FAO Guidelines for the *In Vivo* Conservation of Animal Genetic Resources (Draft)

FOREWORD

The genetic diversity of the World's livestock species is in a state of continuous decline and the animal genetic resources that remain are not used in the most efficient way. To formally recognize and address these problems, the Member States of the FAO developed the *Global Plan of Action for Animal Genetic Resources* (Global Plan of Action), which was adopted at the First International Technical Conference on Animal Genetic Resources for Food and Agriculture in Interlaken, Switzerland in September 2007.The implementation of the *Global Plan of Action* will contribute significantly to

(i) eradicate extreme poverty and hunger, and

(ii) to ensure environmental sustainability, two of the Millennium Development Goals.

The Global Plan of Action is the culmination of an extended process describing the State of AnGR involving the participation of 169 countries. It was adopted by 109 country delegations, who also adopted the *Interlaken Declaration on Animal Genetic Resources*, by which they confirmed their common and individual responsibilities for the conservation, sustainable use and development of animal genetic resources for food and agriculture; for world food security; for improving human nutritional status; and for rural development. They committed themselves to facilitating access to these resources, and ensuring the fair and equitable sharing of the benefits from their use.

The Global Plan of Action is a rolling plan with provisions for the characterization, sustainable use, development and conservation of AnGR at national, regional and global levels. The Global Plan of Action consists of 23 Strategic Priorities, each with its own actions. Most of the responsibility for implementation of the Global Plan of Action rests with National governments, but non-governmental and inter-governmental organizations are also expected to play a major role. Among the responsibilities of the FAO are capacity building and provision of technical assistance to Member States.

To this end, the FAO commissioned a group of geneticists to write the FAO Guidelines for the ***In Vivo* Conservation** of Animal Genetic Resources. These guidelines are part of a coherent set of guidelines including: Guidelines for the **Cryoconservation** of Animal Genetic Resources, Guidelines on **Surveying and Monitoring** of Animal Genetic Resources and Guidelines for **Breeding Strategies for Sustainable Management** of Animal Genetic Resources.

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USER GUIDANCE

The Goal and Structure of these Guidelines

It is the main responsibility of each nation to preserve its genetic diversity on a long-term basis (CBD, 1992). Animal production is vital to mankind and conservation of animal genetic diversity is a way to secure our future. *In situ* conservation is the preferred conservation method (Oldenbroek, 2007): "All objectives of conservation can be reached the best and it offers possibilities for utilization. Besides, the development of a breed can continue and it facilitates adaptation to changing circumstances. However, the risk of inbreeding (caused by mating of relatives and leading to inbreeding depression: a decrease in fitness) and random drift (loss of alleles with a low frequency caused by random processes) has to receive full attention in the breeding scheme of these often small populations." Integration of *in situ* and of *ex situ* methods can provide a powerful conservation strategy. *Ex situ* conservation usually implies conservation in a cryobank. *Ex situ* – *in vivo* conservation, in contrast, is the conservation of a limited number of live animals in small breeding herds or zoos.

The objective of these Guidelines is to provide technical guidance and a decision aid for the available conservation options, and the design and establishment of animal breeding programs that conserve genetic diversity effectively and stimulate sustainable use, usually through the generation of income to keepers of livestock. The considerations and reflections are intended to be relevant to all species of domestic livestock, and where appropriate, species-specific guidance is given.

This document is designed to provide the necessary technical background for organizations or individual actors wanting to set up, implement, and monitor *in vivo* conservation programs in a rational manner and defines the tasks and the actions that should be completed. An emphasis is placed on *in situ* programmes, because such programmes are likely to be the most sustainable. To facilitate this process, the subchapters are written in a fixed format of a Rationale, an Objective, the required Input, the Output aiming of a description of a set of Tasks and a description of the Actions needed to fulfill the each Task and to obtain the desired output.

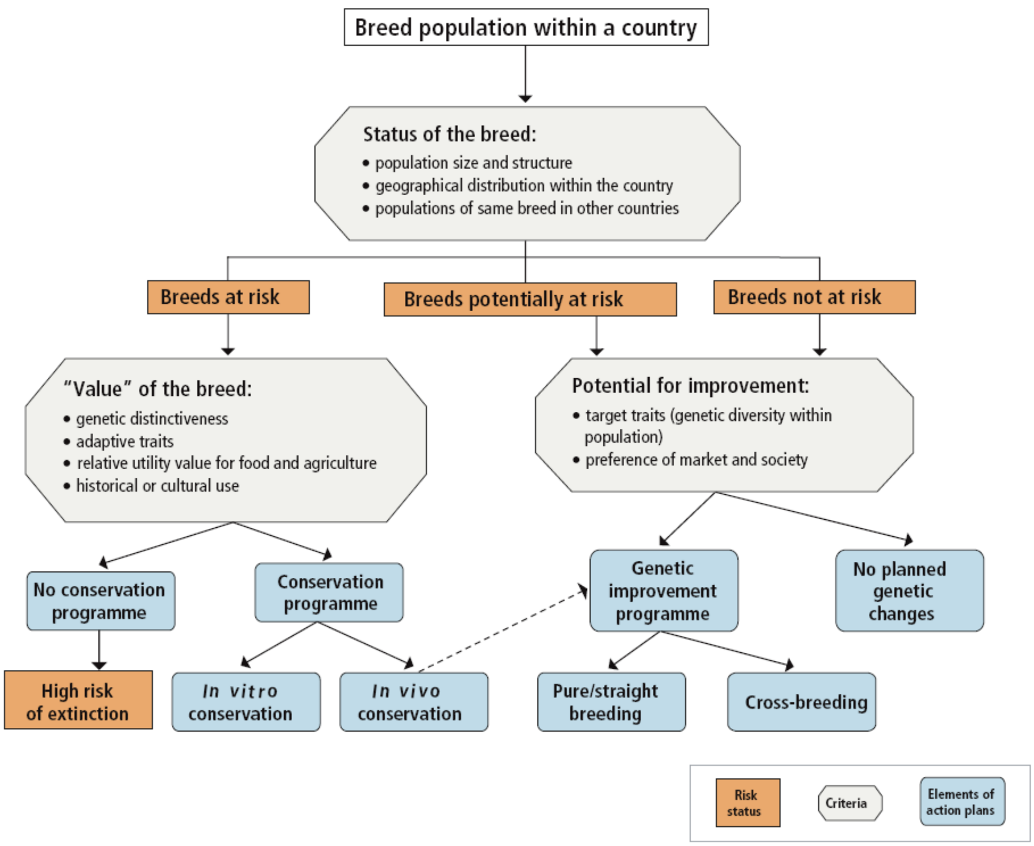
This process of building an *in vivo* conservation program may be initiated or realized under the guidance of the National Coordinator for animal genetic resources. The people operating in the process are advised to consult regularly the National Advisory Committee (page 22 FAO report: "Preparation of National Strategies and Action Plans for Animal Genetic Resources). When such a committee is not in place it is advised to establish an *ad hoc* committee of relevant stakeholders and experts in the field of animal genetic resources and to consult this committee during the process.

Chapter 1 presents a brief background on the importance of livestock and the state of animal genetic resources, reasons for their loss, and objectives and options for conservation of animal genetic resources. Chapter 2 presents methods to identify the breeds at risk, which are therefore candidates for conservation, including assignment to categories based on risk status. Chapter 3 describes the methodologies to decide which breeds are to be conserved, assuming that financial resources for conservation preclude the conservation of all breeds. It comprises the values influencing the conservation value of a breed, methods for prioritizing breeds and the choice of the appropriate conservation strategy. Chapter 4 describes the organization of the institutions required to implement programs for *in situ* conservation. Chapter 5 addresses the design of effective conservation and use programs with special emphasis on the maintenance of the genetic diversity within the breeding populations.

Chapter 6 gives an overview of implementing breeding programmes that combine conservation and sustainable use, largely by improving the productivity of conserved breeds. Presents. Finally, Chapter 7 outlines opportunities to increase the value of local breeds and their products in *in situ* conservation programmes.

These guidelines are following the flow chart of activities in Figure 1, originally presented at page 348 of the *State of the World's Animal Genetic Resources for Food and Agriculture* (FAO, 2007): The (risk) status of a breed is the outcome of the tasks and actions described in Chapters 1 and 2, the value of a breed results from the tasks and action given in Chapter 3, the potential for genetic improvement will be clear performing the tasks and actions in Chapter 4 and the establishment of the *in situ* conservation programs is the result from Chapter's 5 tasks and actions. In addition the tasks and actions in Chapter 6 will help stakeholders to get more profit from *in situ* programs in the future.

Figure 1. Flow chart for national management of animal genetic resources.



1 The Importance of Animal Genetic Resources and Options for their Conservation

1.1 The importance of livestock in a country

RATIONALE

A limited number of species of mammals and birds are kept by humans and play an important role in human life as livestock. These animals, important for food and agriculture, are the result of domestication processes that have been ongoing for almost 12,000 years. Over time, domesticated livestock species have evolved into more or less distinct sub groups or *breeds* (See Box 1.1) through a variety of formal and informal processes. As livestock populations spread from their centers of domestication with human migration, trade, and conquest, they did so as small samples of the existing population and encountered new ecological conditions. In these different ecological conditions, natural selection facilitated the adaptation of these local populations. These populations developed into distinguishable subgroups within the species, differentiated on the basis of adaptive traits, resulting in what are today known as *landraces* or *landrace breeds*. As societies developed and diversified, new demands were placed on livestock, and knowledge and skills in husbandry and breeding were accumulated and led to the development of more specialized breeds and breeding lines.

Box 1.1
The definition of a breed (Woolliams and Toro, 2007)

In a study of the literature Woolliams and Toro (2007) concluded that the question "What is a breed?" is a simple question but difficult to answer. They found the following published definitions from a variety of groups, each relevant and pertinent to their stakeholders:

i. "*Animals that, through selection and breeding, have come to resemble one another and pass those traits uniformly to their offspring.*"
ii. "*A breed is a group of domestic cats (subspecies felis catus) that the governing body of (the Cat Fanciers Association) has agreed to recognize as such. A breed must have distinguishing features that set it apart from all other breeds.*"
iii. "*A race or variety of men or other animals (or of plants), perpetuating its special or distinctive characteristics by inheritance.*"
iv. "*Race, stock; strain; a line of descendants perpetuating particular hereditary qualities.*"
v. "*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 separate groups has led to acceptance of its separate identity*."
vi. "*A breed is a group of domestic animals, termed such by common consent of the breeders, ... a term which arose among breeders of livestock, created one might say, for their own use, and no one is warranted in assigning to this word a scientific definition and in calling the breeders wrong when they deviate from the formulated definition. It is their word and the breeders' common usage is what we must accept as the correct definition.*"
vii. "*A breed is a breed if enough people say it is*."

Continuing definition (v) (FAO, 2007), FAO argue that breed is very often a cultural term and should be respected as such, a perspective clearly articulated in definition (vi), and succinctly summarized in (vii).

Human-controlled artificial selection of livestock in the past 250 years has led, particularly in the more industrialized countries, to the development of individually uniform but highly diverse, distinguishable populations, the so-called *standardized breeds*. This process started in the middle of the 18th century with the breeding activities of Robert Bakewell in England and was based on establishing an ideal, closing the population, recording pedigrees and using deliberate mating and selection to achieve the standardized ideal. In some cases, breeding companies have developed specialized lines with the standardized breeds and selected them intensely for very specific production systems. The interaction between landraces and standardized breeds has involved considerable give and take. On one hand, the landraces played a basic role in the development of the standardized breeds, on the other hand the landraces were threatened by the expansion of the standardized breeds. In the developing countries the landraces still play an important role in the rural areas.

The situation regarding livestock population has never been static, breeds emerged, were crossed to develop new breeds and disappeared over time, but diversity prevailed. This all resulted globally in the existence of today's more than 7,000 reported breeds at the start of the 21th century (FAO, 2007). These 7,000+ breeds represent the world's animal genetic resources (AnGR). They have been shaped by humans to meet demands in the relatively short term, but will need to be drawn upon to address changes in the future.

The livestock sector has to balance a range of policy objectives. Among the most urgent are: supporting rural development and the alleviation of hunger and poverty; meeting the increasing demand for livestock products and responding to changing consumer requirements; ensuring food safety and minimizing the threat posed by animal diseases; and maintaining biodiversity and environmental integrity. As in the past, meeting these challenges will involve mixing breeds, the specialization of a limited number of breeds in breeding programs and breeding individual animals with the qualities needed to meet specific requirements of particular production, social and market conditions. However, in meeting the goal of matching AnGR to development goals, the existence of landrace breeds, standardized breeds and breeding lines is threatened and will result in genetic erosion: a decrease in the genetic variability within the species comprised by the genetic variability between breeds and lines.

The amount of diversity of AnGR is directly related to capacity of livestock populations to adapt to future changes in environmental and market conditions. Therefore, conservation and use of breeds deserve attention and merit the application of adequate knowledge and skills. Within a species, the percentage of the genetic variation between breeds related to the total genetic variation in the species varies between 0.25 and 0.66, depending on the trait (Woolliams and Toro, 2007). The landrace and standardized breeds are the founders of the modern breed types used in intense production systems and of the specialized strains developed by breeding companies.

Many livestock species in rural systems have the ability to transform forage and crop residues, which are inedible to humans, into nutritionally important food products. Products like meat, milk, eggs, fibre, and hides of the more than 40 domesticated livestock species account for 40% of the value of world agricultural output. Livestock products provide one third of humanity's protein intake, as well as draught power and fertilizer for crop production, and thus are essential components in achieving sustainable food security in rural areas. In some developing countries, particularly those where pastoral systems predominate, the contribution of livestock production is even more important. In addition, livestock serves as a very important cash reserve in many of the mixed farming and pastoral systems, thereby providing an important form of risk reduction. The genetic diversity of the domesticated animal species is an essential resource in dynamics of these livestock production processes. Careful genetic management and use of breeds in these processes determine the quality of the conservation of the genetic diversity within the species.

Objective: To produce an overview of the relevant livestock species in the country, the number of breeds within the species and of the functions of the different species and breeds

Inputs:

1. FAO Guidelines for the *Preparation of National Strategies and Action Plans for Animal Genetic Resources*,
2. FAO Guidelines on *Breeding Strategies for Sustainable Management of Animal Genetic Resources*, and
3. The country report on the State of the National Animal Genetic Resources submitted to FAO for the *State of the World's Animal Genetic Resources for Food and Agriculture*

(Country Report).

Output:

- An overview of the species and breeds which are important for the relevant functions of animals in the country.

Task. Evaluate the species and breeds of livestock and their primary functions for your country or area

Action 1. Sample and study the input documents.
It is important to know the existence and the content of a national strategy and an action plan. What is the vision of the government on conservation of animal genetic resources? How does it relate to general livestock and agricultural development plans? Which animal species are important in your country or region? What objectives are considered to be leading in a national conservation plan?

Action 2. Consult the National Advisory Committee for Animal Genetic Resources.
(See page 22 of FAO Guidelines for *Preparation of National Strategies and Action Plans for Animal Genetic Resources*) If such a committee does not exist, then an ad hoc advisory committee on AnGR conservation should be created and consulted for guidance in establishing an overview of species, breeds and functions and for its critical review.

Action 3. Evaluate the Country Report.
Analyze the Country Report, update it with new statistics and ask the Advisory Committee to review it.

Action 4. Summarize locally available breeds and their functions.
Produce a table for each species with breeds x functions and include a short explanation. Have the Advisory committee review it.

1.2 The dynamics of the livestock sector in a country

RATIONALE

Livestock systems are very dynamic (FAO, 2007). Drivers of change in livestock production systems include: (a) growth and changes in demand for animal products; (b) developments in trade and marketing; (c) technological developments; (d) environmental changes; and (e) policy decisions.

The outlook for a breed depends to a great extent on its present and future role in livestock systems. The decline of certain livestock functions often is a substantial threat for the species involved and its breeds specialized for these functions. Perhaps the most obvious example is that throughout much of the world, specialized draught breeds are threatened by the expansion of mechanization in agriculture (FAO, 1996). Similarly, breeds developed for wool and fiber production may be threatened by the availability of synthetic fibers. Availability of alternative sources of fertilizer or financial services also shifts the objectives of livestock keepers and may affect their choices regarding breeds. Opportunities for new livestock functions challenge the use of a species and call for breeds specialized for these new functions. Such specialization can only be realized if the genetic diversity within the species is available, having been conserved in the past. Obvious examples are the use of horses for recreation and sport and the use of the herbivore species for nature management programs.

The present global scenario to meet the global requirement for food for mankind is favoring the intensification, specialization and industrialization of production systems. In these systems only a narrow range of AnGR is used. These systems are rapidly spreading in developing countries. Unfortunately, at the same time that this trend contributes greatly to the required increase in food supply of animal origin, it is a threat to the diversity of AnGR. Many breeds are set aside in this global scenario, because historically they have been selected for a range of traits rather than for particularly high production of one trait. Within the chosen breeds, diversity is also decreased due to the selection of a small number of superior individuals and families. Nevertheless, genetically diverse livestock populations are an important resource to be drawn upon as production systems change and develop. Newly emerging market trends and policy objectives are continually placing new demands on the livestock sector. The prospect of future challenges such as adapting to global climate change underlines the importance of retaining a diverse portfolio of livestock breeds with large diversity in adaptive traits.

Objective: To evaluate the livestock industry and document the roles of the different animal species, the threats to their sustainability and the opportunities for their conservation and use.

Input:

1. The country report on the State of the National Animal Genetic Resources submitted to FAO for the *State of the World's Animal Genetic Resources for Food and Agriculture* (FAO, 2007a) and
2. An update of the statistics in the report.

Output:

- the changes and the expected changes in the use of species, in their numbers and in the number of breeds

Task. Describe the dynamics of the species (breeds) and their functions

Action 1. Describe the use of the different species and breeds in livestock systems.
The basis for this can be found in the country report and should be updated.

Action 2. Describe the drivers for change of the livestock systems in your country and the dynamics of the livestock systems now and those to be expected.
Main drivers mentioned in the literature (Oldenbroek, 2007) are (a) the growth of the human population, (b) the increase in demand for animal products, (c) the request for guarantees for food quality and safety safeguarding human health and animal welfare, and (d) the increased interest of consumers in niche products and in sustainable use of resources. Additionally, developed countries have an increase in nature management with herbivores and hobby farmers in the rural area have become new users of pastures.

Action 3. Describe the trends.
Describe observed and expected trends in the use of species and relevant breeds and the consequences for the species and breeds when the livestock systems will change.

1.3 The national status of animal genetic resources

RATIONALE

As mentioned previously, about 40 animal species have been domesticated for food and agriculture. On a global scale, however, only five species – cattle, sheep, chickens, goats, and pigs – show widespread distribution and have an especially large numbers of breeds. Cattle, sheep and chickens are particularly widely dispersed across the global, whereas goats and pigs are less uniformly distributed. Goats are more common in developing regions and pigs are found in low numbers in predominantly Muslim countries.

The *State of the World's Animal Genetic Resources for Food and Agriculture* (FAO, 2007) reported on the distribution of the five major livestock species according to region and those results are summarized here.

Chicken breeds make up a large majority of the total number of avian breeds in the world. There are around 17 billion chickens, about half of which are in Asia and another quarter in the Americas.

Europe and the Caucasus around 13% of the world's flock, followed by Africa with 7%.

Cattle are important in all regions and have a global population of over 1.3 billion animals, or about one for every five people on the planet. Asia and Latin America have 32% and 28% of the global herd, respectively, with Brazil, India and China accounting for particularly proportions. Large cattle populations are also found in Africa (particularly Sudan and Ethiopia), and Europe and the Caucasus, with largest numbers in the Russian Federation and France. Cattle breeds contribute 22% of the world's total number of recorded mammalian livestock breeds.

The world's sheep population is just over one billion. About half are found in Asia and the Near and Middle East; China, India and the Islamic Republic of Iran have the largest national populations. Africa, Europe and the Caucasus, and the Southwest Pacific have around 15% each; and 8% are found in Latin America and the Caribbean. Sheep are the species with the highest number of recorded breeds (contributing 25% to the global total for mammals).

There are about a billion pigs in the world – one for every seven people. China has the greatest number of pigs and about two-thirds of the global population is found in Asia. Viet Nam, India and the Philippines also have large national herds. Europe and the Caucasus have a fifth of the world's pigs, and the Americas another 15%. Pig breeds contribute 12% to the total number of recorded mammalian breeds in the world.

There are about 800 million goats worldwide. About 70% of the world's goats are in Asia and the Near and Middle East, with the largest numbers in China, India and Pakistan. Africa accounts for just under 15%, with about 5% being found in each of the Latin American and the Caribbean and Europe and the Caucasus regions. Goat breeds contribute 12% to the total number of recorded mammalian breeds in the world.

Less numerous species like horses, donkeys and ducks are also found in all regions, but they show a less uniform distribution than cattle, sheep and chickens. Certain species, such as buffaloes and various camelids are very important in specific regions, but do not have a wide global distribution.

FAO Member Countries are requested to determine the number of livestock breeds present in their territories, monitor their population numbers and report these data internationally. A total of 8,054 breeds are recorded in the database of the Domestic Animal Diversity Information System (DAD-IS), and among them, 1,053 are recorded in more than one country (FAO, 2010). Breed populations (landrace breeds or standardized breeds) occurring only in one country are defined as "local" breeds, while those occurring in more than one country are defined as "transboundary" breeds. Transboundary breeds are further classified as either "regional" or "international", depending on the extent of their distribution. Among the reported transboundary breeds, 504 are regional transboundary breeds, and 549 are international transboundary breeds.

Around 20% of reported breeds are classified as at risk. Of even greater concern is that during the last six years over 60 breeds became extinct – amounting to the loss of almost one breed per month. These figures present only a partial picture of genetic erosion. Breed inventories, and particularly surveys of population size and structure at breed level, are inadequate in many parts of the world. Population data are unavailable for about 35% of all breeds. Nevertheless, it can be concluded that the between-breed diversity within these livestock species is under threat. Moreover, among many of the most widely used high-output breeds of cattle, within-breed genetic diversity is also being undermined by the use of few highly popular sires for breeding purposes. These two tendencies lead to rapid and irreversible erosion of genetic diversity in these species.

Objective: To describe the dynamics of the livestock species in your country.

Input:

1. Historical and present number of animals per breed (e.g. the country report, DAD-IS or for European countries, the EFABIS database),
2. National statistics and strategic and political documents useful to predict breed population numbers in the future.

Output:

- An estimate of the number of animals per breed now and prediction of population sizes in the future

Task. Produce past, present and future number of animals per breed

Action 1: Indicate past and present numbers and analyze trends.
A starting point might be the country report containing the figures around the year 2000. Many countries (Ministries of Agriculture or of Economic Affairs) produce annual statistics. Annual reports of breeding organizations may also be available. Ministries, universities and research institutes regularly produce "outlooks to the future" that can be used to predict trends in the number of animals per species and per breed.

Action 2: Predict the number of animals per breed in 10 years from now.

Based on the number of animals per breed 10 years ago, the present number and the observed trends the number of animals per breed in ten years from now can be predicted. Such a prediction may result in two figures: an optimistic estimate and a pessimistic estimate, together presenting a realistic range.

1.4 Reasons for loss of genetic diversity among livestock populations

There are several factors that place breeds at risk of loss and threaten domestic animal diversity. In the developed countries, the greatest cause for genetic erosion is, by far, the growing trend to a global reliance on a very limited number of modern breeds suited for the high input - high output needs of industrial agriculture. The effect of this trend is that many breeds have lost their function and disappear without notice. In the developing countries, however, genetic diversity is potentially threatened by a variety of factors. In the literature, there is broad agreement regarding the general trends and factors threatening AnGR in these developing countries. For example, Rege and Gibson (2003) suggest the use of exotic germplasm, changes in production systems, changes in producer preference because of socio-economic factors, and a range of disasters (drought, famine, disease epidemics, civil strife/war) as the major causes of genetic erosion. Tisdell (2003) suggests the following as major causes: development interventions, specialization (emphasis on a single productive trait), genetic introgression, the development of technology and biotechnology, political instability and natural disasters. For at-risk cattle breeds in Africa, Rege (1999) lists as major causes replacement by other breeds, crossbreeding with exotic breeds or with other indigenous breeds, conflict, loss of habitat, disease, neglect and lack of sustained breeding programs among the threats. Similarly, Iñiguez (2005) identifies displacement by other breeds, and indiscriminate crossbreeding as threats to small ruminant breeds in West Asia and North Africa.

The increased demand for livestock products in many parts of the developing world drives efforts to increase the output of meat, eggs and milk for the market (Delgado *et al.*, 1999). Crossbreeding and subsequently replacing local breeds by a narrow range of high-yielding breeds is a very widespread consequence of efforts to increase output. The rapid expansion of industrialized pig and poultry production systems in regions with a great diversity of indigenous pig and chicken breeds results in a great need for action to conserve the local breeds of these species. Trends in consumer demand can threaten breeds that do not supply products with the desired characteristics. For example, consumer preference for leaner meat has led to the decline of pig breeds that have carcasses with a higher fat content (Tisdell, 2003, Mariante & Cavalcante, 2006). Other threats to local breeds of livestock are climate change, lack of the necessary infrastructure and services for breed improvement, loss of labour force and traditional knowledge associated with livestock keeping due to the migration to urban areas in search of employment (Daniel, 2000; Farooquee *et al.*, 2004).

These examples illustrate that there are a number of ways in which threats to genetic resources can potentially be classified, with three broad categories: (a) trends in the livestock sector; (b) disasters and emergencies; and (c) animal disease epidemics and control measures.

Objective: To identify and describe the factors that threaten animal genetic diversity in your country.

Input:
1. A description of the drivers for changes in the livestock systems,
2. Documents describing the likelihood of disasters and for disease epidemics.

Output:
- A description of risk factors for genetic diversity that play a role in your country
- A general course of action to decrease the impact of the various threats

Task. Estimate the risks of factors that threaten genetic diversity

Action 1: Analyze the drivers for changes in livestock systems.
Formulate the consequences of these changes for the breeds presently used in the livestock systems. For example, when intensification of animal production is widely adopted as the primary strategy to meet an increased demand for food of livestock origin, the breeds not fitting in these systems due to low production potential will be set aside.

Action 2: Analyze the chances for disasters and disease outbreaks.
Disasters in this respect are wars, floods etc that destroy whole populations of animals. Based on the political stability in an area or a country and based on historic events the chance for a new disaster can be estimated. In most countries ministries of agriculture include a veterinary department producing an annual report. In such reports, overviews include prevailing diseases and threats of importing diseases from other countries. In addition, it may be relevant to examine the institutional policies to be applied in case of a disease outbreak. In many countries, disease eradication procedures may be a real threat for breeds, especially those breeds with small population concentrated in a specific geographical region and on a small number of farms. In this respect, it is therefore relevant to determine to what extent the various breeds are spread over the country.

Action 3: Describe the risk factors for the existence of the breeds and consider corresponding preventive measures.
Based on the outcome of Actions 1 and 2, the risk factors can be summarized: (a) the risk of a breed being set aside due to economic drivers resulting in a continual decrease in numbers, (b) the risk of a short-term severe decline or extinction due to a disaster or a disease outbreak. For the first case, long term rural development, breed improvement and/or marketing programmes may be needed (See Chapters 4, 6 and 7). In the second case, policies with regard to disease control may be altered.

1.5 Objectives for conservation

RATIONALE

In the early 1980's there was an increased global awareness of the important role of animal genetic diversity in the various production systems of the world and of the fact that this diversity was contracting. As a result, a number of countries established national conservation efforts. Depending on the country these activities involved either *in situ* or *ex situ* conservation or a combination of the two. In all cases it became apparent that any conservation activity would require substantial involvement with livestock owners and a diverse group of public and private sector organizations. While at first considerable emphasis was placed upon *in situ* conservation, in recent years, attention (albeit relatively less) has also been given to the establishment of *ex situ* programs, and in particular gene banks. As will be detailed in this handbook, the *in situ* conservation approach may be the most useful approach that governments can use to protect their

AnGR.

From 1970 onwards in many developed countries, the people interested in the maintenance of local breeds founded national breed conservancy associations. These organizations, often with a non-governmental character, initiated *in situ* conservation activities for local breeds with an ecological of historic cultural value and called for actions of governments, breeder's organizations and breeders. Many of these national organizations collaborate on the global level in Rare Breeds International (RBI)[1].

There are a number of reasons why AnGR should be conserved. In developed countries, traditions and cultural values are accepted objectives for conservation, which ensure the development of conservation measures for rare breeds and promote the emergence of niche markets for livestock products. In developing countries, however, the immediate concerns are more for food security and economic development.

In a general way, the objectives for conservation of AnGR fall into the following categories: (a) economic; (b) social and cultural; (c) environmental; (d) risk reduction; and (e) research and training.

- Domestic Animal Diversity should be maintained for its economic potential in allowing quick responses to changes in climate with consequences for the ecosystem, in market demands and associated regulations, by changes in the availability of external inputs, by emerging disease challenges, or by a combination of these factors.
- Domestic Animal Diversity has an important social and cultural role. Livestock breeds reflect the cultural and historical identity of the communities that developed them, and have been an integral part of the livelihood and traditions of many societies. Loss of typical breeds, therefore, means a loss of cultural identity for the communities concerned, and the loss of part of the heritage of humanity.
- Domestic Animal Diversity is an integral part of the environment**.** The loss of this diversity would contribute to higher risk in the production system, reduced ability to respond to changes and degradation of the environment, which may lead to its destruction. Marginal areas and low to medium input production systems, as well as an increased integration of livestock into agricultural production will be important for food production in the developing countries. In developed countries sometimes arable areas are given back to nature and well-adapted grazing animals play an important role in the development and maintenance of these "new marginal" areas. Maintenance and development of adapted breeds are of critical importance to ensure this can be achieved sustainably without adverse environmental impact in both developed and developing countries.
- Domestic Animal Diversity is an important insurance to enable response to possible, but yet unknown, requirements in the future. It is risky to rely on only a few breeds: a concentration on a small number of breeds results in losses of genes and gene combinations that are not relevant at present, but which could become relevant in the future. Conserving domestic animal diversity is reducing the risk and enhancing food security.
- Domestic Animal Diversity should be conserved for research and training. This may include basic biological research in immunology, nutrition, reproduction, genetics and adaptation to climatic and other environmental changes. Genetically distant breeds are needed for research into disease resistance and susceptibility helping to a better understanding of the underlying mechanisms and to the development of better treatments or management of the disease.

Gandini and Oldenbroek (2007) summarized these categories into two main objectives:

[1] http://www.rarebreedsinternational.org/

1. The conservation for sustainable utilization in the rural area including the economical potential, the social cultural role and the environmental services.
2. The conservation of the flexibility of the genetic system including the reduction of risk and the opportunities for research and education.

The first objective is fully exploited through *in vivo* conservation programmes (with *in vitro* as a safety net) and the second objective is met by *in vitro* conservation (with *in vivo* as a facilitating mechanism speeding up the reconstruction of a breed).

Objective: To determine national objectives for conservation by species

Inputs:
1. Governmental livestock development policy documents
2. If available, the National Strategy and Action Plan for animal genetic resources.

Output:
- relevant objectives for conservation for the different species

Task: describe the objectives for conservation which apply in the different species

Action 1: Analyze per species and breed the relevant objectives for conservation.
For a given species or breed, several objectives may apply. A breed can have a cultural value, fulfill an economic function, and contain a unique characteristic.

Action 2: Produce tables of species x objectives.
Two tables should be created to distinguish between the two sets of objectives: (a) the five different objectives mentioned above and (b) the two summarizing objectives of Gandini and Oldenbroek (2007), i.e., sustainable utilization of the rural area and maintenance of the genetic flexibility of the system.

1.6 Determine the position of each breed and a strategy for the future

RATIONALE

As concluded above (Sections 1.2 and 1.4) many breeds are set aside from the commercial production systems or are not involved in such systems. This practice creates the risk for such a breed to decrease in numbers of breeding animals and, in the extreme case, the risk of extinction. The present position of such a breed in its livestock system and a strategy for the future can be obtained in performing a SWOT (strengths, weaknesses, opportunities, threats) analysis (Hiemstra et al., 2010). The present position of the breed is determined by internal factors split into Strengths and Weaknesses. The future is determined by external factors split into Opportunities and Threats. The internal factors can be managed. The external factors create the challenges for a breed. A strategy can be build to use the strengths to take advantage of the opportunities (SO-strategy), to use the strengths to reduce the likelihood and impacts of threats (ST-strategy), to overcome weaknesses by using opportunities (WO-strategy) and to avoid the likelihood of disastrous effects from the weaknesses in combination with threats (WT-strategy)

Objective: To develop a strategy for a local breed, focused on its conservation and use.

Inputs:

1. Characteristics of the breed, its history, its functions and products, the existence of the breed and characteristics of the livestock system(s) where it is used.
2. An analysis of the present and potential stakeholders of the breed, the trends in land use, livestock systems and the welfare and consumption pattern of the human population.

Output:

- a number of alternative strategies for the breed focused on conservation and use.

Task: Determine conservation and use of a breed in the future.

Action 1: Undertake a SWOT analysis of the breed in its present system using the characteristics of the breed and the stakeholder analysis.
The strength of a breed can be, for example, its genetic uniqueness, its adaptation to a production system or its (historic) function in human culture. A weakness of a breed can be, for example, the population size, the average age of the owners or the limited area where the breed is found. Examples of opportunities are a growing need for nature management or an increasing number of hobby farmers or stimulation programs for low input farming. Examples of threats are the importation of high productive animals from a commercial breed or a governmental focus on main stream food production. The subsequent pages have examples of SWOT analyses for two European cattle breeds as well as for a chicken breed in the United States of America (Box 1.2).

Action 2: Prioritize the strengths, weaknesses, opportunities and threats.
Then combine the most important strengths with the most important opportunities and translate it into a strategy for a breeding program and for the use of the breed in a livestock system. Combine the weaknesses of the breed with the opportunities and translate it into a strategy including a breeding and conservation plan that reduces the weaknesses of the breed. Combine the strengths and weaknesses of the breed with its threats and translate it into a conservation strategy.

Action 3: Describe the different alternative strategies for breeding focused on conservation and use and rank them for viability.
Some conservation strategies may work more efficiently for some breeds and species than others. It’s important to consider differences among the strategies with respect to the target breeds when developing conservation programmes.

Itäsuomenkarja, kyyttö – Eastern Finncattle

History

The Eastern Finncattle (EFC) was recognised as a separate breed in the 1890's. The EFC farmers founded a breed society in 1898, which initiated organised cattle breeding in Finland. First, attention was given to breed characteristics and the cows from peripheral villages were regarded as the most pure ones. Then there was a need to improve milk production. From the 1920's onwards the emphasis on exterior traits made way for selection on recorded production. The EFC populations sank to the bottom lowest numbers in the 1980's with only about 50 cows and less than 10 bulls left. At the moment the number of purebred cows is almost 800 and slowly increasing. Animals are typically red colour-sided with a broad winding white band on the back.

