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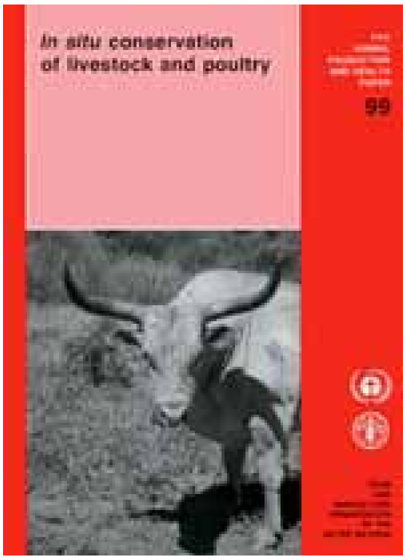

In situ conservation of livestock and poultry

by
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1. Introduction

1.1 Animal Genetic Resources

Animal genetic resources exist in the form of a vast array of breeds and livestock populations which have evolved and adapted over many centuries, to the range of environmental conditions encountered throughout the world. The pressure of selection imposed by climate, soil type, altitude, available food supply, endemic diseases and parasites, management techniques and market demands have resulted in thousands of breeds, types and strains, each with their own genetic make-up, and each adapted to its own specific niche.

The future improvement and development of livestock for agriculture is dependent upon the availability of this genetic variation, which is its principal resource. The requirements for genetically controlled variation are constantly changing over time and are unpredictable. They are influenced by environmental and climatic changes, by changes in market demands, and by the effects of new breeding technologies and DNA manipulation techniques.

The animal genetic resources available throughout the world are in a dramatic state of decline. The development of artificial insemination and other techniques that facilitate easy transfer of breeding material from one geographical region to another, have resulted in widespread cross breeding and the replacement of local stocks through prolonged dilution. In many cases this has been carried out without initial characterization or evaluation of indigenous breeds and with no effort to conserve local strains. It has resulted in the disappearance of a substantial number of local populations, with the consequent loss of their inherent genetic adaptation to their local environments. This increasing loss of identifiable diversity in animal genetic resources has been recognized for many years. Particular concern has been growing with respect to the speed at which uncharacterized breeds are disappearing in some rapidly developing regions of the world where climatic, parasitic or disease pressures could have produced important genetically adapted breeds. (Hodges, 1990c; Office of Technology Assessment, 1987; Weiner, 1989)

There are already compelling examples from cereal and crop production, where industrialized hybrids, selected for greatly increased production, were found to be susceptible to new viral, fungal or insect parasites, which are constantly evolving, and which resulted in dramatic crop failures. Unimproved indigenous landrace stocks were found to contain genetic variation which often included resistance to such parasites. The potential and actual use of these genes for resistance, for incorporation into the production stocks was soon realized. The discovery that unimproved landrace plants had valuable genetic characteristics resulted in the establishment of large scale collections of landrace seed and plant materials for inclusion in national, regional and global germplasm banks (Fowler, 1990; National Academy of Science, 1991a; National Academy of Science, 1991b; Office of Technology Assessment, 1987).

The need for parallel conservation of animal genetic resources, as raw material for future animal breeding programmes, is also recognized and is becoming an important issue in international, regional and national agricultural planning. Conservation is of particular concern in regions of rapid agricultural change, where indigenous stocks and farming methods are being replaced. Areas where climatic extremes or particular parasitic conditions have resulted in genetically modified and unique local stocks which are able to survive under extreme conditions are also a high priority. Such conservation efforts are particularly important in the light of predicted global climate change, and the ability of microbial and insect parasites to evolve and adapt to modern chemical control methods.

1.2 Animal Genetic Resource Management

Since its inception, the Food and Agriculture Organization of the United Nations (FAO) has been concerned with the conservation, evaluation and use of animal genetic resources. In 1980 a joint Technical Consultation with the United Nations Environment Project (UNEP) developed a technical programme which called for global census information of all those breeds still in existence, and a listing of those in danger of extinction. Considerable work was then done to gather and make this information available (Brook, 1978; Dmitriev, 1987; Hasnain, 1985; FAO, 1977a; FAO, 1977b; FAO, 1980a; FAO, 1980b; FAO, 1981; FAO, 1982; FAO, 1986d; FAO, 1989a; Maijala et al 1984; Peilieu, 1984; Yalcin, 1986) (See Appendix 1).

It was soon realized that breed information needed to include details concerning the population characteristics, details of the local environment, management and production parameters. In 1986, the FAO developed generalized descriptors, in association with the European Association of Animal Production (EAAP), for use in breed identification and characterization (FAO, 1986b; FAO, 1986c) linked to a proposed database system (FAO, 1986a)

During 1987, an International Genetic Resource Data Bank was established at the Institute for Animal Breeding and Genetics in Hanover, Germany, and became a joint EAAP/FAO venture (Simon, 1989). It is intended that this database will eventually be moved to FAO headquarters in Rome and will act as a global information centre for populations of livestock and their environmental niches throughout the world. Access to this data will be available to all United Nations member countries.

It was clear that description and characterization of breeds would take a considerable length of time and that urgent action was needed to prevent the imminent extinction of many populations. *Ad hoc* conservation programmes were begun in many countries during the 1970's and 80's, concerned with specific breeds or groups of breeds. However, this action was independent, largely uncoordinated and usually centered on national breeds. There was no global attempt to identify populations in most immediate danger or those of greatest potential genetic value.

In 1990, the FAO helped to establish the basis for three regional genebanks, each with two centres, to act as global depositories for frozen animal genetic material (Hodges, 1989). Full details of the aims and objectives, mechanisms for deposition and access, and protocols for disease control and legal ownership have been developed for these centres (Hodges, 1990a). These genebanks are designed to act as long term stores for the preservation of genetic material which might otherwise be lost. They are an insurance policy for farmers and future livestock breeders throughout the world.

By the end of 1990 all the technical recommendations of the 1980 FAO/UNEP Expert Consultation on Genetic Resources had been initiated (Hodges, 1990b).

1.3 Live Animal Conservation

There are three methods for the conservation of animal genetic resources. The first involves the conservation of animal genetic material in the form of living ova, embryos or semen stored cryogenically in liquid nitrogen (-196 degrees centigrade). The second is the preservation of genetic information as DNA, stored in frozen samples of blood or other animal tissue or as DNA segments. The third is the conservation of live populations.

The advantages, disadvantages and potentials for co-ordination of these systems are reviewed in chapter 4 of this manual, but all are valuable tools with a role to play in the conservation of animal genetic resources.

At the 1989 FAO Expert Consultation it was agreed that frozen embryo and semen technology was cost effective for long term genetic preservation. It was also recognized, however, that there is no single method of preservation which is optimal for all situations. The conservation of live populations *in situ* has a number of advantages, and may be the only option available in some instances. *In situ* conservation is also very flexible in its application and allows for the development and utilization of breeds (Weiner, 1989).

This manual has been prepared to draw together the information and experience of *in situ* live animal conservation theory and practice as it is found throughout the world. It has been written in parallel with a similar manual for the *ex situ* preservation of cryogenic material (Hodges, 1990a) and is designed to assist with the planning, development and implementation of conservation projects and therefore incorporates many ideas and principles already described in previous FAO publications (see Appendix 1).

Chapter 2 reviews the source of animal genetic resources and the many influences which have acted over time to produce the wealth of livestock varieties available today. It explains the processes of genetic change, selection and extinction with respect to species, breeds and genes.

The need for conservation is discussed in chapter 3 with consideration of economic potential, scientific use and cultural importance alongside the need to conserve unique and endangered populations. The size of populations considered to be rare at the species, breed and gene level and the effects of small population size on genetic variation within populations are all discussed.

Chapter 4 outlines the methods of conservation for live populations beginning with a survey of the advantages and disadvantages of *in situ* and *ex situ* conservation. The idea of conserving through separate breeds or composite gene pools are considered along with sampling techniques, selection and methods of random or pedigree mating in small populations.

In the final chapter the practical application of *in situ* conservation programmes are reviewed with examples from throughout the world.

The summary includes a flow chart for the identification of populations in need of conservation, strategies for conservation and suggestions for the implementation of programmes to conserve animal genetic resources *in situ*.

1. Conservation and improvement of heartwater resistant Tswana sheep in a village based project in Botswana.

2. Locally adapted pigs and poultry require no veterinary or feed inputs while producing meat and eggs. (Gaborone, Botswana)

2. Animal Genetic Resources -Terms and Definitions

This chapter seeks to clarify the meaning of animal genetic resources, how they are formed, how they may be expected to change and the major processes which act upon them.

2.1 Genetic Principles

Within the nucleus of every mammal cell there are two complete copies of the DNA (deoxyribonucleic acid) blueprint which determines every genetically controlled feature of the animals development, physiology and much of its behaviour. DNA is a complex chemical which is very stable, can replicate with great fidelity and carries the genetic code. All living cells contain two complete copies of their DNA blueprint, or sets of chromosomes, with the exception of ova and sperm cells which carry only one copy. A new embryo is made up of a complete double set of chromosomes, with one copy inherited from each parent.

The majority of the functional DNA is identical for all animals within a species because it codes for critically important proteins, essential for the creation of a viable organism. For some genetically controlled characteristics there are, however, a number of possible ‘options’. These take the form of slightly different DNA codes which result in animals with slightly different appearance, survival or production characteristics. These may be, for example, differences in coat colour or differences in the efficiency of a particular natural hormone influencing growth rate.

If an animal inherits two different genetic ‘options’, one from each parent, it may exhibit the combined effects of both genes or the effects of only one of the genetic ‘options’. In this case the gene whose effects are observed is said to be ‘dominant’. The gene which is present, and may be inherited by the animals offspring, but whose effects are not observed in the presence of the dominant gene, is said to be ‘recessive’. In this way a gene may exist in a population for many generations without its effects being obvious.

Mutation - The Creation of New Genetic Variation

Throughout the growth of an organism and during the production of sperm and ova cells the genetic blueprint, coded in the DNA chain of every cell is repeatedly copied. The copy mechanism is extremely accurate but spontaneous changes between the original and the copy DNA codes do occur occasionally. This is known as mutation and may be due to either the mis-copying of the DNA sequence, spontaneous breaks and incorrect re-ordering of the sequence, or to damage to the DNA sequence which may be brought about by radiation or chemical interference. Mutation may result in the production of a more efficient functional gene but more often they result in non-functional or deleterious genes.

Rates of mutation have been calculated to be in the order of 1 in 100,000 per generation. An embryo inheriting a detrimental mutated section of DNA from one parent is likely to inherit a normal matching DNA segment from the other parent. In this case the normal piece of DNA will continue to function and there will be no obvious affect on the development and functioning of the animal. When this animal reaches adulthood and reproduces itself, it will pass the perfect copy of the gene to, on average, half its offspring and the miscopy to the other half. Provided its mates carry a normal copy of this particular section of DNA none of its offspring will be detrimentally affected. In this way a rare mutated gene can exist as a ‘recessive’ or hidden gene for many generations. The only time it will become apparent is when both a sperm and an ova come together, with exactly the same piece of mutant DNA. In this instance the newly formed embryo will have two copies of the mutant DNA and no original copy. Success or failure of the embryo will then depend upon the importance of that DNA segment in the development and functioning of the animal. If it codes for a critical gene the embryo will fail, resulting in the appearance of reduced fertility in the parents. If it codes for a less critical gene, a higher chance of mortality after birth or a reduced growth and development rate may result. If it codes for a non-functional section of DNA there will be no affect on development of the embryo.

2.2 The Creation of Breeds

The process of domestication began some ten thousand years ago, and both the process and the domesticated stock produced by it have been carried by migrating humans to all but the most remote regions of the earth. In each region and local area, domestic populations adapted and evolved in response to a great range of selection pressures. In each case the primary factors contributing to the final population were complex and included founder affects, migration, mutation, natural selection and selection by man (Clutton-Brock, 1981; Mason, 1984; Ucko, 1969; Zeuner, 1963).

2.2.1 Founder Affects

The genetic make-up of each and every breed or population is largely dependent upon the genetic make-up of its founder group. This foundation group was in turn dependent upon the selection pressures it had previously encountered and upon the genetic make-up of its own founder group. Thus, as tribes of people migrated across the globe they took samples of their own livestock with them to their new homes. In each location the people and their livestock would adapt through selection which is the survival of those individuals genetically suited, or able to adapt to the new environment. A sample of this population would then be taken with the next human migration to be the founders of a new community in a slightly different situation. Study and measurements of the physiological variation between populations have enabled quite detailed plans of the early migrations of mankind to be produced. Protein electrophoresis, DNA hybridization, restriction site polymorphism techniques and mitochondrial DNA studies can also be used to identify variations between breeds and calculate the genetic distance between populations (Sharp 1987; Nei 1987).

2.2.2 Inflow of Genes

The migration of people and livestock has not generally been in one continuous direction although there are exceptions where geographically isolated populations have been cut off from subsequent migratory influences, as for example in Australia and Iceland. In most regions there has been fairly constant trade in livestock from one community to the next throughout human history. When animals arose through mutation or trade, that had better survival or production characteristics than those found in the local population, more of their adapted progeny would survive and the enhanced characteristics would soon become common or even fixed within the group. Thus, other than geographically isolated situations, a gradual inflow of genes has modified every population that exists today.

