples of successful regional and international networks that contribute to conservation of FiGR.

Similarities and differences between FiGR and FAnGR

Networking and partnerships for *in situ* conservation of FiGR and FAnGR on farms and for their *ex situ* conservation, *in vitro* and *in vivo*, share many similarities. Associations of fish breeders and the farmers and stewards of particular fish species share essentially the same goals as livestock breed and farmers associations, rare breeds trusts etc. However, conservation of wild FiGR in open water ecosystems is mainly the province of different networks and partnerships that are outside aquaculture and more aligned with those for nature conservation in general. Such networks and partnerships have few equivalents for FAnGR.

Summary

Conservation of FiGR clearly has two main, interdependent components: i) conservation *in situ* in open water ecosystems and ii) conservation *in situ* on-farm and *ex situ*. The former is essentially part of nature conservation and has very few parallels, in scale or importance, with conservation of FAnGR, whereas the latter has many similarities with conservation of FAnGR, and these will increase as domestication of farmed fish progresses. Table 2 summarizes the broad similarities and differences between FiGR and FAnGR as discussed in this review.

Table 2. Similarities and differences between the genetic resources of livestock (FAnGR) and farmed food fish (FiGR) with respect to their conservation.

Item	FanGR	FiGR	Similarities and differences†
Species/major farm species	80/14	(500?)/29	+
Fully domesticated species	(>30?)	(<5?)	(-)
Distinct breeds or strains	6,379	('00s ?)	-
Importance of wild relatives	Low	High	-
Potential new farm species	Few	Many	-
Availability of information	Good	Poor	-
Threats to genetic diversity	High	High	+
Conservation, on-farm	Extensive	Limited	(+)
Conservation, open ecosystems	Limited	Extensive	-
Conservation, *in vitro*	Important	Growing	(+)
Conservation, *in vivo*	Important	Important	+
Potentials of biotechnology	High	High	+
Ownership and access	Vague	Vague	+
Networks and partnerships	Many	Many	+

†: + = broadly similar; - = substantially different; (+) and (-) = tending to be similar or different, and/or insufficient information available

Sources: FAO statistics and present author's estimates ('?').

With respect to genetic resources for food and agriculture, including aquaculture, the CGIAR's mandate aligns more with their conservation *in situ* on-farm and as *ex situ* genebanks than as populations in open ecosystems, which is more the province of nature conservation organizations. However, some wild FiGR in open water ecosystems are genetic resources for capture fisheries and/or aquaculture. Moreover, the future development of aquaculture and CBF will continue to have genetic and other impacts on wild FiGR in open waters. Therefore the conservation of captive FiGR for aquaculture and the conservation of FiGR in open waters, for capture fisheries and/or aquaculture, are interrelated and will remain so. The CGIAR and its partners are concerned with fish supply from capture fisheries as well as from aquaculture, and must therefore recognize for both the importance of conservation of FiGR.

The FAO Commission on Genetic Resources for Food and Agriculture includes FAnGR and FiGR within its mandate, but has yet to begin its coverage of FiGR. Conservation of FiGR for aquaculture needs more global recognition and investment. This might be facilitated by including on-farm and *ex situ* FiGR for aquaculture within a broader definition of FAnGR, while retaining the broader term FiGR for these and for all other genetic resources of exploited fish. An alternative might be to continue to regard the genetic resources of farmed fish as separate from the current scope of the term FAnGR and to begin to call them farmed fish genetic resources (FFiGR). There will need to be more discussion and standardization of genetic resources nomenclature anyway because the term animal genetic resources (AnGR) is also being used to mean essentially the same as the current use of FAnGR, excluding farmed fish. Whatever the outcome, the main requirement is to bring investments in conservation of FiGR for aquaculture up to parity with those for conservation of FAnGR.

Aquaculture seems set to provide up to 50% of world fish supply within a few decades and similarities between the farming of some fish and livestock are becoming increasingly obvious (e.g. see Swick and Cremer 2001; Young and Muir 2002). Farmed fish are indeed farm animals. Recognition of this and progressive inclusion of provisions for conservation of their genetic resources with those of livestock would be a logical outcome as well as a tribute to the many historical and ongoing contributions of livestock geneticists to aquaculture.

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In situ conservation: requirements for long-term conservation policy and conservation measures

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In situ conservation of livestock breeds

According to the definition of the Convention on Biological Diversity (CBD), *in situ* conservation has to be understood as safeguarding or reviving viable populations in their natural environment or in an environment designed for domesticated livestock breeds that supports their special characteristics (performance).

Objectives of *in situ* conservation are:

- Long-term *in situ* conservation of populations with the objective to conserve genetic diversity and the special genetic features of breeds;
- Conservation of the phenotype of traditionally and culturally important breeds;
- Sustainable use of a broad diversity of breeds.

In the area of *in situ* conservation, focus is on the living animal and many different factors are required to safeguard a population of a certain livestock breed via *in situ* conservation measures in the long term. Animal management is integrated into economical, ecological, political and social systems, and their slightest changes can cause acute danger for a livestock population in a very short time.

The most important parameters defining the situation of an *in situ* living population are the numbers of female and male animals, effective population size (Ne) and deduced inbreeding parameters. For practical conservation work, however, many more factors have to be considered: the number of animal keepers, structure and situation of keepers, distribution of stock in a region (control of epidemics), demand for breeding animals, support of animal keepers through interest groups, marketing situation, availability of funds, and last but not least the importance of the breed as cultural asset.

What is to be conserved?

In situ conservation means living conservation of livestock breeds in an environment allowing them to exert their characteristics. Old breeds have developed in very close relation to agricultural production factors. These, however, have been changing continuously, with particular dramatic cuts in developed countries during the last 50 years. Fodder yields were much lower in former times because of lacking or less intensive fertilization. For animal keeping, mostly areas were used that were not arable. Today, many of these sites are no longer used at all or only as subsidized landscape management or nature protection areas. Concentrated feed was only given to working animals. Today's fodder basis contains much more protein components and more digestible energy through specific fertilization with nitrogen. The consequences are already obvious. The body weight and body size of the animals, for example, changes rapidly when better fodder is available. Thus, the question of what is worth conserving is an ongoing issue to be discussed within the frame of living *in situ* conservation. Breeding means change and adaptation to current conditions. Breeding does not want to stop change or conserve animals as 'museum species'. When livestock is kept, performance is very important. It is, however, continuously reduced to criteria relating only to production data such as milk and meat yield, number of eggs, etc. Other performance criteria such as longevity, fertility, frugality, good maternal characteristics and cultural importance that apply in a special way to old livestock breeds are given little attention as breeding selection criteria.