Breeding, conservation and promotion

The proportion of recorded cows is 32%. The AI organisation has semen stored from 48 bulls with a total of 75,000 doses. There are also 100 embryos in the cryobank produced from 18 cows (12 bulls). The breeding organisation FABA Service annually lists alternative bulls for each cow, recommended on the basis of overall co-ancestry measures in the population. Since joining the EU, the farms raising EFC cows have received a special subsidy.

SWOT

S: Unique and symbolic germ plasm in Finland.

W: Low milk yield.

O: Special features exploited in product development; 'green care' farms.

T: Less experienced farmers and hobby farmers have no interest in the development of milk production.

Avileña-Negra Ibérica – Avilena Negra Iberica

History

In ancient times animals settled in the centre of the Iberian Peninsula and evolved in isolation and dedicated to agriculture labour, which was also important for meat production. In the past, animals were named on the basis of its area of origin. The Spanish 'Avileña' group of herds located in the mountains of Avila Province and neighbour areas resisted to the regressive process that affected the Negra-Ibérica group. In 1980, both groups joined each other in the Avileña-Negra Ibérica breed. The trend of the population is upwards. In 1978, there were 80,000 suckler cows. Eight years later, there were 90,000 suckler cows, and in 2007 the estimated census showed 115,000 suckler cows.

Breeding, conservation and promotion

The Breed Association was created in 1971, and began to deal with the herdbook in 1975. It coordinated the animal performance recording plus the genetic improvement programmes, and it organised markets, meetings, and breed promotion activities. It has also stimulated farmers to develop breed-specific products. In 1990, the Protected Geographical Indicator Label, the 'Carne de Avila' was created and in 2000 a Breed Label emerged.

SWOT

S: Better functional traits than mainstream breed (e.g. robustness, health, fertility, longevity) and a strong historical link between the breed and the territory.

W: Lower productivity and carcass value than mainstream breeds, and therefore lower profitability.

O: Increase the quality of products, and increase the awareness for traditional local product conservation.

T: Increasing input costs.

Box 1.2
SWOT analysis of Java chicken in the USA

Java chickens in the USA were once common midlevel production birds. Declining numbers in the face of the industrialization of poultry production reduced the breed to a relic status in need of targeted conservation programs if the breed was going to survive, especially with any of its productive potential intact. A SWOT analysis revealed strategies forward.

Strengths – Historic status as a productive range-raised meat bird with desirable carcass characteristics and flavor.

Weaknesses – Reduced growth rates and size. Existence of only two breeding lines of the birds. Diminished fertility and vitality.

Opportunities – Increased interest in consumers on extensively raised poultry meat from identifiable traditional breeds. Improved breeding and population management could reduce inbreeding depression.

Threats – Inbreeding depression (if not managed). Low numbers in few locations.

These factors were combined to result in a program of crossing the two existing bloodlines, and then selecting the result for growth rate, fertility, and conformation. The boost from crossing the two inbred populations regained the previous production level of the breed. A new breeders' organization expanded the number of sites on which the breed was held, which further enhanced the goal of spreading risk of loss of any one population. Splitting the population into several sites also subdivided the risk of uniform genetic drift and inbreeding in the entire breed. Increased production levels led to increased interest on the part of producers interested in alternatives to industrial production, which reversed the steady decline of the breed in both numbers and vitality.

1.7 Comparison of conservation options

RATIONALE

Conservation strategies can be categorized as either conserving animals *in situ*, within the environment or production systems in which they were developed, or *ex situ*, which includes in all other cases. The latter can be further divided into *ex situ* - *in vivo* conservation and *ex situ* - *in vitro* conservation (cryoconservation).

In situ **conservation**

In the context of domestic animal diversity this is primarily the active breeding of animal populations for food and agricultural production such that genetic diversity is best utilized in the short term and maintained for the longer term. Operations pertaining to *in situ* conservation include performance recording schemes and development (breeding) programmes with special emphasis on maintaining the genetic diversity within the breed. *In situ* conservation also includes ecosystem management and use for the sustainable production of food and agriculture.

Ex situ **conservation**

In the context of domestic animal diversity this means conservation away from the habitat and production systems that developed the resource. This includes both storage as live animals away from the habitat (*ex situ in vivo)* and cryoconservation.

Ex situ - in vivo conservation

This implies keeping animals (often a very limited number) outside their natural habitat, so that natural selection is no longer effective in its role to assure adaptation of the population to its original environmental challenges. It is strongly advised to combine this method with cryoconservation. If reconstruction of a population with frozen semen is required, it might be very helpful to use the few purebred *ex situ in vivo* conserved females as founders.

A key question for this strategy is whether or not long-term finance and commitment is available to maintain generations of animals to the standards required for successful conservation.

Cryoconservation

This is the collection and deep-freezing of semen, ova, embryos or tissues which may be used for future breeding or regenerating animals. Cryoconservation is also referred to as *ex situ – in vitro* conservation. A key question for cryoconservation is whether, in the short term, the facilities and expertise required for the collection of the samples can be financed and put in place. The logistics and costs of providing and maintaining storage facilities will need to be addressed before the cryoconservation is carried out.

Complementary roles of *in situ* and *ex situ* conservation

The Convention on Biological Diversity (CBD, article 8[2]) emphasizes the importance of *in situ* conservation and considers *ex situ* conservation as an essential complementary activity to *in situ* (CBD, article 9[3]). *In situ* and *ex situ* conservation are complementary, not mutually exclusive. The exact strategy will clearly depend on the conservation objectives. *In situ* and *ex situ* strategies differ in their capacity to achieve the different conservation objectives.

In situ conservation is often regarded as the preferred method because it ensures that a breed is maintained in a dynamic state. This may be true when the 'dynamics' of a breed are characterised by slow and balanced adaptation to conditions. However, commercially important breeds often suffer from high selection pressure associated to high levels of inbreeding (a few top sires fathering many offspring), while commercially less important breeds often have a small population number and are threatened by genetic drift and extinction. Conserving genetic diversity by keeping live animals outside their production or natural environment (*ex situ* - *in vivo*) not always will be able to guarantee the maintenance of the genetic diversity of a breed. Therefore, it is important that *in vivo* conservation be complemented by cryopreservation of germplasm. In other words, long term *in situ* conservation programs may benefit from a germplasm repository. Table 1.1 shows the relationship between conservation techniques and objectives. This information can be used to find the relevant conservation technique taking into account the conservation objectives that apply for the breed.

From this table it can be concluded that *in situ* conservation is the method of choice. However, it is not a safeguard against diseases and disasters and the loss of alleles by random drift and, therefore, *in situ* conservation should be complemented by cryoconservation. The latter is the method of choice when the flexibility of the genetic system is seen as the only objective for conservation. *Ex situ - in vivo* conservation has little to add to cryoconservation. It may, however, facilitate the regeneration of a breed with frozen semen due to the presence of a few living females from which to start the process.

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[2] http://www.cbd.int/convention/articles/?a=cbd-08

[3] http://www.cbd.int/convention/articles/?a=cbd-09

Table 1.1. Conservation techniques and objectives, adapted (Gandini and Oldenbroek, 2007).

	Technique		
Objective	Cryoconservation	*Ex situ – in vivo*	*In situ*
Flexibility of the genetic system, as			
• Insurance for changes in production conditions	Yes	Yes	Yes
• Safeguard against diseases, disasters, etc.	Yes	No	No
• Opportunities for research	Yes	Yes	Yes
Genetic factors			
• Continued breed evolution / genetic adaptation	No	Poor	Yes
• Increase knowledge of breed characteristics	Poor	Poor	Yes
• Exposure to genetic drift	No	Yes	Yes
Sustainable utilisation of rural areas			
• Opportunities for rural development	No	No	Yes
• Maintenance of agro-ecosystem diversity	No	Poor	Yes
• Conservation of rural cultural diversity	No	Poor	Yes

Objective: To find the appropriate conservation method for a breed.

Input:
1. A list of species to be conserved
2. A description of the theoretically applicable conservation methods

Output:
- A description of the conservation options applicable for each species in your country

Task. Describe the relevant options for conservation for the species and breeds in your country.

Action 1: Describe critically the state and applicability of in situ and ex situ conservation methods.
An *in situ* program can only be effectively organized when an association of breeders exits or when institutions are equipped with farms for this purpose (See Chapter 4). *Ex situ* conservation can only be executed when it is possible to collect, to freeze and to store semen and other materials reliably and safely.

Action 2: Describe the conservation options applicable for each species.
A table can be constructed with rows for the species and breeds and columns for the conservation methods. In maybe worthwhile to distinguish here three methods: *in situ*, *ex situ - in vivo* and cryo.

Action 3: Indicate what is done and what should be done to implement the relevant conservation methods in the relevant species.
This results in a description of activities already taken place and realistic options.

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2 Identification of Breeds at Risk of Endangerment

The overview described in Chapter 1 provided information on the breeds of the different livestock species present in the country and their functions, within the more general framework of the dynamics and trends in the use of livestock resources and opportunities for AnGR conservation.

In this chapter we will discuss the methodology to identify breeds that are at risk, those breeds where conservation attention might be addressed. As a result of censuses, surveys and analysis, the risk status of the national breeds can be assessed.

It is worth pointing out that breeds at risk may not all have a strong conservation value, and that in some countries funds could be insufficient to conserve all breeds at risk. This aspect of determining the conservation value and prioritizing breeds for conservation will be dealt with in Chapter 3.

Determining the level of endangerment for national AnGR

RATIONALE

Each country is responsible for the sustainable management of its AnGR. This also implies that particular attention must be given to breeds in danger of extinction. In 1992 the *Convention on Biological Diversity* specified the need for monitoring biological diversity, with particular attention to those genetic resources requiring urgent conservation measures (Article 7[4]). The importance for monitoring the level of endangerment of AnGR was more recently underlined in the Global Plan of Action: "*Complete national inventories, supported by periodic monitoring of trends and associated risks, are the basic requirements for the effective management of animal genetic resources*"[5]. The Global Plan of Action asks for country-based early warning and response systems. The assessment of the degree of endangerment of the breeds in the country is an essential element in these systems. Cooperation among countries is mandatory for monitoring endangerment in all transboundary breeds.

We can define the degree of endangerment of a breed as being a measure of the likelihood that, under current circumstances and expectations, the breed will become extinct in a specified period of time, and/or that it will lose through time its genetic variation at a non-sustainable rate (Gandini et al, 2004), leading to high proportion of monomorphic loci, loss of fitness and adaptability. These two aspects of breed extinction, loss of animals and loss of gene variants, are obviously deeply interconnected. However, for a general treatment of the problem, we can frame the issue separately in genetic and in demographic terms.

Population size and rate of population decline are the most important factors influencing extinction. Obviously, the smaller the population size of a breed, the greater its risk to be wiped out by a series of negative occurrences (low fertility and/or survival) or a single catastrophic event (e.g. epidemic disease outbreak). Breeds with continually decreasing population numbers will more quickly reach a critically small size at which risk for extinction becomes high. At an elementary level, we can consider a population of a size of N_0 breeding females at a given time, with a multiplicative growth rate of r per year (e.g. r = 1.01 corresponds to an increase of 1% per year). Then, after one year, N_1 will be equal to N_0 multiplied by r, and after *t* years N_t will be equal to N_0 multiplied by r^t (see Box 2.1).

Box 2.1
Growth rate and the dynamics of population size

We can consider, at a given time, a population of size N_0 *breeding females*. In a single reproductive period of one year the population has a multiplicative growth rate of *r*, then after one

[4] http://www.cbd.int/convention/articles/?a=cbd-07.
[5] Global Plan of Action for Animal Genetic Resources, Paragraph 23.

year $N_1 = N_0r$, and after t years $N_t = N_0r^t$. When r = 1 population is stable, r >1 and <1 correspond respectively to positive and negative (decline) rates of growth.

Example of growth dynamics in five years with different initial population sizes and growth rates.

Initial population size (N_0)	Growth rate (r)	Population after 5 yrs (N_5)	Trend
250	1.20	622	+
1000	0.92	659	-
2000	0.80	655	-

The example shows that reaching the size of about 620-660 breeding females in five years time is function of both the current population size (N_0) and the annual growth rate expected in the next years (r). A limit of this simple prediction model is that population growth rate is assumed to be constant through the future years, with no variance across years; for example a population of only 1 breeding female ($N_0 = 1$) with a growth rate of 1.0 is expected to survive with one female forever, that is not realistic because at a certain year the female could generate only males or could die before leaving progeny. Nevertheless, this simple model gives us important information to plan conservation actions, for example on the expected time we have to act to avoid population extinction.

Some complexity in this framework comes from the difficulties to accurately predict the growth rate over years. Very few breeds have available the time series census data required to estimate the growth rate. Most important, the growth rate will usually not have a constant value but will change unpredictably through time. Growth rate might change, for example, because breed profitability, and consequently the farmers' interest to keep the breed, is affected by changes in the market and in the competition with other production sectors, or by introduction of new regulations.

In addition to population size and trend, other demographic factors can influence risk. Concentration of the population in a restricted area or in a limited number of herds might place it at greater extinction risks. An additional element to take into account is the possible presence of controlled or uncontrolled crossbreeding. For each crossbred mating, the breed population size is effectively decreased by one-half an animal, from a genetic point of view and by a whole animal, from the perspective of maintaining a pure breeding population.

To analyse endangerment in terms of loss of genetic variation, one must understand that breeding populations undergo to random fluctuations in gene frequencies (genetic drift) each generation, depending on the sample of animals that are chosen as parents for the subsequent generation. When populations are smaller, these fluctuations tend to be larger and tend to reduce genetic variation because they can more easily result in the loss of alleles from the population. Genetic variation is necessary for the adaptation of the population to changes in the production environment and in market demands, as well as to guarantee response to selection programmes. This topic is discussed in Chapter 5. The inbreeding coefficient (typically expressed as "*F*") is the most commonly used parameter to monitor genetic drift and the consequent loss of genetic variation. Another commonly used parameter is the *effective population size* (N_e), which is defined as the number of breeding individuals in an idealized population that would show the same amount of random genetic drift or the same amount of inbreeding as the population under consideration. An *idealized population* is a randomly mated population with equal numbers of males and females uniformly contributing progeny, not subjected to other forces that change genetic variability, such as mutation, migration and selection. In *real* populations N_e is usually smaller than the actual (census) population size due to a smaller number of breeding males than females, high variance in progeny size in particular among males, and presence of selection. Inbreeding occurs at a rate per generation that is inversely proportional to the N_e, as $\Delta F = 1/(2\times N_e)$. Greater N_e thus is considered advantageous because it is associated with more genetic variation and less inbreeding.

The rate of inbreeding has a predictable form, and has a very important relationship with loss of variation: if σ_g^2 is the genetic variation, then the loss in a unit of time (e.g. per generation) is: $\Delta\sigma_g^2$ =

$\Delta F * \sigma_g^2$. Excessive ΔF might result also to decreases in fertility and productivity (this phenomenon is called *inbreeding depression*, See Chapter 5 and particularly Box 5.1) as well as increases in the occurrence of genetic abnormalities. The well known formula of Wright (1931), $N_e = (4*N_M*N_F)/(N_M+N_F)$, where N_M = number of males and N_F = the number of females, provides a simple estimate of N_e, which gives a useful general idea of the dynamics of genetic variability within a given population. Other approaches for calculation of N_e are more precise for livestock from a technical point of view, because the formula of Wright assumes several conditions that are rarely met in livestock populations (see Box 2.2).

Box 2.2

Basic rules to compute effective population size (N_e)

We have defined above effective population size (N_e) as the number of breeding individuals in an idealized population that would show the same amount of random genetic drift or the same amount of inbreeding as the population under consideration. Livestock populations obviously differ from an idealized population. There are different models to compute N_e, that take into account different aspects in which real populations departure from the idealized population.

The simplest model, generally used, proposed by Wright (1931), takes into account the fact that numbers of breeding males and breeding females are not equal, as $N_e = (4*N_M*N_F)/(N_M+N_F)$, where N_M and N_F are the numbers of breeding males and females, used as parents. Because half of the genetic information is transmitted by each gender, the scarcer gender is the limiting factor that primarily influences N_e.

For example:
Population A: 5 breeding males and 995 breeding females. In total, 1000 breeding animals.
$N_e = (4 \times 5 \times 995) / 1000 = 19.9$

Population B: 20 breeding males and 980 breeding females. In total, 1000 breeding animals.
$N_e = (4 \times 20 \times 980) / 1000 = 78.4$

Recalling that inbreeding occurs at a rate per generation that is inversely proportional to the effective size of the population, as $\Delta F = 1/(2 \times N_e)$, population A is exposed to an inbreeding rate almost four times greater than population B, although both populations comprise the same number of breeding animals.

We must underline that the above N_e model assumes absence of selection and a variance of the number of progeny among breeding animals corresponding to random mating. If selection is present, even some mass selection (i.e. on phenotype), the Wright formula overestimates N_e and consequently leads to an underestimation. Considering that mass selection is practically always present, we suggest the use of the adjustment proposed by Santiago and Caballero (1995) so that the adjusted N_e = original $N_e \times 0.7$. In this example, for population A, $N_e = [(4 \times 5 \times 995) / 1000] \times 0.7 = 13.9$; and for population B, $N_e = [(4 \times 20 \times 980) / 1000] \times 0.7 = 54.9$.
If relatives' information is used for the estimation of breeding values (e.g. with family-based indices or BLUP), unless inbreeding restriction strategies are implemented, adjustment factors even <0.7 should be used. Generally, whenever selection is applied, methods to control and monitor inbreeding should be used, particularly for small populations such as those in conservation programmes (see Chapter 6).

Given that N_e can be computed based on some aspects of the demographic structure of the population (e.g. population size and sex distribution), it can also be used as an indicator of population endangerment.

Therefore, we have two major criteria for evaluation of population endangerment: 1) the demographic criteria (parameter: number of breeding females and its growth rate) and 2) the genetic criteria (parameter: N_e). In assigning populations to categories of endangerment, we will use these two criteria as if they were independent, although the genetic and demographic parameters are obviously correlated.

In addition to future inbreeding, we have also to consider inbreeding already accumulated in the population during the recent past. High past ΔF might correspond to current low genetic variability in the population and therefore poor fitness and adaptability. Cumulated inbreeding can be estimated from the demographic history of the population, such as the presence of *bottlenecks* (periods of time with particularly low numbers of breeding animals) or, if available, can be computed from pedigree information, following standard techniques (e.g. path analysis and tabular methods).

We have by now framed the genetic aspect of endangerment using the generation as temporal unit. However, in planning a conservation programme, we should also work in terms of years. Then we can convert ΔF per generation to a yearly rate by simply dividing ΔF by the average generation length (in years). Generation length varies according to the species and the breeding system, but average generation length for local breeds can be estimated as the following: at least one year for fowl and ducks; 1 to 2 years for pigs; 4 years for sheep and goats; 6 years for cattle, buffalo, llamas and alpacas; and 8 years for horses, asses, and camels.

Breed endangerment is a complex issue, because numerous factors are involved (see Chapter 1), but also because the all the information to estimate the parameters necessary for prediction is rarely available. FAO has selected some simple parameters that can be known in many situations, however, thus allowing most countries to estimate the degree of endangerment of their breeds (see Task 2, Action 1 of this chapter). Different parameters and procedures have been proposed and/or are in use to estimate the degree of endangerment (for reviews see: Gandini et al., 2004; Alderson, 2009; Alderson, 2010; Boettcher et al., 2010). In those countries where more information is available, additional more accurate estimates can be proposed, but it is nevertheless strongly suggested that the simple estimates are calculated as well, to allow for harmonization among methodologies across countries.

Objective: To obtain objective information about the endangerment status of each breed.

Inputs:
1. List of breeds within the country (from Tasks of Chapter 1)
2. Existing information about population sizes, the composition of the populations, trends, geographical distribution of breeds
3. Existing information on the same/similar breeds in other countries
4. FAO *Guidelines on Surveying and Monitoring of Animal Genetic Resources*

Outputs:
1. New information about population size and trends and geographical distribution
2. List of breeds with their respective endangerment status
3. Methodology to update regularly the endangerment status

Task 1. Determine the population size, structure, trend, geographical distribution, and crossbreeding activities

Action 1. Form a task force to conduct breed surveys
An entity with the responsibility of determining the level of endangerment for national AnGR should be identified. As suggested in other chapters, this responsible entity might be the National Advisory Committee for AnGR, a specific task force established by the National Advisory Committee, or any other entity with sufficient knowledge. The FAO *Guidelines on Surveying and Monitoring of Animal Genetic Resources* suggests the establishment of a Strategy Working Group for surveying and monitoring of AnGR. This entity might directly conduct data collection or might coordinate and oversee subcontractors carrying out the survey. National Coordinators should be part of these entities or have a strong collaboration with them. In many cases, both information and expertise on breeds will be scattered in many places, including officially and unofficially recognized breed

associations, leading herds and elite breeders, breed experts, research centers, or universities. For this reason an accurate mapping of these potential sources of information should be done and a task force to conduct breed censuses, and more generally data collection, capable of obtaining all possible information, should be constituted.

Action 2. Gather information about each breed population

Adequate planning of data collection is important in ensuring the success of the survey and the quality of results. Planning should include accurate definition of the parameters to be collected, methodology of collection, identification of sources of reliable information, identification of collaborators, funding. Considering that information on the breeds of the country might be gathered from many different sources, it is advisable, as a first step, to define clearly parameters to be collected, based on criteria and methodology guiding information collection. In this way information will become homogeneous among breeds to be comparable when used to define level of endangerment.

The base set of parameters required to compute endangerment following FAO endangerment categories are:

- total number of breeding females (registered and not registered);
- total number of breeding males (registered and not registered);
- percentage of females bred to males of the same breed, considering that females used for crossing do not contribute to population renewal;
- trend of population size, classified as stable, decreasing, increasing, or, whenever possible, measured by an estimate of growth rate during the most recent years (see Box 2.3);
- presence of conservation programmes, and/or of populations maintained by commercial companies or research institutions, kept under strict control; and
- distribution, measured as: (a) length (km) of the maximum radius of the area within which approximately 75% of the population lies, (b) number of herds and its trend.

The collection of additional parameters facilitates refinement of the risk analysis, to understand the factors causing the breed dynamics and to improve the estimates of endangerment, as further discussed below in Task 2, Action 2. These include:

- number of registered breeding females (or at least an estimated percentage of breeding females on total females). Registered females constitute the part of the population that we can monitor in term of age structure, reproduction capacity, accumulated inbreeding, mating structure, gene introgression from other breeds and can actively participate in selection programmes if these are available;
- number of females registered each year. The annual number of registered female replacements has been suggested as a more accurate measure of population dynamics, mainly because it reflects the current interest of breeders for farming the breed (Sponenberg and Cristman, 1995; Alderson, 2009);
- number of males used in artificial insemination. In case of artificial insemination, contribution of males to the next generation can be highly heterogeneous, accelerating the inbreeding rate (see Chapter 5);
- percentage of introgression per generation through crossing with other breeds;
- presence and type of selection practiced in the breeding programme (mass selection, BLUP index selection, optimum contribution selection, etc.). Selection can consistently accelerate inbreeding rate if methods to control inbreeding are not accurately implemented (see Chapter 5);
- presence of recent or less recent bottlenecks (severe restrictions in the number of males or females in a past generation). These could probably have led to depletion of genetic variability, thus affecting the genetic variation currently present in the population;
- presence of active breeder associations, which is expected to increase the resilience of the breed;
- average age of farmers, as an indication of generational transfer of herds and an early indicator of future breed dynamics;

- cultural attachment of farmers to their breed. High attachment is expected to increase the resilience of the breed;
- economic competitiveness of the breed with other breeds and/or economic activities in the area, considering that population decline has been often associated to lack of economic competitiveness;
- national and regional trends in animal production;
- national GDP and the contribution of agricultural products to national GDP;
- economic and political stability of the country/region;
- risk of catastrophes such as epidemics, drought, floods.

The base set of parameters required to compute endangerment following FAO categories are self-explanatory, with the exception of population growth rate (see Box 2.3). For the additional parameters listed above, a common methodology within the country should be put in place for all breeds, thus allow across-breed comparisons. Several of the parameters are not quantitative in nature, and the use of a classification system is recommended. For example, presence of selection or recent bottlenecks could be categorized as "Yes" or "No". Cultural attachment of farmers could be classified as "High", "Medium" or "Low". In addition the systems used should be harmonized as much as possible across countries that may be collaborating in conservation activities. In this respect, communication and collaboration among National Advisory Committees on AnGR from neighboring countries is advisable.

Finally, we recall the importance of planning adequate human and money resources to carry out successfully data collection.

Box 2.3
How to estimate population growth rate

To estimate population growth rate we need at least two censuses at a time interval of at least several years or about one generation interval (species dependent). The two censuses might refer alternatively to number of total breeding females or number of registered females.

Then, rate of growth per year (r) is estimated as r = anti-log[(log N_2−log N_1)/t], where N_1 and N_2 are respectively the first and the second census of each breed and t the time interval in years between the two censuses. If more than two censuses are available, regression analysis could be used to obtain predicted values of N_1 and N_2 based on the trend across the multiple data points.

<u>Example:</u>
Data: Year 1 = 2000 and N_1 = 1000 breeding females; Year 2 = 2008 and N_2 = 800 breeding females; t = 8 years. Please note that if we refer to the horse species the two censuses encompass about one generation interval, and if we refer to the poultry species the period analysed encompasses about eight generation intervals, although this does not change the value of r.

Computation: r = anti-log[(log 800 − log 1000)/8] = 0.988. The growth rate r is <1, and the population size, measured as number of breeding females, has been decreasing.

Following Box 2.1, we can now compute the population size expected after another 20 years, in 2028, assuming that growth rate will not change.
Then, the number of breeding females in year 2028 is expected to decrease from 800 to 628, $800\times(0.988^{20}) = 628$.
We already underlined in Box 2.1 that this expectation assumes no variance of growth rate during the next years. In situations characterized by a consistent uncertainty, including high economic and political instability, high risk of catastrophes, particularly low level of agricultural fabric, of generational transfer of herds, and of cultural attachment to the breed, etc., the population size and growth rate through years should be monitored continuously.

Action 3. Analyse and interpret data
Data collection is only one step of the process. It is then necessary to analyze and interpret the data with the aim to estimate as accurate as possible the degree of endangerment of breeds and to identify and understand factors, in particular threats, influencing the degree of risk.

Data analysis should be anticipated by an accurate editing of the information directly collected or provided by contributors. To facilitate this step the analysis should be carried out as soon as possible after data collection. Contributors of information may be asked to provide notes useful for the interpretation of the data collected. The accuracy of the estimates of certain parameters can be verified by comparing them to information from other parameters. To give simple examples, the number of breeding males in a population using natural insemination should correspond logically to the number of herds and number of females, trends of populations should be compared to previous estimates, number of females registered each year should be compatible with the number of breeding females registered. The analysis of data might suggest collection of additional information to better understand breed dynamics and endangerment.

FAO Guidelines on Surveying and Monitoring of Animal Genetic Resources discusses in more detail the aspects of collection and analysis data and their interpretation. Specific textbooks and publications can provide details on statistical analysis methods (see Box 2.4 for an example). Conservation of AnGR involves many different aspects and disciplines, from conservation biology to sociology and economics. Discussion with experts of these disciplines might provide useful insight into the data and the consequences of trends observed in the data.

Box 2.4
Analysis of population data: an example.

Statistical analysis allows the understanding of the evolution of endangered populations within each country and insights in the factors affecting population dynamics. Below we report a simple example on simulated data.

Data collected on a hypothetical breed distributed across 8 herds.

Herd code	Herd size (No. of breeding females)	Reproduction	Farmer's Age (yr)
A	8	Natural	73
B	10	Artificial	70
C	60	Artificial	55
D	15	Natural	70
E	175	Artificial	45
F	70	Artificial	40
G	12	Natural	66
H	310	Artificial	42

Herd size: mean = 82.5; standard deviation = 107.8; range 8 to 310.
Herd size distribution: <50 herds (50%), 50-100 herds (25%), >100 herds (25%).
Farmer's age: mean = 57.6; standard deviation = 13.8; range = 40 to 73.
Correlation between herd size and farmer's age = -0.76.
Frequency of artificial insemination = 62.5%.
Frequency of artificial insemination as a function of herd size = herd <50, 25%; herd ≥50, 100%.

The statistical analysis shows that mean herd size provides limited information because number of breeding females varies widely across herds. There is a clear correlation among age of the farmer and herd size, the greater the age the smaller the herd, which could be explained with the fact that older farmers invests less in the farming activity. Larger herds use more frequently artificial insemination. The survival of small herds (50% of herds have less than 15 females) should raise some concern.

Task2. Identify breeds eligible for conservation activities

Action 1. Assign breeds to categories of endangerment
From a conservation point of view the most important outcome of the census and the survey is the categorization of the risk status for the extinction of the breeds. We have seen above that a limited number of parameters are sufficient to give an indication of risk and how the collection of additional information can refine the risk analysis by detecting underlying trends and causes. By combining and analysing the information collected, breeds may be classified in five categories including two subcategories of endangerment: extinct, critical, critical maintained, endangered, endangered maintained, vulnerable, and not at risk. In the absence of information, risk status is unknown.

The method proposed here combines, in terms of criteria and thresholds, the previous system of the FAO (*FAO Secondary Guidelines: Management of Small Populations at Risk*) with more recent proposals from the literature (Gandini et al., 2004; Alderson 2009; Alderson 2010).

The base categorization is based on two major parameters: numerical scarcity (number of females bred pure and their trend) and inbreeding rate (estimated by the number of males). In fact, when the number of males is much lower than the number of females, as in most livestock populations, N_e is approximately equal to four times the number of males and consequently inbreeding rate (ΔF) is inversely proportional to eight times the number of males. These two parameters are used to assign the breeds into six major categories in descending order with respect to risk: (1) *Extinct*, (2) *Critical*, (3) *Endangered*, (4) *Vulnerable*, (5) *Not-at-risk* and (6) *Unknown*. In addition, the categories *Critical* and *Endangered* include special subcategories (*Critical Maintained* and *Endangered Maintained*) to recognize breeds that are at risk according to scarcity and inbreeding rate, but that are actively managed for conservation and use.

Breeds should be assigned to the single category of greatest risk for which they qualify, based on the least favorable parameter of the two considered. In other words, if the number of females in a breed is small enough to indicate a breed is at *Critical* risk, then the breed should be assigned to that category, even if the number of males is large enough to suggest that it should be classified as *Endangered*. A breed cannot be both *Critical* and *Endangered*.

Species can differ greatly in their reproductive capacity, measured as number of breeding females produced by females during their life. Even if census size is equal, populations of species with low reproductive rates, such as the horse, are at relatively greater risk than populations of high reproductive capacity, such as the pig, because the response and recovery from population decline will require longer periods of time and more generations of breeding. For example, because female pigs can produce 10 or more offspring per litter and multiple litters per year, a pig population could easily double (or more) its population size within a single year, whereas the same process would require many years in a horse population. For the sake of simplicity, FAO in the previous Guidelines did not consider different category thresholds for different species. In these Guidelines this refinement is introduced, though in a simplified way. We recommend assigning the livestock species into two groups, the first group characterized by high reproductive capacity (High-RC species) such as pigs, rabbits, guinea pigs, and avian species, and the second characterized by low reproductive capacity (Low-RC species), such as species belonging to the Families Bovidae, Equidae, Camelidae and Cervidae. The Low-RC species group, for the reasons given above, have, for all endangerment categories, thresholds that are equal to 2X those of the High-RC species-group.

Please note that for these Guidelines, with the exception of the category *Extinct*, the presence of cryoconserved gametes and/or embryos, is assumed not to affect the degree of endangerment. The degree of endangerment is established on the basis of the population of animals kept *in vivo*. However, from a practical standpoint, existing storage of suitably sampled germplasm would be justification to assign a *Critical* or *Endangered* breed to the respective *Maintained* category and should be taken into consideration (in addition to the category of endangerment) in determining the priority for conservation (See Chapter 3).

Categories of endangerment

Extinct
A breed is categorized as extinct if it is no longer possible to easily recreate the breed population. This situation becomes absolute when there are both no breeding males (or stored semen), no breeding females (or oocytes) nor embryos remaining. The presence of sufficient cryopreserved material could allow for the reconstruction of a breed, even if no live animals are available (see *FAO Guidelines for Cryoconservation of Animal Genetic Resources*). For all practical purposes, extinction may be reached well before the loss of the last animal, gamete or embryo, because a small number of living animals represents a very small amount of genetic information which is insufficient to keep the breed viable.

Critical
A breed is categorized as *Critical* if: the total number of breeding females mated to males of the same breed is <100 (<200 for Low-RC species); or the overall population is >100 (>200) for Low-RC species) but the number is decreasing and expected to reach the size of 100 (200) for Low-RC species) females within 10 years; or the total number of breeding males is ≤5 (or ΔF is 3% or greater).

Critical Maintained
For breeds for which demographic characteristics assign a status of Critical, but that have active conservation programmes (including cryoconservation) in place, or populations that are maintained by commercial companies or research institutions.

Endangered
A breed is categorized as *Endangered* if: the total number of breeding females mated to males of the same breed is between 100 and 1000 (200 and 2000) for Low-RC species); or the overall population size is >1000 (>2000 for Low-RC species) but decreasing in size and expected to be between 100 and 1000 (200 and 2000 for Low-RC species) females within ten years; or the total number of breeding males is between 5 and 15 (or the expected rate of inbreeding per generation is between 1% and 3%).

Endangered Maintained
Breeds that are Endangered according to demographics can be considered *Endangered Maintained* if active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

Vulnerable
A breed is categorized as *Vulnerable* if: the total number of breeding females mated to purebred males is between 1000 and 2000 (2000 and 4000 for Low-RC species) or the overall population size is >2000 (>4000) for Low-RC species) but decreasing and expected to reach a size between 1000 and 2000 (2000 and 4000 for Low-RC species) within ten years; or the total number of breeding males is between 15 and 35 (or the expected rate of inbreeding per generation is between 0.5% and 1%).

Not-at-risk
A breed is categorized as *Not-at-risk* if the population status is known and the breed does not fall in the categories of Critical or Endangered (and the relative sub-categories) or Vulnerable. In addition, a breed can be considered *Not-at-risk* even if the precise population size is not known, but existing knowledge is sufficient to ensure that the population size exceeds the respective thresholds for the Vulnerable category. Nevertheless, for such breeds the implementation of a survey to obtain a more precise estimate of population size is strongly recommended.

Unknown
This category is self-explanatory and calls for urgent action. A population survey is needed, the breed could be Critical, Endangered or Vulnerable!

Endangerment categories and their thresholds, in the two species groups, are summarized in Table 2.1.