2.2.3 Mutation

Rare changes in the DNA code, caused by miscopying or damage to the DNA chemical do occur and is known as mutation (see section 2.1). Mutation is normally detrimental and often results in non-viable cells, embryos or organisms. Mutated animals may, however, survive with reduced viability, or if the affected DNA sequence was not important the mutated animal may exhibit little or no physiological affects. Very rarely mutations may occur, by chance, which confer a survival advantage on the individual as compared to other animals within the population. When this happens the mutated individual will tend to leave more offspring than other animals in the group. These offspring will inherit the mutated gene from their mutated parent, and the frequency of the new gene will increase within the population. A mutated gene which produces a considerable selection advantage, may result in that mutated gene copy becoming prevalent within the population and may eventually replace the original gene completely. (Goodenough, 1978)

2.2.4 Natural Selection

Natural selection is the term used to describe all the environmental pressures acting on an individual which will result in it succeeding or failing to survive and to reproduce. Only successful individuals will pass their genes onto the next generation. Natural selection results in the survival and successful reproduction of animals genetically adapted to that environment. The principal aspects of natural selection are nutrient supply, climate, parasites and predators and competition within the species.

a. **Nutrient Supply**
   Abundant food supply places no selection pressure on animals, but more commonly food supply is restricted for one or more periods of the year and is often seasonal. It may occur in relatively indigestible forms, or from partially toxic plants, or it may be deficient in critical trace elements. Animals may need to migrate large distances to follow food supplies, or may need to adapt to different diets at different times of the year. There may be restrictions of water supply or available minerals and salts.
b. **Climate**
   Animals have adapted to extremes of cold and heat, to humidity and to drought. There are populations adapted to swim during regular floods, and others that can survive with no access to water for long periods. There are animals adapted to high altitudes, and others whose behaviour and physiology enables them to survive vicious storms. Climatic adaptation is very complex. It involves the metabolism, physical structure and behaviour of adapted animals and it is one of the most valuable aspects of local livestock breeds and adapted domesticated species.
c. **Parasites**
   Parasites and disease exert a constant selection pressure upon all populations of animals. Any animal which has some resistance to, or tolerance of, a parasite or disease will be less likely to be affected by the infection, or will recover faster. Such an animal will be more likely to survive and to reproduce thereby passing its genetic ability to coexist with the parasite on to the next generation. There are examples throughout the world of populations and strains which are resistant to, or tolerant of, endemic parasites and diseases which may have a dramatic affect on other non adapted strains.
d. **Competition**
   Survival and reproductive success in animals is also dependent upon their ability to compete successfully with others of the same species. Natural selection favours those individuals able to locate and defend scarce resources such as food, nest sites and good

shelter. Reproductive success is also influenced by the animal's ability to secure a mate or mates. This success may be affected by direct competitive conflict between males or by female preference for colour, shape or behaviour. The animal's ability to successfully reproduce and rear their offspring is also critical in the survival of their particular genes into the next generation. All of these competitive factors impose strong selective pressures particularly on the genetically inherited behaviour of animals and the genetically controlled ability to adapt behaviour and to learn.

2.2.5 Selection by Man

In order for man to impose his own selection pressure on his animals he must first control some of the principal mortality rates determined by natural selection. He is able to control population size to ensure there is sufficient food for his selected stock, and is able to conserve fodder for periods of the year when forage is not available. He is able to protect his stock from predators and to supply housing or shelter from climatic extremes and is also able to protect livestock from some parasites and diseases.

The lifting of natural selection pressures has an immediate effect on the survivability of individuals within his flocks and herds and enables him to impose his own selection criteria. The principal selection pressures imposed by man are for human food, fuel, clothing, draught work and pleasure.

a. **Human Food and Fuel**
   Selection for milk production may be based on quantity as is the case with the black and white Holstein Frisian dairy cows; the relative constituents of milk for butter or cheese making as with the Jersey, Guernsey and Brown Swiss cattle breeds; or simply the animal's propensity to let down its milk which is an important selection criteria for Murrah buffalo, Sahiwal cattle and many dairy sheep projects. Selection may be for meat production, measured by maximum growth at an early age which is the current trend in Europe, or the ultimate production of a heavy carcass which was the European fashion 80 years ago. In industrialized nations, selection is predominantly for lean meat but traditionally fat meats have been valued for their cooking characteristics, high human food value and to produce fat for fuel. This was the case with, for example, the Mangalitza pigs of Hungary and the Canastra pigs of Brazil. Selection may even be for animals able to withstand regular bleeding to supply blood for human consumption which was important in the Kerry cattle of Ireland at the beginning of the 20th century and is still important in the herds of cattle belonging to the Masai tribesmen of Kenya.
b. **Human Clothing and Shelter**
   Selection pressure has been imposed to produce stronger, softer, warmer, more waterproof or differently coloured fibres. Breeds have been selected for the use of their pelts or skins for soft leather, strong hide, warm or attractive fur. This has often taken the form of parallel selection under very different environmental conditions or in association with other unrelated selection pressures. Thus a breed producing one type of fleece might also be adapted to heat or to cold, to high or to low altitudes or to quite different parasites. For example the Scottish Blackface sheep adapted to the cold wet conditions of Scotland has a dense under fleece for insulation and a long hair coat growing through it, to run off the rain and snow. The Navajo-Churro sheep from the Arizona desert region of the USA, which is historically unrelated to the Scottish Blackface, has an almost identical fleece through parallel selection but the capacity to survive in a completely different habitat with hot dry summers, cold dry winters and very sparse grazing.
c. **Draught and Other Work**

The role and importance of working animals is often greatly underestimated both in terms of the history of our own development, and our future needs, in a world where renewable energy supply is becoming a major issue.

Animals have been selected to assist with every possible labouring job. Dogs, the first domesticated species, have been selected and trained to protect or manipulate flocks and herds of grazing animals, besides those breeds selected to pull sledges across the snow. Breeds of cattle, horses, donkeys, buffalo, as well as elephants, yaks, camels and llamas have been selected for their use as draught animals. These range from fast riding animals, to strong pulling breeds with great stamina. There has been selection for distance travellers, for carriers of light and heavy packs, for steady breeds to cultivate the land and for tractable and easily trained breeds for more complex work.

d. **Pleasure**
No-one who has every worked with livestock can doubt that given the opportunity farmers and livestock breeders will select those animals that appeal to them. Religious, cultural and fashionable fancies exist throughout the world. Selection of the prize bull to be purchased or the young male goat to be saved from the pot have always, and are still affected by the farmer's perception of an 'attractive' animal. This may not be important in economic terms but it has added, through selection, to the range and diversity of livestock varieties in existence and to the richness and quality of rural life.

The final result of these selection pressures in their myriad of combinations is the vast range of distinct populations that exist today and that have existed in the past.

2.2.6 The Identification of a Breed

The term most commonly used to describe livestock populations or varieties is 'breed'. A breed is defined as:

> “a group of animals that has been selected by man to possess a uniform appearance that is inheritable and distinguishes it from other groups of animals within the same species. It is a product of artificial choice of characters that are not necessarily strategies for survival but are favoured by man for economic, aesthetic, or ritual reasons, or because they increase the social status of the owner of the animals.” (Clutton-Brock, 1981)

Pedigree recording has enhanced this definition by supplying detailed parentage and relationship information for many of the 'developed' breeds. The concept of a breed, however, encompasses any population which falls within definable descriptive parameters. In essence it may apply to any group of animals which are located in a geographical area, have some phenotypic characteristics in common and are recognized by the local people as a local type. As acknowledged in Ian Mason's *Dictionary of Livestock Breeds*, the parameters of these groups are not uniform (Mason, 1988). For the purposes of this manual the definition of a breed will be taken in this widest possible sense.

a. **Breed Names**
National or regional surveys of livestock populations may report a large number of different breed names all referring to one basic population. Conversely several distinct strains may share a single breed name. In order to identify distinct populations it is therefore necessary to describe 'breeds' in detail.

Breed descriptions should include size, weight, body shape and characteristics, growth rates and milk yield and, where appropriate, fibre production and quality, and draught ability. These characteristics must also be recorded alongside the description of habitat, food supply, climatic conditions, seasonal extremes, and management practices as well as the historical origins of the breed if these are known (FAO, 1986b; FAO, 1986c). Differences between populations at this level may be significant. However, if the production characteristics and environmental conditions are very similar, and the differences between groups are only slight, for example coat colour, a more detailed examination may be required to determine the closeness of two breeds. There are electrophoretic differences between milk and blood proteins that may be detected and a range of immunological differences that may be used to determine the historical links, common origins and genetic distance of populations. More complex techniques involving the comparison of non-functional or silent sections of chromosomes or DNA fragments are also useful tools for the comparison of related breeds (Sharp, 1987).

b. **International Boundaries**
   Livestock populations frequently cross political boundaries. This issue, however, will be largely addressed by the EAAP/FAO international databank. Once breeds common to more than one country can be identified and the relevant population and production data logged in the bank, international co-operation can be initiated to ensure that optimal use is made of genetically related groups.

2.3 Extinction

Extinction is an irreversible process in which identifiable populations or genetically controlled characteristics disappear. Extinction may be at the species level, for example the woolly mammoth (*Mammuthus Primigenius*); at the sub-species level, for example the passenger pigeon *(Ectopistes Migratorius)*; at the breed or variety level, for example the Lincolnshire Curly Coat pig; and finally at the level of individual characteristics or genes.

2.3.1 Species Extinction

Extinction is part of the natural process of evolution. The one and a half million species, which are now conservatively estimated to exist, represent less than one percent of the total number of species ever present on this planet (Nei, 1975). Extinction is only perceived as a problem when the rate of extinction exceeds that of speciation for a prolonged period, resulting in the reduction of the total variety of life forms. Such a period of mass species extinction has been occurring since the evolution of mankind, and the rate has been accelerating during the past 100 years.

Species extinction occurs naturally when there are changes in the balance of an ecosystem or habitat. These may be changes in the climatic conditions; temperature, precipitation, and wind; changes in the behaviour or effectiveness of predators, prey species, parasites and diseases; competition from individuals of other species for food supplies, nest or roost sites or other limited resources. Species are able to adapt to changes in their environment because individuals within the species are not genetically identical. Thus, some individuals will have a genetic makeup which makes them more likely to survive and reproduce than others of the same species. These genetically 'superior individuals' are better adapted to the environmental and competitive influences prevalent at the time. They will pass their genes on to the next generation. Provided the same selection pressures continue to apply, the genetically controlled characteristics of the species will begin to change, or evolve, towards a better genetic 'fit' of the species to the new environmental conditions.

When environmental changes are very large, or when the genetic variation within a population is very small, there may be too few individuals whose genetic makeup is such that they are able to survive in the new situation. In this instance insufficient individuals will survive and reproduce and the species will disappear.

Within the past 100 years most common species extinction has been related, directly or indirectly to human activity. It has been the result of one or more of a number of influences including: habitat destruction by deforestation, flooding, drainage; poisoning by pollution; changes in climatic conditions which have been influenced locally if not globally by our actions; competition, predation, parasitism and disease caused by introduced species; direct hunting and harvesting by mankind. Most wildlife conservation programmes address these man-made issues (Myers, 1979; Wilson, 1988).

In general, genetically uniform populations are less able to respond to strong selection pressures, resulting from changes in environmental circumstances, than genetically diverse ones. Specialist species which have adapted over time to 'fit' a very stable and specific biological niche have less intrinsic genetic variation. They are therefore less able to change, through the genetic evolution, or respond to dramatic or sudden changes in their environment. The specialists are also often 'Kselected' which means they direct more energy into producing and caring for a small number of offspring. This further handicaps their possible response to sudden changes in their environment. This is the case for example with the mountain gorilla (*Gorilla Beringei*). On the other hand, the generalist species are those able to survive and reproduce in a wider range of situations, and which tend to have more intrinsic genetic variation enabling them to respond more quickly to shifts in their environmental conditions, for example the common rat *(Ratus Ratus)*. Specialists are therefore less able to adapt than generalists. In the long term it is the generalists, those species or populations which are genetically diverse, and can respond to new selection pressures, that will inherit the earth (Beardmore, 1983; Myers, 1979; Soule, 1983).

2.3.2 Breed Extinction

The factors affecting the extinction and disappearance of domestic varieties are closely related to those described for wild species. During the history of domestic livestock breeding there have already been a very large number of breeds which have become extinct. As with wild species, provided the rate of creation of variants parallels the rate of extinction there is no cause for concern. However, for the past 100 years this has not been the case. There has been a high increase in the rate of extinction of breeds and varieties. This represents a dramatic loss of genetic variation within the global pool of domestic stocks.

In Europe alone, 60 breeds of livestock have become extinct this century and a further 200 are considered to be endangered (Maijala et al, 1984). In many other countries undergoing rapid agricultural development and change there has been a tendency to centre livestock breeding programmes on relatively few breeds without fully identifying, evaluating and taking steps to conserve the wide range of local stocks available (Hodges, 1990c).

In agriculture we are constantly selecting for specialization. By definition this limits the genetic variation within the selected population and creates breeds with a better biological fit between the animals and the environment in which they live, both natural and man-made. There is, however, an evolutionary pay off between diversity and efficiency which parallels that described for endangered species. If the environment, natural or man-made, changes rapidly, then the less specialized breed is better able to adapt than the highly selected specialist. For example, two British sheep breeds, the Southdown and Oxford Down are the extremes of selected meat breeds which have suffered for their specialization. The first was developed to sire small early-finishing lambs, while the second is a very large meat breed used to sire large finished carcasses. Both breeds are perfectly adapted to their own markets, but both have been close to extinction in recent years due to rapid changes in market tastes to which they cannot adapt. They now face competition from more generalist meat breeds whose lambs can be finished at a range of weights to fit the market and the fodder available each year.

2.3.3 Extinction of Genes

Genetic variation within a population stems from the existence of different alleles, or genetic options, occurring at the same locus, or address on the chromosome, in different individual animals. The frequency of these alleles remains fairly constant in a large population in a stable environment and is characteristic of that particular population.

The pressures of selection result in some individuals producing more viable offspring than others, but conflicting selection pressures put a limit on the genetically controlled changes that are possible. For example, a larger male may be better able to fight his rivals and secure more mates. However, if this larger animal cannot find or consume enough food to sustain his large body he will not survive and will not successfully reproduce. This example shows simple conflicting selection pressures for both larger and smaller size. In real populations there are many selection pressures acting on individuals and the result is that the frequency of genetic options within populations are in a constant state of flux around a norm. Shifts in the selection pressure will result in a shift in the norm frequency of some alleles. Extreme selection pressure acting against one possible allele in favour of another may even result in the complete disappearance or extinction of the less favoured gene.

The basic principle works for simple Mendelian genes controlling single characteristics, and for quantitative genes which control most of the productive traits. Alleles may therefore become fixed at a frequency of 1 (or 100%), when they are the only remaining option, or 0 when they are extinct.

The principle cause of extinction or disappearance of genes in large populations is selection. In smaller populations alleles may become fixed due to random changes in the gene frequency caused by the chance transfer of genes from one generation to the next. This drift of gene frequencies is enhanced by smaller population sizes and by inbreeding which is the mating of closely related animals. Both result in an increase in homozygotes, or the fixing of alleles at the frequency of 1 or 0 by chance (See section 3.3.2).