It must be said that animals adjust to present conditions through active breeding and *in situ* conservation and that they change with regard to their type and genes. Inbreeding and gene drift also influence the animals' phenotype and genotype; both have to be observed very carefully in small populations. Attention has also to be given to the conservation of diversity within a breed. Individual animals of the same breed always differ with regard to colour, horn shape, body size, etc. Organized modern breeding requires, however, a clearly defined standardized breeding objective that can lead to the disappearance of unique features. Involved breeders have to reach a consensus on all these criteria and put them into practice in breeding programmes.

Who is responsible for conservation tasks?

Animal breeding and the conservation of livestock populations require close cooperation amongst breeders. Breeders are governmental bodies, such as government farms, universities, cooperatives, private farm enterprises, hobby farmers. Diverse coordination tasks must be carried out which are mainly taken care of by official breeding organizations and interest groups. Animal breeding is, according to species, organized very differently. The highest degree of organization is reached for cattle. As regards other species, the largest part of animals is kept and bred privately without integration into official breeding programmes. Particularly poultry and small livestock are entirely in the hands of private associations. For this reason, only few herdbooks are kept that document the precise pedigree of the animals.

In the area of endangered livestock breeds, private organizations (NGOs) have developed which bundle all issues concerning conservation measures and which organize the coordination of breeders amongst themselves. Numerous non-governmental organizations (NGOs) in Europe are linked in a network of the SAVE Foundation (Foundation for the Safeguarding of Agricultural Varieties in Europe). NGOs seldom have the status of officially acknowledged breeding associations. For that reason, they define themselves as a link between private animal keepers and official breeding bodies.

In Germany, the Information Centre for Biological Diversity (IBV) is responsible for documentation and monitoring of livestock breeds.

Table 1. Degree of organized breeding in Germany.

Livestock breed	Percentage of organized/registered animals	Number of breeders' associations	Number of breeds taken care of	Breeds used in agricultural production	Number of endangered breeds
Horse	22	37	105	-	14
Cattle	50	37	54	ca. 10	14
Pig	2	23	16	3	4
Sheep	6	18	50	6	17
Goat	7	14	25	2	3
Overall		**119**	**250**	**21**	**52**

According to AGR – National Programme 2004.

What measures should be taken?

Monitoring of the population size and the definition of the status of endangerment provide the basis for decisions on how conservation measures should be designed. In Germany, a central database (TGRDEU–Central documentation of animal genetic resources in Germany, http://www.genres.de/tgrdeu/) has been established for this purpose. Measures based on monitoring results are carried out according to classification of populations into one of the categories of grade 1–3. They form the basis for the direction of *in situ* measures.

Category	Criteria	Description
1a) Conservation population	Ne < 200	Population strongly endangered, fast action required (conservation programme to stabilize effective population size and minimize further gene losses).
1b) Phenotypical conservation population	Ne < 50	Breeds with Ne < 50 have only few chances to be conserved as own population in the long term. Recommendation to apply cryopreservation, integration into larger related breeds, culturally important.
2) Monitoring population	200 < Ne < 1000	Endangered population that has to be observed. When the number of males is less than 100, a semen cyropreservation programme has to be initiated.
3) Non-endangered population	Ne > 1000	Population not endangered at present in which the effective population size Ne is to be routinely calculated and documented.

Ne = effective population size.
According to AGR – National Programme 2004.

Who is responsible for present tasks and what role will be important in the future?

The superordinate task of conservation measures was handed over to the individual countries through the CBD (Convention on Biological Diversity). They are completely free in designing and establishing measures and mostly use already existing structures in animal breeding to realise CBD specifications. It can be very helpful to appoint a national responsible body to provide direction. The National Coordinators (NCs) for Animal Genetic Resources (AGR) applied by FAO form the cross-link to international bodies. They can exert their influence in the individual countries so that necessary measures can be realised. Very often, political and legal frame conditions have to be adjusted. Effective animal breeding laws are an important instrument, into which the management of AGR should be included. Animal breeding laws also regulate competences of bodies involved in breeding. The EU has furthermore enacted diverse decrees (EC No. 2078/92, EC No.1257/999) which regulate the support and implementation of measures for the conservation of AGR. Moreover, it is recommendable to establish a flexible support system so that special demands of individual breeds can be taken care of. One focus should be on the area of sire management in order to support systematic mating to minimize inbreeding and to conserve valuable blood lines.

Create cooperation

The complex of genetic resources is very comprehensive, and diversity in breeding, production and marketing linked to a special food culture are closely related. In order to facilitate networking in such a system and to help it develop further, appropriate political and economic conditions are required. An important area is to define regulations for production and marketing in a way that allows the long-term development of market sectors for products from AGR which can accordingly be supplied. At the same time, diversity of livestock breeds causes a diversity of regional breeding methods, management systems and marketing concepts. The development of a diversified food culture with regional specialities is part of it.

In situ conservation of AGR can become a self-developing issue when frame conditions allow conservation programmes to go hand-in-hand with appropriate utilization.

Science can also contribute to the value of AGR through documentation of breeds' special characteristics and by putting the issue into an overall context. This has also to be seen with regard to the economic and ecological role locally adapted breeds can play in a world of diminishing resources by contributing essentially to food security and environmental protection.

Institutional issues and frameworks in *ex situ* conservation of farm animal genetic resources

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Problem definition

The nations that have ratified the Convention on Biological Diversity (CBD) have accepted the principles of the CBD as international law. Thus, the signing countries have assumed responsibility for conservation of the national animal genetic resources (AnGR). The subsequent duties of those nations would be to design and implement a strategic plan for breed conservation. The national agricultural ministries could coordinate this work with the involved players within farm animal genetic resources (FAnGR) management of the respective countries. Involved parties include breeding organizations/breed societies that are formally responsible for managing the breeding scheme(s) of the breed(s), and other formal bodies responsible for conservation of endangered breeds, such as the national gene resource committees in some of the Nordic countries or equivalent agencies such as directorates in others.