Action 2. Refine categorization of risk by accounting for other factors.
The thresholds presented above for assignment of breeds to endangerment categories, and reported in DAD-IS, should be used judiciously. They provide a basis to rank breeds within a country according to degree of endangerment. They should also help to identify factors acting on the degree of endangerment for each breed, now and in the future. They should prompt the need for additional data collection and breed monitoring. Their blind application is to be avoided. For example, to simply assume that all populations with more than 1000 (2000 for Low-RC species) females and 15 males are not *Endangered* may be risky. For example, historical bottlenecks or unreasonable mating and selection systems may have resulted in an average relationship and rate of inbreeding in the population that is much greater than expected based on numbers of breeding males and females (See Chapter 6).

The following considerations should be taken into account for the correct interpretation of the FAO endangerment categories:

- Concentration of a major part of the population in a restricted geographical area or in a few herds would usually place it at greater risk to the consequences of catastrophic events (i.e. events occurring rarely but reducing strongly the size of the population) such as disease outbreak, climatic or political upheaval. When the occurrence of such events is considered to be possible, breeds with a concentrated distribution should be upgraded to the next category with increased risk (e.g. from Vulnerable to Endangered). Such an analysis has been developed for United Kingdom, mainly considering risk of epidemic diseases but also breed dependence on specific small habitats (Alderson, 2009).
- To determine the number of breeding females we have always considered the females bred to males of the same breed, considering that females used for crossbreeding do not contribute to population renewal. In addition, it is important to monitor the degree of introgression to both the females and the males of the population from other breeds. Consistent levels of introgression will erode the original genetic variation of the population. Levels of 12.5%, 7.5% and 2.5% introgression per generation have been suggested as thresholds to consider a population Critical, Endangered and Vulnerable, respectively (Alderson, 2010). For the sake of simplicity, this aspect has not been taken into account as endangerment criteria in these Guidelines. However, we suggest, whenever possible, to consider this factor at the national level.

Table 2.1 Endangerment categories and their thresholds, in the two species groups.

		Demographic criteria Number of breeding females[a] current , or expected in ten years time							**Genetic criteria** Inbreeding rate / generation		
Species category[b]	***Endangerment Category***[c]	**<100**	**<200**	**=>100 <1000**	**=>200 <2000**	**=>1000 <2000**	**=>2000 <4000**	**and or**	**> 3%**	**>1% =<3%**	**>.5% =<1%**
High reproduction capacity	*Critical*	■							■		
	Endangered			■						■	
	Vulnerable					■					■
Low reproduction capacity	*Critical*		■						■		
	Endangered				■					■	
	Vulnerable						■				■

[a] Breeding females mated to males of the same breed (see text)
[b] Species categories – High reproductive capacity: e.g. pig, rabbit, poultry. Low reproduction capacity: e.g. horse, cattle, sheep, goat.
[c] Include the respective "Maintained" categories.
The table illustrates categorization as a function of the demographic criteria and the genetic criteria. To take into account the third major criteria, the distribution of animals, whenever the population is confined to small farming area or distributed in a small number of herds, consider to downgrade it by one endangerment class (see text). For example a pig population of 1800 breeding females distributed in three herds or farmed in a very restricted area should be classified as Endangered instead of Vulnerable.

- N_e must be large enough to allow the population to purge deleterious mutants and in this respect $N_e > 50$ has been suggested (e.g. Meuwissen and Woolliams, 1994). However, species differ with respect to generation interval. This implies that populations exposed to similar ΔF belonging to different species will accumulate in a given time period different quantities of inbreeding. For example, a chicken (generation interval of one year) and a horse population (generation interval of eight years) with an inbreeding rate per generation of 1% (corresponding to $N_e = 50$) will accumulate in eight years time approximately 8% and 1% of inbreeding respectively. However, for the sake of simplicity, in the endangerment categories we have not considered different inbreeding rate thresholds for the different species.
- When more information is available and in particular when categorization of a particular breed is borderline, additional analysis should be undertaken in order to refine the knowledge about the degree of endangerment of the breed, its causes and how to conserve the breed. For example, the demographical and inbreeding aspects can be more precisely evaluated by considering the number of registered females, number of males used in artificial insemination, number of herds, and their trends. Pedigree data and information about historical bottlenecks will yield information about genetic variability.
- As indicated previously, populations should be assigned according to the most critical parameter for which they qualify. Populations of several hundred females and a very limited number of males are not uncommon. For example, consider a breed of 2 200 cows, stable in size, that is managed with five bulls used in artificial insemination. This population should be categorized as Critical, based on the low number of males, even though the number of females would qualify the breed as Vulnerable. In such cases it should be underlined that the breed is in a high category of risk due to suboptimal management. By simply increasing the number of males from four to 25, the breed would fall in the category Vulnerable.

As already mentioned, different procedures have been proposed and are in use to estimate the degree of endangerment (for reviews see: Gandini et al, 2004; Alderson, 2009; Alderson 2010; Boettcher et al., 2010). Some methods put the emphasis on population demography (e.g. EC Commission Regulation 445/2002), others on genetic erosion based on the estimation of N_e (e.g. http://efabis.net). It is important to maintain consistency in principles and basic methodology. Then, whenever more information is available, countries may consider developing local criteria and thresholds of endangerment or refine them for the different species in addition to the worldwide FAO system. It is however strongly advised to retain the general demographic and genetic principles presented above and, as much as possible, search for homogeneity among criteria to facilitate comparison across countries.

More specific criteria of endangerment can be developed at the regional level, considering characteristics and data availability common to countries of the region. Such a process is used by the EFABIS database (http://www.efabis.net) for European breeds. In case of breeds farmed in more than one country, degree of endangerment should be first computed at the national level and, in collaboration with the other countries hosting the breed, at the regional or global level. If that exchange of animals or germplasm (semen and/or embryos) among country populations is large enough, national populations can be considered as subgroups of a single large population.

Then, whenever national populations are at risk due to their small sizes, collaboration among countries is mandatory to manage national populations as a larger single population.

Programmes for common management of country-populations should be implemented in particular for Critical and Endangered breeds, with the aim of controlling/reducing their endangerment status.

Box 2.5.
Conservation and use of breeds and of their roles might require larger populations for reasons beyond maintenance of genetic diversity

Breeds, besides being reservoirs of original genetic variation, might have cultural and environmental values. Local breeds have often played a central role for long periods in the agriculture tenures and in the social life of human populations; they can have important cultural values for their association to human communities and for their contributions to socio-cultural functions and rituals (Gandini and Villa, 2003; Gizaw et al., 2008). Erosion of local breeds and their farming systems diversity can results in loss of cultural richness.

In many areas of the world, traditional grazing through centuries has contributed to create and maintain agro-ecosystems of high biodiversity value (for a review on effects of grazing on biodiversity see Rook et al., 2004). Similarly, many landscapes have been shaped through times by traditional farming systems. The results of these co-evolution processes between local breeds, traditional framing systems and the natural environment retain their character and richness as long as grazing is maintained.

Population sizes larger than those given above to reduce genetic erosion and extinction risks might be necessary to guarantee breed roles such as provision of cultural and environmental services. For example, a few herds might be not sufficient to maintain agro-ecosystems such as the Dehesa in Spain (associated with farming of the Iberian pig) or summer Alpine pastures in Europe (associated with farming of the some cattle breeds). The same logic may apply for conservation of the cultural or the socio-economical value of a breed. However, investigations on the effects of number of herds, animals and their distribution on maintenance of cultural and environmental values are not available in the literature and research in this is welcome.

Population sizes larger than those given in Table 2.1 should be regarded as minimum goals. Due to economies of scale, breeds are more likely to be economically self-sustaining as their population size increases, at least to a certain point. Although also in this case no literature is available, it is reasonable to imagine, for example, that population sizes rather small might hamper the development and commercialization of food products linked to the breed and consequently breed profitability. In addition, larger breeds have more scope for combining increased selection while maintaining genetic diversity (See Chapter 6).

Action 3. Design interventions based on the category of endangerment.
What is the relationship between categories of endangerment and need for action?

- Populations categorized as Critical need urgent active management (action) and they may have already lost a major part of their variation. Urgent actions then include the need to determine the genetic status of the populations (e.g. accumulated inbreeding and/or amount of introgression from other breeds) and to estimate the probability of recovering from the critical status.
- Populations categorized as Endangered need action to develop and implement a conservation/development programme (action), to avoid reaching the Critical status, and possibly to upgrade to the Vulnerable status.
- Populations categorized as Vulnerable require the constant monitoring of their dynamics (warning), to understand potential negative forces, and preferably the implementation or improvement of development programmes to increase their economic competitiveness. As in many other fields, preventing breeds from reaching severe categories of endangerment is preferable to applying therapeutic actions.
- Populations categorized as Unknown need urgent analysis action to determine their endangerment status.

Techniques to manage populations at risk will be discussed in detail in Chapters 4 and 5.

Action 4. Disseminate information about risk to stakeholders

The degree of endangerment assumes a precise operational value if we consider that it gives us an indication of the time still available to evaluate options and to act before the breed will go extinct.

It is then important to communicate to all relevant stakeholders the results of the survey and of the analysis and the identity of the breeds at risk. Results will ideally stimulate them to act and will provide information for their work. The *FAO Guidelines on Surveying and Monitoring of Animal Genetic Resources* provide detailed information on how report and communicate results of surveys; these Guidelines also indicate the importance of providing the specific information to the relevant stakeholder groups. It also provides methodology on how identify appropriate messages and how to tailor communication methods.

The effective dissemination of information regarding the endangerment of breeds should also raise awareness among the general public and policy makers. Such activities can therefore facilitate the raising of funds that will be needed to support breed conservation activities. One approach is for each country to develop and publish a “Red List” of breeds at risk of extinction.

Although the dissemination of information at the national level is of primary significance, the exchange of information about breeds at risk is also important on the international level. FAO National Coordinators for Management of AnGR should obtain access to all information that may be useful to update the DAD-IS and EFABIS (for European countries) databases. It is also important to communicate and report difficulties encountered that could be taken into account to ameliorate and make easier subsequent investigations.

Task 3. Update of endangerment status

Livestock production systems in many areas of the world are being transformed at a high rate. These changes may affect demographic trends and the genetic status of local breeds consistently and within short periods of time.

It is therefore advisable to set up within each country a methodology to regularly update the endangerment status of breeds, as well as early warning and information systems capable of monitoring changes in nature and intensity of the major factors affecting negatively breed endangerment. To give an example, crossbreeding activities should be strictly monitored, as well as the number of males and their use, especially in populations where artificial insemination is widely practiced. Efficient monitoring and the analysis of the census data will be instrumental in prompting timely interventions to avoid loss of genetic resources.

The methods to survey the status of animal genetic resources and their threats may change over time as new techniques become available and modifications to the farming systems may occur. In these cases the change from one method to another one needs to be carefully analysed prior to be adopted, in order to ensure comparison between older and newer data in the future.

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3 Determining the Conservation Value of a Breed

Upon completion of the surveys, census and other activities described in Chapter 2, a country will have available a measure of the risk status of each of their breeds. All breeds other than those in the Not-at-Risk category may be considered as candidates for conservation activities. In the ideal situation, a conservation programme would then be developed for each of the breeds at risk. For most countries, however, the costs required to conserve all breeds at risk will be greater than the resources available for conservation.

Conservation of all breeds may also not be justifiable from a rational point of view, depending on the goal of the conservation program. Some breeds may be judged to have no particularly unique or valuable characteristics worth conserving, either for the immediate or long-term, and have little historical or cultural significance. In other cases, some breeds may be very similar genetically, meaning that a large proportion of the genetic diversity of the group can be captured by conserving only a subset of breeds, or in some instances by making a composite population from combining multiple closely related breeds. A decision will be necessary on how the resources available for conservation should be utilized and about which breeds should be conserved.

3.1 Accounting for factors other than endangerment in prioritizing breeds for conservation

RATIONALE

The level of endangerment or risk of extinction is generally considered the most important criterion for determining whether a breed should be subject to conservation activities. As a simple approach, the breeds can be ranked for endangerment and the breeds at the greatest risk will receive the greatest priority for conservation. Other factors may influence a breed's conservation value, however, and countries may wish to consider these aspects as well. Among the factors that may influence conservation priority of a breed or AnGR are the following (Ruane, 2000):

- **Species a breed belongs to** – In general, breeds of species that are more economically or culturally important to a country will merit a greater priority for conservation. In addition, species should have a high conservation priority within the countries where that species was originally domesticated, especially if that species is not common in other areas of the world. For example, in Peru, the alpaca has a high value for conservation and sustainable use for all of the above reasons.
  Practical considerations may also influence conservation priority among species. *In vivo* conservation programmes for small animals, such as poultry, rabbits or even small ruminants will likely be less costly than programmes for larger species such as cattle or horses. Thus, if all other factors (e.g. economic, cultural, etc.) are equal, such species may merit greater priority because more breeds can be conserved per unit cost of resources spent for conservation. On the other hand, larger animals may have more value per animal unit.
  Most formal, objective procedures for prioritization of breeds for conservation are applicable within species, rather than across species.

- **Genetic diversity of a breed –** As noted in previous chapters, genetic diversity is critical for the conservation of AnGR. Two aspects of genetic diversity can be considered in conservation decisions:

    - **Genetic uniqueness of a breed** – conserving breeds that are genetically distinct is an important criterion for establishing conservation priorities. Breeds that are genetically distinct from each other and from the breeds in the Not-at-risk category are particularly valuable. Understanding the genetic history of a particular breed will assist in determining breed uniqueness.

    - **Genetic variation within a breed** – genetic variation provides a given AnGR the capacity to adapt and allows for genetic response to selection. Conserving the most genetically diverse breeds is the most efficient way to conserve the diversity of a given species.

- **Phenotypic characteristics of a breed**

    - **Traits of economic importance** – clearly, exceptional economic productivity of a given breed is likely due in large part to superior genetics. Thus, action should be taken to ensure these genes are available for breeding programmes. Both current and potential importance of particular breed characteristics should be considered. Of course, breeds with currently high economic value are less likely to be at risk in the first place.
    Agricultural economists have proposed a description of values for AnGR that mirrors approaches used to describe other types of resources (See Box 3.1). This system of values facilitates the comparison of attributes that can be immediately marketed financially (such as milk or meat) with those that cannot (such as genetic variation).

    - **Unique traits –** breeds with special behavioural, physiological or morphological traits should be given high consideration for conservation, as these traits are also likely to have a genetic basis.

    - **Adaptation to a specific environment –** the adaptation of breeds to specific environments is likely to be under some genetic control. Thus conservation of these AnGR may be important and should increase the conservation value. Ability to adapt will be especially important if the environment conditions to which the breed is adapted are likely to become more common in the future (such as increasingly warmer conditions under predicted climate change scenarios).

- **Cultural or historical value** – Breeds were developed in part by human intervention and thus can be regarded as part of the cultural or historical heritage of a give region or population that has been passed across the generations and thus should be passed to future generations (Ruane, 2000). Therefore, breeds with greater cultural importance should receive greater conservation priority. In many areas of the world, traditional grazing through centuries has contributed to create and maintain agro-ecosystems of high biodiversity value. Similarly, many landscapes have been shaped through times by traditional farming systems. The results of these co-evolution processes between local breeds, traditional framing systems and the natural environment retain their character and richness as long as grazing is maintained. Thus, breed conservation may have an indirect value for conserving a unique ecosystem. Methods to estimate the cultural value of a breed are available (Gandini and Villa, 2003; Simianer et al., 2003).

- **Probability of success of conservation** – The main reason to prioritise breeds for conservation is to ensure that available resources are invested as wisely as possible. Future sustainability of a conserved breed must thus be considered during prioritization. Factors such as the existence of a breeders' association, organized record keeping, the existence of a stock of semen of past generations' sires or evidence of interest and cooperation among breeders often indicate a greater chance that the breed will survive with only a relatively small amount of formal assistance. On the other hand, breeds that have been diminished in size to only a few animals (and without other resources such as cryopreserved semen or embryos) may never achieve a large and diverse gene pool, regardless of interventions undertaken.

Objective: To determine conservation value for each breed, based on non-demographic factors.

Inputs:
1. List of breeds at risk.
2. Sources of information about factors influencing conservation value, including stakeholders.

Outputs:
1. Information about factors affecting the conservation value of each breed.
2. Ranking of breeds on the basis of conservation value.

Task 1. Assess the conservation value of breeds according to non-demographic factors.

Action 1. Assign responsibilities and assess the conservation strategy.
An entity with the responsibility for determining the conservation value of breeds must be established so that a clear and unambiguous decision can be made. This responsible entity may be the National Advisory Committee on AnGR described in Chapter 1.1, a special conservation task force, or even a single individual with sufficient knowledge of the AnGR within the country. However, for simplicity the discussion in this Chapter will always refer to the "National Advisory Committee" as the entity responsible for prioritization of breeds for conservation.

Action 2. Determine the factors upon which the conservation value will be based.
The first activity of this committee will be to evaluate the conservation objectives of each species (see Chapter 1.3) and, based upon these objectives, agree upon the factors to be considered in determining conservation value of the breeds, as well as their relative importance. If quantitative methods are going to be used to rank breeds (as described later in this section), the National Advisory Committee should agree on numerical weights for the factors used to determine conservation value that are proportional to their relative importance. To aid in this process, economists have suggested assigning the values of breeds to different classes and estimating values in monetary terms. Box 3.1 describes an approach for classifying values, which may be applied to breeds or other animal genetic resources.

The process of rationalization required to obtain a list of specific factors to be used for assessing conservation based on general conservation objective may be facilitated by also considering the conservation strategy. Bennewitz et al. (2007) outlined three strategies to consider.

1. Maximum risk strategy – This strategy considers only the degree of endangerment and can be justified if the main objective is to primarily prevent the near-term loss of breeds at high risk of extinction.
2. Maximum diversity strategy – This strategy considers only the genetic diversity of a breed, relative to the amount of diversity of other breeds that at risk and as a complement to the diversity of the breeds that are not at risk. This strategy may be optimal where a fixed amount of financial support is available for conservation activities and the goal is to capture as much genetic diversity as possible for the funds available.
3. Maximum utility strategy – This strategy considers factors beyond risk of endangerment and genetic variability and should be used if conservation programmes are expected to be partially or fully economically self-sustainable.

Box 3.1
Values of animal genetic resources

From a formal economics perspective, AnGR can have different types of values for conservation. These values can be categorized as follows (Drucker, 2001; FAO 2007b):

- Direct use value – based on benefits obtained from utilization of the AnGR, such as through the production milk or meat;
- Indirect use value – from the support or protection of other activities that produce benefits, such as through ecosystem services;
- Option value – based on potential benefits from having a given resource available for the future, such as genetic variability to respond to market and environmental changes;
- Bequest value – results from any benefits that might be obtained the knowledge that others may derive benefits from the AnGR in the future;
- Existence value – derived only from the satisfaction of knowing that a given AnGR exists, even if no other type of value can be immediately derived.

In most instances, indirect use and option values will be the most important for AnGR. The direct use value will contribute to economic sustainability of a breed and therefore, the potential success of conservation activities. Bequest and Existence values will likely only apply in particular situations.

Action 3. Gather the information necessary to determine the conservation value.

Once a decision has been made with regard to the factors influencing conservation value, research should be undertaken if necessary to determine the level of each breed with respect to each factor. For example, if the phenotypic characteristics of each breed are going to be considered, then this information should be recorded. For traits of economic importance, breed averages should be obtained. The presence of unique traits or of adaptation to a particular environment should be noted, if these qualities had been recognized as important. Pedigrees or genetic markers can provide insight into genetic variation (this topic is discussed in more detail in Chapter 4). Any historical or cultural significance of the breed should be noted.

Ideally, countries will have already characterized their breeds phenotypically and genetically prior to undertaking decision making on conservation. (See *FAO Guidelines for Phenotypic Characterization of AnGR* and *FAO Guidelines for Genetic Characterization of AnGR*, respectively). If breeds have been characterized, then most, if not all, of the information required will be gathered through that process. If characterization has not been undertaken, then the most efficient approach would be to combine characterization and gathering of data for conservation decision making. If this is not possible, then the person or persons responsible for collecting and organizing the information required may need to consult a number of sources. Ideally, the persons chosen to collect the information will have some existing familiarity with the breeds and can rely on this knowledge for part of the information gathering duties. Data for phenotypic traits may be available in the local or international scientific literature or in the local "grey" literature, such as technical reports. Various stakeholders (e.g., farmers and breeders, local historians) can be consulted to obtain information about other factors such as unique traits, breeding history for insight into uniqueness, and cultural significance.

Information about genetic diversity can be obtained from a variety of sources, which may differ in terms of their accuracy. For standardized breeds it will be possible to determine the origin of the breed and the influences of other breeds (introgression) in the past. Pedigree data can be used to estimate the level of inbreeding and its trend over time (ΔF) and therefore, N_e. As discussed more in the next subchapter, genetic markers can be used to evaluate genetic diversity within breeds and genetic relationships among breeds. In the absence of these sources of information, consultation with stakeholders with knowledge of the history of breeds can yield valuable data. Past population bottlenecks (severe reduction in the population numbers) will lead to decreased variation in the current population. Past crossbreeding can be expected to have decreased the uniqueness and distinctiveness of a breed. Widespread use of artificial insemination will likely have decreased N_e, through increased imbalance in the ratio of male versus female parents.

Action 4. Discuss and evaluate the advantages and disadvantages of the breeds.
Chapter 1 (Section 1.6) recommended the undertaking of a SWOT analysis to describe the roles, functions and dynamics of livestock species in each country, to assist in establishing conservation objectives. The information from this analysis, along with the information gathered from Action 3 can serve as the basis for a discussion about the values of each breed and its respective contribution to the various conservation objectives.

Ideally, this discussion should be held by the members of the National Advisory Committee. The merits and disadvantages of each breed should be noted. The results of this discussion and evaluation should be summarized and made available in written form, so that the committee can easily explain their final decisions, if such an explanation is requested by policy makers in the future.

Action 5. Rank breeds for conservation value.
Based on the group discussion and analysis, breeds should be ranked for conservation priority. Both subjective or objective and quantitative approaches can be considered. At the close of the discussion undertaken in Action 4, it may be possible for committee members to simply arrive at a clear consensus on a priority order for the breeds at risk. If a consensus cannot be reached, a vote can be taken to obtain a final decision.

Subjective decisions can also be taken when the responsible entity is a single person. In such a case, it will be important to document the logic followed in the decision-making process in order to inform policy makers and other stakeholders.

To undertake an objective quantitative approach, the attributes for each breed for each factor influencing conservation priority must be expressed numerically. This will automatically be the case for statistics, such as breed averages for economically important traits, but not necessarily for factors such as presence and absence of special traits or cultural importance. For presence and absence of unique or adaptive traits, presence of each trait can scored as = 1, whereas absence can be scored as = 0. When multiple special traits are considered, then results can be summed for each breed. For historical and cultural significance, two options may be considered:

1. Breeds can be ranked for cultural significance, and then assigned scores corresponding to their ranking. For example, for a group of three breeds, the breed with the most cultural importance can be assigned as score = 3, the second = 2 and the third = 1.
2. Breeds can be rated for cultural significance. For example, members of the AnGR conservation committee can each be asked to rate every breed for its cultural importance on a 1 to 10 scale, with 10 being "very important" and 1 being "not important". Ratings for each breed can then be averaged across committee members.

Breeds at the greatest risk for extinction should generally receive the highest priority, so decisions should be made separately for each risk category. When there is only a single factor upon which to base conservation priority, the decision is straightforward. Breeds can simply prioritized (within risk category) based on their ranking for the single factor.

When multiple factors influence conservation value, then a simple multi-factor index can be used to prioritize breeds. The following formula can then be applied to establish conservation values:

$$CV_i = w_{F1} \times (F1_i - \mu_1)/\sigma_{F1} + wF_2 \times (F2_i - \mu_{F2})/\sigma_{F2} + ... + w_{Fn} \times (Fn_i - \mu_{Fn})/\sigma_{Fn}, \quad (E3.1)$$

where,

CV_i = is the conservation value of Breed i

w_{F1} = is the weight (i.e. relative importance) of Factor 1 (e.g. milk yield),

$F1_i$ = is the value for Factor 1 for Breed i,

μ_{F1} = is the average of all breeds for Factor 1,

σ_{F1} = is the standard deviation of all breeds for Factor 1,

and so forth for the rest of the Factors to be considered. Box 3.2 has an example for a situation where three hypothetical breeds must be prioritized for conservation.

Task 2. Disseminate information to stakeholders.

Stakeholders involved in implementing or financially supporting AnGR conservation programmes must be informed about both the results of the breed prioritization and the logic used in the prioritization.

Action 1. Prepare a report on breed prioritization.

The results of the prioritization of breeds should be summarized in a written report that is distributed to stakeholders. The report should also include an explanation of the procedures employed and a summary of the information used to support the analyses.

Action 2. Hold meetings with stakeholders to explain the results of the prioritization.

Stakeholders should be given an opportunity to discuss the results of the prioritization activities and to voice any concerns in the final ranking of breeds. Any concerns should be taken seriously and addressed sincerely, because the efforts made in prioritization will be wasted if stakeholders refuse to accept them and implement programmes according to the recommendations.

Box 3.2

Example: Use of a simple index to prioritize three breeds for conservation

The following is a hypothetical situation for prioritization of three breeds for conservation, based on four different factors. Table B3.2a below has the values assigned to breeds each of the four factors, along with the relative weights assigned to each.

Table B3.2a. Breed values, population averages and weights for four factors to be considered in conservation prioritization.

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

In this situation, effective population size (N_e), genetic uniqueness, annual milk yield per female and cultural importance are the four factors under consideration. This is an example of applying the "maximum value strategy" for evaluating breeds. Two of these factors, N_e and genetic uniqueness, are both measures of genetic diversity. N_e is considered most important by the National Advisory Committee, and thus gets the greatest weight. N_e and milk yield are estimated and measured quantitative factors, whereas genetic uniqueness and cultural importance are based on ratings. Each of the three breeds is superior to the others in one of the four factors: Breed 1 has the greatest milk yield, Breed 2 has the most genetic diversity (for both measures) and Breed 3 is the only breed considered to have any particular cultural importance.

Table B3.2b shows intermediate calculations and final values for the conservation value index for each breed. Standardized values are the factor values minus overall mean, divided by standard deviation. Weighted values are standardized values times weights. Conservation values are the sums of weighted values for each breed.

Table B3.2b. Standardized and weighted values and overall conservation value and rank for three breeds.

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

According to the conservation value index, Breed 2 merits the greatest priority for conservation, because of its superiority in genetic diversity, the most important factor. Breed 3 ranks last despite its high cultural importance, because this factor is not considered as important as genetic variability or milk yield, for which this breed is inferior.

3.2 Use of genetic markers to account for genetic diversity in conservation

RATIONALE:
The importance of maintaining diversity and genetic variation in AnGR has been established in previous chapters. Genetic variability allows for adaptation and genetic improvement and protects against the detrimental effects of inbreeding, such as increased occurrence of genetic defects and decreases in fecundity and viability. Genetic diversity and variation should thus be considered in planning of conservation programmes and in the prioritization of breeds for conservation activities.
Genetic markers based on DNA can be used to derive objective estimates of diversity both within and across breeds and these estimates can be used in prioritizing breeds and making conservation decisions. When breeds have been subject to genetic characterization and molecular genetic data are therefore available, formal methods can be used to objectively account for genetic variability along with other factors when assigning priority to breeds for conservation.

Objective: To evaluate the genetic diversity of breeds and account for it in decision-making regarding breeds for which conservation activities will be undertaken.

Inputs:
1. Information with regard to the general conservation objectives to be addressed.
2. List of breeds at risk for which conservation programmes are to be considered
3. Information about each breed for factors that affect conservation value
4. Molecular genetic information required to evaluate breed diversity

Outputs:
1. Quantified analysis of the genetic diversity of breeds for each species
2. List of breeds prioritized for conservation

Task 1. Gather data needed to apply objective methods of breed prioritization

Action 1. Obtain molecular genetic data on breeds

Genetic characterization is a recommended step in the evaluation of breeds for improvement of their management and development of programmes for sustainable use and conservation. Genetic characterization includes the collection and analysis of DNA from a sample of animals from each breed of interest, in order to evaluate the genetic variability on the molecular level and determine relationships among breeds (Box 3.3). *FAO Guidelines for the Genetic Characterization of Animal Genetic Resources* are available.

Box 3.3
Genetic markers and livestock diversity

Molecular genetic markers are sites of variability in the sequence of DNA that have a statistical association with a characteristic to be measured in different cells, individuals or populations. Various types of markers exist, differing in the types of variation evaluated and the laboratory procedures used. Markers can be "neutral" or affected by the process of selection. Neutral markers are recommended for measuring genetic diversity and population genetic statistics and selective markers are associated with phenotypic traits. In the last two decades molecular markers have been widely used to investigate the genetic diversity of livestock populations. In the late 1980's to early 1990's the use of short tandem-repeat DNA sequences, namely microsatellites, became popular because of their high polymorphism, high information content, speed of assay, low cost and suitability to analysis in automatic sequencers. They have also been extensively used for investigating the evolutionary history and diversity of livestock species.

As a result of whole genome sequencing and HapMap projects, millions of Single Nucleotide Polymorphisms (SNP) have recently been identified in several livestock species. From these, panels including tens of thousands of validated SNPs are already available to the scientific community (e.g in cattle, sheep, chicken and pig) or will likely be available in the near future (e.g. in goat, horse), permitting genome wide scans at a very low cost per data point. SNP panels open up new perspectives to livestock genetics, in particular for the investigation of genome diversity within and among individuals and populations, population structure and inbreeding and for the identification of signatures left by selection. This last application provides an attractive prospect for the identification of genomic regions sustaining traits very difficult to record and directly linked to sustainability.

With the step-change in DNA sequencing technology, whole genome data are a realistic target for population and conservation studies in the very near future. Technology provides new methods to assay adaptive variation in the genome of threatened populations, enabling prioritization protocols to use unique adaptive variants as well as neutral, demographically mediated variation and even to test the association of this variation with environmental variables to identify geographic regions of priority (e.g. Bonin et al. 2007; Joost et al. 2007). By examining all regions of the genome and through genome specific coalescent analysis, the effects of mutation, drift, selection and admixture can be distinguished at a fine scale. Therefore, for example, locally adapted variants can be distinguished from ancestral polymorphisms and hitchhiking selection can be distinguished from admixture.

For reliable results, DNA should be collected from at least 40 animals, at least 10 of each sex. Animals should be as unrelated as possible and should represent the geographical distribution of the breed. Animals should be genotyped by using the most informative system of genetic markers available, considering financial constraints. Current recommendations are to use the panels of 30 species-specific microsatellite markers compiled by the ISAG-FAO Advisory Group and listed in the *FAO Guidelines for the Genetic Characterization of Animal Genetic Resources.* Ideally, genetic characterization data should be obtained not only for the breeds at risk, but also for the Not-at-risk local breeds and transboundary breeds in the country. High genetic similarity to these latter types of breeds indicates low distinctiveness and thus diminishes a breed's conservation value.

Action 2. Agree upon specific genetic objectives for maintenance of genetic diversity
The general objective to conserve genetic diversity may have a specific goal and these objectives will impact the definition of molecular genetic diversity. Different objective approaches to account for genetic diversity are more or less appropriate depending upon the specific type of genetic diversity to be conserved.

For example, the specific goal may be to maintain the maximum amount of joint diversity across breeds. Alternatively, conservation of genetically distinct breeds may be the primary objective. Otherwise, ensuring the maintenance of specific alleles may be important. In most cases, a balance between conserving specific breeds and across-breed diversity will be the most logical objective.

Box 3.4

The use of genetic markers for estimation of genetic distances among breeds

Genetic distance is a quantitative measure of genetic divergence between two sequences, individuals, breeds or species. For a pair of livestock breeds, genetic distance provides a relative estimate of the time that has passed since the two breeds existed as part of a single, panmictic population. Divergence is measured through changes that have occurred through allelic substitution, resulting in different allelic frequencies among breeds.

Many approaches for estimation of genetic distance exist. One that is considered particularly appropriate to account for short term genetic differences, such as those due to breed formation, is that proposed by Reynolds et al. (1983)

$$\text{Reynold's genetic distance} = \frac{1}{2} \cdot \frac{\sum_k (p_{xk} - p_{yk})^2}{\sum_j \left(1 - \sum_k p_{xk} p_{yk}\right)},$$

where, for j different loci and different alleles for each locus and two breeds *x* and *y*, p_{xk} and p_{yk} are the frequencies of allele k in breeds x and y. Various software are freely available for estimating genetic distances from genetic marker data, including TFPGA (http://www.marksgeneticsoftware.net/tfpga.htm - Miller, 1997) and PHYLIP (phylip.com – Felsenstien 2005).

Action 3. Choose the objective method to be applied based on the genetic objectives and the definition of molecular diversity
The application of objective approaches to account for molecular genetic diversity in the

prioritization of breeds for conservation has been reviewed by Boettcher et al. (2010). Various choices exist, which vary according to the definition of genetic diversity. The Weitzman (1992) approach measures genetic diversity according to genetic distances among breeds (Box 3.4) and therefore considers exclusively the genetic differences among breeds and ignores genetic variation within breeds. This approach can be applied when only uniqueness of breeds is considered important and no crossing of breeds is ever expected to be undertaken in the future. The prioritization procedures of Caballero and Toro (2002) and Eding et al. (2002) define diversity according to kinship (Box 3.5) and is suitable when within breed diversity is of primary importance and crossing of conserved breeds is expected to be common in the future. For most situations, future activities will emphasize the maintenance of distinct breeds, with some crossbreeding. Therefore, the definitions of diversity used in the prioritization methods of Piyasatian and Kinghorn (2003) and Bennewitz and Meuwissen (2005), which consider an intermediate balance of within and across-breed variability, will be the best option (Meuwissen, 2009).

Box 3.5

The use of genetic markers for calculation of kinships among breeds

The "kinship" or the "coefficient of kinship" (also known as "coancestry") between two individuals is defined as the probability that single alleles drawn from the same locus of each of the two individuals are identical by descent from a common ancestors. Kinship is used as a measure of genetic diversity and diversity decreases as kinship increases. Kinships can be estimated with pedigree data if the data are sufficiently complete to trace pedigrees back to common ancestors. However, such detailed pedigree data often is missing for many breeds in most countries and is almost universally absent for estimation of kinships across breeds. Genetic markers can be used, however, to obtain estimates of kinship between individuals and average kinships both within and across breeds.

For a single locus with K different alleles, a simple measure of kinship between two breeds can be calculated with the following equation:

$$\text{simple kinship} = \sum_k p_{xk} p_{yk} \,,$$

where p_{xk} and p_{yk} are the frequencies of allele *k* in breeds *x* and *y*, respectively. To obtain a full kinship matrix **M**, this kinship should be calculated for each locus for all combinations of breeds (including for the case when breeds *x* and *y* are the same) and averaged across loci. For an example with three breeds:

$$\mathbf{M} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix},$$

where m_{11} is the average simple kinship across all loci for breed 1 and itself, m_{12} is the average simple kinship between breeds 1 and 2, and so forth.