2.3.4 Extinction is Forever

Genetic engineering and advanced **DNA** technology cannot replace the genetic material lost through extinction.

a. **Species**
   There is work being carried out with **DNA** fragments recovered from the remains of the extinct woolly mammoths *(Mammuthus Primigenius)* found frozen in the glaciers of Russia, and with **DNA** fragments gathered from dried muscle tissue scraped from the preserved skin of a 140 year old South African Quagga pelt. The Quagga *(Equus Quagga)* is an extinct species of Zebra. It is hoped that it may be possible to incorporate these salvaged

DNA segments into the embryonic cells of a closely related species, via genetic engineering techniques. The resulting animals produced in this way would then carry genes from the extinct species. If the inserted **DNA** segments coded for phenotypic characteristics, the transgenic animals would exhibit those genetic characteristics from the extinct species. These projects are scientifically interesting and may be successful, but are unlikely to recreate viable individuals of the extinct species, let alone a viable population of these animals.

b. **Breeds**
   Breeds are identifiable varieties within a species. Once they have been allowed to become extinct they cannot generally be recovered. However, there are instances where the original ancestral populations, or descendant populations still exist, and where the environmental conditions and breed description is well known. In this case it is possible to recreate, through selection, a population which has many of the same phenotypic characteristics and may even carry much of the same genetic makeup. Such a project was begun during the 1920's by the Heck brothers in the Munich and Berlin zoos where they attempted to recreate the extinct cattle ancestor, the Auroch (*Bos Primigenius*). This projects and others like it are interesting, but serve to demonstrate that recreated populations will never have exactly the same genotype as the lost breed. In most cases suitable related or ancestral breeds are not available, and good breed evaluation data for the extinct population does not exist. Reconstruction projects are only able to recreate a few phenotypic characteristics and never the exact genotype of the extinct breed.

c. **Genes**
   Lost genes can theoretically be replaced in one of three ways. Firstly, the same gene may exist in another breed or species and could be re-introduced by cross breeding or by genetic engineering. The problem is our ability to identify and locate such a parallel gene, and then to transfer it with the correct and appropriate control genes needed for its predictable expression.

   Secondly, **DNA** sequences can be artificially manufactured. The problem here is that we must know the **DNA** sequence of the gene before we can manufacture it.

   Finally, a gene may spontaneously appear by mutation. Mutation is the miscopying of the **DNA** of the chromosomes and happens at a fairly predictable and very slow rate. It also occurs at random. Thus the chances of a **DNA** segment mutating to produce a lost gene in an animal with a genetic makeup suitable for the recognizable expression of that gene is extremely low.

   At the present time it is considerably more practical and simpler to maintain functional genes in a genetic environment in which their expression can be predicted than to allow their extinction, and then be forced to attempt their reconstruction.

For all practical purposes extinction is forever, and conservation is a relatively simple insurance policy against genetic loss.

2.4 Conclusion

Natural selection pressure imposed by environmental conditions, climate, parasites and predators, combined with the effects of human selection, domestication, migration and trade have created a vast array of distinct and genetically unique livestock populations. These populations may loosely be described as ‘breeds’ or groups of animals with identifiable characteristics whose offspring resemble them.

Extinction, which is part of the natural process of evolution, is now occurring at a much higher rate than speciation or the appearance of new varieties and forms. Once a species, breed or gene has become extinct it is very unlikely that it can be re-created in the future.

3. Caruncho pigs selected to produce fat meat in Brazil.

4. North Ronaldsay sheep survive on a diet of seaweed and are conserved by the Rare Breeds Survival Trust in the UK.

3. The Need For Conservation

As has been shown in the previous chapter we have inherited a wide variety of genetically diverse livestock populations from our ancestors. There is concern, however, that due to current high rates of extinction, our descendants will inherit a far less genetically rich and diverse selection of livestock breeds and thus agricultural options, unless we take action to conserve them.

The International Union for the Conservation of Nature and Natural Resource's (IUCN) World Conservation Strategy has defined the need for conservation as:

> "The management for human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations. Thus conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration and enhancement of the natural environment." (International Union for the Conservation of Nature, 1980)

Within this concept of conservation the FAO Expert Consultations have defined animal genetic resources as: "all species, breeds and strains of animals particularly those of economic scientific and cultural interest to mankind for agriculture either at present or in the future" (Weiner, 1989).

FAO and other international agricultural agencies more commonly use the term 'animal genetic resources' to apply to breeds or strains of the common domestic species of sheep, goats, cattle, pigs, buffalo and poultry. Horses, donkeys, camels, elephants, reindeer and other domesticated animals are given less attention and are often considered to be of marginal interest. In fact the FAO definition includes all these domesticated species and those species on the fringe of domestication or with potential for domestication. It incorporates, for example, a number of Asian ungulates including the Banteng, Mithan, Yak, Guar, Kouprey, Tamaraw and Anoas (Veitmeyer, 1983); several species of antelope and deer; relatives of the domestic pig including warty pigs, pigmy hogs and babirusa; species of rodent including rabbits, capibara and guinea pig (Veitmeyer, 1991); poikilothermic (cold blooded) animals including alligators, lizards, turtles, fish, shell fish and crustacea; and domesticated insects including honey bees and silk worms.

This manual is written with the major agricultural species in mind but all domesticated animals, and animals with potential for domestication and feral populations should be considered when preparing local or regional conservation strategies.

3.1 The Reason For Conservation

The FAO definition of animal genetic resources eligible for conservation includes animal populations with economic potential, scientific use and cultural interest.

3.1.1 Economic Potential

Endangered populations should be conserved for their potential economic use in the future. Their economic potential may be the production of meat, milk, fibre, skin or draught power. This potential production may be in diverse climatic and environmental conditions. Endangered populations with economic potential may have regional adaptation developed for the country of origin, or adaptations which may be beneficial in other areas of the world where similar or complementary conditions exist. For example the successful use of the Zebu cattle breeds in diverse regions of the world and the use of the trypanotolerant N'Dama cattle breed from the Republic of Guinea in other countries of West Africa (Devillard, 1983). Animals with distinct characteristics may be beneficially incorporated into the breeding programmes of other countries, for example, the prolific characteristics of the once rare Finnsheep (Maijala et al, 1990).

Economic potential cannot be measured by looking simply at performance. Rare or endangered breeds are often highly adapted and their performance should be measured comparatively, within their own environmental conditions. They should not be compared with other breeds in improved or modified conditions or under intensive management. Furthermore, they should be examined with respect to the products for which they were selected and valued in the conditions under which they evolved.

There are many examples where growth rate, prolificacy, or milk production have been measured and used to illustrate the inferiority of purebred indigenous stock over that of exotic imported breeds or their crosses (Hodges, 1986). However, when survivability of the offspring, fertility and longevity are taken into account the indigenous stock are often found to be very productive overall. Two examples of this type of productivity are the Panteneiro cattle from the Pantenal or swampy region of Brazil, and Tswana goats of Botswana in Southern Africa both of which are described in more detail in chapter 5.

It is important to remember when considering economic potential that bioefficiency is not the same as bioeconomic efficiency. That is to say the genetically controlled ability of a population or breed to survive and produce in a region is only one function of its economic efficiency. The economic success of a breed or agricultural system at any one time is dependent upon many manmade variables. These variables include the value of land, the cost of oil and other fuels, the international currency markets and exchange rates, the production efficiency of other breeds and populations in this and other regions of the world, the product shelf-life, travel and storage characteristics, health controls, current marketing strategies, consumer preferences and international political objectives. Changes in any one of these features may shift the balance and enhance the economic value of one breed type over another. For example, a shift in oil prices will affect the cost of cereal production, this in turn affects the cost of feeding grains to livestock and may affect the choice of breeds used in human food production towards more forage efficient stocks.

Finally, crosses between unrelated breeds are not completely predictable in their production characteristics. There are many instances where two pure breeds produce crosses which far exceed the production characteristics of either parent breed due to heterosis. This may be particularly important between breeds which are historically distant or which are each inbred.

This may be due to the two breeds carrying genes of different allelic pairs which complement each other. Highly inbred lines may also demonstrate specific combining ability. This is probably because one line or breed will have become homozygous for some favourable dominant genes and by chance, homozygous for other unfavourable recessive ones. A second unrelated breed would be unlikely to be homozygous for the same undesirable genes. Thus a cross between the two would result in more vigorous offspring (Warwick, 1979). This ‘matching’ of breeds is not predictable. The total number of possible crosses is potentially infinite, and many un-tried crosses could produce valuable production stocks. The South American Criollo cattle whose numbers were in dramatic decline due to replacement by European and Zebu imports, have now been shown to have great potential in commercial crossing where the Criollo first crosses out-produce purebred imported and indigenous stocks.

Populations should not therefore be discarded on the grounds of economic efficiency as measured at any one time, but should be considered with respect to biological efficiency operating within the context of a wide range of possible political and economic situations and a wide range of possible breed crosses (Henson, 1986).

3.1.2 Scientific Use

Endangered populations should be conserved for their possible scientific use. This may include the use of conservation stocks as control populations, in order to monitor and identify advances and changes in the genetic makeup and production characteristics of selected stocks. They may include basic biological research into physiology, diet, reproduction or climatic tolerance at the physiological and genetic level. Genetically distinct breeds are needed for research into disease resistance and susceptibility which could help in the development of better medication or management of disease. It could also help with the identification of specific genes involved in natural disease or parasite control. Some populations may also be used as research models in other species, including man. This is already the case in the use of Ossabaw Island Hogs in the USA. These feral pigs from an isolated island off the east coast of the USA have been shown to have a natural insulin disorder making them a useful research model for human diabetes (Brisbin, 1985).

3.1.3 Cultural Interest

Many populations have played an important role in specific periods of national or regional history. For example, Texas Longhorn cattle in the colonization of the USA, Spanish Merino sheep in the creation of Spain's seventeenth century wealth, or llamas, important as pack animals and fibre producers for the Inca nation of Peru. There are also breeds which have been associated with social and cultural development; the Navajo-Churro sheep whose wool is essential in the production of the native rugs of the Navajo Indians in the USA, or elephants involved in the religious ceremony of the Perehera in Sri Lanka.

There are also many breeds which may be conserved for their aesthetic value. These might include the strain of performing Lippizan horses in Austria, the multihorned and spotted Jacob sheep of Britain, the cork-screw horned Racka sheep of Hungary or many of the ornamental poultry breeds.

3.2 The Objectives For Conservation

The idea of conserving animal genetic resources focusses on two separate but interlinked concepts. The first is the conservation of ‘genes’ and the second, the conservation of ‘breeds’ or populations.

The conservation of ‘genes’ refers to action to ensure the survival of individual genetically controlled characteristics inherent within a population or group of populations. It could, for example, be trypanotolerance, polledness, wool shedding, or a specific milk protein. Such programmes require that the characteristic to be conserved is clearly recognized and identified. It does not, however, require that the genetic function at the chromosome or DNA level be understood. Such a characteristic may in fact be a complicated biochemical function controlled by several sections of DNA on more than one chromosome, but provided the characteristic can be identified in the appearance or function of the animals that exhibit it, a programme can be developed to conserve it as a gene within the population.

The conservation of populations or breeds refers to action to ensure the survival of a population of animals as defined by the range of genetically controlled characteristics that it exhibits. This form of conservation is applied to endangered species as well as to breeds, and is developed to ensure the conservation of all the characteristics inherent with a given population, including many which may not have been recognized, defined, identified or monitored. The differences between breeds may often be due to differences in the frequency of quantitative genes rather than the presence or absence of unique genes. Such a difference in gene frequency may result in dramatically different populations with respect to appearance and production in a given environment.

All proposed conservation projects should clearly define whether the project proposes to conserve ‘genes’ or ‘breeds’. Conservation methods and strategies are not exactly the same for the two objectives.

3.3 The Candidates for Conservation

Opinions have varied over the past forty years as to which animal genetic resources are candidates for conservation. Estimates have been influenced by the relative cost/benefit of conserving all genetic variation as compared to those that can be demonstrated to have predictable economic, scientific or cultural value as described above.

Recent FAO Expert Consultations and meetings of other interested scientists have concluded that all ‘breeds’ or populations which are ‘unique and endangered’ are eligible for inclusion in some form of conservation programme (FAO, 1989b; National Academy of Science, 1992; Office of Technology Assessment, 1987; Wilson, 1988; Weiner, 1989). This definition is based on the belief that it is impossible to determine which characteristics have potential value in the future, because it is impossible to envisage all future eventualities which might include climate change, mutations in disease or parasite populations, the affects of political change, wars, and the availability of energy. This definition has been frequently extended to include popular breeds in which there is rapid genetic change (see section 3.3.5).

3.3.1 Unique Populations

Uniqueness is difficult to define with respect to livestock populations. There are clearly some populations with obviously unique characteristics or traits. For example naked neck chickens (Bodo et al, 1990), seaweed eating North Ronaldsay sheep (Henson, 1978), or the Kuri cattle of Lake Chad whose hollow horns enable them to swim to the lake islands (Adeniji, 1983). There are also breeds or strains which exhibit extremes of quantitative production traits for example, the miniature Dexter cattle of Ireland (Ark, 1976), the prolific Taihu pigs of China (Peilieu, 1984), and the excessively fat Mangalitza pigs of Hungary (Baltay, 1982).

For the vast majority of populations their uniqueness is subjective. It refers to the fact that no other population has the same ancestry, environmental adaptation, human selection, appearance or production characteristics. In effect, the difference between two populations may only be a function of the relative frequencies of the same genes. From the point of view of conservation any population which is historically or geographically isolated or which has had little genetic influence from other breeds over a long period of time, or which exhibits unusual characteristics or traits should be considered to be a unique population.

3.3.2 Endangered Populations - Species

The concept of what constitutes an endangered population varies considerably. In wildlife conservation, that is to say in the conservation of endangered species, a population is said to be endangered when the chance of the survival in the wild is unlikely unless action is taken to conserve that population.

There is no simple numerical level at which a population is defined as being endangered or eligible for consideration as a candidate for conservation. Rather it is dependent upon a number of factors: the actual numbers of animals; the rate of decline in the population size; the closeness of relationship between individuals within the population; the geographical range and the rate of reduction of that range; special threats from introduced species; rapid changes in the environmental conditions including climate, predators and parasites.