The problem arises when the FAnGR are supplied by international breeding companies, as is the case in the poultry sector. What kind of responsibilities do these companies have?

Ex situ conservation

The CBD clearly ascribes priorities to different types of actions: *in situ* conservation has a higher priority than *ex situ* conservation. In the context of *ex situ* conservation of domestic animal diversity, this means conservation outside of the production system in which the breed was developed. This includes both storage as live animals away from the habitat and cryopreservation in some form.

- Ex situ *live conservation*. This is *ex situ* conservation storage as live animals. Examples are domestic animals kept in museum farms or public parks
- *Cryopreservation.* This is the collection and cryopreservation of semen, ova, embryos or tissues that may be used to regenerate animals. Semen seems to be the easiest way of preserving most farm animal species.

In situ conservation: division of responsibilities

Ideally, the set-up shown in Figure 1 should be considered.

The numbers below refer to the boxes in Figure 1.

1. Assumes that the Agricultural Ministry has provided a mandate of objectives for conservation measures and yearly budgetary support to conservation activities. The Gene Resource Committee (GRC) submits annual reports on the agency's activities and costs. Likewise, it applies for renewal of budgetary support.
2. Assumes that the Agricultural Ministry formulates directives for running breeding schemes and an artificial insemination (AI) agency. In the European Union, this is provided through several directives.
3. Utilization of AI expertise within AI organizations and hiring their service for production and storage of cryo-materials can be run considerably cheaper if the GRC negotiates a reasonable agreement, at marginal level costs, for the intake of animals, collection and storage of semen, etc, than establishing a separate national operation. However, the agreement must secure the GRC the following:
    - Ownership of the breeding material, i.e. an agreement between the owner of the animal and GRC or BO/AIC that rights are released from the animal's owner. Furthermore, an agreement

between the GRC and BO/AIC that the conservation material of the endangered breeds is owned by GRC. However, the operation of the regular AI services can be administrated by the BO/AIC as long as they follow the provisions of the agreement.
- This procedure utilizes already available logistics of the BO/AIC, thus securing the adherence to official veterinary regulations required for such operations.

4. The GRC secretariat and the leadership of the breed societies must collaborate on the selection of individual breeding animals that are going to supply genetic material for conservation, i.e. in carrying out the operations according to the current Agreement.

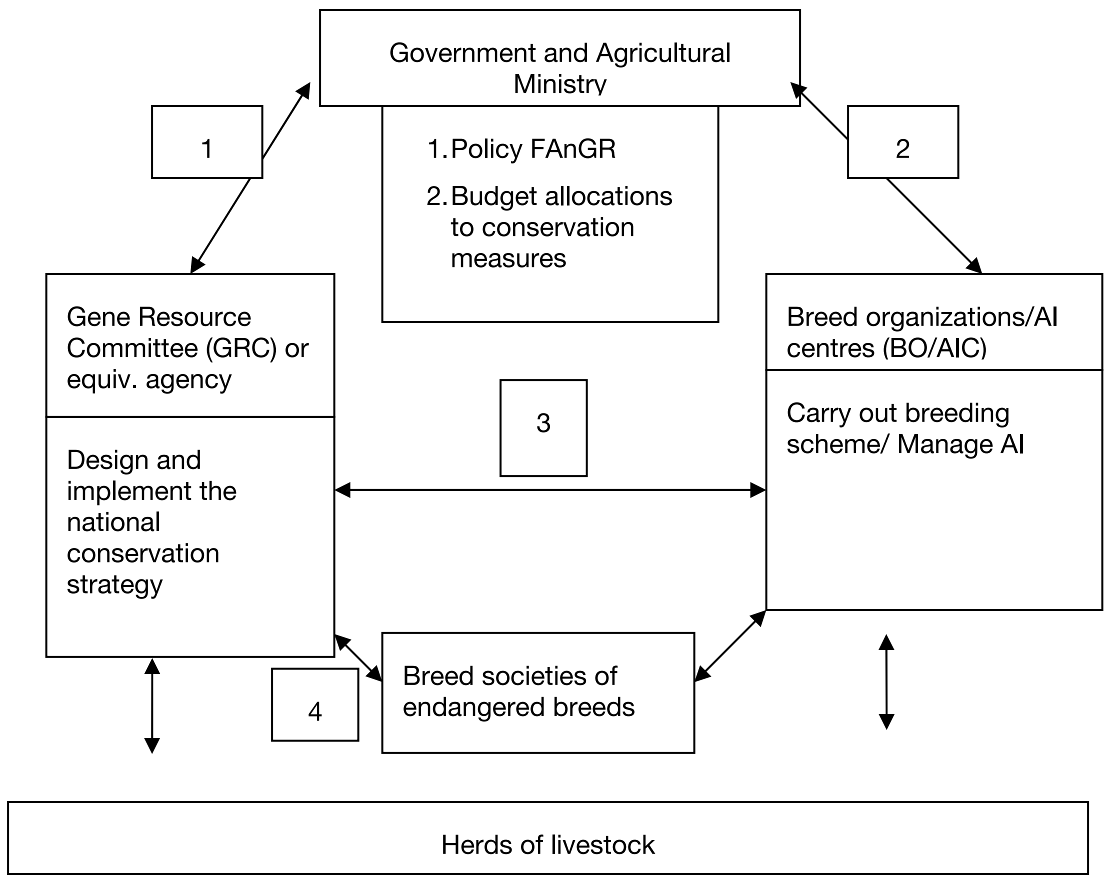

Figure 1. Cooperating partners and their mutual relationships.

Future work

Principal policy

As signatory nations to the CBD meant to put in place regulations to ensure adherence to the principles of the CBD, the responsibility and role of those involved in FAnGR operations must be completely clarified. While the initiative of developing a FAnGR policy is to be taken at the government/ministry level, it will be of great assistance to have committed organizations and individuals who can promote the importance of maintenance of diversity of FAnGR for the future.

Due to the rapid and extensive developments within international trade, it is obvious that small local breeds can hardly contribute to any large economical success. In addition, the CBD can also be regarded as a convention to activate genetic resources for securing the food supply to a growing human population. Thus, this directly implies that FAnGR from commercial breeds are becoming part of the political interest. Sustainable management of FanGR, both of local breeds and of those breeds that are regarded as commercial genetic resources, thus obviously becomes important from a FAnGR point of view.