Note that the estimate of kinship described above is simple and is based on some genetic assumptions that will generally not be true in livestock populations. Eding and Meuwissen (2001 and 2003) describe methods to account for the additional complexity of livestock populations in estimates of kinships. The software Molkin (http://www.ucm.es/info/prodanim/html/JP_Web.htm) can be used to compute average kinships of groups of breeds (Gutierrez et al., 2005).

Action 4: Estimate extinction risk

As noted earlier, extinction risk is generally the most important factor in prioritization of breeds. The prioritization approaches discussed in Section 3.1 account for this implicitly, by recommending that breeds are prioritized within each risk category and that breeds within the higher-risk category be given greatest priority. The objective methods of prioritization with molecular genetic information imply the use of a quantitative estimate of extinction risk.

There are several ways to approach accounting for a quantitative measure of extinction risk:

- First, if the National Advisory Committee is satisfied with the assumption that risk is equal within risk category and does not wish to consider prioritization across categories, the objective approach can simply be applied within risk category, and all breeds can be assigned a equal risk of extinction (0.25, for example), regardless of risk category.
- Second, if the country is willing to assume extinction probability is equal within risk category, but would like to allow for prioritization across risk categories, then reasonable estimates of probability of extinction can be established for each category and breeds within the same category can be assigned the same risk value. For example, extinction probabilities of 0.50, 0.25, and 0.10 may be reasonable for Critical, Endangered and Vulnerable categories, respectively.
- Third, countries may wish to estimate a specific extinction probability for each breed. Three general approaches can be identified for estimation of extinction probability. The first approach is to identify factors assumed to affect breed extinction and use them as parameters to define endangerment categories to which breeds are assigned (Reist-Marti et al., 2003). The second method is to predict the trend in persistence of populations over time through mathematical modelling of population dynamics (Bennewitz and Meuwissen, 2005b). The third approach is to use loss of genetic variation through time as a proxy for extinction (Simon & Buchenauer, 1993). In general, the second and third approaches require historical census and pedigree data, respectively, which may limit or preclude their application in many countries.

Action 5: Determine non-genetic factors to include in prioritization

As has been explained earlier in this chapter, many factors in addition to genetic variability and extinction risk may influence the conservation value of a breed. Many of the objective methods allow for the consideration of such factors in prioritization. The information collected in Actions 3 and 4 in Section 3.1 should be incorporated into objective approaches for prioritization.

Action 6: Prioritize breeds for conservation

Examples of a comprehensive approach for objective prioritization of breeds for conservation has been presented by Reist-Marti et al. (2003) and Gizaw et al. (2009). An adaptation of their approach is summarized step-by-step in Box 3.6.

Box 3.6

Step-by-step overview of an approach for objective characterization of breeds,

Step 1: Estimate extinction risk

Following the framework of Reist-Marti et al. (2003), extinction risk for each breed can be estimated by assigning values to each breed for various criteria that are related to breed survival. Below is an example based on five criteria: 1) population size, 2) change in population size, 3) geographic distribution, 4) presence of breeding programmes, and 5) farmer satisfaction. Examples of other factors that could be considered are level of crossbreeding, ratio of breeding males to females, and level of civil unrest within the country.

For each criterion, ordered categories should be established, with each successive category being associated with greater risk. A fractional value (i.e. <1) should be assigned to each category, with the value increasing in size as risk increases. The range in values should correspond to the importance of the criterion. The sum of all maximum values should be <1.0. Adapting this approach, the following system could be used:

s ~ estimated population size,

- s = 0.0 if population size is ≥ 100 000
- s = 0.1 if population size is between 10 001 and 100 000
- s = 0.2 if population size is between 1 001 and 10 000
- s = 0.3 if population size is < 1 000

c ~ recent change in population size (e.g. previous 10 years),

- c = 0.0 if population is relatively stable or increasing
- c = 0.1 if population has decreased by 10 to 20%
- c = 0.2 if population has decreased by >20%

g ~ geographical distribution

- g = 0.0 if the breed is found in locations across the country
- g = 0.1 if animals tend to be found in a single specific area of the country

p ~ maintenance of purebred animals through formal programmes such as a breeding association or government nucleus,

- p = 0.0 if a strong programme exists
- p = 0.1 if a relatively weak programme exists
- p = 0.2 if no formal programme exists

f ~ farmers' opinions towards the economic or productive performance of their breed – based on a survey with scores assigned on a 4-point scale where 1 = poor and 4 = excellent

- f = 0.0 if average farmer opinion ≥3
- f = 0.1 if average farmer opinion <3

For each breed i, extinction risk is equal to the sum of the values for the five parameters:

$$risk_i = s_i + m_i + x_i + p_i + f_i + 0.05$$

The addition of 0.05 is to ensure a result between 0.05 and 0.95.

Step 2: Assign conservation values independent of genetic diversity

The same conservation value (CV) index procedure shown in Equation E3.1 and Box 3.2 should be applied to all breeds, except that factors associated with the genetic diversity of the breeds should be removed from the calculation, because these factors will be accounted for by the genetic markers. However, in order to use the approach of Gizaw et al. (2009) the CV resulting from Equation E3.1 should be standardized to fall within a range between 0.1 and 0.9.

To obtain standardized conservation values (SCV) from non-standardized (CV), the following procedure is to be used:

1. The breed with the greatest CV (CV_{max}) should be assigned a SCV = 0.9.
2. The breed with the smallest CV (CV_{min}) should be assigned a SCV = 0.1.
3. For a given breed *i* with CV between CV_{min} and CV_{max}, SCV can be determined by applying the following equation:

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

Application of this equation will result in a set of SCV that range between 0.1 and 0.9.

Step 3: Account for genetic diversity of breeds on the basis of marker data

To determine the relative importance of each breed with regard to its genetic diversity, the recommended strategy is to apply the approach of Bennewitz and Meuwissen (2005) to determine the contribution of each breed to a "core set" of breeds that will capture the optimal amount of genetic diversity. The assistance of a statistician or mathematician will likely be necessary for this analysis.

The first step in this procedure is to calculate a matrix (**M**) of genetic relationships (marker-based kinships) according to alleles shared among the animals genotyped from each breed See Box 3.5).

Then a vector (**c**) of contributions of each breed to a "core set" of breeds that maximize genetic variability will be obtained by calculating the following matrix calculation:

$$\mathbf{c} = \frac{1}{4}\left[\mathbf{M}^{-1}\mathbf{F} - \frac{1'_{\mathbf{N}}\mathbf{M}^{-1}\mathbf{F} - 4}{1'_{\mathbf{N}}\mathbf{M}^{-1}1_{\mathbf{N}}} \cdot \mathbf{M}^{-1}1_{\mathbf{N}}\right],$$

where $\mathbf{M}^{-1}$ is the inverse of the kinship matrix among breeds, **F** is the diagonal of **M** (i.e. a vector of within-breed kinships) and $\mathbf{1}_N$ is a vector of 1's of length equal to the number of breeds.

This calculation will yield for each breed a contribution parameter between 0.0 and 1.0. This parameter can be denoted D_i for a given breed *i*. Some breeds will likely contribute little diversity or distinctiveness and will have a contribution of zero.

Step 4. Calculate total utility, which will be the basis for prioritization.

The breeds can then be prioritized based on total utility (U_i) according to the following formula:

$$U_i = 4 \times (risk_i \times D_i) + SCV_i,$$

where,

- U_i is the total utility for breed *i*
- 4 is a constant value that determines the weight placed on the combination of risk and diversity (D) relative to conservation value (SCV) and can be changed according to national priorities. Countries may consider comparing results using different values of this constant.
- $risk_i$ is the risk of extinction for breed *i*, as calculated in Step 1,
- D_i is the contribution of breed *i* to the overall genetic diversity of the collection of breeds, as determined in Step 3,
- SCV_i is the standardized conservation value of breed *i*, from Step 2.

The breeds should then be ordered according to total utility (U) and the breed with the greatest total utility is considered to have the greatest priority for conservation, the second greatest should be considered the second most important for conservation, etc.

Task 2. Disseminate information to stakeholders

Regardless of the prioritization procedure, the stakeholders of conservation programmes must be informed about the priority assigned to breeds. Actions equivalent to those described in Task 2 of Section 3.1 above should thus be undertaken

3.3 Choosing the conservation method for each breed

When the selection of breeds is done and the priority list is made the question raises what conservation strategy should be used? Is *ex situ* the appropriate method or is the *in situ* conservation the method of choice? Or is it better to combine *ex situ - in vitro* with *ex situ - in vivo?*

RATIONALE

As is explained in Chapter 1, in situ, *ex situ* – *in vivo* and cryoconservation have different advantages and disadvantages.

The advantages of cryoconservation are:
- It safeguards the flexibility of the genetic system
- It protects (founder) alleles from genetic drift (founder animals that are no longer in the recent generations of the pedigrees of living animals can be re-used for breeding).

The disadvantages of cryoconservation are:
- It inhibits the breed evolution and adaptation to the environment
- It does not contribute to objectives related to sustainable utilization of rural areas

The advantages of *in situ* conservation are:
- It is an insurance for changes in production conditions and offers greater opportunities for research
- It facilitates breed evolution and adaptation to the environment and gives insight into breed characteristics
- It creates possibilities for sustainable utilization in the rural area

The disadvantages of *in situ* conservation are:
- It does not safeguard the breed against disasters and diseases
- It does not protect (founder) alleles from genetic drift (alleles with a low frequency in the population can easily disappear due to low numbers of breeding animals)

The advantages of *ex situ - in vivo* conservation are:
- It is (but much less than *in situ* conservation) an insurance for changes in production conditions and offers opportunities for research
- It offers an opportunity to regenerate quickly a breed out of the limited number of females available (with *ex situ* conserved semen), without applying a crossbreeding strategy.

The disadvantages of *ex situ - in vivo* conservation are:
- It inhibits breed evolution and adaptation to the environment

- It contributes only minimally to objectives related to sustainable utilization of rural areas
- It does not safeguard the breed against disasters and diseases
- It does not protect (founder) alleles from genetic drift (alleles with a low frequency in the population can easily disappear due to low numbers of breeding animals)

Objective: To choose the appropriate conservation strategy. To find the right conservation technique Gandini and Oldenbroek (2007) proposed a five step approach:

1. Establish the conservation objectives that apply to the breed
2. Rank the conservation methods for their efficacy to reach the conservation objectives
3. Rank the conservation methods for risk of failure
4. Rank the conservation methods for costs
5. Choose the conservation method

Input:

- awareness of the advantages and disadvantages of the different applicable options for the species and breeds to be conserved

Output:

- decisions on the conservation method to be applied for the different species and breeds

Task 1. Determine which conservation methods are available in your country

Action 1. Take an inventory of stakeholders and available expertise and technology
Some conservation methods (cryoconservation in particular) will require special equipment and expertise. Lack of these resources will limit the options available.

Task 2. Match breeds with the most appropriate conservation method

Action 1. Establish the conservation objectives that apply to the breed
The first question to be answered is: why is this breed on the priority list for conservation? The answer to this question could influence the choice of the conservation method. For example, if the main reason is its contribution to the future genetic diversity of the species and to the genetic flexibility, then cryoconservation is first the method of choice. If the main reason is the present function of the breed in the rural area then *in situ* conservation is preferred.

Action 2. Rank the conservation methods for their efficacy
Not all conservation methods have the same efficacy with respect to the conservation objective. When a breed is conserved *ex situ* to accommodate crossbreeding (to introgress some unique alleles) this method is very efficient. When a breed is cryoconserved to regenerate it in a later phase, then the use of semen will be more time-consuming than with embryos because many generations of crossbreeding are required to obtain the conserved breed. When a breed is conserved *in situ* for its present function in the rural area, the enthusiasm of farmers to keep this breed strongly depends on market prices for the products of this breed.

Action 3. Rank the conservation methods for risk of failure

When a breed is cryoconserved the following risk factors may create a failure:

- Material for cryoconservation (gametes, embryos) must meet high sanitary requirements and animal disease might disturb or inhibit collection of this material.
- Freezing, maintenance and thawing of frozen material require special skills and reliable equipment and infrastructures. To avoid risk, professional gene banks often store the material of an individual animal at two different locations.

When a breed is conserved *in situ* risk factors are:

- Disasters and infectious diseases may destroy the population
- Genetic bottlenecks and high relationships between animals may occur, causing inbreeding and loss of alleles by random drift if the population is not maintained correctly
- Farmers have the right to operate their farms according to their own prerogatives and may decide to abandon the breed if maintaining it is not financially attractive
- When a breed is used for landscape management, subsidies are often a substantial amount of farmer's income. If the subsidy stops, the breed is at risk.

When a breed is conserved *ex situ - in vivo* many risk factors may create a failure:

- High relationships between animals may cause inbreeding and loss of alleles by random drift
- Population improvement with a breeding program is limited. Farmers keeping the animals of these breeds often have to be subsidized. If the subsidy stops, the breed is at risk.
- Populations conserved *in vivo* on government farms are also vulnerable to changes in the financial priorities of the central government or respective ministry

Action 4. Rank techniques for costs

For the conservation methods with acceptable risks, the conservation costs should be calculated. The major cost of cryoconservation consists of two parts: the collection and freezing of the material and the use of the material when it will be used to reach the conservation objective (e.g. introgression of alleles or regeneration of the breed). The maintenance costs of an animal gene bank are relatively low. The costs of *in situ* conservation may consist of subsidies to keep animals of the conserved breeds and efforts to realize a breeding program with special emphasis for the maintenance of the genetic variation.

Action 5. Choose the conservation method

Finally, the different rankings for efficacy, risk of failure and costs should be considered. The weight given to each ranking depends of priorities and strategic preferences, available resources and available capacities and institutions. When artificial reproduction methods are well developed and widely applied cryoconservation may easily be preferred. When only natural mating can be applied to maintain the breed *in situ* conservation is the first choice.

Action 6. Apply the chosen methods to reach the conservation objectives

The remainder of these Guidelines provide advice on establishing and operating *in vivo* conservation programmes. For cryoconservation, see the *FAO Guidelines on Cryoconservation of Animal Genetic Resources.*

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4 Organizing the Institutions for *In Vivo* Conservation

Although the context in which an *in vivo* conservation programme will be undertaken will vary greatly from country-to-country, and from one species to another, there are aspects which will be common among all programmes. Among the most important of these commonalities is the need for organization and a plan for sustainability. Organization is critical, because many stakeholders usually will be involved in these programmes. Although these stakeholders will have some of their own objectives, they should all share a common goal of maintaining the breed in significant numbers to avoid its extinction and genetic erosion.

A wide array of stakeholders is important to the future of breeds and their conservation. In each individual breed, the relative importance of some of these stakeholders will be greater than that of others, but usually a combination is critical to long-term conservation success. Common stakeholders for animal genetic resources include breeders (farmers and pastoralists), owners (farmers and pastoralists), users (e.g. draft animals and breeding bulls), government institutions, breed associations, breeding companies, research organizations, nongovernmental organizations, consumers of the breed's products, and marketers (Oldenbroek, 2007; Hiemstra *et al*., 2010).

Breeders usually own a significant part of the genetic resource, and are the most essential stakeholders. They are central if the goal is to maintain the breed without subsidy (Hiemstra *et al.,* 2010). Success depends on an understanding of and commitment to conservation of purebred, viable populations. Successful efforts generally involve multiple owners, working together for the survival of the breed. This is distinct in important ways from the usual pattern of ownership of plant genetic resources.

Associations of breeders contribute in several ways to conservation of animal genetic resources, including participation and communication with the National Advisory Committee (FAO 2009; see Chapter 1), serving as a source of information on the breed and its role in agriculture to those outside of the breeder community, product development and promotion, markets, breed promotions, and technical support for breeders. Associations manage herdbooks and performance recording, and are targets of organization and support. Often they are a biased sampling of owners, with a disproportionate share of larger herds as well as those with high levels of management and innovation.

The stakeholders that are not private owners can have important roles, but it is always important for them to work closely with private breeders. Generally, the non-private institutions (both governmental and nongovernmental) should support private efforts and involvement of private breeders for future security of the genetic resource.

Especially in several Asian, South American and African countries governmental breeding farms are important reservoirs of breed resources, making breeding animals and semen available to private farmers in situations where they would otherwise be unable to access this selected breeding material. These institutions have a very real responsibility to assure that their programs lead to both short-term and long-term benefits for farmers.

Governmental organizations can be effective in promoting and rewarding cultural and social benefits of breeds. European countries increasingly recognize the value of local breeds for grazing management of natural areas and the maintenance of historically and culturally relevant countryside. These values are difficult to recognize and reward by the private sector alone. Many hobbyists keep and breed local breeds as a leisure activity. These non production activities with local breeds offer a great opportunity for the conservation of local breeds, but need institutional support for the proper conservation and management of the genetic diversity.

Educational (university) and private research institutes also play roles in conserving breeds. These can be especially important in providing technical support for managing the genetic viability of small populations by careful attention to population structure and mating strategies. Private breeding companies likewise manage important populations of several breeds in several species, although these primary resources are usually unavailable to the private sector. Many breeds or lines no longer developed for immediate commercial goals are set aside without long term conservation plans.

This chapter gives the rationale, the tasks and the actions required by the different stakeholders with special emphasis for the breeding organizations.

4.1 Involving farmers in community-based *in situ* conservation

RATIONALE

The conservation of AnGR under sustainable management at the farmers' door is one of the most effective and practical ways of conserving the animals with a minimum of inputs. This approach does not involve large financial expense and is feasible under field conditions. However, as there has been change in the management and production system after intensive and mechanized agriculture, major emphasis should be on the economics of the livestock breed that needs to be conserved. Sustainable conservation of animal breeds with participation of farmers will be successful only if it is economically viable. Hence the projects on conservation for improvement and utilization of breeds should define their objectives clearly, especially with respect to those characteristics which the breed has been traditionally valued. Conservation efforts should begin with characterization and evaluation of breeds and identification of characteristics of economic/social/cultural value specific to each breed. See the *FAO Guidelines on Phenotypic Characterization of Animal Genetic Resources.* These activities should be done following a participatory approach, involving the farmers and breeders as much as possible, both to increase the accuracy of the information upon which the conservation programme will be based and to ensure interest and ownership by the farmers of the programme, to increase its sustainability. The role of an outside entity will primarily be to provide the inputs to improve the long-term survival of the target community and to provide technical support. FAO (2003a) has made available a publication on community-based programmes for management of AnGR.

Objective: To design with farmers an *in situ* conservation programme that they will implement with the assistance of outside agencies, which ensures maintenance of an AnGR because it promotes autonomy of the community and sustainability of the livelihoods of its members.

Inputs:

1. A breed at risk of extinction, but deemed of high value for conservation

2. Basic knowledge of the location where the breed is raised and the lifestyle of the community of farmers and production system employed, their animals and their facilities
3. An indication by farmers of their interest in breeding and conservation

Output:

- a sustainable *in situ* conservation programme based on the active participation of farmers

Task 1. Identify the clear target for conservation activities

Action 1. Pinpoint and study the geographic area where the breed is kept.
With the background information on the breed to be conserved, the core area of the breed's region should be identified for adoption of selected villages to implement the conservation and improvement programme.

Action 2. Choose the communities with which work will be undertaken.
Several specific villages distributed in different parts of the breed's home region should be identified as candidates for the programme. The precise number of villages will depend on the population size of the breed to be conserved, its distribution across the area and across farms and the resources available. If available, previous knowledge about the interest in participation and cooperation by farmers may assist in the selection of target areas. The programme is likely to be more successful if farmers and stakeholders are motivated and facilitated to establish and participate in an organized programme. The farmers who own the animals that are truest to the ideal type targeted for conservation (e.g free from crossbreeding, superior phenotypic traits) should be encouraged to participate.

Task 2. Undertake a detailed participatory study of the farming community

Once the candidate communities have been chosen, the next step is to engage with them. In most cases, the completion of the activities described in Chapters 1 to 3 will yield only the information necessary to understand which breeds should be conserved and why. Much more information is needed to develop a sustainable community-based programme for their conservation. The previous chapters have dealt exclusively with matters dealing directly with conserving the AnGR of interest. Community-based programmes will likely have to expand their scope, to include preserving and improving the likelihoods of the community members, so that the AnGR is conserved in a complementary way. Multidisciplinary studies using participatory approaches will be necessary. Studies using participatory approaches are among the most effective approaches for information gathering from rural communities and will establish a line of communication for the further collaboration that will be needed in implementation of the conservation activities (Franzel & Crawford, 1987) and have been used frequently in AnGR management (e.g. Duguma *et al.,* 2010). FAO (2003b) has produced general guidelines on participator approaches in agriculture and rural development.

Action 1. Undertake preparatory work including making initial contact with community leaders and agencies that may act as a liaison with the community.
It will often not be possible to apply a very prescriptive, top-down approach, by simply visiting the community and undertaking the study. Rather, a step-by-step process of engagement to inform the members of the community of the intentions and goals of

conservation work and any complementary activities will usually be necessary. In particular, the leaders of the village or the prominent farmers ("Master Breeders" in Western terms) will be the first contacts to make. It may be helpful to work through the assistance of a liaison that already has experience working with the community, such as a non-government organization or government extension service.

Action 2. Enlist the research team and perform the studies.
At the community level, the problem of AnGR conservation will likely be multi-faceted, due to the large number of possible threats to breed sustainability (see Chapter 1.4). Thus the research team should be multi-disciplinary, in order to address not only genetic factors, but also economic and social aspects.

The study should be designed to collect information on a wide number of topics, including standard production and breeding practices, outputs from the animals and their utilization or marketing, marketing opportunities, sources of inputs to farming activities, and existing constraints to the system. In particular, the specific threats to the sustainability of the genetic resources should be determined in detail. Finally, an assessment of the willingness and capacity of community members to participate in conservation activities should be included.

Action 3. Evaluate the results.
The results of the participatory surveys should be evaluated in a comprehensive manner in order to determine the most logical, practical and efficient manner to conserve the animal genetic resources in question. A follow-up meeting with the community members is recommended.

Task 3. Propose the *in situ* conservation programme based on farmer's participation

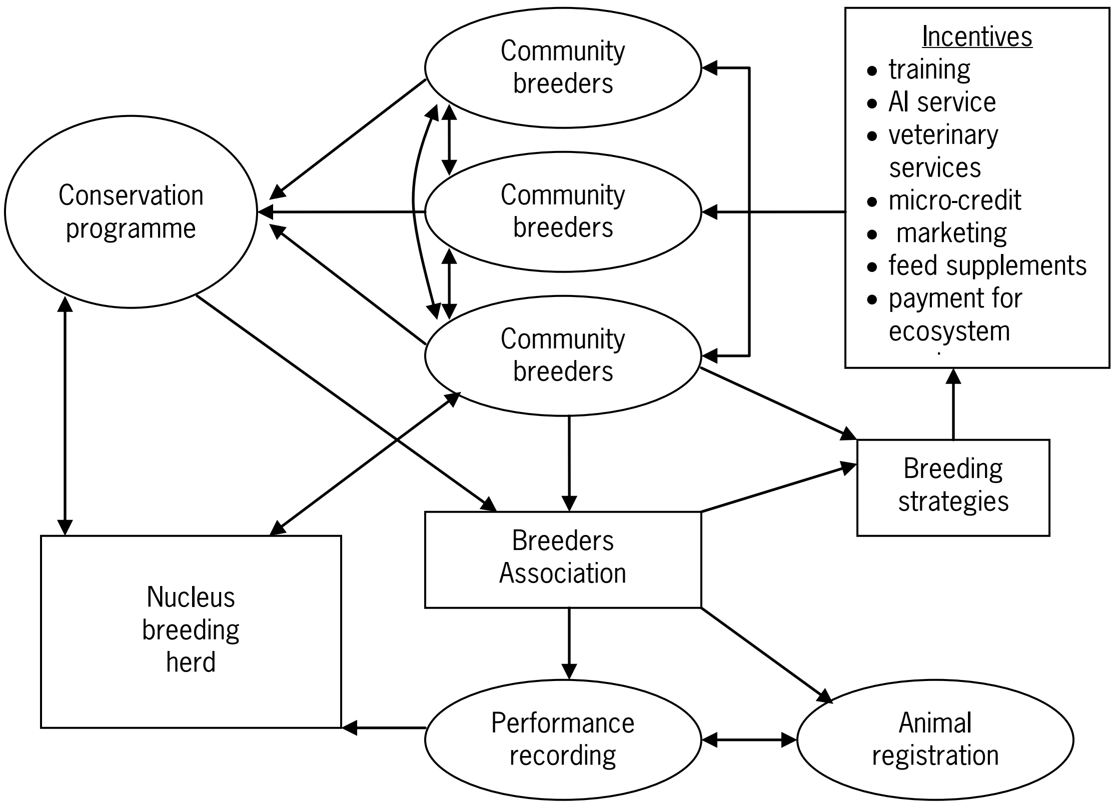
Figure 4.1 shows the possible interactions among stakeholders in a community-based programme for management and in vivo conservation of animal genetic resources. The rectangular text boxes indicate where outside assistance can be provided to encourage the adoption of activities that could facilitate the conservation of a breed through a community based-breeding model.

Sometimes outside investment may be necessary to implement activities to help ensure breed sustainability, especially in the initial phases of the programme. Construction of abattoirs maybe required for meat production or milk collection and processing facilities may increase market access to dairy farmers and, as a result, their income and the economic sustainability of their animal keeping activities. Outside assistance may be necessary to promote such opportunities to potential investors. Farmers may also be willing to invest in technologies to improve productivity, such as artificial insemination or veterinary services or supplemental feeding, or in training to improve marketing (e.g. in cheese or yogurt production), but may not have availability to credit services through which to obtain investment funds. Provision of such services may be an option to indirectly support *in vivo* conservation.

Action 1. Organize farmers into a breeders association
Animal genetic resources are almost always owned by a number of different individuals rather than any single person. Each individual generally has the right to manage his or her animals as he or she prefers. However, some interests are shared across breeders and some goals can be accomplished more easily as a group rather than by individual

actors. Therefore, the formal organization of owners of a genetic resource into a breeders association can yield benefits both for the individual owners and for the sustainability of the breed. It also creates a single entity with which the government or non-governmental agencies can work with, increasing efficiency. Details about establishing and monitoring breeder associations are in Sections 4.1 and 4.2.

Figure 4.1. A simple diagram of the interactions among the possible stakeholders in a community-based breeding programme.



Action 2. Work with the community to establish a breeding programme
The community (or breeders association) may be willing to work with the government or other stakeholders to develop and adopt a breeding programme to improve the productivity and maintenance of genetic variability (as described in Chapter 5), but may require assistance in organization and technical matters. Outside assistance can facilitate the adoption of breeding goals and the development, implementation and maintenance of breeding programmes.

For example, working together as a breeders association, the community may identify the target traits for selection within the breed. This is generally considered the most important issue in genetic improvement of animals in a conservation program. The objective should be clear enough to exploit the genetic potential existing in the population to the maximum extent possible. Genetic improvement of a breed under conservation for a specific objective will increase its merits gradually. The community may then actively participate in promoting and creating a brand for specific products derived from the breed conserved. Such measures will strengthen the economic value of the animals which can ultimately lead to its self-sustenance. In such case, the external support from the government can be gradually withdrawn while allowing the breed society to take over and continue the efforts in this direction. Details about establishing selection objectives are in the *FAO Guidelines on Breeding Strategies for Sustainable Management of Animal Genetic Resources.*

A breeders association can then take responsibility for aspects of operating the breeding programme, such as identification of animals, performance recording and genetic evaluation, with or without financial and technical assistance from the government. Such activities are one of the major advantages of a breeders association, because individual breeders will typically lack the time and technical capacity to operate such programmes and benefits are gained in efficiency by having these activities performed by a central agency. In fact, associations for different breeds or for transboundary breeds present in different (neighbor) countries may increase efficiency by collaborating on these activities.

Action 3. Establish a nucleus herd for management of genetic improvement.
A nucleus herd of up to several hundred superior females and sufficient numbers of superior fertile males (~1 per every 10 to 20 females) in the native home region of the breed may be a key tool in population management. Within a nucleus herd, selection and mating decisions can be controlled more strictly, so that more effective but more complex approaches for animal genetic resource management can be applied (see Chapter 5). Assuring an “open” nucleus design, which establishes a relationship between farmer and institutional herds that allows for gene flow in both directions, with ongoing identification of superior animals in both populations, may be particularly attractive for local breeders. They can benefit both by obtaining superior germplasm from the nucleus and having the opportunity to sell at a premium price their best animals to the nucleus.

Action 4. Provide incentives and complementary institutions
Farmers and breeders of livestock have an exceptional amount of indigenous knowledge and may thus already be sufficiently skilled in managing their breed, but the breed may still be at risk due to factors out of their control or an insufficiency in a particular capacity that could be overcome through training. The simple provision of specific incentives or other assistance may be all that is needed to direct a breed at risk back on a sustainable course. For example, farmers may be abandoning a given breed, or even animal production in general, because they cannot market the products at a price or quantity high enough to ensure a satisfactory livelihood. Assistance in improving productivity or establishing a consistent market for the breed’s products may increase the income of farmers, thus providing support to the livelihoods of the community and, likewise, helping ensure the survival of the breed. Alternatively, perhaps farmers are actually providing a service that can be regarded as a common good, such as maintenance of genetic diversity or ecosystem preservation, that is not being properly valued by the market economy. Thus, payment for these services could be considered, as long as such payments are not market-distorting and respect various international trade agreements. These options are discussed in more detail in Chapter 7.

The loss of a particular breed may also be related to wider-scale rural development problems, such that breeders (and their children) are giving up farming entirely to seek other opportunities. In this case, incentives such as those discussed above may not be sufficient. Therefore, it is important to consider well the wider-scale threats to the sustainability of AnGR. Perhaps it may be necessary to establish non-agricultural services, such as improved educational opportunities for children, improved health care and local off-farm employment opportunities to help sustain the community in general.

4.2 Establishing a well functioning breeders association

RATIONALE

Breeders associations (also known as "breed societies" or "breed associations") can be essential to the long-term success of conserving animal genetic resources by playing many roles, including as serving as an effective monitor for threats to the breed. Most standardized breeds are well-served by breeder organizations that have well-documented procedures and functions. In most cases the functions of breed organizations for standardized breeds have been assumed as a universal model for other classes of breeds. Landraces usually have less organization and definition, but still have a very high priority for effective conservation. Frequently some details of the model for standardized breeds need changes to effectively accommodate the needs of landraces.

Organization of landrace breeders presents numerous challenges. If herds have been isolated for long periods of time, each breeder is very likely to consider his or her own herd to be the only typical one, which may lead to fragmentation and difficulty to establish common goals (See Box 4.1). The leading traditional breeders are often elderly, and may not have heirs interested in continuing with the family livestock. This threatens breed continuity, as the culture surrounding the breed is easily lost. Getting beyond individual pride and self-interest is challenging but is key to long-term success. Traditional breeders have assumptions and beliefs that vary, and which are the framework under which the breed developed and survived.

Box 4.1
Associations of Colonial Spanish Horse Breeders in the USA

Breeders of Colonial Spanish horses in the USA conserve a very fragmented and dispersed breed based on landrace and feral animals. The result of strong local attachment has left many breeders with a skewed appreciation of the overall breed, and an intense focus on only the local resource. The result is 20 different breeder associations for this breed, which numbers at most 3,000 animals. Fragmentation makes long-term management and survival precarious. As a reaction to this a few associations with an inclusive philosophy now also promote the breed. The fragmentation of breeders is the result of strongly held opinions on breed purity, but at some point this only leads to a smaller and smaller gene pool that cannot avoid high levels of inbreeding in the long term.

Breed associations are generally membership-controlled, democratic institutions. Members have requirements for active membership and participation, and agree to a set of rules. They get to participate in shared decision-making, are eligible to register livestock, and benefit from recording schemes and promotional efforts.

Objective: To create a well functioning breeders association.

Inputs:

1. Genetic and demographic data on the breed.

2. List of breeders who keep animals of the breed.
3. Some knowledge of the history of the breed and its present functions.
4. Knowledge of goals of the breeders and history of cooperation.

Output:

1. A well functioning breeding organization with a description of:
   - The requirements for membership
   - The registry protocols
   - The bylaws
   - The dues and fees for members
   - The communication methods for education and training
   - A mechanism for conflict prevention and resolution
2. Communication between the breed association and national entities responsible for management of AnGR.

Task 1. Determine willingness of members the community to establish a breeders association.

Action 1. Discuss the possibility of a breeders association during the initial participatory studies.
The success of a breeders association will largely depend upon the number of breeders participating and their willingness and enthusiasm. The level of interest should be evaluated as soon as possible, to avoid futile investment of time establishing an organization that is not sustainable. The community members should be made aware of the benefits of breeders associations, and the inputs required.

Action 2. Identify specific members of the community that may have a particular interest in joining a breeders association and serving in leadership roles.
A breeders association is a nongovernmental organization and will only be successful if its leaders are well-respected in the community and committed to the association and to maintaining the breed.

Task 2. Develop and implement a process with the relevant stakeholders through which a breeding organization is described and established.

Action 1. Determine requirements for membership in the association.
Most breed associations have different classes of membership. Full membership in many associations is limited to people actually breeding. Breeder-members have voting rights, which assures that control of the breed's future is determined by those most affected by decisions and they contribute to the conservation of the breed.

For landrace breeds, an important determination is which breeders are to be included as representing the traditional landrace breed. This decision determines the foundation and forever shapes the descendant breed. Deciding on which breeders and which animals to include within the breed usually occur simultaneously, because each affects the other. Outside entities, such as governmental or nongovernmental organizations, can help guide through this step. It is best to include those animals that are purebred to the local genetic resource and to avoid any with known outside breed influence. However, if the number of verified purebred animals is too small to obtain a viable breeding population, standards may have to be relaxed somewhat to allow animals with a high proportion of the desired breed to be included in the foundation stock (See Box 4.2).

Box 4.2
Incorporating non-purebreds into a breed founder population

The concept of resemblance through common hereditary descent is a useful addition to the contents of any definition of a breed (See Box 1.1). The resemblance through common hereditary implies that ideally a breed has no exchange of genes with another breed, i.e., that no introgression of genes from other populations takes place. Therefore, as a rule of thumb in practical breeding, no more than 12.5% foreign genes are to be accepted within a breed (i.e. one of the 8 great-parents is from another breed). When the percentage of an alternative breed(s) is greater than this amount, then an individual would be considered a member of a different "breed" and not allowed to be a member of a foundation population. Standardized herdbooks usually do not consider individuals with more than 12.5% foreign genes as purebreds and most have much stricter roles for this percentage.