The classification for endangered status is based upon the long term survival change of the population being considered. This survival chance can be estimated using population models which incorporate all the relevant variables. These variables include rates of population decline and effective population size (Ne) which incorporates: the sex ratio and age structure of the population; inbreeding rate and genetic drift; genetic diversity within the population; and the length of time the survival plan needs to operate. As a rough guide, a population of less than 10,000 animals may be considered in need of some form of intervention with respect to species conservation (see appendix 3.1).

Effective Population Size

Effective population size (Ne) is determined by the relative genetic contribution of each animal to the next generation. For a more detailed discussion of the calculation of effective population size see appendix 3.2.

Effective population size is greatly affected by the ratio of males to females active within the population such that 4 males and 4 females constitute the same effective population size (Ne), as 100 females and only 2 males.

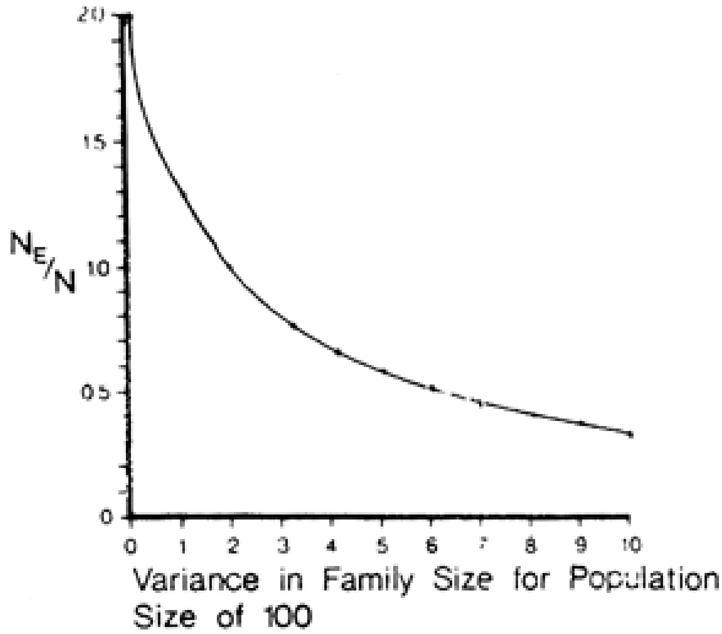
Table 1

Nos of males	Effective population size (in whole nos) with varying nos of females								
	4	10	20	30	40	50	60	80	100
1	3	4	4	4	4	4	4	4	4
2	3	7	7	8	8	8	8	8	8

4	8	11	13	14	15	15	15	15	15	
10	11	20	27	30	32	34	36	36	36	
20	13	27	40	48	53	57	60	64	67	
50	15	33	57	75	89	100	109	123	133	

Effective population size is also affected by relative fertility, family size and longevity. This is because it results in some individuals contributing more progeny to the next generation than others. This is especially important in a small population with limited population growth.

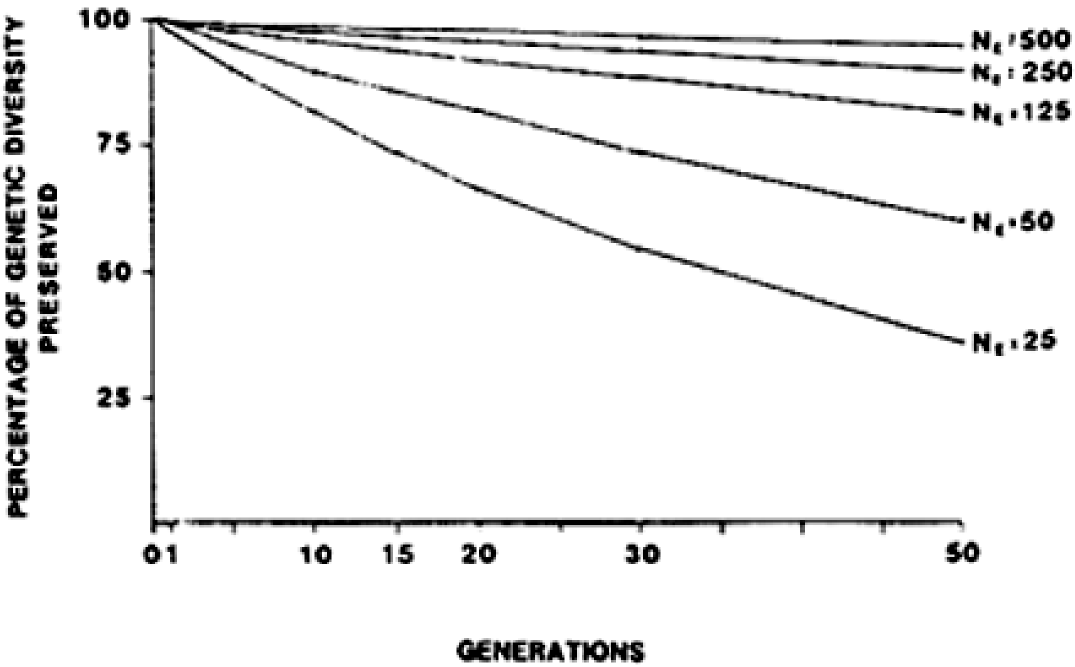
Figure 1



Depression of effective population size (Ne) due to inequality of lifetime family sizes - that is the total number of surviving and reproducing offspring each adult animal produces (after Foose, 1983).

Heterozygosity is the measure of genetic variation within a population and, as already described in chapter 2, is closely linked to the long term survival chances of a population. Heterozygosity refers to the number of genetic options available within a population at a single address on the chromosome. The amount of heterozygosity or genetic variation begins to decrease at an accelerated rate, once the effective size of the population (Ne) falls below 100.

Figure 2



As a general rule, programmes for the conservation of captive endangered species are limited by the number of spaces available within the participating zoos. This may be a serious limiting factor in the survival chances of a population, especially when the population limit is close to the minimum effective population size needed for long term survival. When the increase in population size is not limited, population increasing from very low numbers can reach an inbreeding equilibrium and completely recover their chances of survival (Yamada, 1983).

IUCN Categories

The International Union for the Conservation of Nature (IUCN) provides clear definitions for the rarity of species in its international Red Data Books. These definitions relate to the survival chances of the populations and take all the variables of population structure and environmental factors into account.

Wildlife conservation, based upon these categories is most commonly centered around the *in situ* conservation of populations in their natural environments. This involves the protection of wildlife habitats and requires that sufficiently large reserves are maintained to enable the target species to exist in large numbers. The population size must be sufficient to enable the necessary genetic diversity to survive within the population, so that it has a good chance of continuing to adapt and evolve over time. This reserve size can be calculated for target species by examining the population density in naturally occurring situations. The reserves must then be protected from intrusion, or destruction by man, and against other catastrophes.

Ex	Extinct	Not found in the wild for 50 years
E	Endangered	In danger of extinction, survival unlikely if causal factors continue to operate
V	Vulnerable	Likely to become extinct in the near future if causal factors continue to operate
R	Rare	Small population not endangered or vulnerable but at risk
I	Indeterminate	Known to be in category E, V or R above but insufficient information to determine which
O	Out of danger	A population which was on the list but is now recovered

For severely endangered populations, or those for which long term habitat protection is not a viable option, or where sufficiently large reserves cannot be secured, breeding programmes must be designed. These might simply involve the controlled movement of males from one 'island' reserve to another in order to enhance the gene flow within several geographically isolated subgroups. Other programmes for which suitable habitat is no longer available must be based entirely on captive breeding programmes and the uncertain hope of maintaining a viable remnant population in a closely controlled environment.

Similar categories and strategies should apply when dealing with domestic animals in which the entire species, rather than just strains or varieties within a common species are involved, for example the South American camelidae, the yak, camel and elephant.

3.3.3 Endangered Breeds

In common domestic species for which varieties, strains or breeds are in danger of extinction, the population levels at which action needs to be taken can be much lower. In these cases the common strains or breeds can be used for cross breeding, grading up or as surrogate mothers in an embryo transfer programme. Despite this the range of numbers used to determine the point at which a population is in need of conservation varies considerably from many European estimates in the hundreds to FAO estimates in the thousands (Hodges, 1990c).

The large difference between the European estimates and the FAO estimates stems from the fact that they are based on completely different objectives. The European estimates are based on the minimum number of animals needed to maintain a viable population. Such viable populations are the living parallel to the *ex situ* cryogenic store designed to conserve extractable genetic material. The FAO estimates, on the other hand, are based on the minimum number needed to maintain a population or breed in which future selection and improvement can be carried out.

In general terms the endangered status of domestic populations can be considered in exactly the same way as those described above for wild species. (see Table 3.)

Table 3

Categories for Domestic Populations

Extinct	No possibility of restoring the population, no pure bred males or females can be found.
Critical	Close to extinction, genetic variability reduced to below that of the ancestral population, action to increase the population size is essential if it is to survive.
Endangered	In danger of extinction because the effective population size (Ne) is too small to prevent genetic loss through inbreeding which will result in a reduction in the viability of the breed. Preservation must be enacted.
Insecure	Population numbers decreasing rapidly.
Vulnerable	Some disadvantageous affects endanger the existence of the population and some precautionary measures should be taken to prevent further decline.
Normal	Population not in danger of extinction, can reproduce without genetic loss, no visible changes in population size.
	(after Bodo, 1989)

In order to convert these general terms into figures of population size, birth and survival rates, sex ratios and levels of variation must be taken into account. Table 4 has been proposed as a basic term of reference for uniparous populations of cattle, horses and buffalo (Bodo, 1989).

Table 4

status	No breeding females	Estimated effective average population size				
		Sex ratio				
		5:1	10:1	30:1	50:1	1000:1
Critical	<100	33	18	7	4	-
Endangered	100–1,000	333	182	65	39	-
Vulnerable	1–5,000	1,666	909	309	196	10
Insecure	5–10,000	5,000	2,727	930	588	30
Normal	>10,000	33,333	18,181	6,201	3,921	195

(after Bodo, 1989)

3.3.4 Endangered Populations - Genes

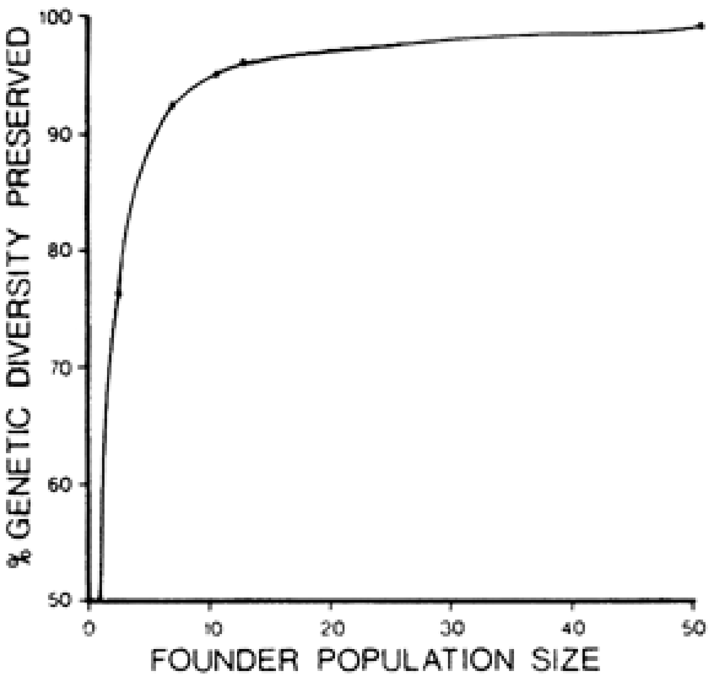
The mechanism for the conservation of individual genes within populations is closely linked to the conservation of species and breeds. The most important feature of a small population conservation programme is the rate of genetic loss. The increase in homozygosity within a small population results in the loss of ability to adapt, inbreeding depression and, ultimately, extinction. Viable population size must therefore be linked to the ability to conserve genetic diversity within any conservation population.

The maintenance of genetic diversity is linked to the effective population size and to the number of founder animals (see 3.3.2 above).

Founder Populations

Populations based on very small numbers of founder animals are less likely to survive than those based on a larger number of founders. A population based on less than 5 or 6 females is highly unlikely to survive. However, only marginally larger populations based on 9 or 10 founder females may survive provided the population is allowed to increase rapidly. If this happens a maximum level of inbreeding is reached after about 30 generations and will then level out (Yamada, 1983). There are examples of populations which have recovered from extremely small founder groups including the Pere David's Deer (*Elaphurus Davidianus*) and European Bison (*Bison Bonasus*) (Frankel & Soule, 1981).

Figure 3



Average percentage of genetic diversity (as measured by heterozygosity) contained in founder populations of various sizes. It is assumed that founders are unrelated and non inbred. Diversity preserved is equal to (1–1/2 Ne) x 100% (after Foose, 1983).

3.3.5 Populations in Rapid Change

Concern has also been expressed for common breeds undergoing periods of rapid genetic change. These are the intensively selected breeds, often involving the use of high levels of advanced technology including artificial insemination (AI) and embryo transfer. These breeds are producing at a very high level under intensive management, veterinary care and feeding regimes. They include breeds likely to be affected by the introduction of transgenic technology. They are the intensively selected dairy cattle breeds of the temperate regions and the industrialized pig and poultry stocks. Conservation may be needed of samples of these populations as they change to ensure that alternative selection options exist. Collection of cryogenic samples would be a useful precaution enabling future changes in direction within these breeds. The establishment and maintenance of live control populations as *in situ* conservation projects, would not, however, appear to be necessary provided cryogenic storage was possible.

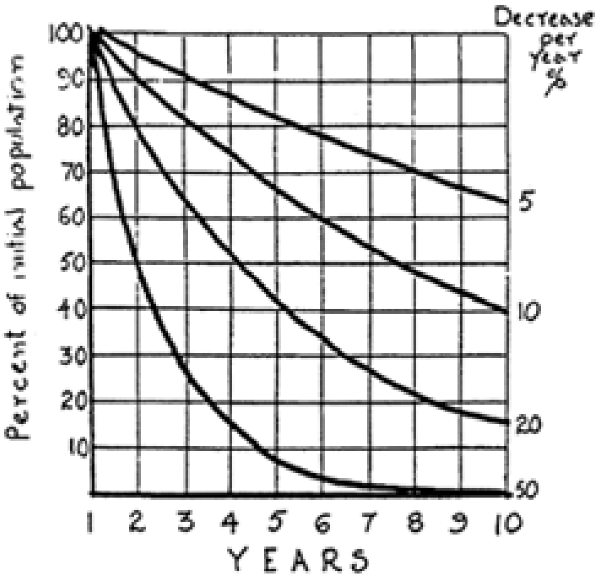
3.4 Action To Identify Conservation Stocks

In cases where the disappearance of a population is imminent, action to conserve that breed should be taken immediately.