Strategic policy

Prioritizing the values of the endangered breeds is a big task for the future management of FAnGR. The challenges encompass:

- ranking the breeds as sources for future supply of applicable genes;
- ranking the breeds by their cultural/historical value.

Another challenge is to minimize the scope of *ex situ* conservation, by determining a sufficient level for future needs. It should be obvious that *the properties* of a breed preserved by cryopreservation (semen, ova, etc.) must be classified and compared to other breeds in order to be of future practical use. There is an obvious lack of knowledge of the value of the unique breeds in relation to others. Thus, scientifically determining the value of each breed becomes a challenge with regard to providing a reliable foundation for making correct *ex situ* decisions.

Cryopreservation as a method should be evaluated for future optimal use of cryobank material (according to Wooelders H. et al. 2003. In: Proceedings of the Workshop on Cryopreservation of Animal Genetic Resources in Europe. Paris, February 23 2003. pp. 67–76):

1. As backup in case genetic problems occur in the living population, i.e. loss of allelic diversity, inbreeding, genetic drift, occurrence of deleterious genetic combinations;
2. For breed reconstruction, in case of extinction or loss of a substantial number of animals;
3. To create new lines/breeds in case of breed extinction;
4. As backup to quickly modify and/or reorient, evolution/selection of the population;
5. For research.

In this case, cryopreservation is multifunctional and may be used in an optimal way for the whole area of conservation and sustainable use of FAnGR.

A system for formalizing the national responsibility could include the following aspects:

- The national authority may require the inclusion of sustainable management policies into the directive of national clearance of licensed breeding schemes, embracing active breeds as well as breeds under *in vivo* conservation;
- The indicators of sustainable management and their critical risk values should be annually defined and reported to the national authority. These indicators may be:
  - Efficient population size of the breed;
  - Use of a sustainable breeding goal, and avoidance of a negative trend of its critical traits (e.g. reproduction, health and mortality);
  - Managing genetic variation through clear and transparent policies and selection procedures;
  - Sufficient evidence that the genotype–production environment interaction does not come into effect;
  - In the presence of genotype-by-environment interaction, procedures for ensuring selection are performed, as closely as possible, in the production environment, or an environment that resembles the average production environment. This is particularly relevant to selection environments with high inputs and outputs since such environments can render the animals genetically less robust and vulnerable to less intensive production environments;
  - Maintaining the genetic diversity arising from among-breed variation.

Mechanisms for cooperation

The experiences from Nordic countries show that it is important to stimulate collaboration between partners interested in animal breed conservation. Key to establishing such collaboration seems to be that ministry and government officials within a country must have an understanding and real interest in conservation of animal genetic resources. Enthusiastic people linked to organizations within agricultural communities often start the initiative, but it is essential that a conservation organization that is part of the official national system be established, with a clear mandate and annual budget, activities and reporting.

Conclusions

- *Ex situ* conservation should be effectively and rationally organized in order to limit costs. The storage of cryo-material should be annually evaluated with respect to its relevance to the breed's living population.
- If nations take proper responsibility for their FAnGR, *ex situ* conservation should not be the only way of storing a breed's genes. If this is done, then the properties of the breed should be evaluated before its genes are preserved.
- A problem facing species for which only 2–3 international breeding companies supply the 'production genes' worldwide is that these companies may not have any responsibility to any nation. Who guarantees the maintenance of future diversity?
- The Nordic Council of Ministers has developed a strategy for sustainable development that covers FAnGR for the Nordic Countries.
- Indicators for sustainable management of FAnGR must be developed and monitored.

National approach for management of animal genetic resources: China's experience

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Introduction

Biological diversity is the basis for the existence and development of human society and has received increasing attention of the international community in recent years. In June 1992, more than 150 countries, including China, signed the Convention on Biological Diversity. Farm animal genetic resources (FAnGR) are an important component of biological diversity, and animals have a close and direct relationship with human beings. Demand for animal product, in terms of both variety and quality, is increasing in many countries. To achieve sustainable, stable and efficient animal production, it is important to strengthen the conservation and effective, rational and sustainable utilization of FAnGR.

The Government of People's Republic of China has attached great importance to the conservation and utilization of FAnGR. This paper will give a brief introduction to the general situation of China's animal production in the first section, highlight the national strategy for conservation and management of AnGR and its implementation in the second section, and present future work in the final section.

General situation of animal production and the diversification status of FAnGR in China

China is one of the most populous nations in the world. The total population of China reached 1.266 billion in 2000. China has used less than 10% of the world's farmland to feed 22% of the world's population. The continuous development of the animal production industry has played an important role in achieving this. The proportion of animal production in agriculture increased from 18% in 1978 to 30% in 2001.

Since the implementation of reform and open policy, China has obtained an enormous development in animal production. In 2000, China had total meat output of 61.254 million tonnes, poultry egg output of 22.432 million tonnes, dairy product output of 9.191 million tonnes and sheep wool output of 0.293 million tonnes, increases of 210%, 180%, 93% and 22% respectively over outputs in 1990. In 2000, per capita output was 48.4 kg of meat, 17.7 kg of eggs and 7.3 kg of dairy products. At present, China has among the largest outputs of animal products in the world, ranking first for meat output and poultry egg output. However, dairy production is very backward and sheep wool output cannot meet the demand of the domestic wool textile industry.

Changes have taken place in the livestock industry to meet the consumers' changing demands:

- pork production accounts for 65.8% of the total meat output, which has decreased by about 27 percentage points since 1978;
- the proportion of beef, mutton and poultry meat output has significantly increased to 33.9%. Of these, poultry meat production has increased fastest, now accounting for 19.7% of total meat output.

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Due to its diverse geography, ecology and animal production systems, and long history of animal production, China is one of the countries that have the richest FAnGR in the world. According to current investigation, China has a total of 576 animal and poultry breeds, of which about 75% are native. These native breeds have acquired specific characteristics through long-term selection and breeding. Up to now, they still play an important role in animal production in China.

Significant changes in China's FAnGR have taken place in the past 20 years. The population of 41.9% of native breeds has decreased to various extents.

- In 1983, the Ministry of Agriculture (MoA) confirmed the extinction of ten breeds;
- In 1999, the MoA confirmed the extinction of seven breeds, 14 breeds were listed as at risk and 41 breeds as endangered.