In addition to a full regular membership for active breeders, associations may consider other types of memberships as a means to expand interest in the breed (and perhaps revenue for the association) while limiting influence over breeding policy. Such additional classes of membership may include associate membership for nonbreeders or "junior" memberships for nonadults. These members typically do not vote, but are entitled to all other benefits of membership. In breeds with functions other than commodity production, such as horses, it can be necessary to include nonbreeders as full members. In such breeds, nonbreeders contribute to the breed through promotion and use, and their voices must be heard in breed association decision-making.

Including new breeders is essential, and these should be from inside as well as outside the original cultural group holding the breed. Efforts to include new breeders can sometimes threaten traditional breeders, because the breed is then removed from their control. With an expanding group of breeders comes cultural change that affects how the breed is selected and valued. Managing these tensions is challenging.

Where possible, have special designations for long-term traditional breeders. These are unlikely to fully participate if the association uses the standardized breed organizational strategy. Special allowances in registration procedures, membership dues, or other accommodations can assure their participation.

Action 2. Establish registry protocols

Most associations register animals and validate pedigrees. Procedures must be consistent and uniformly applied. A variety of software programs are available, and each has strengths and weaknesses. The pursuit of complete accuracy comes at an economic cost, and DNA validation of pedigrees is unrealistic both for animals of low individual economic value, as well as for animals raised in extensive situations.

Registry function of a landrace breed association often mimics standardized breeds. For extensively-raised traditional landraces, especially in multi-sire herds and in animals of relatively low individual value (poultry, goats, and sheep) other procedures are needed. One strategy is to register and monitor entire herds or flocks rather than individual animals. It is very important to assure purebred breeding. Procedures and validation must be tailored to fit each individual case, as they must reflect the realities of the local culture and local husbandry practices.

Landrace associations must develop methods to include candidate animals into the registered population Some approaches can be applied on an animal by animal basis (see Box 4.3), whereas some breeders associations have procedures that apply to whole herds (See Box 4.4). In economically developed countries it is common for landraces to have a short period in which foundation animals are registered, after which the registry is closed to only animals with registered parents (and grandparents). This is a typical strategy for standardized breeds but works poorly for landraces because isolated pockets of purebred animals are likely to continue to be discovered for a long time. Procedures for inclusion of newly encountered animals must be developed, and must be applied uniformly and fairly.

Performance and type classification recording schemes are important in many breed associations, especially where selection programs are desired by breeders. These data are useful for breed improvement schemes, and breed associations are the logical place to maintain these data.

Box 4.3
Incorporating non-registered animals in the herdbook

Inclusion of candidate animals should follow documentation of the origin and type of the animals. Evaluate history of the population (geography, foundation stock, length of genetic isolation, and the source and frequency of any additions of animals other than the landrace). Also evaluate the phenotype of the animals. Where possible use DNA evaluation to detect introgression from other breeds, but interpret results carefully, as *bona fide* members of a landrace from a long-isolated pocket of the breed will often have DNA variants novel to the ones found previously. These animals could be particularly valuable to the breed, for their genetic distinctiveness, adding to genetic diversity. If desired, a progeny test can be done to validate the ability to reproduce the traditional type. This is less important if DNA validation is possible, but is useful in cases where candidates have novel variants (color, horns). Inclusion of newly discovered animals is also important for some standardized breeds. Including these animals can be essential to long-term conservation success with very rare breeds. Newly discovered animals must enter the breed on equal footing with existing animals, or their genetic contribution will be diluted out so that any potential benefit from their inclusion is lost, especially if these are “graded up” with existing bloodlines.

Box 4.4
Protocols of the Coastal South Native Sheep Alliance

The Coastal South Native Sheep Alliance in the United States of America has developed new protocols for dealing with landrace conservation. Organization and rules are minimal, but a commitment to purebred breeding is the main objective underpinning the group. The basic rules include:

- Sheep of other breeds are not to be kept on the same property as a Gulf Coast flock recognized by the Alliance. This prevents introgression from other breeds, especially where animals are not individually identified and multi-sire mating systems are used.
- Each flock submits a brief flock history, including original sources, and foundation year.
- Additions to the flock are documented by source, date and sex. Ideally additions only come from other flocks recognized as purebreds by the Alliance.
- Each flock participant reports census figures annually, with sources of any additions.

- If breeders maintain different bloodlines, each is tracked as a separate flock.

These rules protect the genetic integrity of the breed, while allowing it to persist as a traditional local resource. This requires breeder commitment, and even the low level of breed-specific activity (documentation of flocks, documentation of additions, annual census) can be enough of a change from tradition to result in noncompliance.

Action 3. Establish bylaws

Election procedures

A well-defined form of decision-making can avoid confusion and controversy. Bylaws determine the mode of voting and the role of members in various sorts of decisions. One extreme is completely democratic, whereby members vote on every decision, and is limited to small associations. Larger associations usually have officers and/or a board of directors which makes decisions, with periodic elections to renew the board and assure that it reflects the will of the membership.

It is important to establish election procedures, including the frequency of elections. These rules encourage general membership participation and develop loyalty and a feeling of member ownership of the association. Participation of original breeders must be assured, and may require recognition of their status.

Board of Directors

In most associations the members elect a board of directors, and the board enacts specific procedures and policies. The number of directors can vary, but to assure continuity it is best to have staggered terms. If a board has six members, with three-year terms, then each year two of the board positions can be elected. This allows the two new members to serve with two that have served for four years, and two that have served for two years. This assures continuity, but also refreshes leadership with new ideas and enthusiasm. To assure this end many associations limit the number of consecutive terms that any individual board member can serve. Most boards include a convening president, vice president, secretary, treasure, and in smaller associations a registrar.

Action 4. Determine membership dues and fees.

Dues for membership and fees for various services of the association, such as registration, are an important source of revenue to sustain the costs. In most situations dues and fees are set by the membership or board of directors. Dues and fees must be set fairly and uniformly, and should have few changes over time. Dues and fees send the message and reinforce the concept that registration and participation are valuable. Depending on the goals of the association and variability in herd size, some breeders associations may charge only membership dues with no additional fees for registration of animals. This encourages registration of all animals and promotes the participation of breeders with large herds.

Action 5. Establish communications methods for educational and training programs.

Association communications have several different purposes, each with a different mechanism. Communication between breeders establishes a community of breeders. The goal is to foster a feeling of belonging and participation so that breeders feel involved and essential for the future of the breed. Newsletters, meetings, websites and electronic chat groups can all foster this.

Associations also need to educate breeders on effective breed maintenance. The goal is an informed and committed membership, knowledgeable about population dynamics and their importance to conservation. Breeders must also understand breed type as it relates to traditional use and value. Educational methods for this include newsletters, meetings, websites, electronic chat groups and field days or workshops.

Efficient and accurate communication is especially important for landrace breed associations. Breeders must understand the character of landraces. Landraces no longer benefit from past cultural and communication isolation that led to their development, so ongoing conservation efforts must now be deliberate and planned. This requires good communication. Breed associations have an important role in promoting the breed and its products to an audience outside the breed association membership. Marketing and other promotional activities are essential for long-term sustainability. (See Box 4.5)

Box 4.5
Promotion of the Leicester Longwool Sheep

The Leicester Longwool Breeders Association in the United States has come to play an important role as the guardian of the largest national flock of this breed (Sponenberg *et al.* 2009). The breed association discourages the usual competitive showing in favor of "card grading" in which each sheep is individually evaluated by three judges for compliance to the breed standard. Following evaluation, each sheep is awarded a "card" determined by their relative quality: blue cards for superior breeding stock, red cards for good breeding stock, yellow cards for acceptable breeding stock, and white cards for those unacceptable as breeding stock. This process is educational because one of the judges speaks to the observers following the evaluation of each sheep, explaining the process and the results. This assures effective education on breed type for both breeders and the general public.

Action 6. Develop and adopt a procedure for conflict resolution.

Because breeders associations comprise individual breeds, conflicts among members are certain to arise. Most conflicts are between individual members or breeders, but some arise from fundamental differences in basic philosophy of animal production and use. It is important to have mechanisms in place to spot conflict early and to resolve it fairly and quickly. The goal of conflict resolution must always take into account the breed and its need for engaged and involved breeders that communicate and share. Conflict resolution is especially important for landrace associations because they have more traditional and isolated breeders. These conflicts must be judiciously solved if the landrace is to expand rather than contract to the point of extinction. In some cases, conflicts can be foreseen and prevented or at least minimized. See Box 4.6 for a specific example where a breed association developed certain policies and practices accounting for cultural differences among members.

Box 4.6
Accounting for cultural differences among members of breeders associations

Breeder organizations for landraces must always reflect underlying cultural norms. This is especially challenging if a single breed is held by more than one cultural community. In the USA, the Navajo-Churro sheep has centuries-long connections with both Navajo (indigenous) and Hispanic communities in New Mexico and Arizona, and more recently with Anglo breeders and enthusiasts. This landrace became endangered in the late

1900s, so breeders and breeding became organized to assure that the breed did not drift to extinction. Breeders were fortunate to have key individuals in all three cultures that reached out to the other communities. These leaders built an organizational norm of cross-cultural appreciation and inclusion. Cultural diversity in the group is not ignored, but embraced and celebrated as an important aspect of breed conservation. This assures that cultural diversity serves effective conservation rather than defeating it, by assuring a strong commitment to the sheep breed and its future (Sponenberg and Taylor, 2009).

Developing an inclusive association can be daunting. The Navajo-Churro registry depends on inspection of each candidate sheep presented for inclusion in the flock book, even if both parents are registered. This model works best with modern Anglo-American communities that are familiar with such procedures. The same procedures are foreign to many Navajo and Hispanic breeders whose families have been raising this breed for centuries. To assure success the organization has Navajo-speaking and Hispanic inspectors dispersed throughout the traditional range of the breed so that traditional breeders have relatively easy access to inspection of their sheep. Having inspections done by members of the same cultural group facilitates communication, encouragement, and participation.

Breed-specific promotions for both wool and meat of the Navajo-Churro sheep have linked participation in the breed organization with good economic return for breed-specific products. Linking participation, breed recognition, and enhanced commercial utility has assured a viable association. Participation in the association has become an important way for each of the various communities to emphasize their individual culture and its contribution to the breed, which has increased a sense of ownership of the breed and its future.

Ideally, a consensus can be reached and all members of the association will agree on a common strategy for breed conservation and development. However, in some cases the conflict may not be resolvable and the breeding association may be split into factions, each of which will have its own goals (See Box 4.7). However, in these instances population management is particularly important, because splitting the population will result in sub-groups with smaller N_e and decreased resources for association activities.

Box 4.7

Introgression poorly accepted in the Texas Longhorn breed

Criollo cattle throughout the Americas illustrate how selection can affect breeds. The Romo Sinuano of Colombia has changed conformation with subsequent greater acceptance by mainstream beef marketing channels. In contrast, breeders of the Texas Longhorn split over the philosophic choice of either selecting for improved production or maintaining a traditional phenotype. In some cases within the Texas Longhorn breed, the change to commercial type was accomplished through introgression. Traditionally-minded breeders had trouble separating out changes in type based in crossbreeding from those that resulted from selection alone. Most traditionalists decided that it was safest to select for traditional type with no changes. This has split the breed into two groups, and the more traditionally-minded ones with commitment to purebred conservation are resistant to changes in type and conformation. This effectively conserves the breed, but fixes conformation and production with little room for improvement. The consequences of this are uncertain, although success is likely as the breed continues to excel in environmental adaptation and is sought as a maternal base for crossbreeding.

4.3 Auditing the breeding organization and its activities

RATIONALE

Many breed associations need support from either governments or from nongovernmental entities in order for them to function well in conservation of AnGR. This support may be justified by the fact that activities of the association contribute to benefits for the public, such as maintenance of biodiversity, rural development and increased food security. Support may be financial or logisitical. The provision of support justifies the undertaking of periodic assessment of the associations' activities. Evaluating the performance of these associations assures that the resources provided are being used effectively in conservation work.

Whether or not out outside support is being provided, a breed association should still undertake periodic auto-evaluations of the same aspects, to ensure its members are being properly served and its goals with respect to animal genetic resource management are being effectively achieved.

Breed associations should actively assess the role of the breed as an AnGR. This should include assessments of demand for it, and threats to it (FAO, 2010). This function usually requires a strong breed association, and weak or inactive ones rarely succeed with this, making them likely to be overlooked by national efforts (FAO, 2009).

Objective: Develop an auditing process for a breeders association and its breeding and conservation plan.

Inputs:

1. The laws and bylaws of the breeders association.
2. A description of its activities including the breeding and conservation plan.

Output:

- the description of an auditing procedure for a breeding organization and its activities.

Task 1. Evaluate participation and decision-making procedures

Action 1. Describe and evaluate and describe the mechanisms for participation.
Strong breed associations encourage broad participation from their members and producers (FAO, 2009). Members should feel welcome to participate and to contribute. Some associations get dragged into various controversies, and while some individuals may hold very strong opinions, in most cases the breed itself loses support and breeders. Ensuring that an association functions in a way that assures a sense of community and benefits all members to a fair degree is an important consideration.

Action 2. Evaluate the decision-making processes.
Breed associations need shared and open decision-making procedures to foster broad ownership of the association and high levels of participation. The actual keepers and breeders must be consulted and considered for a successful program. (FAO, 2010).

Breeders and keepers have intimate knowledge of the actual production system. Their participation must be assured by respecting their opinions and attitudes.

Action 3. Evaluate the provision of benefits to association members.
Breed associations should provide expert or technical support for their breeder members (FAO, 2010), including husbandry, health care, animal selection and animal breeding techniques, and strategies for long-term viability of the breed.

Action 4. Evaluate the procedure for inclusion of new members.
Evaluate the mechanisms and adequacy of inclusion of new breeders, including membership protocols, and actual participation by old and new breeders in the association and the registry. Breed associations should be inclusive and welcome new breeders. This is especially important for landrace breeds. It is essential that the community of breeders for each breed is growing rather than shrinking. Strengthening cooperation among breeders is an important role for associations (FAO, 2010).

Task 2. Evaluate the genetic purity of the population.
As noted previously, public support to a breed association may be justified if the association is actively maintaining biodiversity by promoting maintenance of a valuable genetic resource. If this objective is not being reached, then continued support may not be warranted.

Action 1. Evaluate the level of purebred breeding as opposed to deliberate or casual introgression. This evaluation needs to include both overt and fraudulent introgression, as well as inclusion of crossbreds through inattention. Breed associations must insist on pure breeding and emphasize this to members. Commitment to pure breeding should be openly stated as a core value of the association. Competitive activities such as animal shows or production award contests are a way to promote breed interest and reward active participation. In some cases, however, awards in the show ring or production contest can go to animals with obvious introgression from other breeds, and if not prevented by the breed association this can send a very damaging signal to the breeder membership. In general, the association should insist that breeders recognize and appreciate the breed for what it is rather than trying to change it through crossing.

Action 2. Check accuracy of parental information.
Correctness in animal identification is important to ensure freedom from undesired crossbreeding and precise evaluation of breeding values. As mentioned previously, routine DNA tests will not be practical in many situations, but breeders associations may care to adopt a programme that randomly checks the parentage of a proportion of animals by using DNA from the individual and its putative parents. The government may wish to audit such a programme, especially if support is being provided for identification and performance recording.

Task 3. Evaluate the status of the AnGR under management.

It is important for the breeders association to maintain its identity and concept of ownership of the breed. These aspects will be largely influenced by the autonomy of the association with respect to the breeding programme. However, if outside financial support is being provided, then some reasonable conditions to this autonomy may be applied. Occasional audit of the population and breeding programme may help to evaluate the breed’s prospects for sustainability.

Action 1. Evaluate the population structure and its use in the breeding program.
Procedures for designating strains or families within the overall breed, mechanisms for census of the breed, and evaluations of population structure should be appraised. Effective breeders associations periodically monitor the population structure of the breed. Education of breeders against temporary fads in breeding is important, as breeds need to assure a broad representation into the next generation. Situations where breeders chase after a few bloodlines will result in a bottleneck. This practice is damaging in common breeds, and disastrous for breeds at risk of extinction. Breed associations should educate breeders on healthy population structure. Recognition of the value of different strains or bloodlines within the breed can be very helpful, especially in landrace breeds where variation in different bloodlines can be relatively large. Breed associations should monitor the census of the breed, including the details of strain and bloodline numbers.

Action 2. Evaluate the breeding and conservation programme
The plans for management of the genetic variability of the population should be appraised, including periodic exchanges of breeding animals among breeding herds, and any cryoconservation activities, such as targeted freezing of gametes from underrepresented animals. If the breeding and conservation plan involves genetic improvement, then the genetic and phenotypic trends of the population should be checked to gauge the effectiveness of these activities. Breeders associations should be alert to herds and individual animals of enhanced diversity and importance to the future of the breed (FAO, 2005). Breeders associations can actively promote rules and protocols to avoid genetic erosion by promoting relevant genetic exchanges among member herds (FAO, 2010). These need to be broad so that no single herd swamps the breed providing a disproportionate share of breeding animals.

4.4 Centralized *ex situ* conservation on institutional farms

RATIONALE

In situ conservation is usually the preferred option for *in vivo* conservation of animal genetic resources, due to the advantages discussed in Section 3.3. However, in some situations, *ex situ* conservation is a more practical option. For example, a breed may have reached a population size too small to be raised by a group of farmers. Alternatively, perhaps a breed's worth is primarily in term of options and existence values (See Box 3.1) and thus not profitable to be kept by farmers, but may still need to be immediately accessible in its live-animal form. Perhaps a need for tight central control of breeding is required and such control can only be afforded by *ex situ* conservation on a nucleus farm. Such programmes are typically operated by governmental and not-for-profit nongovernmental organizations, rather than by the commercial sector.

In many countries, institutional animal farms are owned by government and nongovernment organizations that are dedicated to research, teaching, and development. Most of these farms maintain economically important breeds of different animal species, and are used as demonstration centers as well as for the production and dissemination of superior germplasm. For example, India has a well-developed system of institutional farms. Establishing organized breeding farms is important, especially for genetically-eroded local animal breeds which have very small numbers and are scantily scattered in their home regions.

Ex situ conservation of livestock breeds by establishing breed-specific farms involves a substantial investment of both infrastructure and resources. For these reasons, *ex situ* conservation programs are usually limited to a few very unique breeds and maintain relatively small populations. As explained in Chapter 5 the genetic constitution of a small population can change rapidly through genetic drift, possibly resulting in the loss of genetic peculiarities and reduction in genetic variability, so the most important challenge in managing the population in *ex situ* conservation is to sustain genetic variability.

Objective: Establish and maintain populations of important genetic resources in centralized breeding herds.

Inputs:

1. Lists and characteristics of local breeds that are candidates for *ex situ* conservation,
2. Knowledge of the location of individual animals from these breeds including private breeders and existing institutional farms.

Output:

- Institutional herds for local breeds of low census with active programmes for maintenance of their genetic variability.

Task 1. Undertake the necessary preliminary planning, including feasibility studies, and secure access to facilities and funding.

Action 1. Analyze the available institutional breeding farms.
An *ex situ – in vivo* conservation programme will be more financially feasible if existing facilities and personnel can be used. These should include governmental and nongovernmental farms.

Action 2. Determine the breeds to be targeted by the conservation programme.
Following the procedures of Chapter 3, establish the targets regarding which breeds to include in breeding farms, paying close attention to those local breeds that have not already been targeted by existing programs.

Action 3. Perform a feasibility study.
As noted earlier, *ex situ* conservations of animal genetic resources *in vivo* is an expensive undertaking and requires substantial planning. The population will likely not be financially self-sufficient, so the agencies (public or private) supporting the activities have to be convinced of their value. A feasibility study must be undertaken to determine the costs of establishing and maintaining the conservation programme. The costs must consider initial acquisition and maintenance of animals, acquisition of new or refurbishing of existing facilities and their maintenance and personnel costs. Any revenues expected to be generated by the herd should also be accounted for.

Action 4. Identify possible donors.
In addition to the government, non-governmental agencies with an interest in conserving the diversity of agricultural genetic resources should be considered.

Action 5. Prepare and present proposals for conservation plan to government officials

and/or donor agencies.
A strong argument will be needed to convince donors to provide support for the conservation activities. The value of the animal genetic resource to be conserved must be stressed, including the opportunity costs of its loss. A well-done feasibility study (Action 3) will aid in preparing the proposal.

Task 2. Implement and operate the conservation programme.

Assuming Task 1 is completed successfully, the real work of establishing and operating the *ex situ* conservation programme can get underway.

Action 1. Establish the populations of animals at the institutional farm.
A general consensus suggests an N_e of 50 as a reasonable goal for conserved populations of AnGR (Smith 1984; FAO, 1998). This need not be an immediate goal to be achieved at the establishment, but can be strived for over time through breeding management and continual acquisitions. In addition to stock that may already be available on the institutional herd, animals can be purchased from the farmers and breeders in the local breeding tract. These animals should be free from disease or any noticeable defects, conform closely to the desired breed characteristics and be as unrelated as possible. If possible, they should have above-average performance for traits of economic importance (production and adaptive traits to promote economic self-sustainability of the farm). The best available breeding males (at least 1 per every 10 females) should also be procured. These animals should be maintained at the farm, along with their offspring.

Action 2. Develop breeding and husbandry strategies for the institutional herd.
Given that the institutional situation allows for central control over breeding decisions, the most advanced systems for control of genetic variability (i.e. minimal coancestry or optimal contribution theory – Chapter 5) should be applied. Given the value of the genetic resources and substantial investment by government or private donors, exceptional effort must be taken to minimize the risks from diseases, accidents, genetic drift, inbreeding and contamination from other breeds. If selection is being practiced, and because of the potential of genetic drift, there are chances of developing a genetic gap between the original breed in its native region and the population in the conservation programme and this possibility should be monitored if this is a concern. This "adaptation to captivity" is generally considered more important for wild animal species (e.g. Frankham, 2008), but may be relevant for livestock, especially those with a particularly harsh natural environment.

Action 3. Establish a gene bank (i.e. in vitro cryobank) for periodic storage of germplasm from animals in the ex situ – in vivo programme.
Maintaining genetic material from animals in the original population will allow recovery the genetics of the population drifts from its original base and will facilitate reconstitution of a catastrophic event (e.g. disease, fire or natural disaster) wipes out a significant portion of the live population. *Ex situ* conservation on a single farm carries risks, as all of the live animals are

Action 4. Organize farmer and institutional participation in production and use of males.
Ideally, the *ex situ* population can be used as a resource in the active management and improvement of the *in situ* population. For example, superior young males from the herd can be made available for use in the general population.

For more additional details and particular advice on *ex situ – in vivo* management of animal genetic resources with very small populations, one may wish to consult Guidelines of the European Livestock Breeds Ark and Rescue Net (ELBARN, 2009)

4.5 Dispersed *ex situ* conservation involving institutional and farmers herds

As noted in Section 4.4, the establishment and operation of an institutional farm for *ex situ – in vivo* conservation of AnGR can require a significant investment. One of the feasible solutions to overcome this constraint is to expand the population by the use of "dispersed" or "decentralized" model incorporating resources already available at established government farms with non-government institutional farms and private individuals who are willing to keep the animals on a commercial or "hobby" basis.

Many existing institutional facilities are already involved in important conservation activities. Nearly all could easily be brought to play a more significant role in this effort with little or no adverse effect on their other important development and animal breeding roles. The institutional farm can be established as an AI centre, nucleus herd and/or and germplasm repository and farmers would be users of the germplasm, as well as suppliers. Facilities for frozen semen production may be developed in such farms in order to disseminate the germplasm from purebred males typical to the breed to the collaborating farmers. Networking of several breed-specific herds can be initiated for integrated breed conservation and systematic genetic improvement. A basic design of the model is shown in Figure 4.2. An example of how institutional farms India could be used for conservation is in Box 4.7.

For this model of *ex situ* conservation, the participation of livestock farmers and role of development organizations is very important.

Objective: Establish and maintain populations of important genetic resources in one or more institutional nucleus and decentralized breeding herds.

Inputs:
1. Lists and characteristics of local breeds that are candidates for ex situ conservation,
2. Knowledge of the location of individual animals from these breeds including private breeders and existing institutional farms.
3. Secured support from the government or a development agency.

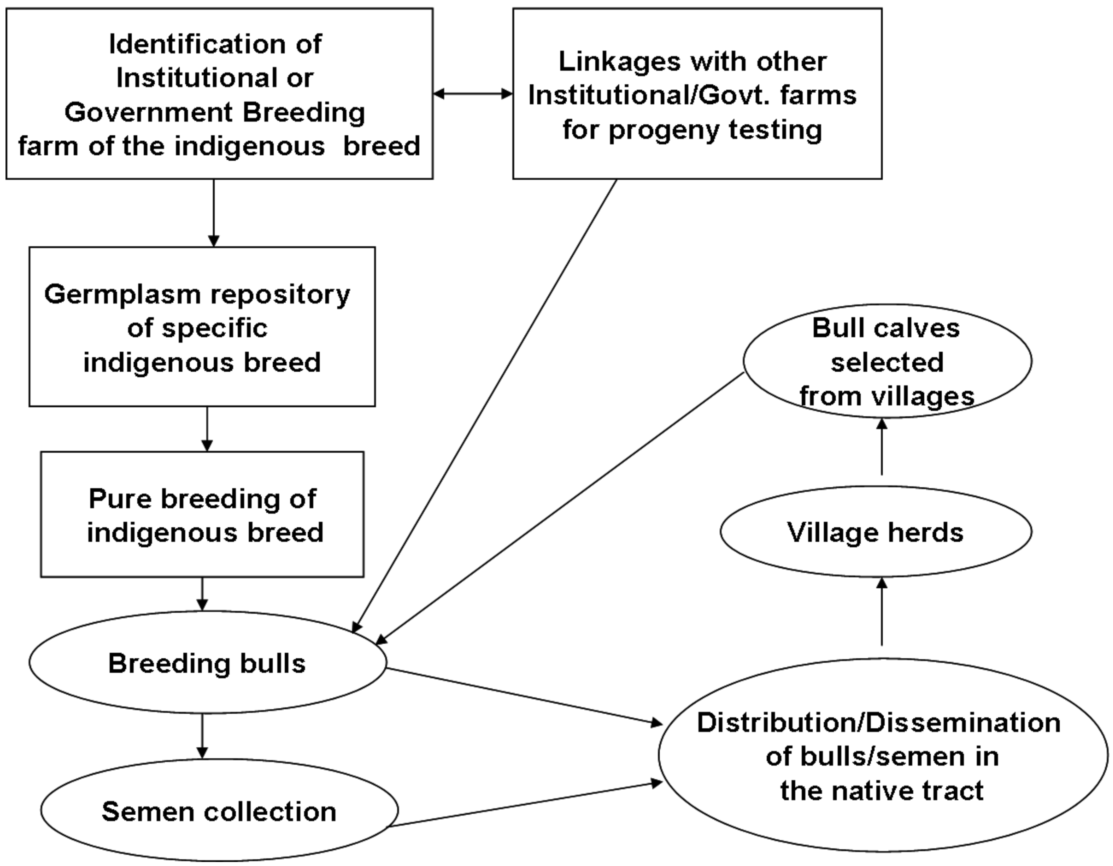
Output:
- A network of institutional and local farmers' herds with an active programme for sustainable management of an at risk breed of livestock variability.

Task 1. Establish the conserved population.

Action 1. Identify the base animals.
From the institutional herd and farmers' households, females (at least 25, but preferably >50 animals) should be identified on the basis of breed characteristics and performance

traits (for performance and for adaptation) and be tagged and recorded. In addition, bulls (preferably at least 1 per 10 to 20 females) should be identified and tagged. The owners of candidate bulls may be provided an incentive per female per year for rearing the animals and retaining purebred animals.

Figure 4.2 An example of a decentralized programme for *ex situ* conservation of an animal genetic resource by employing institutional and farmers' herds.



Task 2. Manage the conserved population.
Various approaches can be undertaken to manage the conserved population. Described below is a programme that is based on distribution of male animals and/or semen. Box 4.8 describes a real example of how special farms in India called Gaushalas can be used to support *in vivo* conservation programmes.

Action 1. Mating of base animals to produce new males.
The base females should be mated/inseminated with a bull/semen of the same breed. The farmers can be contracted to rear the male progeny born from these bred females up to six months. A total of at least 40 unrelated young males would be selected (>50 is preferred). Hereafter, two approaches can be followed depending upon participation of farmers and development agencies.

Action 2(a). Development agency or institutional farm.

If AI technology is available, the selected young males are purchased by the development agency or institutional farm. The agency then rears the males until maturity, and then trains them for semen production. At maturity, a total of 25 males (depending on the size of the female population) are selected on the basis of growth, semen quality and freezability. As many as 3 000 semen doses from each male (more prolific species will requires fewer doses) may be collected, cryopreserved and used in for breed improvement and conservation. The surplus breeding males are distributed to the farmers for natural mating in the breeding tract.

Action 2(b). Livestock Farmers.
Individual farmers rear the selected males and receive an incentive payment for maintenance costs. The farmers maintain these breeding males and provide breeding services to the animals in that area through natural mating. The farmers would charge a fee for the breeding services in order meet the expenses for further maintenance of these breeding males, at which time the incentives would stop and maintenance would be expected solely from breeding fees.

Action 3. Design breeding and mating strategies.
Selection of males and distribution of semen and bulls for mating should be practiced to maximize genetic diversity according to the general theories described in Chapter 5 and the conditions and technical capacity of the country. When capacity is low, sire use should be equilibrated as much as possible, when technical capacity is greater, optimum contribution theory can be used in bull selection.

Box 4.8
Conservation model involving Gaushalas in India

The Gaushalas of India are institutional self-contained cow shelters with their own land and housing facilities. They are usually supported by a combination of donations and government assistance. There are currently more than 4 000 Gaushalas across India. Most of these Gaushalas primarily cater to the needs of non-lactating, weak, unproductive and stray cattle, but it is estimated that more than a quarter of them have the potential to be used for *in vivo* conservation activities (Sadana, 2007). Many Gaushalas in India maintain purebred animals of different indigenous breeds, often in greater concentration than can be found in surrounding herds of local farmers. A few progressive Gaushalas are repositories of well described indigenous cattle breeds, and produce quality males, thereby contributing directly to the conservation and improvement of these breeds.

However, they do not have sufficient resources and technical support to most effectively conserve and improve these animals. The following actions could be undertaken to utilize these progressive Gaushalas more effectively for *in vivo* conservation:

- Identify the Gaushalas with a large number of purebred animals for breeds at risk.
- Ensure support to develop infrastructure necessary to transform these Gaushalas from rehabilitation centres into genetic resource centres.
- Within each Gaushala, group and house separately the purebred and non-purebred animals – choose these purebred animals selectively if population sizes permit.
- Implement identification, performance recording and breeding programmes for the selected animals.
- Improve the purebred stock through selective breeding.
- Distribute excess purebred stock to the local community, targeting farmers that are willing to continue purebreeding of the animals.

An agreement should be made with the participating Gaushalas not to resort to crossbreeding or other such practices which may dilute the genetic purity of the breed. In return, the Gaushalas could be provided scientific and technical support, as well as financial assistance, if necessary. The Gaushalas would be encouraged and supported in identifying unique and value-added products of the indigenous breeds so as to increase their economic value.

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5 Designing the Conservation and Use Programme – Maintaining Genetic Variability

As shown in previous chapters, the degree of endangerment of a population and, consequently, its probability of survival is greatly dependent on the levels of genetic diversity it harbors. High levels of genetic variability will provide adaptability to changes in the environment or the production system and will prevent the rise of inbreeding and its deleterious consequences. Small populations, as those breeds subjected to conservation programmes, are more prone to lose genetic information. Therefore, the implementation of correct management strategies is crucial for that kind of populations. The following tasks are formulated to implement the two possible strategies.
First: for maintaining genetic variability within small populations:

1. Adopt a general breeding strategy to maintain the conserved breed, based on a clear understanding of options for maintenance of the genetic variability
2. Consider the adoption of a mating strategy to decrease inbreeding
3. Incorporate cryoconservation in the management of genetic variation in the *in vivo* programme.

Second: for optimizing selection response and genetic variability within small populations:

1. Adopt a general breeding strategy to maintain the conserved breed.
2. Design a breeding programme generating genetic improvement while maintaining genetic variability

5.1 Maintaining genetic variability within small populations

RATIONALE

In livestock populations of a stable size, the loss of genetic information (alleles contributing to the genetic variability in the population) is usually due to selection and genetic drift. Natural selection acts to eliminate the deleterious alleles while artificial selection will tend to fix those alleles that improve the phenotype of carriers. In small populations not subjected to an explicit process of artificial selection, the impact of natural selection is small (most of the genetic variants are neutral with respect to phenotype) and the fate of an allele (i.e. its eventual loss or fixation) is mainly driven by genetic drift, which is a random process. Genetic drift is the fluctuation of the frequencies of alleles (i.e. the number of copies of them in the population) due to the finite and random sampling of gametes to generate offspring (Falconer and Mackay, 1996). This random sampling operates at two levels. First, if the number of offspring is small and reproduction is not controlled (i.e. mating is random resulting in variable numbers of offspring per individual), some members of the population may not contribute offspring to the next generation. Therefore, the genetic unique information of these animals will be lost while other animals will contribute multiple copies of their information. Second, to generate an offspring, each individual contributes a gamete carrying just one of the two alleles in each position of its genome. If the parent is heterozygous (i.e. it carries two different alleles in that locus) only one of the variants will be transmitted to any given offspring. Therefore, there may be loss of genetic information even if all individuals leave offspring.

The consequences of the drift process for small populations are: i) an increased chance that none of the copies of a particular allele are transmitted and, thus, this allele will disappear in the next generation (loss of genetic information); ii) the probability of mating between relatives (i.e. inbreeding) increases, and so does the probability of inheriting identical copies of an allele in any gene. This increased proportion of mating between relatives occurs in small populations even when mating is random and the probability of intra-family mating increases as the size of the population is smaller. For example, in a population of size two, offspring in the first generation are full-sibs, and so on. Of course, inbreeding arises in populations of any size if relatives are mated deliberately. The probability of homozygosity by descent is greater the higher the average degree of relationship between individuals of the population. Increased homozygosity reduces the expression of fitness-related or productive traits, compromising the survival of the population, in the process called inbreeding depression (See Box 5.1).

Box 5.1
Inbreeding depression

Species of domestic animals are diploid, which means that each individual carries two copies (two alleles) of each position (locus) in its genome. At a particular locus, the two alleles can be the same (we say it is *homozygous*) or different (*heterozygous*). The performance of an individual for a trait will depend on the type of alleles it carries. Sometimes one allele gives a visible effect only if it is in homozygosity (i.e. when both alleles the same). Such alleles are called *recessive*. If that allele has deleterious effects (confers lower expression for the trait) heterozygous individuals will have a normal performance but they will be *carriers* of the deleterious allele. Genetic drift promotes an increase in the number of homozygotes. The deleterious alleles that were undetected through the compensatory effects of heterozygosity become more frequently exposed and the mean value for the trait decreases. If the allele has effects on fitness-related traits the consequence is a lower probability of survival of the population. If the trait controlled by the locus involves productivity, the mean performance of the population will decrease and the profitability of the breed will be compromised. In either of these situations (decreased fitness or decreased profitability), the risk of extinction will be increased, meaning that small population size brings threats that are both demographic and genetic.