In general there is a range of information needed in order to identify populations which should be considered as candidates for conservation. The following types of information should therefore be gathered and used in the definition and planning of a conservation strategy:

i. General descriptive information on the species, breed or type and geographical location. The basis for this information is available in Ian Mason's *Dictionary of Livestock Breeds* (Mason, 1988). Additional information is being collected throughout the world and will be held on the EAAP/FAO Global database (Simon, 1989).
ii. Estimate of the number of animals, males, females and totals and the population trend. This information is more readily available in some countries than others but many nations carry out regular livestock censuses which could be extended to include breed specific information.
iii. The percentage of the female population being used in cross breeding. By estimating the number of purebred males and females alongside the number of young stock with evidence of cross breeding it is possible to estimate the rate of breed dilution. Even a 20% per year decrease in pure bred young stock will result in a very dramatic crash in population size over a relatively short space of time.

Figure 4



The affects of annual rates of decrease on population size (after Hodges, 1990a).

iv. The number of herds or breeding units. A few very large herds may be more vulnerable to diseases, or the affects of economic or political changes than a large number of smaller herds.
v. Estimates of the health risk. Populations in regions where lethal epidemics are endemic may be at greater risk than those in regions where such diseases are not present.
vi. Estimates of other risks, political, climatic or economic. In particular the risk of draught, storms, flooding, war or rapid socio-economic change which could result in the disappearance of indigenous populations.
vii. Characterization of the breed which includes the measurement and description of external appearance, production characteristics, climatic adaptation, disease resistance, parasite tolerance, management and any other special feature. It may also involve the collection of biochemical information from blood types, milk proteins and the comparative analysis of DNA fragments. All of this information is useful in determining the long term conservation strategy with respect to a breed but is not essential in establishing an initial programme to prevent the early loss of a breed or population.
viii. Existence of conservation projects. Projects already in existence to maintain, utilize or conserve breeds at the local, national, or regional level may influence the need for further action in breed conservation.

3.5 Conclusions

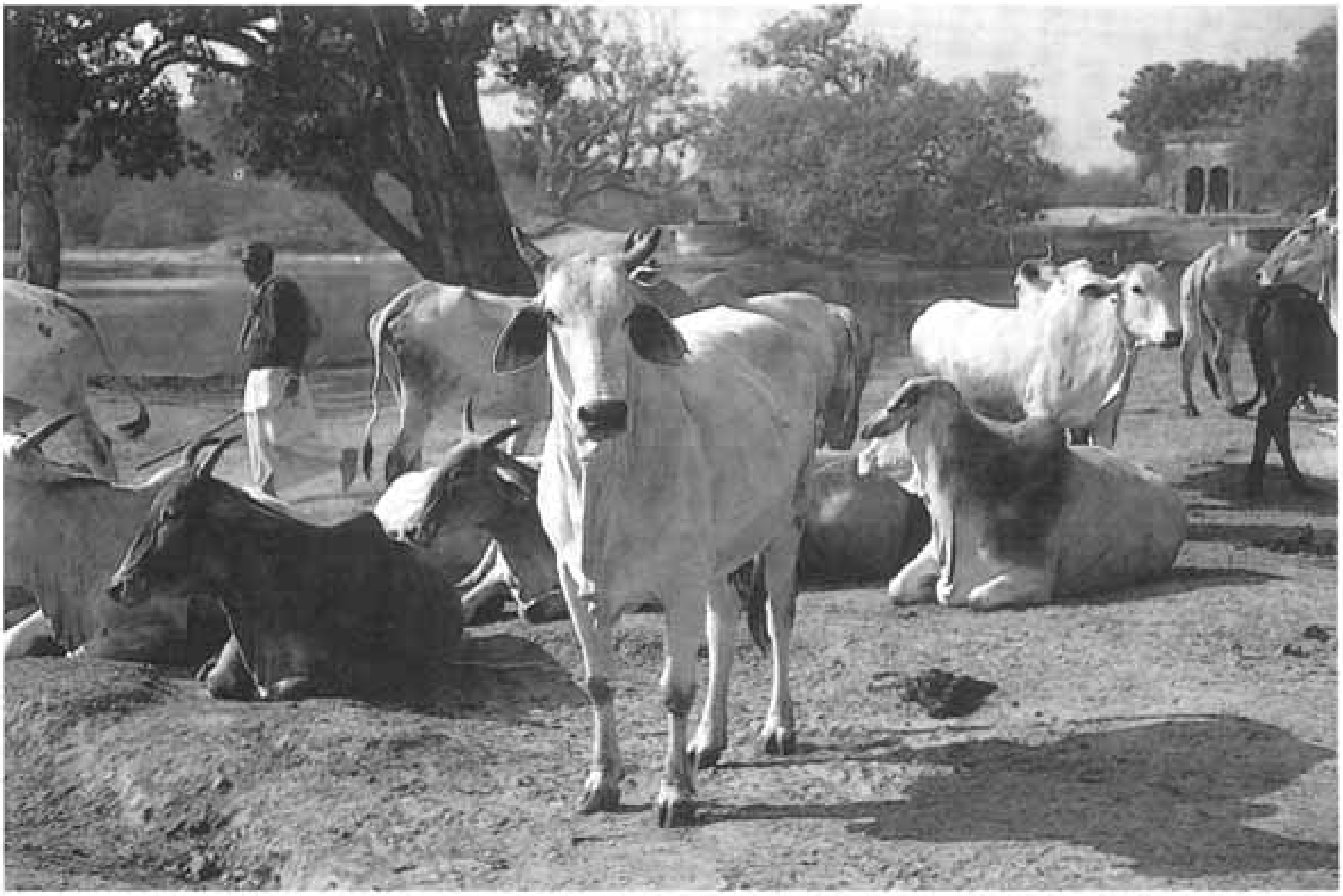
The conservation of animal genetic resources is deemed to be essential in the light of the rapid loss of varieties and breeds through dilution and breed replacement. All varieties of domestic species and species with potential for domestication are considered to be important candidates for conservation. Populations with economic potential, scientific use and cultural or aesthetic interest are of particular importance but all populations which are unique and endangered should be incorporated into conservation efforts.

The general definition for species and breeds in need of conservation ranges from minimum numbers in the hundreds needed to conserve a living survival unit, to much larger populations in the thousands required to maintain populations able to adapt, evolve and be utilized in the future. The effects of small population size on the rate of loss of genetic variation within populations is closely linked to the number of parent animals contributing offspring to the next generation and

this effective population size (Ne) must be kept as high as possible in order to prevent dramatic loss of variation in small populations.

Finally, the information used to identify populations in need of conservation is shown to range from simple information available from the farmers familiar with the breeds, to that supplied by detailed biochemical and scientific research.

5. The last remaining herd of Mulefoot Hogs in the USA has been conserved by an individual farmer.



6. Hariana cows conserved at a religious ‘Gupsala’ in India.

4. Conservation Methods

4.1 *Ex Situ* versus *In Situ* Methods

Ex situ preservation involves the conservation of plants or animals in a situation removed from their normal habitat. It is used to refer to the collection and freezing in liquid nitrogen of animal genetic resources in the form of living semen, ova or embryos. It may also be the preservation of DNA segments in frozen blood or other tissues. Finally it may refer to captive breeding of wild plants or animals in zoos or other situations far removed from their indigenous environment.

In situ conservation is the maintenance of live populations of animals in their adaptive environment or as close to it as is practically possible. For domestic species the conservation of live animals is normally taken to be synonymous with *in situ* conservation.

Ex situ and *in situ* conservation are not mutually exclusive. Frozen animal genetic resources or captive live zoo populations can play an important role in the support of *in situ* programmes. The relative advantages and disadvantages of the major systems are therefore reviewed here with a view to identifying the relative strengths and areas of mutual support.

Table 5

		Ex Situ	*In Situ*
i.	COST - initial set up cost	rel high	low-high
	- maintenance cost	low	rel low-high
ii.	GENETIC DRIFT - initial	rel high	low
	- annual	none	moderate-high
iii.	Applied to all species	no	yes
iv.	Safety/reliability	good-bad	moderate
v.	Local access	mod-poor	mod-good
vi.	International access	good	not good
vii.	Population Monitoring	none	good
viii.	Environmental adaptation	none	good
ix.	Selection for use	none	good

4.1.1 Cryogenic Preservation

a. Advantages

The relative cost of collecting, freezing and storing frozen material, as compared to maintaining large scale live populations, has been estimated to be very low (Smith, 1983). In particular, once the material has been collected, the cost of maintaining a cryogenic store is minimal. Such banks require little space and few trained technicians. A very large number of frozen animals from a large number of populations can be stored in a single facility.

Cryogenically preserved populations suffer no genetic loss due to selection or drift. The method places a sample in suspended animation and that sample remains genetically identical from the time of collection to the time of use. (The effects of long term radiation are considered to be negligible.)

Frozen animal genetic resources can be made available to livestock breeding and research programmes throughout the world.

b. Disadvantages

The principal disadvantages of *ex situ*, or cryogenic preservation lie in the availability of the necessary technology and access to the frozen populations.

Cryogenic stores are not expensive to run but they do have annual capital maintenance requirements. In particular they require a guaranteed supply of liquid nitrogen which must be imported into many countries with expensive foreign currency or aid.

Cryogenic stores have no intrinsic value with respect to financial income unless material can be sold for research and development. They do not produce food or other agricultural commodities and might therefore be deemed to be expensive luxuries in periods of financial austerity.

Cryogenic storage is ideal for the preservation of defined 'genes' or recognized characteristics. Quite small samples ensure the inclusion of all but the rarest genes (see Table 7, section 4.3.1). However, the cryogenic method is less effective in the conservation of 'breeds' where the relative frequency of genes is important.

The methods of initially sampling and collecting genetic material from a limited number of animals to be incorporated into cryogenic storage can result in an initial genetic drift. Thus there is a shift in gene frequencies between the original population and the cryogenically conserved sample population.

The technology necessary for semen collection and freezing, and for superovulation, ova and embryo flushing and freezing is readily transferred throughout the world, however, it is expensive for countries in which the technology is not yet established. The technologies are not yet developed for all species, viable pig and poultry embryos, for example, cannot currently be successfully thawed after freezing. There are also instances where the technologies may be developed but the livestock themselves are not accessible for semen or embryo collection, for reasons of politics, ownership or their remote location.

There is a potential danger in cryogenic storage, from large scale loss of material due to serious accidents. This could be due to human error, power failure, loss of liquid nitrogen, fire, flood, storm, earthquake or war. Such risks can be reduced by keeping duplicate stores in different regions but remains a serious concern.

Linked to the danger of global loss of cryogenic material due to accident, is the danger that regions or nations might lose access to the material. This could be due to their failure to develop or maintain the technological ability to access the frozen stores. There is also the fear of political change which might affect the rights of access to global or regional banks.

Cryogenically preserved populations cannot be studied characterized or monitored. They are not easily available for comparative trials or for research projects. It takes a number of years to regenerate a cryogenically preserved population to review or re-evaluate it in changed circumstances, or to utilize it as a breeding population.

Cryogenically preserved populations are not able to adapt through gradual selection, to changes in the climate or disease background of the local or global environment.

Finally animal disease control in the future could make the use of frozen material laid down in a relatively disease prevalent period, too dangerous to use. This is already a problem with European semen banks which have been collected under a number of different health regulations and testing regimes over the past fifty years. The majority of these stores will be deemed unsuitable for use in Europe under new European Community animal health directives to be implemented in 1992 (National Cattle Breeders Association, 1991).

4.1.2 *In Situ* Conservation

a. Advantages

The major advantages for *in situ* conservation relate to the availability of technologies and the utilization of the breeds.

The *in situ* conservation of live populations requires no advanced technology. There are optimal sampling strategies (see section 4.3.1) and breeding strategies (see section 4.4), but the basic needs of an *in situ* programme are already available and affordable throghout the world. The farmers of every region and nation know how to manage and maintain their local strains. They already have the capability, all they require is direction.

In situ projects can ensure that financial commitment to the conservation of animal genetic resources involves helping to improve the livelihood of farming communities associated with the breeds targeted for conservation. Live conservation projects involve animal utilization and are net producers of food, fibre and draught power (see table 6). They do not require the importation of expensive materials, skills or equipment.

Live conservation programmes may survive major political or environmental upheaval, wars, or climatic disasters that could eliminate frozen stores, especially those needing imported frozen nitrogen. Sufficient numbers of breeding units must be established and maintained, however, for each conserved population.

In situ projects enable breeds to be properly characterized and evaluated in their own and related localities. They allow for comparative trials, research and crossing experiments.

This method of conservation also allows populations to adapt to changing environmental conditions and endemic diseases.

The maintenance of live herds allows for selection and improvement of populations within the sustainable constraints which will be discussed later (see section 4.3.2).

b. Disadvantages

The disadvantages of *in situ* conservation are brought about by a lack of complete control over the many factors which influence the survival of individuals and therefore the genetic makeup of the conserved population.

In situ conservation projects require land and people which are limited resources in some regions of the world. Continuation of all conservation projects is dependent upon unpredictable financial and political change particularly if they are government or institutionally run. They do have the capacity to produce agricultural commodities and sell livestock to supplement their budgets (see Table 6).

Genetic drift is an inevitable feature of all live animal conservation projects, even when steps are taken to minimize the problem. Selection and the resultant shift in the gene frequencies within a population are a real possibility, and may even be a legitimate objective of some programmes. Selection is a particular concern when it is applied to populations being maintained under modified environmental conditions and should only be made within locally sustainable conditions (see section 4.3.2).

In situ conservation incurs the possible threat of disease eliminating whole, or substantial parts, of a conserved population, particularly if the conserved herd is in a single or only a few linked locations. Diseases may also act as a major selection pressure within a population, and may substantially change its characteristics.

Finally, live animal conservation programmes do not assist in the easy international transfer of animal genetic resources as compared to the movement of frozen material. Moving live animals is relatively more expensive and there are international restrictions on the movement of animals to control disease.