There are many factors that cause the population decline of domestic animal genetic resource, such as the inability of some native breeds to meet the market demands due to poor productivity and lack of awareness of the value of some native breeds. Therefore, many exotic breeds were introduced as a simple substitution or for blind crossing with native breeds. As a result, the population size of some native breeds declined, and some breeds are even endangered.

National strategy for the conservation and management of FAnGR

Political support

The Central and provincial governments have included FAnGR conservation in national/provincial economic and social development plans, encouraging enterprises and individuals to take part in the conservation and scientific development of animal genetic resources. Practical plans for animal resources conservation were formulated and developed by the government at all levels.

On 23 August 2000, the MoA announced the inventory list: 78 key conservation animal breeds at state-level.

Legislative aspect

In 1994, the State Council issued "Regulations on Breeding Livestock Administration". Later, the MoA issued detail implementation regulations. Many provinces (autonomous regions and municipalities) formulated related administrative measures, which have provided the basis for legal administration. The MoA established the China National Commission for Domestic Animal Genetic Resources Administration, published the list of state level animal and poultry breed resources, and established native breed conservation farms (areas) at state-level. At present, the MoA is drafting the "Animal Husbandry Law", which will include FAnGR conservation as an important component. It has concrete stipulations on the legal responsibility of conservation work, resulting in the adherence of conservation work to legal procedures.

Financial support

The Chinese Government has invested a lot of money to strengthen the conservation of native breeds and has established numerous excellent conservation farms and bull stations in various parts of the country. During the Eighth Five-Year Plan period, the MoA had identified 83 key state-level breeding farms and undertaken construction of some conservation farms for elite native breeds. Provinces, prefectures and counties have established conservation and breeding farms for native breeds, defined conservation areas, formulated conservation programmes, undertaken herdbook registration and developed conservation and breeding work in a planned way.

Since 1995, the Government has started projects on FAnGR conservation. According to the conservation principle of 'key, endangered, and special performance characteristics' and the distribution of breed resources that urgently needed conservation, the State has allocated special funds for FAnGR conservation throughout the country. The annual input fund is 16 million RMB (approximately €1.6 million), allocated to 40 projects. These combine *in situ* conservation and *ex situ* conservation of genes and are focused on the increase of live animal populations and corresponding infrastructure.

Institutional aspects

On 4 January 1996, the MoA approved the establishment of the "China National Commission for Domestic Animal Genetic Resources Administration," with the main task of assisting the administrative departments in overall management in the field of domestic animal genetic resources.

The Commission hosts the National Focal Point for the Management of AnGR. The National Focal Point is responsible for cooperation with international organizations, i.e. the Global Focal Point based at the Food and Agriculture Organization of the United Nations (FAO), and compilation of the Country Report for the preparation of the First Report on the State of the World's Animal Genetic Resources (SoW-AnGR).

China has established State genebanks in Beijing and Jiangsu, and preserved a set of original breeds and germplasm materials. At present, China has preliminarily established a livestock and poultry resource conservation system, which has laid a good foundation for the sustainable development of animal production in China.

Survey and scientific research

The Chinese Government started an animal and poultry breed resource survey in the 1950s. In 1976, the MoA organized the agricultural, scientific and educational departments of the whole country to undertake a fairly large-scale animal and poultry germplasm survey. Through nine years of efforts, China clarified the status of breeds in most parts of the country. In 1995, a supplementary survey was made of the remote south-west and north-west areas. During a four-year period, 79 new breeds or populations were discovered. The survey on animal genetic resources has provided the basis for formulating policies for their conservation and rational utilization, for formulating overall animal production development plans and for developing international cooperation and exchange in animal production science and technology.

In the past 20 years, China has strengthened basic research on animal resources, conducted systematic research on germplasm characteristics of some animal and poultry breeds and genetic distance estimation, and achieved certain results in the theory of systematic conservation of animal breeds and conservation methodology. This has provided scientific support for the development of conservation work.

Public awareness

To celebrate its tenth anniversary and to promote public awareness of the importance of FAnGR, the China National Commission for Management of Farm Animal Genetic Resources will release a stamp collection. The stamp collection will include images of 78 key farm animal breeds identified at State level. The list of 78 key breeds was announced on 23 August 2000 by the MoA.

Future work

Monitoring and evaluation of FAnGR

Future work will include conducting a nation-wide survey of FAnGR, establishing a FAnGR collection and monitoring system through a network across the entire country, and monitoring the status regularly. In order to assess dynamic changes in the genetic resources of existing breeds, the main tasks will be to carry out a trace survey on the resources and collect the most updated information; apply modern information technology to upgrade the database to a dynamic national information system; and undertake systematic and long-term evaluation of the characteristics of the genetic resources.

Establishment of the test centre for germplasm

Future work in this area foresees using modern biotechnology methods to test animal genetic resources at molecular, cell and population level and undertaking research on genetic diversity in order to understand the features of germplasm, their molecular basis and their genetic relationship. A laboratory and testing facilities for livestock and poultry will be constructed in Beijing, instruments and equipment will be purchased and a computer network installed.

Improvement of the genebank

It will be necessary to improve the laboratory for conservation and apply cryopreservation technology to meet the long-term storage requirement for some rare animals and endangered animal resources. Initially, embryos and frozen semen will be stored, complemented by use of embryo bisection, appraisal and cloning, *in vivo* collection of eggs, *in vitro* fertilization, etc. to preserve the genetic material. Under the precondition of introducing small herds of livestock for live animal conservation, it is required to conserve 250 embryos and 1600 doses of semen for each breed. Frozen semen storage has been used to preserve 17 endangered breeds, such as Jiulong Yak, Fuzhou Cattle, Qinghai Yak, Bohai Black and Tan Sheep, while embryo storage was used to preserve 16 breeds, including Mongolia Cattle, Liaoning Cashmere Goat, Zhongwei Goat, and Tong Sheep.

A Poultry Conservation Farm has been established in Jiangsu Province and will be expanded to preserve a total of 40 local poultry breeds, including Pudong, Dagu and Qingyuan Partridge, with the requirement of at least 300 hens for each breed.