The inbreeding coefficient (F) is a measure of diversity that ranges from 0 (non inbred) to 1 (completely inbred individuals, lacking variability). Inbreeding is unavoidable in small populations and if the pedigree can be traced back far enough, common ancestors will invariably be found, demonstrating that all animals are related. Therefore, the average F of a population is dependent on the definition of a reference/base population where all individuals are assumed to be non-inbred and unrelated (e.g. founder individuals when pedigree recording started). Consequently, populations with many generations of genealogy will tend to have high average F, whereas populations with shallow pedigrees will exhibit low F.

Because of this bias due to depth of pedigree data, a more informative parameter is the rate of inbreeding (ΔF) defined as the change of inbreeding, per generation, relative to the amount of inbreeding that is still possible to occur (i.e. $1 - F$). The advantage of this concept is that it is independent of a reference population, allowing the comparison between populations with different known history. Under several assumptions, ΔF can be calculated through simple formulae, helping in the prediction of the future performance of a population, the determination of the minimum composition of a viable population or to design management strategies, as will be demonstrated later in the chapter.

The ΔF is also a useful parameter to describe the present situation of a population allowing us to detect events that occurred in the history of the population (e.g. bottlenecks, or periods when the population went through a reduced number of individuals) and also helping to determine the endangerment status of the breed (see previous chapters). Genealogical analysis provides other parameters like founder genome equivalents, founder representation, effective number of ancestors, etc. (Caballero and Toro, 2000) to discover how well the population has been managed in the past and decide the priority for its conservation.

As previously explained in Chapter 2, effective population size (N_e) is a commonly used parameter to evaluate the genetic variability of a population, based on the assumption that larger populations will be less subject to random drift and will thus have more genetic variability. To review, the N_e is the size of an idealized population that has the same rate of inbreeding (ΔF) as the real population to be conserved. An idealized population has equal number of males and females, all of which have an equal opportunity to produce offspring. There is a close relationship between ΔF and N_e ($\Delta F = 1/2N_e$) and, consequently, both parameters describe the same concept. For most situations, the loss of genetic variance is also proportional to ΔF, which demonstrates that this parameter is a useful measure of the ability of a conservation programme to maintain genetic variability.

The relationship between individuals (measured through the coancestry coefficient, *f*, i.e. the probability of two individuals carrying identical alleles by descent) is another helpful parameter due to its connection with classical measures of diversity. The global coancestry of a population reflects to what extent the genetic information found in the different individuals is redundant. Mathematically, the population coancestry is = $(1 - H_e)$ where H_e is the *expected heterozygosity* (also known as *gene diversity*), a typical measure of genetic diversity. When the numbers of males and females in the population are different, the global coancestry must be calculated as ¼ of the mean coancestry between males, plus ¼ of mean coancestry among between females, plus ½ of the mean coancestry between every possible pair of sire and dam. The coancestry coefficient is also related with inbreeding due to the fact that *F* of the offspring is *f* of the parents; an individual cannot carry alleles that are identical by descent if its parents did not share that allele, as each of the alleles at a locus comes from a different parent. Both *F* and *f* can be easily calculated from genealogies. Consequently, it is highly recommended that, when the production system and physiology of the species allows, the pedigree of the population is traced along the generations by recording the sire and the dam of every individual. Several computational methods have been developed to calculate these parameters in any pedigree, including some that can deal efficiently with large genealogies. Free software is also available to perform such calculations, for example ENDOG (http://www.ucm.es/info/prodanim/html/JP_Web.htm - Gutiérrez and Goyache, 2005).

The minimum acceptable N_e has been defined as the N_e of a population which is safeguarded from extinction due to effects of inbreeding depression (or other threats related to reduced genetic variability). In general, 50 has been established as an acceptable N_e, at least to guarantee the survival of the population in the short- and medium-term. Consequently, the desired ΔF per generation should not exceed 1% [$\Delta F = 1/(2\times50)$]. This figure can be obtained with different population structures, in terms of combinations of males and females. For example, with no selection (i.e. random number of offspring per parent) 25 breeding males and 25 females yield the desired value, but a decrease in the number of males has to be compensated with more females. For example, the combinations of 20 males and 34 females and 14 males and 116 females also yield N_e of 50) (for computation of N_e see also Chapter 2, Box 2.2). The management procedures implemented in the population will change the numbers of breeding animals required, being lower when only conservation strategies are applied and higher when selection for a particular trait is performed (see Chapter 6). Of course, these are minimum numbers and greater sizes are always to be preferred for long-term survival of a population.

The conclusion from the above explanation is that management strategies should be directed to the minimization of genetic drift effects through the minimization of ΔF or the maximization of N_e. The knowledge of the factors affecting N_e will aid in the design of effective conservation strategies. When the N_e of a population drops significantly lower than 50, it may reach a level where it cannot be sustained, due to the negative effects of a lack of genetic diversity on fitness and fecundity. Such a situation is referred to as an *extinction vortex*, because population numbers are expected to uncontrollably decrease each successive generation (similar to water draining from a sink or bathtub). For such populations, a more radical strategy of *genetic rescue* must be applied (See Box 5.2).

Box 5.2
Genetic rescue

When a population is not fit enough to reproduce itself and, thus, the number of breeding animals are irrevocably decreasing every generation (going directly to extinction), the population has become trapped in an extinction vortex and is said to be in *genetic melt-down*. The cause for a population to enter in melt-down situation could be excessive inbreeding reached in the past (a bottleneck) and a great drop of the genetic variability levels. When this occurs there are two possible actions to implement. First, we can change the environment of the animals (e.g. establishing an *in vivo - ex situ* programme) to a more favourable one where the animals can receive greater veterinary care and the fitness of individuals is high enough to survive and reproduce. Attention must be paid to avoid the adaptation to these new favourable conditions, however, as this may preclude the reintroduction of the population in its natural production context.

A second alternative is a limited crossing with another breed that is adapted to a similar environment and, ideally has similar phenotypes for the important or specific adaptive traits of the endangered breed. This process is known as *genetic rescue*. The number of introduced individuals should be kept to a minimum, but even a small amount of foreign genes can have a large effect. For example, if a proportion p of exogenous alleles is introduced, the proportional reduction in inbreeding is $1 – (1 - p)^2$. With 10% of foreign alleles, the inbreeding of the population is reduced by nearly 20%, depending on the initial F. For example, with F = 0.30, an introduction of 10% of outside alleles leads to a population with F = 0.24. The whole process has to be very carefully controlled, however, to avoid excessive introgression of exogenous genetic information. Among the crossbred offspring, those showing the original phenotype should be selected to create the next generation by backcrossing with purebred individuals from the local breed, until most of the foreign genetic information has been removed. Molecular markers can also be used to increase the accuracy of these selection decisions in the purging process of foreign alleles.

Objective: Understand the factors associated with genetic drift and develop strategies to minimize its occurrence.

Inputs:
Knowledge of the following characteristics of the breed to be conserved:
1. Size of the population
2. Reproductive capacity of the species
3. Possibilities for exchange of genetic material among stakeholders

Output:
- A general breeding plan that will minimize genetic drift and maintain genetic diversity

Task 1. Adopt a general breeding strategy to maintain the conserved breed, based on a clear understanding of options for maintenance of the genetic variability.

Action 1. Include as many individuals as possible from the start, as drift depends on the number of individuals available.
Animals should be healthy and, as far as possible, non-inbred and unrelated. However, animals should not be eliminated if the capacity and financial resources of the programme allows it. Efforts should be made to involve all the herds of the breed within the programme. Thus the program begins with the maximum possible variability and opportunities to diminish the action of drift are utilized. Also, females that have previously or routinely crossed to males of other breeds should be recovered and used exclusively for within-breed matings. Of course, if conditions permit, the real population size should be increased as quickly as possible to avoid extinction due to demographic stochasticity and to increase the N_e.

Action 2. Equalize the number of breeding males and females.
The transmission of half of the genetic information is due to each sex. Therefore, the less represented sex will be the deciding factor for the decrease in N_e, irrespective of the number of individuals of the other sex. For example, under random contributions of offspring, a population with 2 males and 1000 females has the same N_e as a population with 4 males and 4 females. With just one male all the descendants will be half-sibs and average F will increase from zero to 0.125 in just one generation.

Action 3. Prolong the generation interval.
The ΔF is defined per generation, as genetic drift occurs due to the random sampling of alleles when gametes are produced. However, if the generation interval (i.e. how long it takes to replenish a set of parents; see Box 5.3) is longer, the same ΔF per generation has to be divided among more years, diminishing the loss of genetic diversity per year. Generation interval can be increased by keeping individuals as long as they are able to reproduce and extending their use in time by using their cryopreserved genetic material.

Box 5.3
Generation interval

The generation interval (L) is the genetic unit of time for a population. It is defined as the average age of parents at birth of their straight-bred replacement. In many cases this parameter will be approximated by the average age of the parents at the birth of all the offspring, but this need not to be so. Due to differences in reproductive life spans, the generation interval may be different for males and females and should be calculated separately. Since half of the alleles are contributed to the population by males and half by females, the generation interval is the average generation interval of the breeding males and the breeding females. For example, if offspring are born when the sires are one year old, and 60% and 40% of the offspring are born when dams are one and two years old respectively, L_s = 1 and L_d = 0.6*1 + 0.4*2 = 1.4 years. Consequently, the population L is the average of both sexes and, thus, 1.2 years. The longer individuals are used as breeding animals the greater L will be.

Action 4. Equalize the contribution of each individual:
The rationale of this action is to provide the same opportunity to all animals to transmit their genetic information. In a simple situation of equal numbers of males and females and no selection, the effective population size is approximately $N_e = 4N / (2 + S^2_k)$, where N is the census size and S^2_k is the variance in the number of offspring contributed by each individual. By equalizing the contributions of individuals, S^2_k becomes zero and the N_e is twice the population census size (the highest possible N_e). In simple terms, equalizing contributions could be realized by obtaining one son from each male and a daughter from each female in the next generation, but such a planning can be realized only under highly controlled conditions.

When conditions permit, Action 4 can be applied in a regular/hierarchical system. In such a scenario, an equal number of females are mated to each male every generation. The general idea is still equalizing the contributions and maximising the probability of every individual to transmit its genetic information. The strategy acts by performing a type of within-family selection so that one male is obtained from each male family and one female from each female family (Gowe et al., 1959). Under this procedure, the formula for the rate of inbreeding is $\Delta F = 3/(32N_M) + 1/(32\ N_F)$ (where N_M and N_F are numbers of breeding males and females, respectively) which is less than the ΔF obtained with random contributions [$\Delta F = 1/(8\ N_M) + 1/(8\ N_F)$].This strategy can be refined to get even smaller ΔFs by controlling not only the contributions of parents to offspring but also from each individual to its descendant across generations (Sánchez-Rodríguez et al., 2003) - see Table 5.1).

Table 5.1. Rate of inbreeding in percentage and effective population size (in parenthesis) predicted under different management regimes

Nº of males and females	Random selection	Within-family selection	
		Gowe	**Sánchez-Rodríguez**
3 ♂ 9 ♀	5.6 (8.9)	3.5 (14.3)	2.9 (17.2)
5 ♂ 25 ♀	3.0 (16.7)	2.0 (25)	1.7 (29.4)
6 ♂ 18 ♀	2.8 (17.9)	1.7 (29.4)	1.4 (35.7)
10 ♂ 50 ♀	1.5 (33.3)	1.0 (50)	0.8 (62.5)

Note that the formula for random contributions above only holds in the absence of selection on a trait, which is highly unrealistic for domestic animals. There is always some mass selection because owners keep the individuals with high performance and thus co-select relatives more often than by chance. Thus, this selection should be accounted for as shown by Santiago and Caballero (1995), as seen in Chapter 2. A simple recommendation could be dividing the ΔF arising from the formula by a factor of

0.7. However, under the regular system methodology, within-family selection (i.e. selecting the best of the sibs from each family) can be applied without increasing the rate of inbreeding (see Section 6.2).

Sufficient equalization of contributions from individuals can be achieved with rather simple strategies. When reproduction is by artificial insemination, an approximately equal number of semen doses from each sire should be collected and distributed in order to minimize the variance of female progeny size from males. In addition, each sire should leave only one sire to the next generation (or an equal number of sires if the population is growing), and in this way the variance of the male progeny size from males is reduced to zero. With natural insemination sufficient equalization of the contribution of males might automatically occur. With highly prolific species, some attention should be also given to equalize contribution from females, to avoid that a limited number of breeding females will contribute progeny to the next generation.

When pedigree data are available, a more flexible, but also more sophisticated, methodology can be applied, the minimum coancestry contributions methodology. As explained earlier in the chapter, the coancestry coefficient (f) is a measure of the probability of sharing identical alleles by descent. Relatives come from common ancestors and, therefore, they could carry identical copies of alleles. In that sense we could say that some genetic information in relatives is redundant and it does not matter which relative is transmits it as long as the shared alleles pass to the next generation. Consequently, the individuals effectively contributing to the future population and the number of offspring from each individual can be derived on the basis of their coancestry with the rest of the population. Animals that are closely related to the general population will be penalized (and only be allowed to produce a few or no offspring), but relatively unrelated individuals will be promoted to produce more offspring as they are assumed to carry unique information which will be lost if they do not contribute. This strategy leads to minimise the rate of inbreeding, at least in the short- and medium-term.

This minimum coancestry contributions methodology is robust against deviations from ideal conditions (accounts for related founders, does not need regular schemes, can cope with mating failures). It also allows for imposing restrictions according to the physiology of the species (e.g. maximum number of offspring from any individual). There are some practical disadvantages, however. First, this approach requires tight control of the reproductive process and thus may only be applicable in an *ex situ* situation, such as a nucleus herd. Second, the required calculations are computationally complex. The aim of the strategy is finding the set of contributions c_i (i.e. number of offspring per individual i) which minimizes the function $\Sigma\Sigma\ c_i\ c_j\ f_{ij}$, where f_{ij} is the coancestry between every possible couple of individuals i and j. Even for small populations the number of feasible solutions is huge, and finding the optimal solution requires the use of complex algorithms and the aid of computers. Therefore, expertise is required to implement this methodology. The free software METAPOP (http://webs.uvigo.es/anpefi/metapop/ - Pérez-Figueroa et al., 2009) facilitates the implementation of this management procedure in a conservation programme without artificial selection.

The minimum coancestry contributions strategy was originally developed to work with co-ancestries calculated from pedigree data. It is thus strongly recommended that the pedigree of the animals is recorded in any *in vivo* conservation programme, so the coancestry can be calculated for the management of the population and so the ΔF can be used for monitoring the success of the conservation programme. The benefits obtained from the recording of the pedigree (just the sire and dam of every animal) generally exceed the extra cost this procedure implies.

When pedigree data are not available, molecular information can be used in the management of populations to decrease genetic drift. Molecular markers can be a powerful tool to the management of the populations and technological advances are continually decreasing the costs of molecular analyses, thus increasing the feasibility of their use. The different possibilities include:

1. recovery, reconstruction or correction of partial genealogies (e.g. through paternity analysis for the solving of uncertain parentage – Jones et al., 2010);
2. the estimation of pedigree coancestry from molecular measures of similarity (Ritland, 1996);
3. the replacement of coancestry matrices based on pedigrees with the corresponding molecular coancestry matrices (Fernández et al., 2005).

The outcome of these three alternatives can be the input for the implementation of the minimum coancestry mating strategy. Several computer tools exist for the estimation of pedigree relationships from markers, for example SPAGEDI (http://ebe.ulb.ac.be/ebe/Software.html - Hardy and Vekemans, 2002) or COLONY (http://www.zsl.org/science/research/software/colony,1154,AR.html – Jones and Wang, 2009).

Even when the conservation programme includes pedigree recording, it would be advisable to use molecular information to determine the genetic relationships among the founders of the programme. Most populations under conservation have been maintained with a limited number of individuals (parents) for one or more generations. Thus, assuming non-related founders is highly unrealistic and can lead to incorrect management. Minimum coancestry contributions management methodology is able to integrate such information, correcting for the disequilibria generated in the unmanaged generations elapsed before the program started. A rough idea of relationship between founders can also be deduced from historical data on the origin of each of them.

Action 5. Consider the use of embryo transfer in species with low reproductive rates.
As noted earlier, reproductive biotechnologies such as artificial insemination and embryo transfer are occasionally cited as factors contributing to breed endangerment, as they facilitate the spread of germplasm across long distances and allow for decreased N_e by decreasing the number of parents. However, the real reasons for breeds being at risk are factors such as relatively low productivity and a lack of policies for their maintenance. In fact, when used strategically, these technologies can enhance conservation programmes.

For example, embryo transfer can increase the number of offspring per female. Increasing the number of offspring per female can have two positive effects. First, assuming that recipient females are of another breed, embryo transfer can be used to more quickly increase the census number of the population. Second, increasing the number of offspring per female can help equilibrate the ratio between male and female parents, especially if each female embryo donor is mated to multiple males. Sexed semen can provide similar (but smaller) benefits, at least in populations where not all males are used for breeding.

Embryo transfer can also extend the generation interval, if used to obtain offspring from females that are no longer able to maintain pregnancies of their own. This benefit can be augmented further when combined with cryopreservation (see Task 3).

Task 2. Adopt a mating strategy to decrease inbreeding

In the long term, the number of parents chosen and the number of offspring they produce are the main factors impacting genetic variability. However after the selection of the parents, inbreeding and its detrimental effects can be further controlled depending upon how the selected parents are mated with each other.

When selected parents have to be mated, several considerations can be formulated to choose the mating design. At least for one generation, the amount of genetic variability transmitted/lost to/from the population is not dependent on the mating scheme but only on the number of offspring each individual contributes. However, the level of inbreeding is really influenced by the way couples are formed. The inbreeding of an individual is just the coancestry between its parents. The greater the relationship between sire and dam the higher is the inbreeding of their progeny. Therefore, it seems sensible to avoid the mating between relatives, given that inbreeding is an important threat for the fitness of an individual and for the survival of the population.

Action 1. Set a limit on the level of relationship between mates.
The simplest way to decrease inbreeding is by avoiding the mating of individuals exceeding a certain threshold of coancestry, for example full-sibs (i.e. f = 0.25) or half-sibs (e.g. f = 0.125). When several generations of the pedigree are known, the type of relationships that can be found are more complex: in these cases, information on specific matings to be avoided could be made available to each farmer. If potential mates are already inbred, then this factor should also be accounted for.

Action 2. Establish the ideal set of matings for the entire population
A generalization of the above methodology has been developed and can be applied across a population. This generalization is called the *minimum coancestry mating* design, and consists of finding the set of potential mates with minimum average coancestry between partners (i.e. sire and dam). The methodology delays the rise of inbreeding, although does not reduce ΔF in the long term (Woolliams & Bijma, 2000). As is the case with the previously described optimal method of fixed contributions, the number of possible combinations is huge and the use of mathematical and computational techniques is required to solve the problem. Minimum coancestry mating can be performed with the aid of METAPOP (http://webs.uvigo.es/anpefi/metapop/ - Pérez-Figueroa et al., 2009). Obviously this methodology can only be implemented in situations where mating is under central control, however, a situation that rarely occurs in field conditions, but may be encountered in *ex situ* populations.

Action 3. Apply simple methods that do not require pedigree information
In the absence of genealogies another mating strategy can be used. The idea is arranging *n* families of individuals in a virtual circle. Then, male offspring from Family 1 is always mated to females of Family 2; males from Family 2 are mated to females of Family 3 and so on. Males of Family *n* are mated to females from Family 1. Because of the structure of the mating programme, this strategy is called the *circular mating* design. This methodology is easy to implement and assures low rate of inbreeding in the long-term, although it may induce higher levels of inbreeding in the short-term. When the

population is maintained in different herds, and each herd is considered as a “family”, this procedure converges to what has been called the *rotational system* of breeding management. In such a system some individuals are regularly (every year, generation, etc.) exchanged between neighboring herds and random mating is performed in the herds. This obviously implies some organization and acceptance from all participating farmers. Past experience has shown that such a programme can be a total success or colossal failure, depending on the level of organization and cooperation among farmers.

When females give multiple births in their lifetimes (i.e. which is the ideal scenario, as it increases the generation interval), factorial matings should be used. This means that each female should be given the opportunity to mate to different males. This way the number of possible mating combinations is larger and solutions are better in terms of the amount of maintained diversity and the levels of inbreeding. Under hierarchical mating, if the production of large full-sib families is combined with selection (natural or artificial) the probability of selecting relatives is high. Moreover, if a male carries a dominant deleterious allele, the female genetic information has a high risk of being lost because all of its descendants may carry the deleterious allele. But if the female is mated to several males, its contribution will be safely transmitted through her offspring with other male partners.

Performing the management of a population in two steps (i.e. first: the selected individuals and their contributions are determined and second: the mating design is chosen) may lead to complicated and less realistic situations. For example, it may require the mating of a female with two males, which is impossible for many species in the same oestrous period without the use of reproductive techniques like MOET (Multiple Ovulation and Embryo Transfer). Therefore, it could be advisable to make both processes in a single step in a procedure called *mate selection*. The basis of this approach is determining the number of offspring to be born from each possible set of mates instead of from each single individual. In this way all physiological or logistic restrictions can be accounted for (e.g. females mated to just one male, maximum number of females per male, limiting just one offspring per couple to avoid the generation of full-sibs, etc.).

Task 3. Incorporate cryoconservation in the management of genetic variation in the *in vivo* programme.

Cryopreservation (For more information, see the *FAO Guidelines on Cryoconservation of Animal Genetic Resources)* is another useful tool in a conservation program (Meuwissen, 2007). This technology provides a two-fold benefit to the program, as it extends the reproductive lifespan of individuals (i.e. increases the generation interval) and also increases the real population size and N_e as more individuals (which are more likely to be unrelated or less-related) are available at the same time. The storage of semen or embryos can address different objectives.

Action 1. Store genetic material from all animals at the start of a conservation programme

A first objective may be to use the collected material as a “backup” of the breed, keeping all the genetic diversity present at the beginning of the programme (one generation in case of embryo’s or somatic cells; two generations in case of semen). In case of population extinction in the future, the breed can be recovered from the stored material. The creation of such a bank is required for highly endangered breeds that are likely to disappear in a near future. Obviously, storing material from all individuals would be feasible and logical only for a small population.

In this situation, the germplasm is primarily being stored for “insurance” purposes, and the probability that it will be needed is (hopefully) small. Therefore, approaches such as the storage of somatic cells, with low collection costs, but high utilization costs (i.e. for cloning), may be a logical option.

Action 2. Use cryoconserved material continually for management of the genetic diversity
A second objective of the cryopreservation is to reinforce the *in vivo* programme. This strategy can be applied in a discrete way to help the population to recover from a risky situation (e.g. any catastrophe leading to reduced population size). But the cryopreserved material may also be used continuously as part of the normal management procedure for the population. In this scenario, collection of material for the bank should be a continual and permanent process to replenish the doses already used.

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6 Options for Breeding Programmes Combining Conservation and Sustainable Use

Breeds usually become rare from inadequate economic return to keepers who need good economic return for their inputs and labor. The availability of highly specialized (exotic) breeds with a higher productivity speeds up this process. The process stems from a system that ignores the contribution of breeds beyond mainstream commodities. For the mainstream commodities high input – high output breeds are used in highly conditioned environments. In this process adaptation, disease resistance, longevity, and services that the animals provide are often overlooked. Some countries now recognize and reward these contributions of the rare low input low output breeds to their national life and to sustainable food production at a low cost basis.

Mirkena et al., (2010) summarized the genetics and adaptation in farm animals: "Adaptive fitness is characterized by survival, health and reproductive related traits. The wealth of knowledge generated so far indicates that genetic variation for adaptive performance particularly disease resistance is ubiquitous both within and among breeds of livestock indicating that genetic studies on adaptation of farm animals can be determined at three genetic levels: species, breed and unique genetic variation among individual animals within a breed. In the warmer tropical areas, where pathogens and epidemic diseases are widespread, climatic conditions are stressful, and feed and water are scarce, locally adapted autochthonous breeds display far greater level of resistance and adaptation due to their evolutionary roots as compared to imported breeds. There are three pathways of genetic improvement: improvement of local breeds through purebred selection, breed substitution (by other local breeds or, more frequently, by exotic breeds), and systems of crossbreeding (terminal crosses, rotations, formation of synthetic lines). Whichever pathway to follow, choice of the most appropriate breed or breeds to use in a given environment or production system should be the first step when initiating a breeding program and due attention must be given to the adaptive performance. A major limitation is that selection for less heritable traits such as fitness-related traits results in low selection response due to measurement problems and the underlying antagonistic biological relationships between productive performance and adaptive traits. The appropriate strategy for any breeding program would therefore be to set suitable selection goals, which match the production system rather than ambitious performance objectives that cannot be reached under the prevailing environment. An area-specific approach utilizing the existing resources and taking into account the prevailing constraints appears to be the only reasonable sustainable solution. Such an approach would also enable in situ conservation of animal genetic resources, the only viable and practical conservation method in less developed countries compared to ex situ or cryopreservation approaches. Therefore, the importance of identifying the most adapted genotype capable of coping with the environmental challenges posed by any particular production system" is crucial.

The production potential of rare breeds is usually poorly documented due to the high cost of performance recording. Adaptive and fitness traits are often anecdotal. Technical support can reverse this, but low economic return still threatens immediate breed survival. Long-term survival is meaningless if short-term survival is not assured. Improving economic performance can take several different paths, and each of which allows farmers adequate return to justify maintaining the breed. Governmental support or incentive payments can help with short-term rescue but are unlikely to be sustainable in the long-term (Hiemstra, 2010).

Two main breeding strategies for enhancing economic performance are: 1) to increase the production levels of commodities by breeding (Section 6.1) and 2) to apply crossbreeding between local breeds (with their unique adaptive and fitness traits) and (exotic) breeds with a high production potential (Section 6.3). In small populations of local breeds it is very important to optimize the selection response and the genetic variability within the population (Section 6.2).

6.1 Improvements through breeding

RATIONALE

The most obvious route to enhancing economic performance is to increase the production of standard commodities (meat, milk, eggs, fiber). Success is most likely where the production potential of the local breed is high but has not been documented. Such situations are rare, and benefit directly from initiated attention to classic animal breeding and improvement schemes. The success of these endeavors will vary from place to place, and is most likely to be greatest in challenging environments where international production breeds face major hurdles in survival and production due to problems with adaptation and fitness (See Box 6.1).

Box 6.1
Local breeds better adapted to Bolivian circumstances

The Ayapaya llama is a local strain with high production potential that had been overlooked by most development programs. These llamas are kept by the Wallat'ani highland community in Bolivia, and have better fiber traits than lowland animals. Selection of local animals has been established as a formal activity (in contrast to unorganized past efforts) and benefits the local community (Valle Zárate 1999). Similarly, some local Bolivian guinea pig strains are better than imported ones for litter size, number weaned, and total weight produced. (Valle Zárate 1999). Identifying these local resources of high production potential is important for long-term production use.

Selecting for enhanced production in local breeds (in the pure indigenous breed) is an important option. This has been effective in several situations. Selection implies change, but it has to be realized that not all changes may serve the long-term interests of the breed or its breeders. If done carefully and if local adaptation is constantly assured, then the result can be well adapted, productive breeds. Examples abound of the success of this approach: Nguni cattle in South Africa, Spanish goats in the United States of America (Box 6.2), Mertolengo cattle (Portugal), and Colonial Spanish Horses (Americas). Establishing a purebred nucleus herd with an important role for recording of traits and selection of breeding animals can benefit not only selection for production, but also can enhance publicity for the productive potential of the breed (FAO, 2003).

Box 6.2
Optimum body weight for Spanish goats guarantees adaptation to Texas's climate.

In the 1960s West Texas ranchers began selecting local Spanish goats for production characters. Selection alone, with no crossbreeding, has increased mature female size from 35 kg to 70 kg. Breeders then discovered that females over 60 kg were less well adapted to the challenging semiarid West Texas environment. Once they relaxed their perception of the ideal weight back to 60 kg the breeders were able to have the increased production they sought, as well as the environmental adaptation they needed. Larger and non-adapted exotic breeds had little opportunity to compete. Relaxing selection pressure on size and growth rate alone allowed for more selection on meat conformation. The result has been a very productive genetic resource that is also exquisitely adapted to its environment.

Most indigenous breeds have not undergone selection that specifically targets production of commodities. In such cases it is often possible to make relatively rapid gains in production traits in the first few generations of a selection program. This provides more long-term security for the communities holding the indigenous breeds than can a crossbreeding scheme. Although, this outcome will not always be intuitively accepted because the initial improvement in production in a purebred selection program will lag behind the initial boost imparted by crossbreeding and the heterosis effects in the first cross. Part of the reason for relatively high gains from selecting within an indigenous landrace is the relatively high heritability of production characters, and the relatively low heritability of traits of adaptation and resistance. This means that more rapid and secure progress can be made by selecting an adapted resource for production than can be made by selecting a more productive resource for adaptation. Landraces are very likely to be more variable than are standardized breeds, and the highest performing animals of landraces can have great productive potential. Unfortunately, the mental image of a highly productive, temperate breed can sometimes overpower the long-term strategy of selection within a locally adapted breed, with breeders impatient for a quicker solution to the high demand for commodities.

Breed census size affects how useful selection can be. In the case of numerically small breeds, it is difficult to manage population genetics considerations over against selection needs without creating potentially dangerous bottlenecks. Therefore, although a short-term goal of an in vivo conservation programme should be to achieve an N_e of 50, the long-term goal should be to exceed this threshold. Principles outlined in Chapter 5 should be carefully applied to maintain genetic variation in the long term. More numerous breeds can focus animal recruitment on both population maintenance as well as selection for improved production. In developing countries, within-breed improvement programmes can contribute to improved income and livelihood of people who depend on low-input systems. These breeding programmes must have outputs which are consistent with the producer's objectives and need to be driven by incentives from the market to justify the producer's investment. The bottom line is that successful adoption of a technology (e.g. artificial insemination) depends on its feasibility and the compatibility with the needs of the farmer and the production system. It has to be relatively simple, relatively cheap, and above all, involve relatively low risks. It is necessary to look at the production system holistically, and involve the producer at every stage in the planning and operation of the breeding programme, integrating traditional behaviour and values (Van Arendonk, 2010).

Most indigenous breeds must be selected for increased performance to be competitive for standard commodities. The immediate economic needs of the owners demands this, and any selection should conserve the breed as a genetically, historically, and culturally distinct livestock genetic resource. Options for increasing performance must be carefully evaluated for long-term effects on the evolution of the breed, its requirements and the genetic diversity within the breed.

Effective ways to cheaply and accurately measure performance are important and often require creative strategies for animal identification and record keeping (See Box 6.3). Systems that function in one production environment may not be feasible in another (See Box 6.4) The goal is a system that works to consistently identify those animals that are top performers in the local environment so that they can be selected for breeding and their contribution to the next generation can be assured.

Box 6.3
Simple recording system for fertility improves fertility in the long term in Venuzuela

Some large commercial beef ranches in Venezuela have changed from measuring individual growth rates of calves to putting more emphasis on female fertility and longevity as greater contributors to overall herd productivity. One easy solution to monitoring fertility was to brand an "X" on the back of any cow failing to wean a calf in any year. No cow is allowed two "X" marks, as she is culled after failing a second time. The result has been increased fertility in commercial cow herds, with the record system being marked on each individual animal and readily read in the field. Year of birth is also branded onto the animals, giving an easy evaluation for both longevity and fertility. Similar systems might include ear tags or ear notches for cattle and other species.

Box 6.4
Molecular selection not feasible due to lack of infrastructure and cultural familiarity in Peru alpaca population

In Macusani, Puno, Peru the alpaca export market disrupted the local market for alpaca breeding stock and other products. This caused a change in breeding objectives. An attempt was made to change from traditional systems to more high-tech systems that used marker-assisted selection and pedigree-based programs. These all failed in the local situation because they were not sustainable in this remote region due to lack of both infrastructure and cultural familiarity with these techniques. Recapturing the previous traditions of visually classing males for breeding has helped to once again make advances in the production of alpacas with high local value and appreciation.

Objective: To development a breeding program for local breeds to increase production.

Input:

- Assessment of productive potential of local breeds. Be sure to put a value on the traits of interest (production), and include non-market contributions such as adaptation and longevity of production. Ability to walk and forage are essential traits in many environments, and are often overlooked. The history of selection and use, and the relative completeness of documentation of breed productivity help guide decision making.

Outputs:

1. Strategies for increasing performance in purebreds and, where relevant, of crossbreds.
2. A comparison of these strategies for immediate commodity production as well as for long-term security of adapted AnGR for local food security.
3. Analysis of the costs of the breeding program, which should be kept as low as possible for the low input - low output breeds under study.

Task. Implementation of a breeding program with selection for production

Action 1. Analyze history of selection within the breed.
The selection, exchange and use of sires, along with any records of gains from selection should be collected and analyzed. Evaluate also the population structure of production potential relative to type of holding. Determine where top producing animals of the breed are located, and how they are being used.

Action 2. Decide on the production and potential breeding goal traits that should be improved by breeding.
Decide on production traits to be measured. Include commodity traits (meat, milk, and eggs) as well as longevity, fertility, environmental adaptation, and ability to withstand stressors such as walking long distances to forage. Defining traits carefully can benefit well adapted breeds (See Box 6.5). The *FAO Guidelines on Breeding Strategies for Sutstainable Management of Animal Genetic Resources* (FAO, 2010) also provides advice on identifying important traits and determining breeding goals. Replacement rates and mortality can demonstrate superiority in adaptation, as can rebreeding intervals or litter sizes. Cost of rearing replacements is important, as is the quality and quantity of feed or the need for special management considerations. Labor and veterinary costs should be included, and the return from production. Lifetime profitability is a key component. Adapted livestock are likely to have long productive lives, as well as multiple outputs, products, and services beyond the usual market commodities. Fertility and mortality are major traits, and in general smaller animals will exceed the performance of larger ones (FAO, 2010).

Box 6.5
Fleece quality as a sustainable breeding goal in a sheep breed in Chiapas
In Chiapas, sheep production among the Tzotzil people changed from local landrace to crossbreeding 20 years ago, to enhance the production of meat. However, the Tzotziles do not consume sheep meat. This, as well as declining quality of fleeces for local textile needs, led to no increase in incomes of sheep producers when compared to the previous traditional systems. Performance for culturally relevant traits was then recognized as a sound breeding objective, which led to an effective open nucleus breeding system, based on selection for fleece quality, visual inspection, and organization of ram distribution controlled by the local community. Attention to local practices assured greater participation as well as enhanced economic return. The producers, environment, and the local culture all became beneficiaries of a well-thought sustainable system (Perezgrovas et al., 1997).