4.1.3 Co-ordination of Cryogenic and Live Conservation

Cryogenic methods allow for animal genetic resource material to be suspended, unchanged, for long periods of time. Live conservation efforts enable breeds to be properly evaluated, monitored and used in the present changing agro-economic climate as well as being available for future farmers and livestock breeders. The two strategies are not mutually exclusive and should be considered as complimentary strategies which may be easily and beneficially linked.

Table 6

Economic Production and Recreational Uses Arising From Live *In situ* Conservation Projects

	Species				
	Cattle	Goats	Horses	Sheep	Poultry
Economic Use					

Tractive power	×		×		
Direct production of food	×	×	×	×	×
Dams for crossing for meat	×			×	×
Production of furs		×		×	
Production of wool/fibres		×		×	×
Specialist Uses					
Use in prison, school and hospital farms	×	×	×	×	×
Pasture and lawn management	×	×		×	
Forest management		×	×		
Utilization of harsh environments	×	×		×	
Utilization of marginal areas	×	×	×	×	×
Specialist Products					
Sera for research	×	×	×	×	×
Non-allergic milk production		×		×	
Veterinary or medical research	×	×	×	×	×
Experimental research	×	×	×	×	×
Education Sport and Leisure					
Aid to education	×	×	×	×	×
Zoos	×	×	×	×	×
Tourist attractions	×	×	×	×	×
National parks	×	×	×	×	
Farm parks/museums	×	×	×	×	×
Pets/social company		×	×	×	×
Hobby farming	×	×	×	×	×
Sport and leisure			×		
Folk art			×		×
Ceremonial	×		×		

(after Maijala, 1986)

Collecting and freezing of semen is far simpler in most species than collecting and freezing of embryos. Recent development in the technology to mature ova from the ovaries of slaughtered females has produced a relatively cheap and easy method for the collection of haploid cells from females to parallel the collection of sperm. It is likely that this technique will become increasingly useful as the methods become more widely available.

Maintenance of semen alone does not allow for the recreation of a pure breed, but only for 'breeding back' through a crossing programme but, by using a large sample of semen from different males alongside a relatively small population of live females it is possible to maintain an entire population of animals. The use of artificial insemination (AI) in *situ* conservation of populations enables a much larger number of males to be used in the breeding programme than would be practical if they all had to be maintained as live adult males. This automatically increases the effective population size (Ne) and reduces the minimum total number of live animals that must be maintained to produce an acceptable level of inbreeding and genetic drift (Smith, 1977). This strategy could be particularly useful in species or varieties where the technology for collecting and freezing of ova or embryos is not well developed or available, for example with pigs and poultry; or for endangered species where no alternative host for preserved embryos could be used as is the case with the Indian elephants for example.

Use and replenishment of frozen semen collections alongside a live population will enable breeds to adapt to gradual and permanent changes to the environment. It will allow for the changes necessary to respond to a background of disease and parasites which will gradually mutate over time. It will also allow for current and accurate data to be collected and maintained on breeds. Over time disease control, nutritional knowledge and veterinary care will improve. It is therefore important that breeds are monitored in these changed circumstances and are not continually judged by their production characteristics as measured in less developed situations in the increasingly distant past.

4.2 Gene Pool Versus Separate Breed Conservation

The conservation of endangered species, breeds or populations is an attempt to maintain genetic resources in an identifiable and potentially usable form.

Endangered species must be conserved in separate species units because it is not possible to out cross or pool different species. Endangered breeds of the common species, however, may be maintained as separate 'breeds' or may be combined or pooled into groups of breeds or composites for the purposes of conservation.

4.2.1 Separate Breeds

The advantage of conserving a distinct separate 'breed' is that it has a defined set of characteristics and parameters. Its appearance, behaviour, production, and native environment should all be known or can be determined. A breed represents a group of animals with a known range of genetic variation with predictable and characteristic effects. Such a population can be screened for undocumented characteristics in the future and desirable genes can be accessed through conventional breeding techniques or genetic engineering.

The disadvantage of conserving 'breeds' separately, is that there are a very large number of them, and that many have very similar characteristics.

4.2.2 Gene Pools

The conservation of genetic variation in a gene pool or breed composite requires less resources than individual breed conservation. Many breeds may be combined into a gene pool of a size considerably smaller than that required for separate programmes. There are, however, a number of serious disadvantages with gene pool conservation;

i. A well described breed is by definition predictable in its appearance and production, while a gene pool or composite population is not predictable in the expression of those characteristics.
ii. The identification of animals carrying a specific gene within a composite may be impossible

to determine because expression of the gene may become masked by alternative alleles found in the other breeds in the composite. This may be the case even if the presence of the gene in the pool is known, because it was a feature of one of the breeds included in the original breed mixture.

iii. Valued genetic characteristics may be caused by the interaction of a number of genes always found within one breed. In a gene pool such complementary genes may be separated resulting in the disappearance of the valued characteristic within the composite. This could be the case with some forms of parasite resistance for example, where a physiological adaptation might be linked to dietary preferences or behavioural characteristics. Thus there may be unpredictable genetic interactions between breeds resulting in the disappearance of expected characteristics or the appearance of new unexpected ones.

iv. It is generally believed that a composite conservation population may be considerably smaller than the total size of separate breed programmes for each of the breeds maintained independently. Such a strategy may result in a larger number of the pre-existing genes being lost over time through drift.

Gene pools or composites can be used effectively to conserve genes that affect obvious morphological features which can be easily identified. For example, colour or extreme quantitative traits such as the prolific Boroola gene associated with litter size in sheep. However, such individual traits can be equally well preserved in many species, by cryogenic techniques.

Pooling of breeds should never be considered until the separate breeds or identified populations have been properly characterized. The gene pool is not a useful strategy for the conservation of very varied populations. It may be used for the conservation and selection of a number of closely related breeds with economically important traits, whose physiology and adaptive characteristics are similar. For example, there are four recognized breeds of goat in the desert region of North Eastern Brazil. Each comes from a slightly different area and are distinguishable by their colour patterns. The Moxoto are light cream with black points, the Rapartida are cream with dark forequarters, the Caninde are black with a yellow belly and the Morota or Curaca are solid white in colour. However, beside the name and colour differences initial research suggests that their environment, size, growth rate, production and survivability are very similar (Mariante, 1991). If this is confirmed a more effective conservation, selection and improvement programme could be developed by pooling the breeds rather than maintaining separate strains.

When gene pools are deemed to be beneficial no more than two or three populations should be combined in order to keep the frequency of most the alleles at a useful level.

4.3 Conservation of Small Live Populations

4.3.1 Creating The Sample

Before sampling can begin clear objectives must be defined with respect to the objective of the programme. In particular consideration must be given to whether the programme is to conserve unique genes within the population or the breed itself (see section 3.2).

a. Sample Size

As a general rule the larger the sample or founder group, the greater the range of genetic variation that will be incorporated into the conservation programme.

Where the conservation herd is to act as a nucleus which will interact with other farm or village herds, the sample may not be finite. In this case exchange of genetic material will be possible between herds in the future. In breeds where the conservation herd is likely to be all that will survive of the breed, it is essential that as many founders as possible are included. In this case no more diversity can be maintained than is included in the initial sample.

Relatively few unrelated individuals can represent a considerable genetic diversity. The chance that a population sample of size N, will not contain a gene whose frequency in the population is p, may be expressed as (1-p) to the power of 2N.

Thus in a reasonable size sample there is a good chance that all the available genes will be included unless they were at a very low frequency in the original breeding population. A sample of 25 males and 50 females is recommended as a minimum for a live conservation programme. This has been calculated to result in a loss of less than 1% of the possible genetic variation present in the original population (Smith, 1983).

It has also been shown that even quite small founder groups of less than 10 females can survive and produce viable living populations. It is possible to ensure the survival of almost all the genetic variation present in such small founder groups with a carefully planned breeding strategy (see 4.4). In such cases it is advisable to avoid future or frequent bottle necks in the population size, as this will inevitably result in a dramatic reduction in genetic variation and possible extinction. The optimal strategy for conservation is then to increase the population size as rapidly as possible.

Table 7

Gene Frequency	Number of sires at a probability of	
	.01	.001
.01	229	344
.05	45	67
.10	22	33
.25	8	12
.50	4	5
.75	2	3
.90	1	2

The number of sires that must be sampled to reduce the probability of an allele with the frequency P being excluded from a sample semen store to below 0.01 or 0.001 (after Notter and Foose, 1987).

Once a population has reached its holding size, if one is to be imposed, it is important to design a programme to minimize selection, inbreeding and drift so as to maximize the survival of the genetic diversity found within that population and its chance of survival along the same lines as for the conservation of any small population (see section 4.4).

b. Statistical Sampling Techniques

Methods of sampling fall into three major categories; random, stratified and maximum avoidance techniques.

i. A random sample is one in which every animal has an equal chance of being selected for the sample as every other animal. By definition the sampler has no control over the specific animals selected and can make no judgements about typical or atypical animals being included or excluded from the sample. Relatively small samples collected in this way from populations in which there is a lot of genetic diversity, may result in a shift in gene frequency between the initial population and the sample population, due to chance.
ii. By dividing a population into strata, or groups of similar animals and then sampling the various groups at random, it is possible to ensure a reduced shift in genetic makeup between the sample and the original population.
iii. In situations where the pedigree of the animals within the population is known, it is possible to create a sample which represents the largest possible number of ancestral or founder animals. In this case animals will be selected for inclusion in the sample because they share no common ancestors. No common ancestors is normally taken to mean no common ancestors as parents, grandparents or great grandparents.

c. Practical Sampling Techniques

The principal objective in sampling a population to create a conservation unit, is to attempt to include as much of the genetic variation inherent within that population as possible. Thus animals should be selected from throughout the breeds normal geographical range and should incorporate all the characteristics normally associated with the breed. Furthermore, when breeding records are available, closely related animals should be avoided in order to make room for unrelated individuals.

The major problems associated with sampling a breed in order to establish any kind of conservation programme are: availability of suitable stock due to disease, political restrictions and ownership; conformity to breed description; and degree of dilution by other breeds.

i. **Restrictions**

   Not all groups of animals that constitute a breed or identified population are equally available for sampling for inclusion in a conservation programme.

   Some geographical regions or individual herds may have endemic diseases not found on the conservation farms or co-operating regions. Some herd owners may not be willing or able to participate in supplying animals to a conservation programme. Finally part of a population may be situated on the other side of a political boundary making access difficult or even impossible. In each of these cases the subpopulations excluded from the programme should be very carefully considered with respect to their potential contribution to the programme. If possible it should be determined how different the subpopulation is to the available one by careful comparison of: the environment, which may be more or less extreme; visible phenotypic differences; simple physiological differences; such as blood types or milk proteins; or differences between the structure of the chromosomes or DNA fragments. Any of these studies might suggest that the subpopulation represents a unique and important subsection of the population. If this is not the case the subpopulation may be omitted from the conservation sample. However, if they are deemed to be important, action may need to be taken to establish disease control or parallel conservation efforts.

ii. **Conformity**

A pure conservation scientist will look at a conservation programme in terms of maintaining the maximum genetic variation possible within the conservation flock or herd. This conflicts to some extent with the value of conserving a breed with its predictable and known set of characteristics in a known environment. Sampling, for a programme whose objective is 'breed' conservation, should reflect this breed description and samples should be taken from within the known parameters of the breed. Individuals exhibiting extreme characteristics might be included in a frozen store with the appropriate information in the associated database. Animals on the fringe of the breed parameters will often be the result of cross breeding with exotic or introduced breeds in the relatively recent past.

iii. **Diluted Breeds**

There can be serious practical problems associated with historically well defined breeds which have been extensively diluted. In many cases a limited number of animals may remain which exhibit some of the characteristics which were typical of the old breed. In this case it may be possible and desirable to define parameters for the conservation group, increase the population size as rapidly as possible, and then select from within the group to eliminate the 'foreign influence' and re-establish a new population which exhibits as much as possible of the original breed characteristics. For small populations selection should be imposed on males only, to reduce the risk of inbreeding. This strategy has been employed with the Cikta sheep in Hungary (Bodo, 1984) and similar programmes have been developed for the Navajo-Churro in the USA (McNeale, 1970).

4.3.2 Selection

It is often said that within the conservation of small populations no selection pressure should be imposed because it would reduce the levels of genetic diversity intrinsic within the population. In practice this is an impossible restriction to place on any conservation programme. Selection at some level will inevitably occur in all live conservation programmes and is essential in order to maintain the characteristics of the population.

Wild species are maintained by natural selection and it is recognized that in order for these species to have a good long term survival chance natural selection must be allowed to continue to act upon them. One of the problems of conserving wild species in captivity is that there will be drift in the genetic makeup of the population due to the lifting of natural selection pressures. For example albinoism is a rare recessive gene found in many populations of mammals. Because the gene is rare in the population, individuals exhibiting the albino characteristics are extremely rare. They also stand a much lower chance of surviving into adulthood and reproducing because they are much more likely to be predated than their camouflaged fellows. This fact ensures that the gene remains rare. In a captive situation where there are no predators an albino individual is far more likely to survive and to reproduce, thereby passing its albino genes onto the next generation. The frequency of the albino gene will therefore increase within the population and consequently so will the chance of albino individuals appearing in future generations. This is a very obvious and visible example of genetic drift due to the lifting of natural selection pressure, but it demonstrates the subtle shifts in genetic characteristics which may occur in populations protected from normal selection pressures.

The selection pressures imposed by the environment and by man that have created domestic breeds and populations are equally important and are discussed in chapter 2 of this manual.

In the case of naturally selected characteristics, it is just as important for domestic populations as it is for wild species to be able to continue to exist and adapt within their normal environment. For example, breeds adapted to climatic extremes, unusual diets or heavy parasite or disease infestation should continue to exist under this selection pressure. Animal welfare issues should clearly be taken into account. Allowing natural selection to work does not imply non-intervention and does not require that non-adapted animals be left to slowly die. It does provide the opportunity for the selective culling of those individuals which are clearly not functioning as well as would be expected in the breed's normal environment.