Construction of conservation farms and areas

The MoA has put forward a conservation inventory of 78 local breeds at national level. The priorities for breed conservation will be based on the inventory, although some breeds that are endangered at the provincial level will be preserved. The priorities for this work are local breed collection, expansion of buildings and stables, and instrument and equipment purchasing. A number of conservation farms for pigs, poultry, cattle, sheep, goats and horses will be constructed, expanded or modified. Conservation areas will cooperate closely with conservation farms. Conservation areas will be established in the central production zone and have systematic breeding plans.

Promoting public awareness and education

It is planned to continue to make use of traditional media for publicity while also fully taking advantage of the fast communication, wide coverage and low cost of the Internet to strengthen the publicity on conservation and public understanding of the importance of conservation. The core objective is to construct a "China Farm Animal Diversity Network" with rich content and fast update.

Finally, it will be important to speed up the establishment of a research and consultant team on FAnGR and strengthen personnel training. This would include reinforcing personnel training through multiple forms, including training courses and symposiums to improve research and management skills.

State of the conservation of trypanotolerant cattle genetic resources in West Africa

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Abstract

The original cattle of Africa were humpless (taurine) cattle able to survive under trypanosomosis pressure; this biological singularity is called trypanotolerance. There are many breeds of taurine cattle in West Africa. Currently, the total taurine cattle population is increasing, but the number of humped (zebu) cattle is increasing faster. Moreover, within the wide variety of taurine breeds, some have very small population sizes and are threatened by extinction in the short term. The main causes of the decline of taurine breeds are described in this paper, and some thoughts about conservation issues are given.

State of knowledge

Characteristics of the trypanotolerant cattle in West Africa

The original African cattle are humpless taurine cattle (*Bos taurus*) (Hanotte et al. 2002), which evolved under high trypanosomosis pressure. These cattle, present in West Africa, are considered trypanotolerant, i.e. they are able to survive and produce under trypanosomosis pressure (Murray et al. 1984), whereas other breeds (exotic taurine and *Bos indicus* cattle) that were imported to Africa later are not able to survive under trypanosomosis pressure without veterinary intervention. Trypanotolerant *B. taurus* breeds of West Africa are divided in two main categories: the West African longhorn (the N'dama) and the West African Shorthorn (WAS), which is made up of a savannah type (SWAS) (Baoule, Somba, Namchi and others) and a dwarf type (DWAS) (e.g. Lagune). The geographic distribution of trypanotolerant *B. taurus* cattle is similar to the geographic distribution of tsetse flies, the vectors of trypanosomes.

West African taurine cattle breeds are trypanotolerant, adapted to hot and humid areas, and are considered to be resistant to ticks and tick-borne diseases or associated diseases such as dermatophilosis. They are generally small, especially the WAS; the average wither height is about 100 cm in the Baoule and 80–100 cm in the Lagune. They are considered sensitive to cattle plague (Paramyxoviridae) (but this disease does not exist anymore in the area) and contagious bovine pleuropneumonia. Moreover, they give low milk yields (N'dama: 1.4–2.6 l/day; WAS: 1.5–2.0 l/d; Peul Fulani: 2–3 l/d; Azawak: 7–8 l/d).

Population changes

The total population of cattle in West Africa increased considerably in recent years. The absolute number of *B. taurus* cattle increased from 6.92 million in 1985 to 8.03 million in 1998 (Agyemang 2000). In 1998, N'dama cattle accounted for 66.5% of pure taurine cattle, SWAS for 31.5% and DWAS for 2%.

However, if the total population of West African *B. taurus* cattle increased, their proportion of the total cattle population decreased due to greater increases in numbers of *B. indicus* cattle: the proportion of N'dama declined from 13.10% in 1985 to only 10.5% in 1998; that of SWAS decreased from 5.3% to 4.2%. The proportion of trypanotolerant cattle, even including cross-bred cattle (e.g. Borgou), decreased from 26.5% to 19.2% (Agyemang 2000).

In addition to these general data, some special cases deserve specific comments. For instance, it is considered that the Pabli breed (SWAS in Benin) has disappeared (PDE III 2002). The Lagune breed population seems also very small: in Ivory Coast, 1000 individuals were counted in 1985, and no recent data are available (Yapi-Gnaore et al. 1996). In Togo, Lagune population is thought to be fewer than 1000 individuals. Only Benin has a large population of Lagune, with more than 20 000 individuals, but the Lagune breed is clearly at risk. In Ivory Coast, the Baoule breed accounted for 73% of the cattle population in 1973, but only 39% in 1998. No information is currently available.

Finally, if the absolute number of trypanotolerant taurine cattle seems to be high, particular cases can be observed with very small population sizes for some breeds. An overall trend in the spread of *B. indicus* cattle and cross-breeding must be taken into account.

Causes of the spread of B. indicus *and cross-breeding*

The advance of *B. indicus* and cross-breeding is linked to the decrease in trypanosomosis pressure, to socio-economic changes and also to genetic improvement programme policy.

Tsetse habitat is being progressively destroyed by agricultural development and deforestation. More and more land is being cleared and the agricultural landscape has evolved very quickly, particularly in the limit of tsetse flies' distribution. Growing some crops, such as cotton, has a large impact on tsetse fly populations, which are very sensitive to pesticides. Moreover, control of tsetse flies is an objective of the African States (see PATTEC: Pan-African Tsetse and Trypanosomiasis Eradication Campaign).

With changes in agricultural practices and the need to increase productivity, farmers prefer large cattle for draught power and milk production, which favours the larger *B. indicus* cattle over the smaller taurine breeds. Some pastoralists do not hesitate to use trypanocidal drugs to allow their *B. indicus* cattle to survive under trypanosomosis pressure.

It is worth noting that no national policy has been established in the various states of West Africa in order to prevent genetic erosion or promote genetic improvement (Belemsaga and Thévenon 2003). There were some initiatives aimed at genetic improvement of cattle breeds, but all broke down when the donors left the programmes (Belemsaga and Thévenon 2003). There is no support from the states. There are no long-term programmes, except one conducted on N'dama cattle by the International Trypanotolerance Centre (ITC)). In the absence of national genetic improvement programmes, farmers take initiatives themselves and, from their point of view, the best way to get rapid results is to carry out cross-breeding even if the results are not sustainable.

Issues: need for conservation and development

A workshop that brought together delegates from the member states of the Centre international de recherche-développement sur l'elevage en zone subhumide (CIRDES) was held in Cotonou in 1993 (Belemsaga and Thévenon 2003). The workshop drew the following conclusions.