Action 3. Implement identification, registration and performance recording.
Choose an appropriate system for identification and registration (pedigree recording) of individual animals. Measure the performance traits of these animals. All traits must be evaluated in all populations to assure that none is omitted from final decision-making steps. Deciding how to measure production is important, as different measures yield different results. For example, measuring only first lactation records will select very different animals than will selecting for lifetime production. Production measures should maximize long-term economic return, and factors such as longevity and cost of inputs can demonstrate the advantage of indigenous resources over imported ones.

Action 4. Selection for type, production and fitness traits should be recorded and *implemented in relevant environments.*

Improved commodity production can pull against maintenance of traditional type in some breeds, especially when animals are adapted to compromised environments. Measures of productivity for such breeds should include productivity with low inputs in compromised environments. Lifetime productivity can measure longevity and survival (fitness), as a useful addition to measures such as growth rate or lactation yields per day. If survival in compromised environments is necessary, then adaptation to that environment must be taken into account in selection programs.

Action 5. Decide on the selection and breeding strategy that is most likely to succeed in improving production.

For conservation, the most common approach will be to apply a pure breeding strategy. However, sometimes the productivity of the animals ranking low in genetic ability for production can be enhanced by crossing them with a more productive breed. In this respect it may be worthwhile to capture the value that a pure breed has in providing hybrid vigor to crossbred offspring that can be marketed while the pure breed is maintained (FAO, 2010).

6.2 Optimizing selection response and genetic variability within small populations

RATIONALE

One of the options for increasing the probability of survival of an endangered breed is making the breed profitable. Increasing the productivity of a breed will usually make it more profitable and therefore increase its chances for self-sustainability. However, improving the genetic ability for production of a population and maintaining its genetic variability (N_e) are antagonistic processes. Some compromise is required.

Applying artificial selection to improve a trait will provide benefits for the profitability of the breed but will have unfavorable effects on the genetic diversity of the population, as it will be shown later on. Classical theory on the response to artificial selection establishes that the gain (G) in the mean value of the trait per year can be calculated as

$$G = i\rho\sigma^2/L$$

where i *is* the selection intensity, ρ the correlation between the estimated and the real breeding value of the individuals, σ^2 the genetic variance for the trait and L the generation interval. Consequently, to obtain greater responses, the values of i, ρ and σ^2 should be increased and the value of L reduced.

Selection intensity is a measure of the pressure we put on the population and is related to the proportion of selected to candidate animals in the population. Larger values are obtained by selecting fewer individuals as parents for the next generation; but this will reduce N_e, which is in conflict with the main objective of a conservation programme, and will lead to higher levels of inbreeding and reduced genetic diversity. More accurate estimates of breeding values (i.e. increased ρ) are often obtained by using information about relatives in addition to the individual phenotype. This strategy will lead to the co-selection of relatives, especially for traits with a low heritability, contributing again to the loss of diversity and the increase of inbreeding. Short generation intervals will also increase the gain but, as noted earlier in this chapter, also increase the amount of genetic variability lost per year. The presence of σ^2 in the numerator of the equation gives another reason for the maintenance of genetic diversity (i.e. high σ^2) in the breed, as response is greater when σ^2 is larger and no response for a trait can be obtained if there is no genetic variation. In summary, all the actions that can be taken to improve the gain in response oppose the general objectives established, from the genetic point of view, in a conservation programme. Consequently, some balance must be established between the various forces.

Objective: To improve the productivity of a breed while avoiding the loss of genetic variability as much as possible

Inputs:

1. Knowledge of the following characteristics of the breed to be conserved:
    a. Size of the population
    b. Reproductive capacity of the species and
    c. Characteristics of the production system
2. Awareness of country's livestock development objectives and existing and potential markets for animal products

Outputs:

1. Agreement among stakeholders with regard to traits to be improved and relative importance of genetic gain and maintenance of diversity
2. Clearly defined selection goal in terms of the trait(s) to be improved
3. A general breeding plan that will optimize genetic improvement and will maintain genetic diversity

Task 1. Adopt a general breeding strategy to maintain the conserved breed

Action 1. Determine which trait or traits are to be improved in the conserved breed
The determination of the objective of selection (i.e. the breeding goal: the trait or traits we want to improve in our population) has to be done in consultation with stakeholders. This process is described in more detail in the *FAO Guidelines on Breeding Strategies for Sustainable Management of Animal Genetics Resources*. This evaluation could be done in concordance with the studies conducted to describe the conservation values of the breed, as explained in Chapter 3. If the presence of a particular characteristic has been claimed to be an important factor for the maintenance of the breed, this characteristic should obviously be included in the breeding goal, because the reduction in performance for that trait would diminish or cancel the justification for keeping the breed. If this characteristic is a qualitative trait, we must be sure that selection to improve other productive traits does not cause the characteristic to disappear from the population.

Selection aiming at a specific niche market can make the animals more valuable. Therefore, the trait(s) crucial for the breed to be competitive in that market should be found. For example, if milk from that breed is going to be used for the manufacture of a particular type of cheese, traits to be selected are those related to milk (protein) quality, protein percentage and the amount of milk produced. To derive a breeding goal we should determine the increase in profit when one trait is improved by one unit. The latter yields the relative value of each of the traits, which can be summed up to form the breeding goal. Then, a selection index has to be set up from traits that are measurable and which correlate as highly as possible with the breeding goal. Ideally, breeding goals should be kept as simple as possible to assure improvements on the really important traits are obtained. Secondary traits can initially be controlled simply in requiring the breeding animals meet minimum acceptable levels for each trait and then these traits will be incorporated into the selection index later on, when the selection programme is well established and the population has increased its census size. Control or elimination of genetic defects may be an example of selection for a secondary trait (See Box 6.6).

Box 6.6
Genetic defects

Genetic defects tend to be more common in populations with low genetic variability. Populations at the start of conservation programmes may show genetic defects at frequencies of greater than 10%. Consequently, besides the development of a breeding programme on other traits, explicit actions have to be taken to remove the genetic information provoking the disease.

The effect of strategies will depend on the genetic determination of the defect. Genetic defects are often controlled by a single gene and, thus, the inheritance of the disease and the detection of carriers of the deleterious alleles is simple. In many cases the deleterious allele is recessive and thus only expressed when in homozygous form (i.e. in double copy). Such defects are more common in small populations (particularly with small N_e) because homozygosity is increased when genetic variability is decreased. When the defect is recessive, many individuals (heterozygote) will carry the allele but not show the defect. Genealogies may be used to identify the individuals with a high probability of being carriers. To eliminate the defect, first animals showing the disease and then carriers should be avoided as parents of the next generation, as long as the programme is not compromised by a too large reduction in breeding individuals. If DNA test exists for the gene responsible for the defect, individuals can be genotyped and carriers will be unambiguously detected and excluded from the breeding programme.
When the trait has a polygenic determination and behaves as a quantitative trait with different degrees of expression of the disease, a regular selection programme should be implemented to eradicate the defect from the population. In any case it should be stressed that restrictions on the loss of genetic diversity must be included for the breed to avoid troubles due to the rise of inbreeding (e.g. slow down the eradication of the recessive allele).

Action 2: Agree upon the acceptable rate of inbreeding in the conserved population
The acceptable rate of inbreeding per generation (ΔF) will depend on the status of the population and the characteristic of the species. For highly endangered breeds the values proposed earlier in this chapter can be used for pure conservation programmes, that is $\Delta F \leq 1\%$. As long as the population is not in the Critical or Endangered categories we can relax the restrictions and choose for a larger ΔF. In commercial breeds, there is a general consensus that the maximum acceptable ΔF is about 2%, but it may also vary between species. Remember that the more emphasis given to the maintenance of diversity, the lower the response on the selected trait, and vice versa. One recommendation may be to make (beforehand) predictions about the expected gain for a range of ΔF and choose the compromised solution that best meets both objectives.

Task 2. Design a breeding programme generating genetic improvement while maintaining genetic variability

Depending on the species, production system, ownership of animals and level of central control of breeding decisions, technical capacity and infrastructure, and various other factors, the following actions can be taken to achieve some selection response while maintaining genetic variability at an acceptable level.

Action 1. Determine the ideal number of parents when applying mass selection

The first approach to the control of inbreeding during selection is the determination of the number of males N_M and females N_F that would give the desired (acceptable) rate of inbreeding (ΔF) and then select the best N_M and N_F from each sex. Ideally, all selected parents would then contribute an equal number of offspring to the next generation in a process that is called *truncation selection*. The optimal combination of sexes can be obtained through use of the formulae presented in previous chapters, such as $\Delta F = 3/(32\ N_M) + 1/(32\ N_F)$ (Gowe et al., 1959).

Action 2. Apply within-family selection

A simple and more effective way to control the ΔF while improving the genetic expression for a productive trait is implementing within-family selection. As explained before, within-family selection consists of selecting one male from each sire family and one female from each dam family (i.e. each sire is replaced by one of his sons and each female by one of her daughters). Following that strategy, the population maintains a larger *Ne* than with random contributions (see Table 6.1), but there is still some room for selection. Instead of choosing at random a son or daughter from each family (as before hypothesized for non selected populations) we can select the best one in terms of our traits of interest and, therefore, some gain in the traits can be obtained. The selection intensity will depend on the size of families, but in any case the rate of gain will not be exceptionally large because this approach exploits only the within-family variability and ignores the genetic differences between families. Notwithstanding, within-family selection is a sensible and easy way to get low ΔF in selection programmes.

Action 3. Apply family selection

With structured populations, the opposite situation to within-family strategy is family selection, where all selected individuals are taken from the family (or group of families) with the highest average trait value. This methodology provides greater response but also leads to great losses of diversity and high rates of inbreeding, as all selected animals are close relatives. However, one can consider a wide range of combinations from within-family to family selection (see Table 6.1). For example, consider a situation with eight families of four males and four females each for which there is a need to select a total of eight animals of each sex. The two extreme combinations are 1) taking one individual of each sex from each family (represented by C1 in the table) or taking the animals from the two families with the highest mean value (C2). But there are several intermediate solutions which will differ in the response they yield and the effective population size they imply. All solutions have to be tested to find the one that yields the desired rate of inbreeding.

Table 6.1. Different ways of selecting individuals from eight families and the expected responses to selection and inbreeding (in percentage) that they imply.

	Distribution of family sizes									
Combinations	Number of male/female pairs taken from each family								Response	F(%)
C1	1	1	1	1	1	1	1	1	5.90	7.96
C2	4	4	0	0	0	0	0	0	17.42	42.76
C3	4	3	1	0	0	0	0	0	18.17	35.81
C4	4	2	2	0	0	0	0	0	17.87	33.26
C5	4	2	1	1	0	0	0	0	17.78	30.59
C6	3	3	2	0	0	0	0	0	17.30	30.59

C7	3	3	1	1	0	0	0	0	17.21	27.80
C8	4	1	1	1	1	0	0	0	16.38	27.80
C9	3	2	2	1	0	0	0	0	16.91	24.87
C10	3	2	1	1	1	0	0	0	16.24	21.79
C11	2	2	2	2	0	0	0	0	14.91	21.79
C12	2	2	2	2	1	1	0	0	14.85	18.57
C13	3	1	1	1	1	1	0	0	14.23	18.57
C14	2	2	1	1	1	1	0	0	13.56	15.20
C15	2	1	1	1	1	1	1	0	10.83	11.66

Taken from Toro and Pérez-Enciso (1990)

Action 4. Implement weighted selection

Notice that the use of the above methodologies reduces *ΔF* at the cost of lower responses in gain than obtained through mass selection with a fixed number of males and females selected. Ideally, commercial breeding companies operating in a competitive world would like to control ΔF without losing response. Therefore, a new methodology should be used. In a strict truncation selection, the selected individuals should each contribute the same number of offspring to the next generation. But if this condition is relaxed and differential contributions are allowed, we can actually select more individuals without losing selection intensity while getting larger N_e (see Box 6.7 for an example). This is possible because the best individuals are allowed to contribute relatively more, with their contribution proportional to their genetic value (phenotype or estimated breeding value). This methodology is called *weighted selection*. The disadvantage of this strategy, however, is the need to keep more individuals as selection candidates with an increased cost for the maintenance of these extra animals.

BOX 6.7
Weighted selection

This example is taken from Sánchez et al. (2002). In a population under truncation selection, each generation 32 individuals of each sex were evaluated and eight were selected. Consequently, each selected individual contributed four sons and four daughters to maintain the census size. For the value of a morphological trait this resulted in a selection intensity of 1.235 and the effective population size was 19.8. When weighted selection was implemented, the optimal scheme corresponded to selecting 12 individuals of each sex but the number of offspring to get from each of them was different, (with 6, 4, 4, 3, 3, 3, 2, 2, 2, 1, 1, and 1 offspring taken from the respective individual, ordered from highest to lowest in genetic value). In this scenario, the selection intensity was exactly the same (1.235) but N_e was nearly the doubled (31.5), as more less-related individuals contributed offspring.

Action 5. Apply optimum contribution strategy for selection

Weighted selection determines the particular contribution to the next generation of individuals based exclusively on their genetic value for the selected trait(s). The simple approach described in Box 6.7 is only correct, however, if the genetic relationships between animals are equal for all pairs. However, this condition is not realistic in the real world, as differences in relationships would for sure be present. When pedigree information is available, a theoretically superior solution is possible. Accounting for the coancestry of candidates as part of the decision criteria is a logical approach for minimizing inbreeding for a given level of genetic response. The idea of this approach is to set the contributions of individuals proportional not only to their genetic value for the selected trait but also to their degree of relationship with the rest of the population. Following this strategy, if there is a group of relatives that have high values for the trait of interest, not all of them will be allowed to contribute offspring. This methodology is referred to as the *Optimum Contributions strategy* (OC) and it is recommended as the most powerful way of dealing with genetic gain and inbreeding at the same time (Meuwissen, 1997). Not surprisingly, however, as was the case with minimum coancestry contributions, the implementation of OC requires a highly controlled production system and the utilization of complex mathematical procedures (see Box 6.8).

BOX 6.8
Optimum Contributions

To better account for the two opposing forces, genetic response (ΔG) and genetic variability (ΔF), both of them should be included in the objective function but with opposite sign ($+\Delta G$ and $-\Delta F$). The expected mean value for the selected trait of the next generation components can be estimated as the product of the value of parents by the number of offspring they contribute. Expected inbreeding, as explained before, is obtained by multiplying contributions and co-ancestries. Therefore, the objective function to optimize is $\Sigma\, c_i\, v_i - \Sigma\Sigma\, c_i\, c_j\, f_{ij}$, where c_i is the contribution of individual i, v_i is it genetic value for the selected trait and f_{ij} is the coancestry between individuals *i* and *j,* which is considered for every possible pair of animals. In practice, the term regarding ΔF is treated as a restriction, and the algorithm searches for the solution (i.e. combination of offspring contributed by each individual) with the highest ΔG but not exceeding the desired value for ΔF. Several methods have been proposed to solve this optimization problem, all of which require the use of computer programs. The program EVA (http://eva.agrsci.dk/index.html - Berg. et al., 2006) is one of the available software to manage a selection program with restriction on the inbreeding levels.

6.3 Crossbreeding local breeds for enhanced production

RATIONALE

With respect to conservation, crossbreeding may seem counterintuitive, but it may be a valuable option in certain situations. The concept of using limited crossbreeding for genetic rescue of an extremely endangered population with small N_e has already been introduced (See Box 5.2). There are, however, other instances where crossbreeding may be able to play a logical role in a conservation programme. Crossbreeding can be particularly beneficial when the objective for conservation is to maintain the beneficial genes of a population at risk, rather than the breed itself.

Crossbreeding provides the opportunity to combine the genetic characteristics of different breeds. Crossbreeding is recommended when multiple breeding goal traits exist that have antagonistic genetic relationships, such as between production and fertility or between production and quality of the product. It can be difficult to improve such traits simultaneously in a single breed. For example, combining the adaptive traits of a local breed with the production trait of an introduced exotic breed might be attractive. But crossbreeding is only effective and sustainable when the breeding system is carefully chosen beforehand, well planned, and strictly carried out by the farmers. An entire chapter is devoted to crossbreeding in FAO Guidelines on *Breeding Strategies for Sustainable Management of Animal Genetic Resources* (FAO, 2010).

One simple strategy for maintaining the local genetic resource is to crossbreed the non-descript and low-producing surplus local females. This procedure of limited, targeted crossbreeding not only saves the more productive well-defined local breeds but also uses the lower-producing animals for their maximum contribution for local commodity production.

Well-defined breeds that have been characterized as to production potential should be managed through breeding systems with the purpose of enhancing their productivity, and should not be used for crossbreeding. These breeds should instead be improved through selective breeding within the pure breed. More non-descript populations, or those that are crosses of local breeds, can have their production improved by using genetically superior germplasm from either local well-defined improver breeds or from exotic breeds that are relevant for the local production systems.

Unregulated and unmonitored crossbreeding can rapidly erode the numbers and genetic integrity of any breed that is used widely for crossbreeding. The utility of many breeds comes specifically from their role in organized crossbreeding systems, so attention must be given to maintain a sufficiently large and well-managed purebred population to assure continued availability of these animals for the crossbreeding system.

When a breed is used in a crossbreeding programme, specific information should be collected during breed surveys and characterization. Information that is useful about the breed's role in crossbreeding include population numbers and the current proportion of purebred breeding as opposed to crossbred production. The number of females mated pure quickly captures this aspect of the breed's dynamics. The data collected should also include the ultimate fate of crossbred and purebred offspring, and whether these are terminal (i.e. marketed without producing offspring) or used for further reproduction. Assessment should include the relative quality (high, medium, low) of the animals used in pure breeding and those used in crossbreeding. It is important to describe the role of each sex in the crossbreeding production system (e.g. Are males used for crossbreeding with other breeds, or are females used in this role?). Ideally, purebred populations are also undergoing selection for enhanced performance as measured in both purebred and crossbred offspring.

The basis for planning and implementing any crossbreeding program is the knowledge of what is wanted as a result. When an increase of production of a local breed is the objective, crossbreeding the local resource with an introduced breed may be considered. A fairly common and simple approach that is used for improving production is crossing a local breed with a more productive international breed. This can be done with a goal of effectively replacing the local genetics by continual successive crosses to the introduced breed or by *upgrading* by crossing to the introduced breed until a high proportion (>90%) of the introduced breed is obtained. The replacement strategy is clearly *not* conservation and in fact often fails in tropical regions due to lack of local adaptation of introduced breeds when compared to local AnGR. Breed replacement must therefore be thoroughly investigated before local AnGR are eliminated (or the local genetic material should be cryoconserved) because local resources usually have a logical long-term contribution and their survival and availability must be assured. Exotic breed introduction should usually not even be considered unless the enhanced production (locally realized, and not only potentially possible) is at least 30% greater than that from the pure indigenous breed (FAO, 2010). And, when this is the case, a system producing F1 animals and conserving the pure local population should receive primary consideration. As noted previously, a sound strategy is to use crossbreeding for the relatively lower-producing portion of the indigenous breed, reserving most productive local animals for purebred breeding.

According to Schmidt and Van Vleck (1974) different crossbreeding systems can be applied. Two main classes can be distinguished: 1) systems that require maintenance of the purebreds (purebred and rotational crosses) and 2) development of a new (synthetic) breed by systematically mating crossbred females and crossbred males.

Purebred crosses

- Two-way crosses: In this system, individuals of two pure breeds are mated and the offspring are only used for production and not for breeding. For example, the dairy cows with the lowest breeding values for milk production in a herd are not selected as dams for replacements, but are mated to a bull from a beef breed to produce offspring with a higher ability for beef production than a pure dairy calf.
- Three-way crosses: two-way cross females are mated to a sire from a third breed to produce offspring used for the production goal. For example, in pork production two breeds with a high fertility and maternal traits are occasionally crossed and crossbred sows are then mated to a sire from an excellent pork producing breed to result in a high number of piglets with the characteristics desired for pork production. Sometimes the two-way cross females are mated back to a sire of one of the parent breeds - this is known as a backcross. Sexed semen can be used to enhance such a crossbreeding programme if animals from one sex are more desired for production purposes (See Box 6.9).
- Four-way crosses or double two-way crosses: two-way cross females are mated to two-way cross males to produce the animals used for the production goal. An: example: in the specialized poultry production, in egg and broiler production, such a cross is the preferred breeding method of the multinational breeding companies.

Box 6.9
Effect of sexed semen in producing a final cross in dairy cattle
(Van Arendonk 2010)

The availability of sexed semen in dairy cattle has been eagerly anticipated for many years, and recent developments in fluorescence-activated cell sorting have brought this technology to commercial application. In recent years, a number of AI companies have started to offer sexed semen to their farmers. Semen sexing provides the potential to increase the numbers of offspring of one sex in a closed population, thereby increasing the intensity of selection for that sex. Semen sexing enhances the farmers' ability to obtain a larger number of replacement heifers from its own herd. In a herd with a stable herd size, semen sexing could be used to breed replacement heifers from the cows with the highest genetic merit. This will create a one-time lift of the genetic level of the herd. The largest economic benefit of using sexed semen in pure-bred herds would come from the ability to use the remaining dairy cows for the production of cross-bred animals for meat production Semen sexing can be used to increase the efficiency of producing F1 dairy hybrids. For an F1 scheme to be sustainable, part of the purebred population needs to be mated to bulls of that breed to produce replacements. The number of cows that need to be mated for breeding replacements can be nearly halved by the use of sexed semen. In addition, the number of F1-females that are produced can be nearly doubled by using sexed semen. In other words, the number of purebred cows that need to be kept for the production of F1 hybrids can be reduced by 60 to 75% depending on the sex ratio resulting from the use of sexed semen. The economic benefit of this reduction is largest when purebred cows and crossbred cows are competing for the same resources. Benefits are smaller in a stratified crossbreeding system, such as that used in Brazil where dairy farms buy replacement F1 females, than in the poultry or swine industry. Those females are produced in areas of less expensive land, using Holstein semen on Brazilian dairy zebu breeds.

When two-breed crosses are used with imported genetic resources, it is strongly recommended to utilize the local breed as the source of pure females to be mated to sires of the exotic breed. Two-way-crosses require only a limited number of sires of the breed, so maintaining a population solely for production of males could result in greatly reduced census size, which would increase the risk of extinction. Breaking the cycle in which low census numbers limit the potential of within-breed improvement is difficult in local breeds. Small population sizes limit the selection intensity that can be applied and/or increase inbreeding. If a higher census can be coupled with good record keeping and selection, then progress can be made in increasing productivity, which will subsequently increasingly the breed’s value and help secure its sustainability in commercial settings. If the only perceived value of a breed is as a component of a crossbred population, then securing the breed in sufficient numbers for purebred selection will be difficult. Numerically insecure breeds are likely to be overlooked resources for commercial purposes, and therefore remain rare (See Box 6.10)

Box 6.10
A crossbreeding example with Criollo cattle in Bolivia

Breeds that excel in crossbreeding have complicated issues surrounding their use and conservation. The Criollo Saavedreño cattle breed of Bolivia is widely used for mating with Gyr, Holstein, and Brown Swiss cattle to provide crossbred dairy cows for commercial use in the tropical lowlands of Bolivia. While the Saavedreño bulls meet with a brisk demand for this purpose, the purebred cows are in much less demand than are crossbred females. This situation has assured that the census for the breed is relatively low (some few hundred head mostly in a single government installation). As a consequence, selection within the breed remains somewhat low when compared to breeds of higher census. Production is unlikely to diminish but selection differentials are unlikely to be high enough to quickly increase genetic merit for productivity. This situation becomes a cycle in which low census prevents within-breed progress in selection for production, which in turn assures a continuing low census.

Rotational crosses

- Crisscrosses: a two-way cross female is mated to a sire of one of the two breeds and their female offspring are mated to a sire of the other breed used to produce the original two-way cross. This alternating pattern of sire breed usage is then continued in subsequent generations.
- Three-way rotation: Sires of three breeds are used in successive generations on the crossbred dams of the previous generation.
- Multi-breed rotation: It is clear that such rotation schemes can be extended to the

use of four breeds (four-way rotation) or to the continued use of sires of new breeds (indeterminate rotation).

An advantage of rotational crosses is that it is not necessary to exchange females between herds or villages, which decreases costs and reduces disease transmission. Only the sires of the breeds involved have to be purchased by the owners of the females. Artificial insemination will even eliminate the need to purchase the males. Another advantage is the rotational systems maintain high heterosis - 67% with a two-breed rotation and even more when additional breeds are involved. A disadvantage is that the producing and reproducing offspring represent different combinations of breeds and thus show a high variation in phenotype. Rotational schemes involving a high number of breeds can be problematic in terms of monitoring and require the availability of a wide variety of germplasm. Three-way rotations may be the most efficient compromise.

The development of a synthetic breed

Many breeds have been developed by interbreeding within crossbred groups following an initial cross of a temperate production breed to one or more locally adapted breed (or more complex combinations with more than two breeds). An example is given in Box 6.11. Selection usually stabilizes the exotic inheritance at around 50%, because in most cases any exotic influence above this results in a decline in most important economic traits, due to poor adaptation. Synthetic breeds benefit from broadening of the initial genetic base of the crossbred populations by periodic infusion of fresh germplasm with high merit, including influence from the exotic as well as from the indigenous breed. To avoid high levels of exotic inheritance it is essential to maintain purebred populations of the parental local breeds. The long-term objective of synthetic breed production should be stabilization of the crossbred synthetic breed which is well adapted to the local environment and production system.

Box 6.11
Development of Karan Fries Cattle

Karan Fries cattle were developed by the National Dairy Institute of India beginning in 1971. The breed formation process started from a base of Tharparkar (T), a local Zebu breed, and three exotic breeds Holstein-Friesian (H), Brown Swiss (B) and Jersey (J). A critical first step in the development process was to perform a study to determine the appropriate exotic breeds and the optimum level of exotic inheritance for evolving a synthetic breed suitable to Indian production systems and climatic conditions. To initiate, F1 offspring were created by mating T females to males from each of the three exotic breeds. The resuting F1 females from each initial cross were then mated with Holstein-Friesian semen to obtain crossbreds with 75% exotic inheritance consisting of two-breed crosses (¾H × ¼T) and 3-breed crosses (½H × ¼B × ¼T) and (½H × ¼J × 1/4T). No significant improvement was shown by 3–breed crosses over the H×T F1 crosses, however.

A few H×S (Sahiwal) crossbreds were also added to this crossbred population, adding this Indian breed to the previously used T. No significant differences were observed in performance among 75% H×S, 50% H×S and crosses with 75% exotic germplasm (each with 25% T). Heterosis for growth, reproduction and production traits was not statistically significant for two- and three-breed crosses, indicating that genetic improvement could be best obtained by exploitation of additive genetic variance. In 1980 the breeding committee of the Institute decided create a new "breed" by merging all of the experimental crossbreds with ≥50% exotic inheritance, with further improvement to be brought about by selective breeding and *inter se* mating. The new synthetic strain was named "Karan Fries".

At the time of the merging of the different genetic groups, about half of the population comprised crossbred cows having exotic inheritance of 50%, about a quarter having exotic inheritance of 75% Holstein-Friesian and the rest having 75% exotic germplasm from two breeds (i.e. (½H × ¼J × 1/4T or ½H × ¼B × ¼T). The average level of exotic inheritance was subsequently reduced to around 62.5% per cent by using F1 bulls of high breeding value from other cattle breeding organizations. In order to bring about genetic improvement in this synthetic breed and to study its utility under farmers' conditions, the progeny testing of Karan Fries bulls was begun.

The proportion of H in the Karan Fries is now believed to be between 40 and 50%. Milk production averages about 3 500 kg per lactation, whereas the national average is less than 1 000 kg. Daily milk yield can exceed 50 kg per cow under optimal management.

All three of the crossbreeding systems (purebred crosses, rotational crosses and development of a synthetic breed) may be considered when developing a crossbreeding programme for conservation, although the synthetic breed approach will likely involve the loss of one breed during the creation of another.

Objective: To develop a stable crossbreeding system that conserves a local animal genetic resource

Inputs:

1. A local breed at risk for which development of a crossbreeding programme is a viable option for conservation
2. Information about the breed at risk, including its population size and risk status and its strengths and weakness and the opportunities and threats that may affect its long-term sustainability
3. A description of the local situation in terms of both the production systems and markets for products
4. Inventory of characteristics of other relevant local breeds and exotic breeds. This includes production characteristics as well as breeding programs for maintenance and improvement, and their roles in crossbreeding systems.

Output:
A sustainable programme for maintenance of a local AnGR, either as a pure breed that contributes animals to a subsequent programme or in the form of its beneficial genes, when incorporated into a synthetic breed.

Task 1. Develop a system for crossbreeding to conserve a local AnGR

Crossbreeding programmes that are not-well planned are likely to fail, or at least to not reach their desired objectives. A comprehensive plan for crossbreeding should thus be devised before commencing any activities. The National Advisory Committee on AnGR may responsible for this plan, or may choose to form a special ad hoc committee. The committee should include key stakeholders.

Action 1. Outline the desired outcomes of the crossbreeding system.
The primarily goal of any conservation programme will be the maintenance of the target indigenous breed. In addition, the secondary outcomes that support the achievement of that goal should be formulated. The commodities to be produced should be considered and overcoming constraints of the production systems must be accounted for.

Action 2. Evaluate the status of the targeted indigenous breed.
The activities described in Chapters 1 to 3 will provide most, if not all of the information needed to make informed decisions on the establishment of a crossbreeding programme for conservation. Among the most important pieces of information are census results for estimates of actual and effective population size, knowledge of the strong and weak traits of the breed and the particular threats for its survival. Awareness of the main stakeholders for the breed and some indication of their willingness to participate in crossbreeding are also crucial.

Action 3. Evaluate the other breeds that are potentially available for inclusion in the crossbreeding plan.
Crossbreeding will only be viable if genetic material of the complementary breeds in the cross is readily available in sufficient and sustainable quantities. A list should be made of all such breeds. Both other local breeds, from which live animals may be available, and exotic breeds, for which only semen may be available, should be considered. Then the status of these breed in the local habitat, production system and agro-ecology should be determined through literature review and/or surveys that document their respective phenotypic characteristics and performance levels. Special attention should be given to unique genes or traits that impact the complementarity with the local breed.

Action 4. List the potential crossbreeding systems that might function in the relevant conditions.
A critical initial decision will be whether or not the local breed in question can realistically be maintained as a purebred population. All purebred crossing and rotational systems require the maintenance of a population of purebred animals. Purebred crossing systems will require the largest populations, because they require the availability of two groups of females 1) to maintain the pure population and 2) to produce F1 animals. Rotational crossbreeding systems will generally only require the production of sires for germplasm in crossbreeding.

Consistent with recommendations from Chapter 2, the N_e of the purebred population should be ≥50, excluding the purebred females that are crossed to produce F1 in purebred crossing systems. Larger population sizes are preferable, obviously, to allow for greater selection within the pure breed. When N_e is significantly less than 50, incorporation into a synthetic breed may be the most practical option.

Maintenance of purebred populations will also require the availability of stakeholders (either farmers or government institutions) that are willing to maintain the breed, even though their production potential will likely be less than crossbreds.

Action 5. Describe the function of the indigenous breed and complementary breeds in the crossbreeding system.
Important and unique attributes of local breeds to be exploited through crossbreeding usually include disease resistance and stress resistance, quality and composition of

animal products, adaptation to different environments or farming systems, and the ability to utilize coarse roughage and crop residues. The complementary breeds often are chosen to increase productivity.

Action 6. Choose the optimal crossbreeding system.
Develop crossbreeding to enhance performance of the low-producing local cattle, and reserve high producing local cattle for use in pure breeding systems. Where crossbreeding is going to be inevitable, establish protocols for assuring some use of high producing local cows for purebred breeding and retention of males that can be widely used locally. Determine how many breeds (usually between 2 and 4) are needed to attain the final desired mix of traits that will result in the desired economic performance. The crossbreeding system should also be characterized according to the gender of animals contributed by each breed, assuming this differs by breed.

Action 6. Present the plan to a wider group of stakeholders for final approval.
Although key stakeholders should be intimately involved in the planning of a crossbreeding programme, the final plan should be presented to a wider group of stakeholders for discussion, revision if necessary and final approval. In particular, the farmers that will be implementing the programme and subject to its costs and benefits must be consulted.

Task 2. Organize the logistics, implement and monitor the crossbreeding plan.

Once a the genetic plan for crossbreeding has been developed and agreed upon by stakeholders, the next step is to organize, launch and operate the plan, including monitoring of its success. These activities are presented in detail in the FAO Guidelines on *Breeding Strategies for Sustainable Management of Animal Genetic Resources* (FAO, 2010), but will be summarized here.

Action 1. Prepare the plan for the start of the cross-breeding programme.
Before a crossbreeding programme can be launched, various factors have to be accounted for. For example, specialized personnel may need to be appointed to manage the programme. Infrastructure for communication and transport of animals may be needed. A financial analysis of the programme may be warranted, especially if substantial investments are required.

Action 2. Set up the financial and organizational structures.
If outside investment is needed, these funds will have to be secured, most likely from the government or specialized non-government organizations. The crossbred animals may require different management than for the local breed involved in the crossing programme, so training activities for farmers may be required.

Action 3. Implement the crossbreeding programme.
The cross-breeding programme will require continual attention and monitoring to detect and resolve unexpected problems. The appointment of a committee of particularly competent livestock keepers to aid in providing advice is recommended. Extension services should be established or strengthened for dissemination of solutions to problems encountered.

Action 4. Organize the delivery of crossbreeding services.
Crossbreeding programmes may require systems for exchange of germplasm that are

more complicated than for purebreeding programmes. For purebred crosses, F1 animals may be produced on one or more farms and distributed to others. For rotational systems, breeders will need to have access to males of a variety of breeds, either as live animals or through AI. Programmes for synthetic breeds will likely benefit from the establishment of breeders associations and AI services. Support for research on ways to improve the programme will likely be beneficial.

Action 5. Improve the crossbreeding services and promote uptake.
Promotion of the crossbreeding programme will help increase the number of farmers involved, which will likely improve its success through various economies of scale and thus improve the sustainability of the local germplasm. Programmes for animal identification, performance and pedigree recording will also contribute to the genetic improvement of animals and aid in general management of mating systems, as well as provide documentation for evaluation of the programme.

Action 6. Evaluate the crossbreeding programme for benefits obtained and sustainability.
The programme will need to be periodically evaluate to determine if its objectives are being met. In particular, programmes established to contribute to conservation need to be evaluated in terms of their effects on the breed to be conserved. The results of these analyses should then be reported to all stakeholders, including farmers, policy makers and any funding agencies.