Selection within breeds by man is not fundamentally different from the approach to natural selection described above. In projects established to conserve unique genes or characteristics the appearance of atypical animals may be considered beneficial. If a population has been developed for its own particular production characteristics, for example its wool, milk or draught power, and the objective is ‘breed’ conservation, the population should be conserved with these breed specific characteristics. Thus a limited amount of selection should be an integral part of breed conservation. This selection should be targeted at maintaining the known characteristics and parameters of the breed. It should not be used to reduce the genetic diversity found within a breed being conserved in a small population, but rather to limit the effects of individual outstanding or unusual animals and to prevent traits previously alien to the breed becoming common. The objective should be to conserve an identified group of animals with known parameters. This should not be conservation of just a colour pattern or horn shape, or the conservation of a breed name attached to a herd which has long ago lost the characteristics for which the original breed was valued.

The important general features of such selection are:

i. Selection should not be carried out in very small populations where inbreeding may be a problem. The population should first be allowed to increase in size (see 3.3.4).
ii. Most livestock breeding programmes involve the use of more females than males. Selection may be imposed on males whilst maintaining the influence of as many founders as possible through the unselected females.
iii. Selection should be carried out within the adaptive environment and should be against characteristics which prevent the animal from functioning well in that environment, or from exhibiting the production characteristics typical of the breed.

Selection for or against features relatively common within a breed should be considered very carefully. Advantageous characteristics may be positively selected in the context of conservation, but this should be done in larger programmes as described in section 4.6 of this manual.

Selection against so called ‘undesirable’ characteristics common to a breed should only be carried out once the real affects and interactions of these characteristics are known. Congenital splitting of the upper eyelid in multihorned breeds of sheep, for example, has been shown to be closely linked to the genes causing the development of the impressive four horns. Selection against the eyelid condition, which has no selective disadvantage in the natural environment of these sheep, resulted in a dramatic reduction in the frequency of four horned individuals within the UK population (Henson, 1981).

Similarly selection was carried out among the seaweed eating sheep of the Orkney Islands to remove monorchid ram lambs which were found to be very common. This selection was done without first identifying if the condition was historically common, why it was so prevalent within the population and if it was linked in any way to the breeds remarkable ability to survive on a diet of the seaweed laminaria. This breed is considered in more detail in 5.4.2.

A similar type of selection has been reported in the Ethiopian programme to supply drought resistant bulls of the indigenous cattle to the devastated regions of Eritrea. These cattle are the only animals that will survive in the region and the project is an excellent one. However, one of the characteristics used to select bulls for redistribution was ‘a straight back’ (Relief Society of Tigray, 1986). Although a feature used to select European cattle it is not a characteristic known to be linked to the ability to survive in extreme drought conditions. Selection, if it is to exist in conservation herds must, therefore, be justifiable with respect to the important and locally valued features of the breed.

4.3.3 Inbreeding

Inbreeding is the mating of closely related animals and results in an increase in homozygosity. It reduces the amount of genetic variation within the population as compared to an outbred population. The chance that closely related animals carry the same mis-copied, non-functional or deleterious pieces of DNA inherited from a common ancestor is quite high. Inbreeding will tend to result in more homozygous animals which have inherited two copies of the less efficient gene. For this reason the general affects of continuous inbreeding are seen as a reduction in fertility and viability particularly with respect to survival after birth and growth rate to weaning (Falconer, 1981; Lasley, 1978; Warwick, 1979; Wright, 1977).

Conversely mild inbreeding combined with intensive selection can be used to improve livestock breeds so that superior animals with more effective genetic characteristics have more influence over future generations than inferior ones. In many important developed breeds more than 80 or 90% of the population can trace their pedigrees back to one or two superior individual animals. This selection combined with low level continuous inbreeding concentrates the desired genes and enables deleterious genetic characteristics to be selected out. This method of continuous low level inbreeding and elimination of deleterious genes has resulted in domestic populations that can withstand much higher levels of inbreeding than wild species which are not normally exposed to inbreeding pressures (Frankel & Soule, 1981).

In small populations inbreeding can be controlled by careful planning of the breeding strategy but it remains a function of small population size. In situations of very small populations where close inbreeding is the only option it is better to mate brothers and sisters than parents to offspring. The inbreeding coefficient is the same in both cases but sib matings help to equalize the genetic contribution to the next generation from the two parent lines. In this situation the objective is to carry as much genetic variation from the founder group into the next generation as is possible (see section 4.4).

4.3.4 Small Population Size and Drift

Within small populations inbreeding is a function of the population size, because the chance that any two individuals mated together will be related, or share common ancestors, is increased. If a strategy of random breeding is assumed within a population, it is possible to estimate the rate of inbreeding, which will vary according to the number of breeding animals in the population.

The rate of inbreeding (δF) in a small population is calculated as

$$\Delta F = 1/2Ne$$

where Ne is the effective population size. The effective population size is affected by the ratio of males to females, longevity, and variance in family size (see appendix 3.2).

In turn, the rate of inbreeding reflects the drift in genetic variation within the population. Genetic drift in a small population is the loss of genetic variation through random chance. There may be a number of different DNA options at one address on the chromosome which code for a number of different possible phenotypic characteristics. For example blue, brown or green eyes. If there is no selection pressure the likelihood that any one option will be passed onto the next generation is affected by random chance. In a very small population this may result in the frequency of the options 'drifting', by chance, until they will become fixed at the frequency of one or zero in the population.

The percentage of genetic diversity conserved over time decreases rapidly with smaller population sizes (see fig. 2). Thus the amount of heterozygosity or genetic variation present in each generation begins to decrease at an accelerated rate once the effective population size (Ne) falls below 100.

The level at which a small population conservation programme can be established is determined primarily by the rate of inbreeding, or the rate of loss of genetic diversity, which is considered to be acceptable over a specified period time. An absolute minimum effective population size of 50 is considered necessary for the survival of zoo populations of wild species where breeding strategies can be very closely controlled (Frankel & Soule, 1981).

4.3.5 Minimum Size Of Conservation Herds

The ratio of males to females is very important in the calculation of the minimum of animals needed to conserve a population. This is based on the effective population sizes, or the number of animals contributing genetic material into the next generation (see section 3.3.2).

Small effective population sizes result in an increase in inbreeding which results in a loss of heterozygosity or genetic diversity (see section 4.3.3).

Programmes to conserve endangered domestic animals have been proposed that would result in inbreeding rates of between 1 and 4% per generation. It is possible to maintain inbreeding rates at this level, with populations of between 12–25 males and 100–250 females.

It has been estimated (Smith, 1984) that the following minimum number of animals are required for the conservation by management of endangered breeds of the common agricultural species.

These estimates take into account the number of males and females in the breeding unit and the number of young replacement males and females joining the population each year. They may be taken as absolute minimum for the maintenance of a conservation herd and require carefully planned breeding programmes. Calculations of minimum population size and loss of genetic variation are theoretical, although Wright's inbreeding coefficient, central to all the calculations, does not always correlate with the observable affects in particular populations. This observable difference in real populations is due to the actual number of common ancestors in the group and the severity of the particular deleterious genes they happen to carry.

The American Association of Zoological Parks and Aquaria 'Species Survival Plans' for endangered species similarly incorporate minimum population sizes with a breeding strategy which requires the replacement of individual animals by their offspring in a controlled and planned way, in order to maximize the use of limited animal spaces in the zoo programme.

Table 8

No.s males	No.s females	Total	Ne	% inc in inbreeding/generation assuming random mating
50	50	100	100	0.5
20	80	100	64	0.78
10	90	100	36	1.39
1	99	100	3.96	12.63
20	50	70	57.1	0.88
10	50	60	33.3	1.5
1	50	51	3.92	12.75

(After Brem, FAO, 1989)

Table 9

	Cattle		Sheep		Pigs		Poultry	
	m	f	m	f	m	f	m	f
Size of breeding unit	10	26	22	60	44	44	72	72
No. of breeding animals entering each year	10	5	22	12	44	18	72	72

In these programmes an effective population size of 500 is considered to be an absolute minimum for the long term survival of a conserved population. This may be obtained theoretically with an actual number of only 250 animals if the sex ratio is held constant at one to one and every animal contributes equally to the next generation (Franklin, 1980).

4.4 Small Breeding Programmes - Recommendation

1. Begin with an adequate sized sample of animals who should ideally be unrelated, non-inbred and fertile. They should represent the range of genetic types found within the population. If possible a sample of at least 50 males and 50 females should be included.
2. Expand the population as rapidly as possible, to a minimum effective population size of 500 animals (see section 4.3.5).
3. Maximize the effective population size (Ne). To achieve this ensuring that as many animals as possible contribute offspring to the next generation (see appendix 3.2). Effective

population size may be enhanced by:

   i. Equalizing the sex ratio.
   ii. Standardizing the litter size.
   iii. Standardizing the longevity.

4. Equalize the representation of the founders, (i.e. the animals in the original sample). It is important that as many of these founder animals as possible are represented in each generation.
5. Manage inbreeding, in most cases the best strategy is to keep inbreeding to a minimum. There are situations in sublined populations where alternative strategies might be chosen (see appendix 5.4).
6. Subdividing the population may be a useful option (see section 4.5.5). In particular this strategy may help to control the possible spread of disease between conservation herds.

4.5 Breeding Strategies

The three principal methods for establishing a conservation breeding programme for small populations are based upon the methods of natural breeding, random mating and pedigree breeding.

4.5.1 Natural Breeding

The natural breeding strategy adopted by wildlife conservation programmes involve ensuring that sufficient animals exist in the conservation area to allow normal mating structures to exist. Thus territorial or harem behaviour is allowed to proceed as it would in a normal wild population, such that the strongest and best adapted males mate with the majority of the females. Intervention may take the form of removing older males after one or two breeding seasons to ensure that younger individuals have the opportunity to reproduce. Action may also be taken to transport males from one ‘island’ reserve to another in situations where wildlife sanctuaries are divided by inhospitable or impassable man made obstacles.

This strategy of conservation is also used on the conservation of feral or very extensively managed domestic populations. The conservation of Ossabaw Island hogs on Ossabaw island in the USA (Brisbin, 1985) and the primitive ancestral flock of Soay sheep on the Island of Hirta (Jewell, 1974) are good examples of this method. These strategies require larger minimum population sizes than those discussed in 4.3 above, and should only be considered for populations of many hundred individuals in situations where most of the males will be allowed to remain with the female herds. The ancient wild cattle of Chillingham have survived for seven hundred years with a very limited population size and a natural breeding structure although there is evidence from blood type examination, of considerable homozygosity within the breed (Henson, 1983).

4.5.2 Random Mating

The random mating system is designed to ensure that each adult animal has an equal chance of leaving an equal number of progeny. Statistically the progeny numbers fall into a Poisson distribution. Models can be developed to randomly select mates. This method has been used unsuccessfully for small populations of poultry where 40 pairs of parents per generation has been calculated as acceptable.

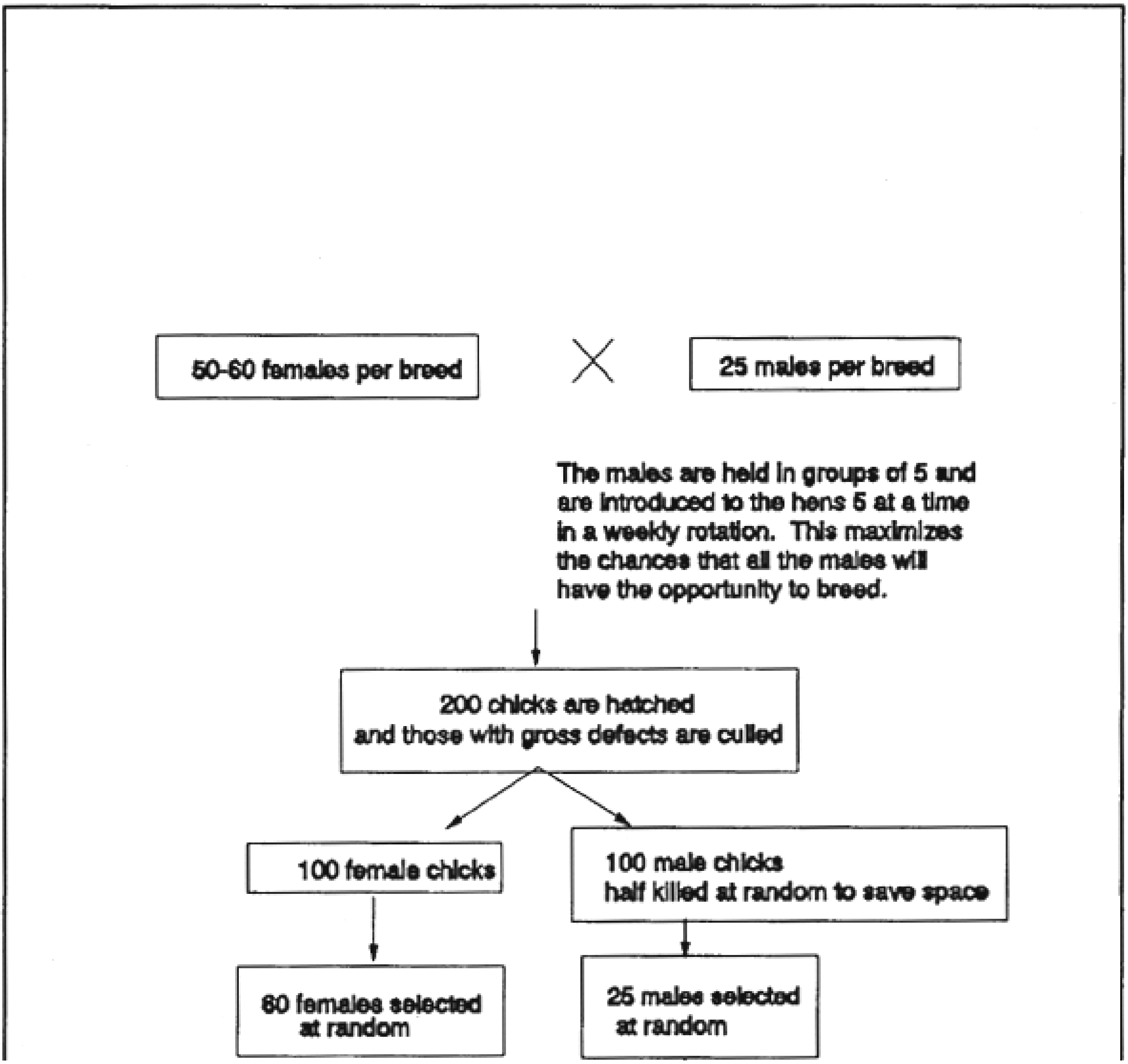
In practice, Professor Crawford in Canada has maintained 17 middle level poultry stocks using a random mating strategy for a period of up to 24 generations. The populations are 11 hens, 1 turkey, 1 guinea fowl, 1 duck, 1 Muscovey duck and 2 goose lines. No significant reduction in fertility or hatchability which might be associated with inbreeding, has been observed. All birds are bred at one year of age to minimize the effects of selective mortality.