Economic interest

It is essential to promote an economic interest in improving local cattle breeds. Conservation programmes that involve farmers and give them part of the responsibility for the breeding would reduce the likelihood of breed extinction (Reist-Marti et al. 2005). The first step is to carry out an economic evaluation of trypanotolerant cattle in order to promote their breeding. What are the ways to promote their use? How can we motivate smallholders to breed these cattle? What are the potentials of the breed and what are the production objectives? How can we increase productivity?

Moreover, it is essential to get the support of the states. Only an alliance of farmers and politicians will guarantee long-term success. We must remember that the increase in livestock productivity in developed countries has resulted partly from genetic improvement programmes supported by governments.

Need in knowledge increase

There are no recent data on population size. New studies on genetic characterization (Moazami-Goudarzi et al 2001; Hanotte et al. 2002; Ibheaga-Awemu et al. 2004; Freeman et al. 2004) brought new data on cattle in West Africa. For instance, neutral markers can differentiate between Somba and Baoule breeds, both of them being SWAS (Freeman et al. 2004), but are the differences significant from a selection point of view? What are also the relationships between DWAF populations? More accurate studies on genetic characterization and production capacities are needed. If allocation of financial resources requires choices concerning conservation priorities, objective data are needed (Simianer 2005).

Current initiatives

A 10-year project funded by the Global Environment Facility (GEF), "*In situ* conservation of endemic livestock in West Africa," has recently been established in four countries: Mali, Senegal, Gambia, Guinea-Bissau. It focuses on N'dama cattle, Djallonke sheep and the West African Dwarf Goat. Forty-five percent of the West African trypanotolerant cattle population is present in these four countries. However, it is unfortunate that only one cattle breed, and that the most abundant, the N'dama, is taken into account.

Conclusions

Projects are urgently needed to characterize and conserve FAnGR in West Africa. Micro-projects currently exist. For instance, Benin is conducting a project on the conservation and genetic improvement of the Borgou breed, a stabilized cross-bred. But these projects need long-term financial and technical support to achieve their objectives. Moreover, in order to optimize the actions from different states, it is essential to promote joint programmes at a regional level. These actions must connect farmers and governments to guarantee sustainability.

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Development of *in situ* micro-projects in farm animal populations of the mountain regions of North of Vietnam (BIODIVA Project)

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Abstract

For a number of geographical and historical reasons, the mountain areas of North Vietnam have preserved an extraordinary ethnic and domestic animal diversity of huge genetic, economic and cultural interest. This paper presents the 'bottom-up and top-down' strategy implemented in the BIODIVA project through complementary policy and socio-economic, scientific and technical approaches. In close collaboration with smallholders and with the help of local and national authorities, our work comprises field inventories of animal populations and farming systems, collecting data on breeding systems, including smallholders' traditional knowledge and needs, and complex data analysis using a geographic information system. The final objective of this *in situ* conservation project, a management partnership with local authorities and communities, is to set up several original and concrete development micro-projects with programmes ranging from women's education—as it is mostly women who are in charge of animal rearing—through micro-credits for breeding and integrated ecotourism pilot projects to, more conventionally, specific *in situ* genetic improvement programmes that are well-adapted to the environment and increase the value of remarkable gene pools present in the farm animal's genetic resources. On a more global scale, this project might help the local communities to improve and diversify their animal production whilst respecting their cultural traditions and allowing for quick responses to environmental changes. It will reinforce the government's capacity to control the ecological, social and economic stakes of biodiversity, at a time when private companies are investing massively in this sector. Finally, BIODIVA will, in future, allow Vietnamese institutes and public laboratories to integrate important regional and international projects concerning the conservation and management of genetic resources within the framework of the Rio and Cartagena Conventions.

General context

The wealth of biodiversity in Vietnam is of great interest to the worldwide community. In the past 50 years, geographical and historical factors have isolated Vietnamese mountain areas from the great disruptions which have changed the shape of traditional production systems in South-East Asia. Such isolation has resulted in the 'preservation' of local animal populations and species while greatly limiting anthropic pressures, preventing the introduction and breeding of exogenous domestic livestock—so-called 'improving breeds'—and restricting contact with exotic animal species and populations. Biodiversity surveys conducted in the region are recent and still incomplete, but they show an exceptional richness. Recent estimates have shown that the country shelters approximately 275 species of mammals, 826 species of birds, 260 reptiles, 82 amphibians, 500 freshwater fish, 2000 seawater fish and more than 12 000 plant species (FAO & IUCN/WCS data). In the past few years, several great mammal species (Saola, Giant Muntjac, Java Rhinoceros) have been (re)discovered in near-inaccessible areas of the Annamitic Cordillera.

More than 50 ethnic groups living in these areas cultivate differentiated ecosystems. Culture-breeding systems, often found in self-sufficient communities, shelter six of the main domestic species (bovines, bubals, equines, pigs, caprines and poultry) combined with complex systems. Such genetic diversity in traditional livestock has been and remains regularly maintained. It is characterized by repeated contact with the wild species from which the main and still locally present domestic species originated.

This exceptional animal diversity is facing many anthropic threats other than damage to the environment (e.g. deforestation): 'modern' intensified breeding systems favour a small number of breeds which are highly productive but high cost, at the expense of local breeds, which are usually more hardy and better adapted to the harsh conditions of mountainous regions.

Bearing this in mind, the Vietnamese government decided ten years ago to work within the framework of a long-term national biodiversification action plan (BAP) and focus its efforts on the following: identification; implementation of national regulations, methods, techniques and resources to be associated with the survey; characterization, conservation and development of genetic resources, with particular emphasis on animal biodiversity of economic and genetic interest.

It would thus be wise to identify specifically designed production methods which would enable the improvement of the mountain populations' living conditions while protecting and developing the biodiversity of local domestic species.

In this global context, we started our work by identifying several research questions and scientific actions to be put in place. The results will allow us to identify possible pilot projects and field micro-projects to be developed in strong collaboration with the people concerned.

Research questions

The goal of the BIODIVA project is to "inventory, characterise, preserve and valorise the remarkable genetic diversity of domestic animal populations in northern mountain regions, in order to allow all Vietnamese players, and especially rural populations living in disadvantaged areas, to find long-term answers to some of the main ecological, economic and social challenges of the future."