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7 Opportunities to Increase the Value of Local Breeds in *In Situ* Conservation Programs

7.1 Opportunities for sustainable use of breeds to be conserved

RATIONALE

Several opportunities exist for the sustainable use of breeds to be conserved (Oldenbroek, 2007) that can result in higher income for the owners of the animals of the local breeds in the conservation process:

- Improvement of the management of the animals at farm level. The production level of animals is a combination of their genetic ability and the management practiced: e.g. quantity and quality of the feed supplied, housing and vaccinations against diseases. Improvement of the management also improves the production of breeds with a lower genetic ability for production comprised in a conservation program with positive effect on economic returns.
- The development of high quality products for niche markets. Breeds have genetic differences in production potential and in the quality of their products. In general selection for high production has a negative effect on quality of products. Breeds to be conserved may have a lower production potential, but they potentially can be the source of high quality products for niche markets (e.g. cheese, sausages and ham) which can then be sold at a greater per-unit price, compensating for the decrease in the amount of product.
- The value of high quality products of rare breeds maybe enhanced and secured by the contribution of various factors related to the connectedness of food products to their places of origin. Such originality factors can be used for promotion and can be supported by labeling the products. These activities require collaboration with breeders, producers and marketers to realize the enhanced price for the high quality products, as well as with the comsumers, to ensure that sufficient demand exists.
- The exploitation of the potential ecological functions of species and breeds in nature management can generate an income in addition to the prices for the products. In many areas of the world natural grasslands, wetlands or heath land areas would change over to forest if the grass or heath were not shortened regularly. The grazing ability of herbivore species is a unique opportunity for conservation of these areas and is realized already in many countries. Well adapted breeds of cattle, sheep, goats and horses can be conserved in large numbers to fulfill this task in a natural environment.
- Governmental support or incentive payments may be obtained for the potential societal and cultural functions of species and breeds in tourism and societal events. This opportunity is often discussed but realization seems to be very difficult.

Objective: Document the opportunities for a breed to be conserved

Input: List of breeds by species and characteristics of each breed.

Output: A description of the opportunities for a breed for exploitation to generate more income.

Task. Select the opportunities for the utilization of a breed

Action 1. Determine the relevant opportunities in your country or local area for the species that the breed belongs to.
Improvement of farm management is the first to be considered, as will usually yield the fastest results, can be applied in almost all situations and can complement other approaches. Not all opportunities are relevant for all species. For example, organic farming is usually not a good option for horses, and management of natural areas has limited opportunity for chickens. Milk (cheese) production is a real opportunity for milk producing cattle, sheep and goat breeds.

Action 2. List the characteristics of the breed and combine them with the different opportunities (farm management, specialized or niche production, hobby, nature management, or others).
For example, a two-way table can be created for each breed, with the breeds characteristics listed vertically along the left margin and opportunities in columns running right to left across the table. Cells in the table can be marked when opportunities are relevant for the corresponding breed characteristics.

Action 3. Describe the realistic opportunities for the breed.
Based on the relevant combinations of characteristics and opportunities identified in Action 2, specific measures to take advantage of the opportunities can be proposed. The activities and required to take exploit the various opportunities should be outlined, as well as the relevant stakeholders. The strengths and weakness of the opportunities should be noted, in addition to any obstacles to be overcome. The chances of success of a programme to implement the opportunity should be assessed.

7.2 Improvement of the management through extension activities and Master Breeders programes

RATIONALE
Although genetic improvement is permanent and cumulative and therefore promotes sustainability, it must be regarded as a long-term, multi-generational process. A complementary approach to help ensure breed sustainability is through improved management. Improved management can contribute greatly to improved production from indigenous breeds, and provides owners with enhanced economic return in the near term, helping them to maintain the breed until the effects of genetic improvement can be realized. Management should go along with breeding and genetic aspects of breed maintenance. It is important for improved management to remain within the economic, social, cultural and environmental constraints of the local situation. In most situations duplicating a temperate-zone intensive-production model is neither possible, nor sustainable, nor wise for long-term breed maintenance. Extension activities are a very effective way to build capacity by farmers in improved management and can be implemented in cooperation with breeders associations.

Most breeds can benefit greatly from the contributions of a few “Master Breeders.” Master Breeders are livestock keepers that have a great deal of “indigenous knowledge” allowing them to manage their animals well and to also do a good job of selecting animals (See Box 7.1 for an example). Programmes that identify these individuals and then disseminate their knowledge and techniques are useful for all breeds. Master

Breeders have expertise in both management techniques and genetic selection, and this is important knowledge for future generations. This knowledge should be put in a form that can be widely disseminated to benefit future breeders as well as the breed itself.

Box 7.1

The role of Master Breeders in the revival of the "Heritage Turkey" in the USA

The American Livestock Breeds Conservancy (www.albc-usa.org) has countered the slow erosion of traditional breeding techniques with a "Master Breeders" program that captures their knowledge and experience. The first effort involved the production of nonindustrial "Heritage Turkeys." Heritage Turkeys comprise of a variety of breeds of domestic turkey in the USA that retains various traditional characteristics that are no longer present in the modern commercial strains. Among these characteristics are the ability to survive under extensive management conditions and to reproduce without the aid of AI. Turkey production in extensive settings was once common, but is now a rare alternative to industrial production. As small extensive systems declined in number, so too did the techniques used to raise turkeys, select breeding birds, and assure that production characters remained at a high level within the constraints of an extensive system. Key breeders were identified and interviewed, and their techniques were then distributed to a broad audience through a series of workshops in different geographic regions. This programme has increased the number of Heritage Turkey breeders using time-tested selection techniques in their flocks, which puts these resources on a firm footing based on productive potential. Master breeders are often also experts in marketing their breeding stock and the unique products of their animals.

Master breeders combine both knowledge and art, and their strategies come from years of careful observation and experience. Their techniques are often intuitive, so they can be difficult to quantify and document. A careful outside observer can help define their practices so that others can benefit from the years of experience.

Objective: Create strategies for benefiting from master breeders and to disseminate their knowledge.

Input:

1. A list of master breeders

Output:

1. Compilation of knowledge of Master Breeders
2. A strategy for benefiting from Master Breeders
3. Learning materials for dissemination of knowledge from Master Breeders

Task 1. Undertake an inventory of master breeder's knowledge and experience.

Action 1. Identify Master Breeders.

Actively search for highly regarded breeders in each breed. They may be identified by the performance of their animals and their reputation within the breeder community. Therefore, sources of information are records of performance (assuming such a record-keeping system exists) and surveys of breeders.

Action 2. Interview Master Breeders carefully to fully discover the techniques and attitudes that lead to their success.

Observe Master Breeders at work, to uncover details that are second nature to the breeder and are key to their success. Careful observation can tease out small details of management and selection.

Action 3. Document and define the intuitive management techniques.
The techniques of Master Breeders must be communicated to be accessible. In the past this was accomplished by one generation working closely with the previous one, but this is increasingly unlikely and not applicable for broader extension activities. Documenting and communicating these methods helps to bridge this gap. Pay special attention to facilities, and animal handling techniques.

Action 4. Document and define the intuitive selection criteria.
Selection decisions are usually based on techniques that have proven valuable over years. Some techniques may appear illogical, but have valuable consequences in the population. Document these for future generations. Note what traits are being measured or noticed, and what consequence these have for production or viability.

Task 2. Disseminate the knowledge of Master Breeders and encourage its application.

Action 1. Make the results widely available.
Tools for dissemination of Master Breeders' knowledge can include handbooks, educational books, brochures, websites, seminars, and workshops. Workshops and field days can be particularly helpful by bringing people into direct contact with the Master Breeder, thus creating an opportunity for future networking, and can emphasize transmission of ideas and techniques on animal improvement. In many instances, knowledge that is transferred first-hand through visual means and hands-on experience will be retained more readily than when gained from reading.

Action 2. Reward or otherwise recognize Master Breeders for their contributions.
Most Master Breeders do what they do through their own initiative, either for personal satisfaction and/or to make their animals more productive and profitable, and thus would not necessarily expect to be rewarded for their actions. Nevertheless, they may appreciate formal acknowledgement of their activities and contributions to breed conservation. Many breeders associations have award programmes to annually recognize outstanding breeders. Certain countries offer similar awards for people that make particular contributions to conservation of local breeds. An example from India is given in Box 7.2.

Award programmes can be beneficial, not only for rewarding existing Master Breeders for their contributions to breed sustainability, but also to encourage novice breeders to apply their techniques and become Master Breeders in the future.

Box 7.2
The "Breed Saviour Award" in India

India is the putative centre of domestication for various livestock species and the home of a large amount of genetic resources for food and agriculture, both with respect to plants and animals. Therefore, conservation of these resources is a national priority. To help aid in the *in situ* conservation of livestock breeds, the world renowned plant breeder Dr. M.S. Swaminathan proposed the idea of "Breed Saviour Awards" to recognize individual livestock keepers or whole communities that make notable efforts to conserve and improve local livestock breeds. This programme is being supported by the National

Biodiversity Authority, along with two non-governmental organizations, SEVA (Sustainable agriculture and Environmental Voluntary Action) and the LIFE Network. The award comprises a prize of 20 000 rupees and a special certificate and is given annually to 20 honorees.

7.3 Opportunities for breeds to be conserved through niche markets for high quality products

RATIONALE:

Worldwide there are several examples of breeds that produce high quality and distinctive products, with the products contributing to effective breed conservation. Efforts to enhance the value of breed-specific products are as valid as efforts to enhance levels of production in a breed and may be a more realistic scenario for breeds of species where a few extremely productive breeds dominate the market. When breed-specific products obtain a premium in the marketplace the result is increased monetary return to producers, with an increase in breed security that comes from that. In some cases enhanced value is due to a unique product, in others it is due to enhanced appeal due to local sourcing. Niche marketing can be ideal for certain situations if the products are marketed in a way that emphasizes traditional techniques and local ties (LPP *et al*., 2010). Such efforts can involve existing traditional products, and can also include newly developed products with unique characteristics.

These efforts can help local breeds that have somewhat less productive potential to compete with common international breeds that have been intensely selected to generate high yield of mainstream commodities. Promotion comes from consideration and attention to the uniqueness of breed-specific products. Breed-specific products can have broad appeal to consumers that are interested in regional products, and can be especially important in safeguarding local genetic resources that are firmly tied and readily identified with a specific region. In many situations careful development of the product and the marketing are needed (LPP *et al.*, 2010).

Box 7.3

Heritage Turkeys cut across ethnic and religious boundaries in USA

One of the most successful promotions in the USA has involved several traditional turkey varieties raised in traditional systems. This promotional effort contrasts these Heritage Turkeys with the more common (and inexpensive) industrially produced birds. One of the more important unifying cultural events in the USA is a Thanksgiving Day celebration in late November that involves a celebratory meal. This meal has traditionally involved consumption of turkey and associated side dishes, and is a celebration that cuts across ethnic and religious boundaries in the USA. Nearly everyone participates, and it is in a very real sense the one focused celebration common to nearly the entire country.

The linkage of turkey with the celebratory Thanksgiving Day meal has made it possible to promote traditionally raised, heritage varieties of turkeys for this one feast. Though the cost of the heritage birds may outstrip commercially produced birds by up to ten times, the demand for these special heritage birds is currently so high as to go unmet. This demand has dramatically increased the demand for poults of these varieties, which has in turn allowed hatcheries to greatly increase the size of their breeding flocks. The consequences of this increased demand have reversed the trend to certain extinction of many of these varieties, and this reversal has been directly related to promotion of a specific product, raised in a specific way, for a specific feast. This is all the more remarkable because this elite demand is miniscule when compared to the millions of industrial birds consumed on this day, but has still served to reverse the fates of several traditional varieties of turkeys. Increasing numbers of breeder birds has also increased the interest of breeders in traditional techniques of bird evaluation and selection. Through this the previously successful practices of the early and mid 1900s have been recaptured from a very nearly complete loss.

Breed-specific promotions have a host of challenges as well as opportunities (LPP *et al.*, 2010). Challenges include the fact that local breeds can lack recognition, and products from them can be available in such low quantity as to make marketing difficult due to uneven or sporadic availability. Organizing local and pastoral producers can be a hurdle that is difficult to overcome, and making links to a stable ongoing market can be problematic. On the positive side, local products often have uniqueness than can be marketed. Exploiting the local character of such products and their producers can have a very beneficial effect in the local area. Assuring that the local character is emphasized can also result in a focus on the local resource and local traditions, working to save both. Benefits accrue locally, and result in an overall increase in local economic capacity.

Focusing on breed-specific products has the advantage of providing a reasonably secure market niche for a breed's unique capabilities. In many situations this requires a market with the potential to value uniqueness over more standardized commodities, and cash-strapped societies are less likely than more affluent ones to afford this relative luxury. While this is generally the case, it also remains true that traditional products can and do find increased demand even in societies in which disposable income is minimal. The price differential for the preferred local product can easily provide enough economic advantage to help breeders of local breeds. As incomes rise and disposable income becomes more available, these traditional products can gain an increasingly large share of the total commodity market.

Objective: to develop a business plan for the marketing of high quality products of a breed to be conserved.

Inputs:

1. A list of the unique characteristics of the breed to be conserved
2. Knowledge of the potential for interest by consumers in purchase of niche products
3. Awareness of constraints to developing and marketing niche products

Outputs:

1. A list of potential niche products from the breed. This will usually include traditional products as well as more innovative and creative new products.
2. A plan for marketing of the products

Task 1. Create a list of potential products and services from the breed, and prioritize these for feasibility in under the constraints of the production and marketing environment.

Action 1. List the characteristics of the breed that could possibly be exploited by *marketing.*

Activities described in Chapters 1 to 3 will provide the basis for identifying and developing niche products. The special traits of the breed and their products will have been identified through this characterization process. This information may be augmented by additional surveys of key breeders and other livestock keepers, potential customers and other members of the value chain such as processors, manufacturers and marketers. Box 7.4 explains how keepers of a certain breed of sheep capitalized on the special characteristics of its wool.

Box 7.4

Fleece characteristics are exploited in Chiapas Mexico and safeguard local breeds.

The shepherdesses that steward the sheep from Chiapas Mexico have specific fleece characters that have traditionally been key components in the production of the local textiles that are important culturally. Through programs that provided for the input of these shepherdesses, as well as for their ongoing participation, these factors have been incorporated into selection programs for the local sheep breeds. This has resulted in enhanced appreciation for the sheep, increases in census, and also increased dedication on the parts of the owners for the effective conservation of the sheep (Perezgrovas 1999). This is the goal of organizing breeders of landrace breeds, and is a very effective example of success.

Action 2. Identify the markets for the breed-specific products.

A complement to Action 1 is to identify potential markets. Market identification can also be done prior to emphasizing the particular products. Box 7.5 shows an example of how a new market was found for an existing product.

Box 7.5

Tourists buy pochos from wool of the Linca sheep in Argentina

The Linca sheep of Argentina is an endangered local breed of coarse-wooled sheep that has tradtionally been used for the manufacture of distinctive ponchos and other textiles. A producer's cooperative has now targeted these distinctive products for promotion to the tourists which come to the picturesque region in which the breed persists. This has greatly increased the value of the raw wool, and has also employed shearers, spinners, and weavers in the local community to assure a supply of the distinctive textiles.

Action 3. Conduct a workshop in which stakeholders at all stages of the production and marketing chain come together to creatively formulate potential plans.

These should include producers (farmers and pastoralists), nutritionists, retailers, butchers, food manufacturers, cooks, consumers, marketers, craftspeople. This should produce an extensive list of products and services that could potentially be marketed to niche consumers.

Action 4. Prioritize the products and services from the breed, targeting a few of the obvious ones for production and promotions.

Various factors may influence the market potential of a niche product to support breed conservation. Highest priority should be given to any products that already have a recognized place in the market that can be realistically expanded with more promotion, resulting in either greater sales or prices or both. This approach is called "market penetration" and is usually the simplest and most successful strategy. Another relatively safe strategy is to seek to spread an existing product to new markets, thus increasing total revenues. The most risky strategy is to develop entirely new products. This approach requires both product and market development. Box 7.6 shows how this somewhat risky strategy can have high rewards for breed conservation.

Box 7.6
Desert Dessert ice cream helps conserve Raika camels in India

The conservation of Raika camels in India has involved production and marketing of one fairly obvious commodity, ice cream made from their milk. Creative marketing came up with the name "Desert Dessert" for this distinctive product. As this breed has always been used for milk production, this product is an extension of traditional use. In addition, creative efforts at new product development have used the manure from the breed in paper making, which is then used to manufacture greeting cards. This unusual product has met with demand that far exceeded expectations, so that production tends to always lag behind the demand. Both of these products – one more traditional, one very novel – have increased the economic return to the pastoralists stewarding the breed. This has made the traditional systems surrounding the breed and its production much more secure.

Task 2. Evaluate the feasibility of using niche products to support a breed's conservation.

Action 1. Write a business plan and organize a short production and marketing chain for each product.
Seek the consultation of an economics or business expert to help formulate a business plan and to map out the market chain. This will also involve the collaboration with other stakeholders along the proposed market chain. To be successful in marketing a special product from an indigenous breed, it will be necessary to distinguish it from the standard products in the marketplace that can be produced by mainstream breeds. This factor must be considered in the business planning. Distinguishing a product can be approached through four ways: product, price, place and promotion, also known as the "four Ps" or the "market mix". A common strategy is to market a breed-origin product based on its increased quality, or at least the perception of higher quality, or distinctive taste or appearance. One usually hopes that such unique products will command a higher price in the market than do mass-produced animal products (See Box 7.7). The place for marketing can also be important, both to distinguish the product and to capture some added value. Direct marketing, for example, can yield multiple benefits. It can "cut out the middleman", increasing the margin of the sale returned to the farmer and perhaps increase loyalty from customers that want to be sure about the source of their food. Promotion is an essential part of niche marketing, inasmuch as the entire business plan will likely be based on reaching new customers that may not be aware of the positive characteristics of the breed-based product.

Box 7.6
Rose veal of Randall Lineback cattle is sold in US restaurants

Randall Lineback cattle in the United States are an old, local triple-purpose (milk, meat, draft) breed that became rare due to its inability to compete against specialist dairy and beef breeds. Its meat and milk production levels are such that competition in mainstream commodities is unlikely to succeed as a strategy for assuring breed security. Therefore, breeders of Randall Lineback cattle sought to establish and market a distinct, higher value product. Creative promotion of “rose veal” (meat from yearling animals) has established a ready market for this product in restaurants, and the premium that is obtained contributes to economic return for the producer.

Action 2. Undertake a formal analysis of the business plan and potential market.
Formulation of the business and marketing plan should be followed by a market survey and feasibility analysis. Establishing a niche market will require investment in both time and money. One-time costs will be incurred in preparation and marketing will require continuing expenditures. Market research will provide some insight as to whether customer demand will be sufficient to repay such investments.

Action 3. Produce a relatively small amount of the product and market it on an experimental basis.
Even if the business plan and market analysis suggest that profitability is highly likely, it may be prudent to start on a small scale. For breeds with a low census, starting on a small scale may be necessary. If the marketing programme is supported by outside investors, these investors may want to see some return on their investment before supporting scaling up.

Action 4. Evaluate sales and increase production according to market demand.
An objective of almost any *in vivo* conservation programme will be to increase both real and effective population size to take the breed out of risk for extinction. Complementary niche marketing plans will have to evolve and grow in concert with the breed census. This may involve simply selling more product in the same market, expanding to new markets, creating new products or any combination of these options. Care must be taken, however, to ensure that expanding the market does not affect the factors that made the product attractive in the first place (e.g. quality and distinctiveness) and that the market can handle any increased demand without negative effects on the price.

7.4 Enhancing the value of existing niche products of breeds to be conserved

RATIONALE:

In many cases it is not immediately obvious which specific characteristics of the breed may be used to develop high quality products for a niche market. In such cases a study should be carried out first to determine the characteristics. In other instances, breed related products may already exist, but are not being exploited fully. An important element that may be targeted in marketing is the originality of the high quality products, particularly with respect to its place of origin (See Box 7.8).

Box 7.8
Role of qualification labels for regional products

Tregear *et al.* (2007) concluded that qualification processes may bring socio-economic benefits to rural areas. These may play a role in linking local and non-local actors and the non-local actors can bring extra revenues in the local area. Qualification labels, like PDOs and PGIs are market mechanisms, information signals used by producers to stimulate favorable consumer responses, particularly when consumers are faced with choosing between products within the same category. Tregear et al, (2007) further argue that specification and labeling of a product raises its market profile and distinguishes it from competing items. Qualified producers of the regional product distinguish themselves from others by following a defined code of practice that attains certain standards or quality levels, for which consumers are willing to pay a premium. An example of existing qualification labeling is the labeling of organic products where the labeling is based on the control of the organic production methods and principles. In many rural areas of Europe regional foods with a strong historic background are produced and marketed in niche markets. To safeguard production in rural areas and to protect the products of rural producers the EEC made regulation 2081/92. The focus is in EEC-regulation 2081/92 offering Protected Designation of Origin (PDOs) and Protected Geographical Indications (PGIs). For PDOs products must have quality characteristics from the local area, while for PGIs products have a specific quality attributable to the local area (Tregear et al., 2007). These protection tools are already in place to improve the profitability of local rare breeds. For example, in the French Northern Alps the milk of Abondance and Tarentaise cattle breeds is used for the production of Reblochon and Beaufort cheeses and in Italy the Reggiana cattle breed produces the milk for the processing of Parmigiano Reggiano cheese (Gandini and Oldenbroek, 2007). The interest in Europe (and overseas) for regional products has fostered the success of organizations such as Slow Food (www.slowfood.com).

Van der Meulen (2007) developed a methodological tool is to evaluate the contribution of various factors to the connectedness of food products to their places of origin. Four factors of originality can be distinguished:

1. Territoriality reflects the link of a specific breed to a specific region. This includes the different phases from growing to selling: agriculture, processing, distribution and restrictions (delimitation) as subfactors. It enhances the appeal of products as local in origin, from a local genetic resource.
2. Typicity reflects the uniqueness of the products, incorporating aspects of the other three factors. This includes unique aspects from commodity production to final product and is linked to the place of origin by agriculture, landscape, processing and exterior tools used (as subfactors).
3. Traditionality reflects long-standing production methods and final products. This includes aspects of local culture and history (e.g. legends, written documents), production methods, and culinary culture as contributing subfactors.
4. Communality reflects the shared experience and the collaboration between primary actors in the phases of agriculture, processing and distribution, and works with traditionality to incorporate local culture and production systems. .

The market value of products of breeds that are targeted in niche markets is determined by all four factors mentioned above. The contribution to a breed to each of these factors can determine the value of the products of the breed in a niche market. The use of trademarks can protect the producers of these unique products.

In some regions, mostly in developed countries, rarity in and of itself has a value for breeders of certain local breeds. When a breed is attached to regional identity it can become the target of ownership and conservation both by local elites as well as more generally. In this case the tie of local identity with a specific breed can greatly facilitate keeping of a local breed. Challenges of this approach include a change in the selection environment of the breed, especially if it becomes relegated to a hobby pastime for relatively wealthy individuals. Changes in selection environment can be especially important if dictated by competitive showing or exhibitions. Animal selection by breeder groups with an eye for traditional type can be an effective countermeasure against the tendency for type to shift over time.

Box 7.9
Organization of regional production chains

Consumers perceive an added value to information about the place of origin of their food (Van der Meulen 2007). The distance between producers of food and the consumer is determined by the organization of the production and transportation, and includes:

- Farmhouse origin food products. These are offered in farm shops, gift baskets, box schemes and specialized food stores.
- Farmers-group origin food products. These come from a group of farmers producing and selling food, working with codes of practice and with registered geographical names and logos as collective trademarks.
- Region-label origin food products. Several products may be sold under the same single label. The raw materials may come from several farms in that area, and products are usually made by single producers.
- Regional-typical origin food products. For these there are multiple producers, with a product-related geographical delimitation, a long lasting tradition over generations and a distinctive production process and final product. The raw material doess not always come from the traditional production area.
- Artisanal origin food products. These are produced by small scale individual food producers and the product is named after the place they are located or the producer involved. The emphasis is on the processing techniques and not on the origin of the raw material.
- Appropriated origin food products. These are former regionally typical origin food products that have become appropriated by a single company in the long term or by mergers.

In these different types of organization for regional food products the distance between the farm of origin and the consumer varies greatly. The methods of processing likewise vary from simple up to complicated. These factors result in the need for qualification labels to guarantee the origin of the food, the production method or the way and place of processing.

Another way to improve the value of commodity products of a breed is to adopt a production system that deviates clearly from the mainstream production process and is clearly defined, e.g. organic production.

Box 7.10
Doubling the price for lambs of the Drenthe Heath Sheep

The Drenthe Heath sheep arrived in the North East part of the Netherlands 6000 years ago. They were kept and survived on the infertile sandy grounds covered with heath. Through adaptation and natural selection the Drenthe Heath sheep became a rather small animal with good legs and a low fleshiness. The carcass weight and the meat/bone ratio is low. It is the only Dutch sheep breed with horns. Nowadays the flocks are used for nature management, guided by a shepherd and this setting is very attractive for tourists visiting the area. Approximately, 2000 ewes are registered in the Drenthe Heath Sheep Herdbook. Recently the sale of lambs as Drènts Heidelaom started. The lambs are produced in a well defined chain. This doubled the price the shepherd got for a lamb sold at an anonymous lamb market. The chain was organized as follows:

First, the “organic” management of the herd and the “organic” growing of the lambs until slaughter was organized. This way of working is controlled and awarded by the official Skall organization for organic agriculture. Second, a small abattoir in the neighborhood was contracted where the lambs are slaughtered in an animal friendly way. Third, the carcasses were transported and sold to a specialized butcher producing organic leg of lamb, lamb chops and lamb sausages. These products are sold by the butcher at organic farmer’s markets in cities in the Western part of The Netherlands. Fourth, together with the Foundation for Conservation of the Drenthe Heath Sheep the Slow Food organization in the Netherlands was consulted. Due to the special natural treatment and nutrition of the sheep and their lambs the Drenthe Heath lamb has a special “wild’ taste. Therefore, and due to the cultural historic aspects of the sheep and the product it was recognized in the Ark of Taste by the Slow Food Organisation. Fifth, with other flocks arrangements were made to collaborate resulting a in a Presidium of the Slow Food organization: Drenthe Heath Lamb or in the language of the region Drènts Heidelaom.

Inputs:

1. Knowledge of a breed’s distinctive products, production process and roles
2. Awareness of current marketing systems and their potential to enhance the value of breed-specific products

Output: A plan to enhance the value of the high quality products of a breed.

Task. Formulate opportunities to enhance the value of the high quality products of a breed

Action 1. Describe the products of the breed, the markets available for them, and relevant trademarks.
This involves a detailed look into products as well as the products that compete for market share. Where an alternative exists to the breed’s products, the relative value of each must be evaluated.

Action 2. Assign a score for each factor (quality, distinctiveness, access to markets) for each different product.
Each product must be evaluated objectively for issues of quality and distinctiveness that will lead to enhanced demand. In addition the supply must be evaluated to assure that any potential market demand can be met.

Action 3. Describe the opportunities to enhance the scores for the different factors and to apply for trademarks.
For each product determine ways that will enhance quality, distinctiveness, or market access. Trademark protection can be useful in minimizing competition for these niche products.

Action 4. Develop plans to enhance the value of the products through manufacture, trademark, or marketing.
This stage may involve people with special expertise in production and marketing, but with a consideration and appreciation for local and unique aspects of the product and its manufacture.

7.5 Exploiting the ecological functions of species and breeds in nature management

RATIONALE:

In many areas in the world, traditional grazing with herbivores created and maintained ecosystems with a high biological value. In countries with intensive agricultural systems arable land is set aside and given back to nature. When in that case no additional measures are taken, these lands will be change over to forest in a foreseeable time span. Grazing with herbivores can prevent this forestation process and might maintain the desired open landscape. In many countries nature management with cattle, sheep, goats and horses can maintain natural grasslands, wetlands or heath land. These herbivore species differ in grazing behavior and even between breeds within a species small differences do exist (Saether, 2006). The choice of the species and the breed should be carefully adjusted to the required grazing effects and the physiological characteristics (robustness) of the species and the breeds, especially under harsh circumstances. In nature management often takes place in large areas with a low stocking density. This means that a large number of animals is required to fulfill this task. This offers great opportunities for breeds of herbivore species to be conserved.

Objective: the determination of the opportunities to use species and breeds for nature management.

Input: requirements for species and breeds in nature management and relevant characteristics from species and breeds available

Output: a selection of species and breeds that maybe used in nature management

Task. Select species and breeds for nature management

Action 1. Interview the stakeholders involved in nature management and describe the requirements formulated by them for nature management with herbivores.

Action 2. Describe the grazing behavior of species (and breeds if available).
Collect information on relevant characteristics of the species and breeds with special attention for adaptive traits to harsh environments.

Action 3. Match the requirements with the relevant information of the species and the breeds.
Decide which species and breeds might be effective in nature management.

Action 4. Write an action plan how to incorporate species and breeds in nature management and how to make that profitable.
Often this is realized by the income obtained from nature management and the sale of meat of the breed involved as meat produced under natural conditions.

7.6 Exploiting the potential societal and cultural functions of species and breeds in tourism and societal events and incentive payments for these functions

RATIONALE:

Some breeds in need of conservation fulfill several services which may be poorly recognized or formally valued by society. Most of these are related to broad benefits to society beyond a specific marketable product. Among these are the roles species and breeds have as attractive elements of the rural area while being outside for tourists creating traditional agricultural landscapes. In many societies animals fulfill societal services with a cultural or religious aspect. Some breeds may provide several services and functions, such as the Madura breed of cattle in Indonesia (See Box 7.11). In the case of some of these non commodity services, the general benefit to society and to the local economy can warrant governmental support or payment of incentives to owners and keepers for these social and cultural benefits that are otherwise difficult to quantify and reward. In most countries this opportunity is still a challenge for the owners of animals of local breeds.

Box 7.11
The cultural value of Madura cattle in Indonesia

An important local cattle breed in Indonesia is the Madura cattle breed (Barwegen, 2004). Phenotypic evidence suggests that Madura cattle could have been derived from three-way crosses, between *Bos* (*bibos*) spp., *Bos indicus* and *Bos taurus* types. Madura cows have a small head, while the head of the bull is bigger. They have a long body in relation to their legs. Their hoofs are strong. Their height varies between 1.16 m and 1.24 m. The Madura cattle is reported to be one of the best draught animals in the world relative to its size. This breed is mainly confined to the island of Madura (Madura Island is a densely populated, small island, of some 4497 km^2 area of land, located off the northeast coast of Java). Madura cattle are extremely well adapted to the climate at the isalnd. The farmers use all crop residues and large quantities of browsed and fallen leaf material to feed their cattle. The climate is tropical with definite wet and dry periods. Madura cattle bring both economical and cultural values for the Maduranese people. They are used in the *Karapan,* a famous traditional bull race in Madura Island. A strong cultural feeling of the people towards Madura cattle exists, as well as towards the *Karapan* racing. Next to *Karapan*, there is the traditional activity *Sonok*, which is a contest of harmonious walking of two cows or heifers with accompanying traditional music.

Objective: To incorporate the societal and cultural functions of a breed in a programme for its conservation

Inputs:
1. List of breed characteristics
2. Reports of any important cultural and social functions such as unique phenotypes which have become a part of the cultural landscape or participation of animals in cultural events,
3. Names of important stakeholders.

Output: a proposal for governmental or private support or incentive payments or a business plan to obtain market recognition and generate financial returns.

Task 1. Identify the most important social and cultural functions of a breed.

Action 1. Determine the present and potential social or cultural functions of a breed.
Phenotypic characterization will ideally identify the most important characteristics of breeds within a country, but particular social and cultural functions may not necessarily be noted. Discussion with key stakeholders should be undertaken to not only record these functions but to obtain addition background on their history and importance.

Action 2. Document the various elements and societal groups using and benefiting from these functions.
Beneficiaries from social and cultural functions will usually encompass a wider group than the farmers and livestock keepers that use the animals for income generation. When the function is religious, all persons following that particular religion may be beneficiaries. When a function is cultural, all persons within the geographical area of interest may derive some benefits. When the presence of the breed attracts tourists, operators of local hotels, restaurants and stores would have a financial stake in the breed's maintenance. When a breed somehow contributes to rural development in a more general sense, then the greater public benefits, perhaps even those living outside of the local community where the breed is indigenous.

Action 3. Valuate these functions and services in terms of potential loss if the function is unfulfilled.
In most cases, the functions referred to in this section cannot be easily marketed, as their benefits are dispersed across a wide range of stakeholders, each of which derives a small amount of utility, which may be difficult to measure or estimate. In addition, the breeds will usually have been providing these services in question for many years. Therefore, determining the added value of these services may not be practical and it may be simpler to estimate the value of the breed's contribution in terms of loss if the functions and services were no longer available. For example, the Valdostana cattle in Italy is associated with a special festival that draws many tourists to its locality (See Box 7.12). The loss of this breed could be measured by expected decreases in hotel, restaurant and other revenues tied to the festival.

Box 7.12
The cultural value of Valdostano cattle in Italy

The Valdostana Castana cattle is farmed in the Aosta Valley, in the South Western Alps of Italy. Gandini and Villa (2003) showed that a considerable cultural value can be attributed to this breed, in that it has been a central element of rural Valdostana life, and today acts as a custodian of local culture. These cattle have a considerable influence on the valley landscape, being taken up to alpine pastures in the summer. The Fontina cheese and different gastronomic traditions are linked to the breed. Furthermore, the breed is used in the "Battle of the Queens", a tradition which developed from the older "Queen of Horns" traditions and consists of a series of competitions between cows. All these aspects are currently exploited by summer tourism, but only partially are recognized by the market: Fontina cheese is highly requested at the national level, and people pay to attend the final tournament of the Battle of Queen in Aosta. However the important cultural breed role of maintaining the rural landscape is not captured by the market. Nevertheless recent economic investigation among summer tourists and residents indicate a consistent willingness to pay for the breed role in maintaining landscape (Gandini, 2010, pers. comm.). The challenge is to get the market to recognize and capture this consumer interest.

Action 4. Determine the best approach (public or private) to incorporate cultural and social functions into breed conservation.

Task 2. *Prepare a proposal to solicit support from potential suppliers in local, regional or national governments or from private entrepreneurs.*

Task 3. When the market recognizes a cultural or social value write a business plan to exploit these values.

Task 4. Development of a proposal for governmental support, incentive payments or market recognition for the social functions of a breed

Action 1: List the present and potential social or cultural functions of a breed.

Action 2: Valuate these functions in terms of potential loss if the function is unfulfilled.

Action 3: Document the various elements and societal groups using and benefiting from these functions. Seek for market recognition.

Action 4: List potential sources for support or incentive payments from the constituencies that are benefitting from the services.
These may include community or regional governments, or other broadly-based social groups with an interest in the landscape and social/cultural maintenance.

Action 5: Write a proposal to solicit support from potential suppliers in ministries or from incentives funds.
When the market recognizes a cultural or social value write a business plan to exploit these values.

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