Several global research questions have been defined:

- Where does current and real knowledge of traditional farming systems in these mountain regions stand, in terms of its ethnic and socio-economic aspects?
- What is the exact inventory of the six main domestic animal species living in these ecosytems, and what are their zootechnical and economic characteristics of interest?
- What are the exact economic networks and market commodity chains in these regions? How can we promote the use of these local resources as 'reservoirs of species, populations, individuals or interest genes' for the improvement of animal productivity and products quality?
- What concrete actions should be developed in these specific mountain areas so as to avoid the past mistake of transferring badly adapted exogenous animals? Is it possible to set up *in situ* improvement selection plans of endogenous individuals selected for their adaptation capacities? Is there any interest in trying an intermediate mode of selection?
- Within a framework of sustainable development and poverty reduction, what is the best way to improve the living conditions of mountain communities and protect their cultural traditions and way of life?
- What is the exact situation regarding human and animal health, veterinary structure and actions, disease resistance and, possibly, identification of genes or molecules of commercial interest (industrial or pharmaceutical)?
- How can we raise awareness in local and national authorities and policy-makers, whilst remaining within the boundaries of local and national preservation policies, so as to make them take into account the evolution of consumption habits?

Scientific actions

In order to try and answer the aforementioned general and specific research questions, we have set up scientific projects which are mainly focused on the model province of Ha Giang in the mountain areas of North of Vietnam. These projects are divided in four parts as follows:

In situ *inventories of animal biodiversity of socio-economic and cultural interest*

This will be achieved by building up a set of actions: compiling existing information on the traditional farming (breeding) systems of ethnic minority smallholders; inventory campaigns of animal populations; ground surveys and biological sampling for the *in situ* evaluations of the surveyed animals' characteristics, and for the measurement of their zootechnic performance in collaboration with the communities; and finally, the study in experimental stations of the most remarkable or threatened individuals. For all the above projects, a system of genetic information management will be set up after the conceptual pattern has been defined; it will be used for the capture, validation and treatment of data, mostly using geo-referencing and thematic mapping of the sampled animal populations and genetic materials.

Genetic characterization and database analysis

The biological material sampled during the inventory campaigns will be listed, packaged and stored in a perennial and secure way (cryobanks of tissue, cells and DNA). Biological analysis, made possible by a technical aid grant for the transfer of technologies, should be carried out in a context of technical training (devices, analysis, security) leading to a qualification (PhD, Master and post-graduate diploma). The analysis of population genetics, included in a more global approach such as a geographic information system (GIS), will help us to identify areas, villages, human and animal populations of interest, reservoirs of genes, etc. in order to develop concrete field actions in close collaboration with the smallholders concerned.

Setting up of local pilot projects to preserve/valorize animal biodiversity of economic and cultural interest

Several local projects of animal biodiversity preservation in rural environments will be carried out. Initially, local and national technical agents dealing with animal production, animal health and animal preservation will be involved in successive awareness campaigns and training sessions. Farmers will have the opportunity to attend village workshops and will thus become aware of projects and be kept informed of scientific results (key species, characters of interest, etc.). Outstanding animals will be selected and *in situ* projects of reproduction/multiplication and performance results will be implemented. Commercial channels will be integrated through animal labelling, product quality, ecotourism and the organization of producers.

Vietnam's biodiversity richness and its preservation stakes: Information and awareness-raising

At field level, after a preliminary inventory of ethnic minorities' general level of education, and in particular of smallholder communities' knowledge (know-how) of animal breeding, awareness campaigns need to be organized. This is the subject of a specific education micro-project in collaboration with local authorities. On a scientific level, several publications will be produced and regional symposiums organized on the subject of 'genetics and biodiversity' and 'reproduction biotechnologies and physiology'. A national seminar on the "regulations guiding the preservation and valorization of the Vietnamese fauna's genetic heritage" will take place. Finally, a Web site will be created and managed in association with FAO. As for the general public, documents in Vietnamese will be released in collaboration with national authorities (documentaries, atlas of animal biodiversity in Vietnam, awareness CD-ROM, etc.). Continuous exhibitions (City farm for children in the Hanoi Zoo) as well as temporary *in situ* travelling exhibitions (in schools, universities, etc.) will be organized.

The originality of this project's suggested approach consists of combining field projects with a more theoretical approach to genetics. It will enable a more precise understanding of the dynamics of animal populations being studied, and a better way of reconciling preservation with reasoned *in situ* exploitation of biodiversity by local communities. The communication and awareness campaign is an important element which will bring the project to its full potential.

Final beneficiaries and sustainability

The final beneficiaries will be the mountain ethnic groups of Northern Vietnam, for whom animal genetic resources are an essential, permanent feature linked to food, economics and culture. They will benefit from well-adapted *in situ* development micro-projects which might be pilot actions for future integrated development projects on a larger scale. These populations will also benefit from communication and awareness campaigns on economic and cultural biodiversity.

Indirect beneficiaries will be: (i) the two neighbouring countries of the Indochinese Peninsula (i.e. Laos and Cambodia), which face the same constraints in surveying and preserving their own animal biodiversity (which is very similar to Vietnam's) and that, for the time being, do not possess the abilities required to develop such studies; (ii) the international scientific community, which will gain from the preservation of exceptional species and from the description and survey of the wild and domestic gene reservoirs of major economic families.

This project will achieve the sustainable transfer of numerous skills. The Vietnamese partner laboratories will have to be equipped, and their staff trained in basic techniques and in molecular genetic methods applied to animals; they will also have to be trained in the use of the main information management tools that will be generated. The anticipated development of animal production in Vietnam will need to be supported by high-performance and selected animal material (dairy cows, pigs, poultry, fish culture and aquaculture, etc.), and will have to rely on the scientific and technical competences created by the project.

In terms of impact on the environment, on the decrease of poverty, and on the integration of women in development, the whole rationale of this project is based on the valorization of a natural resource (i.e. animal biodiversity) for the sustainable development of some of the poorest and most threatened communities in Vietnam. Such valorization should be carried out through the conservation of species, spaces and ecosystems which shelter biodiversity and are thus beneficial to the environment. Finally, women are in charge of domestic animal livestock in most of the minorities. The increase in animals' ecological, social and economic value will strengthen the recognition of women's role and thus their integration in development.