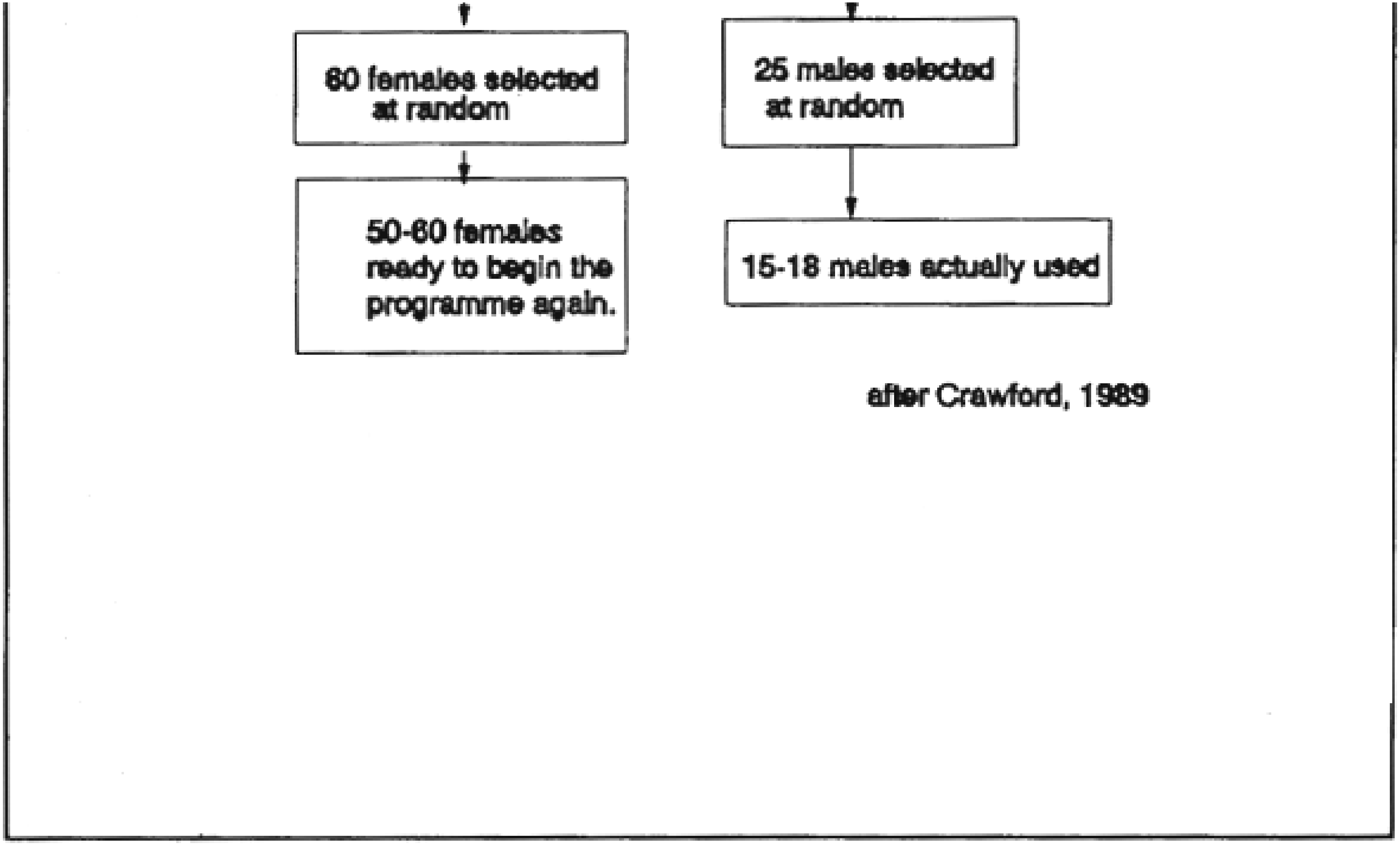
The principal problems encountered with this system of random mating has been the variation between adults or between families in a number of survival characteristics which include;

i. the reproductive potential of individuals or families,
ii. the relative rates of fertility,
iii. the viability of offspring and their ability to survive to maturity.

All of these variables can quickly skew the distribution and accelerate genetic drift. This method of breed conservation is ideally suited to groups or herds of animals which can be easily identified as a group and where matings can be controlled between groups, but where individual identification of animals is not practical.

Table 10





4.5.3 Pedigree Breeding

By monitoring the pedigree of animals in a conservation breeding programme it is possible to ensure that each animal or family contributes equally to the next generation. Within a population of fixed size, each male can then be sure to contribute one son to the next generation and each female, one daughter.

In wildlife conservation programmes for zoo animals an effective population size of 500 is the target for long term conservation of zoo populations. This can be achieved with an actual population of only 250 animals if the sex ratio is held constant at one to one and each animal contributes equally to the next generation (Franklin, 1980). Each animal produces at least two litters by two different mates. No more than one offspring will be selected for the breeding programme from each litter. Each male will be replaced in the breeding population by one son, each female by one daughter (Foose, 1983). If carried out correctly this strategy confers negligible genetic loss over an extended period of time. The problems are practical ones. Not all animals breed equally well in captivity and some will not mate with their selected partners. There is also a problem with the public's perceptions of conservation which is not compatible with the elimination of individuals born in a litter but not needed for the breeding programme. This is particularly difficult in zoos where the public constitutes a major source of funding. It is a less serious problem in the conservation of agricultural animals where the surplus can be used for human consumption in the normal way.

The basic structure of random mating within pedigree lines has been effectively used for domestic breeds and in particular for poultry (see table 11).
This system involves considerably more time, more expensive equipment in terms of individual cages and more skilled technicians for artificial insemination than the basic random flock system described in 4.5.2 above. However, it should result in lower inbreeding coefficients and far less genetic drift than the basic random system.

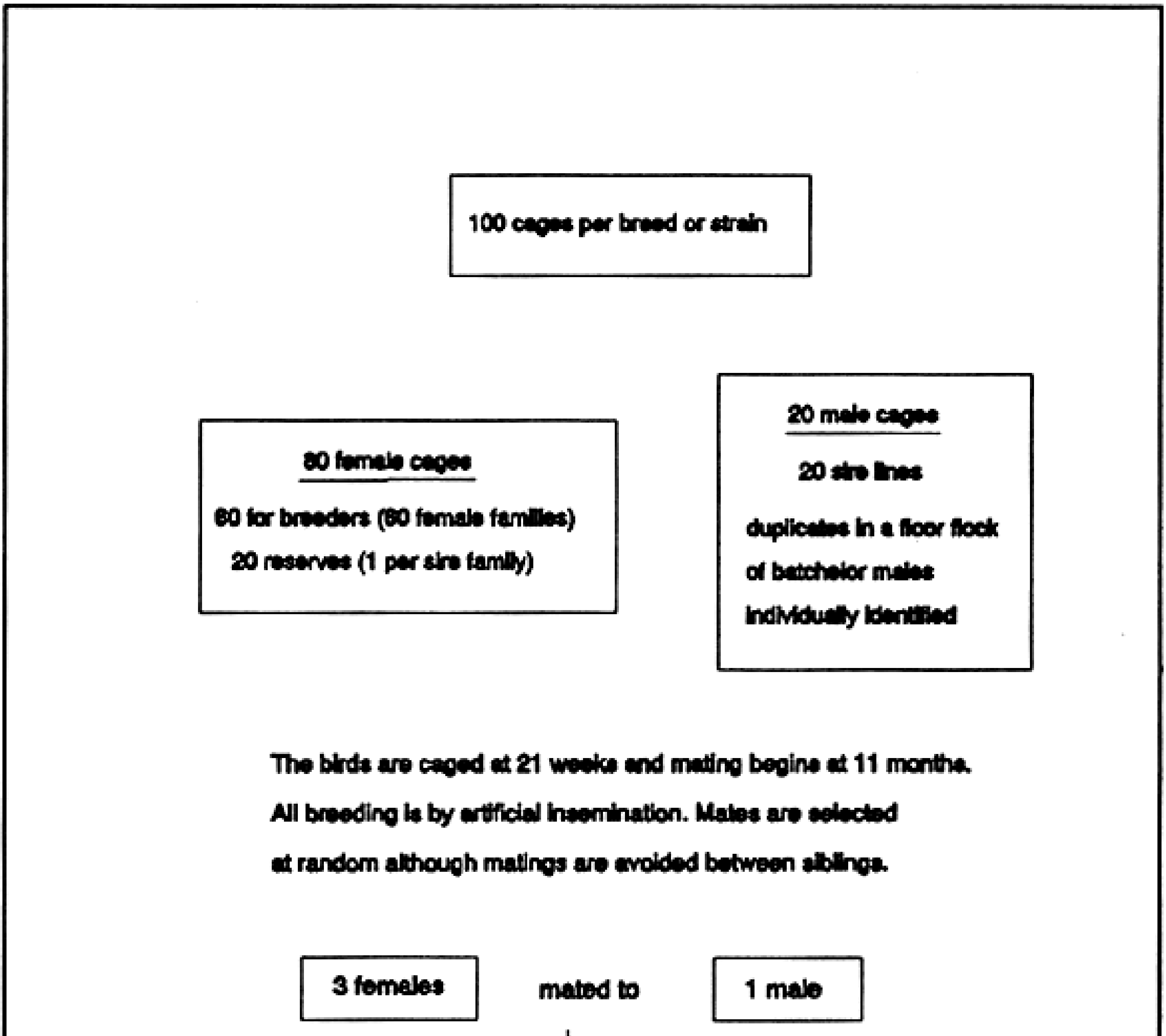
In practice the system has shown lower fertility than the flock system due to technical and practical problems with the use of artificial insemination. It has also brought to light a serious infertility problem in one female line of one of the breeds which was masked in the random flock system (Crawford, 1989).

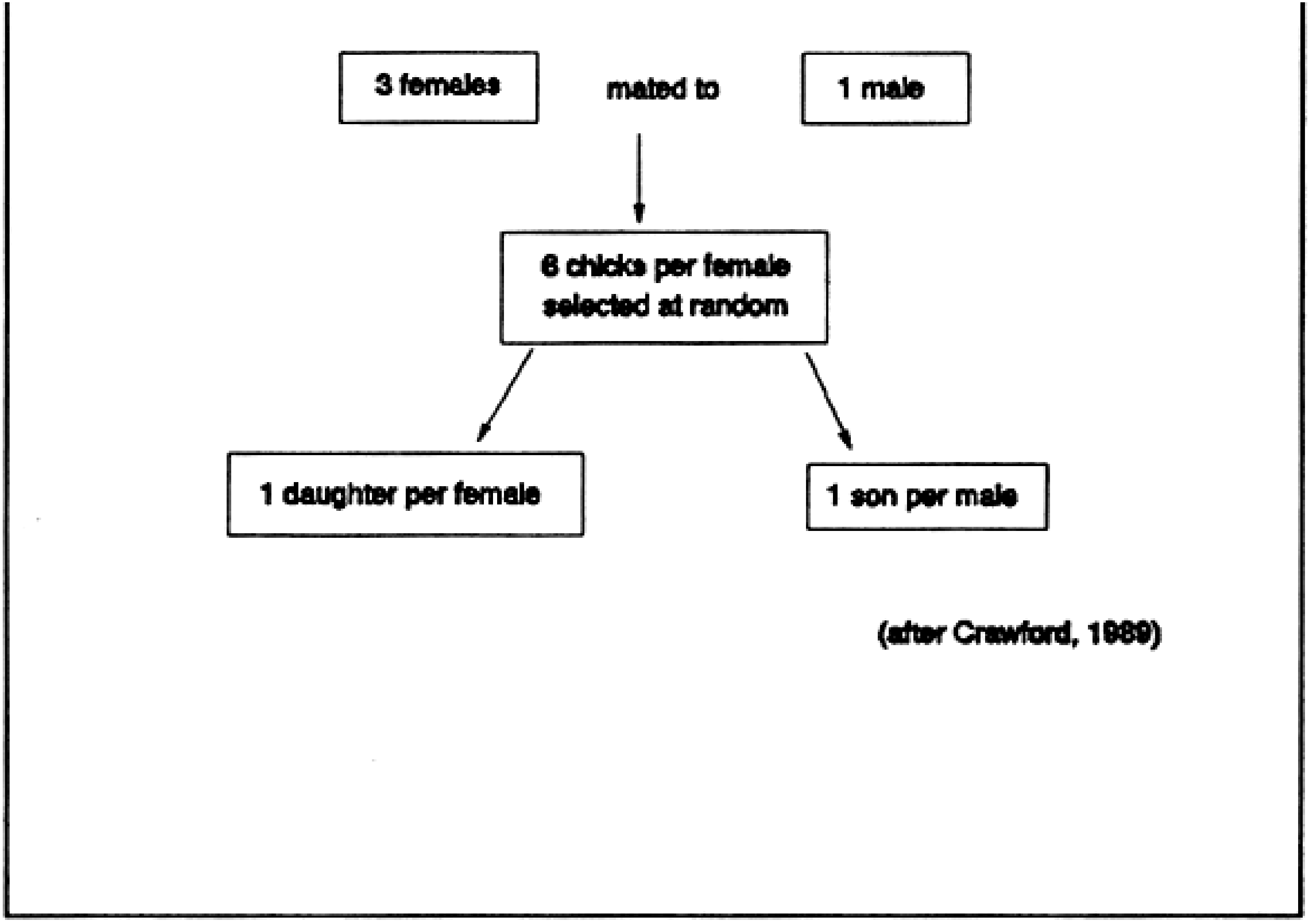
Pedigree systems are more effective in monitoring inbreeding and therefore loss of genetic variation over long generation intervals. They also supply important relationship information to help monitor genetic diseases or defects that may occur.

4.5.4 Maximum Avoidance

The random breeding strategy described above helps to ensure that the chance of variation at any one genetic loci being lost, is kept to a minimum. However, once pedigree records are available the optimal strategy to minimize inbreeding from one generation to the next is through the maximum avoidance method. This involves selecting mates which are the least related to one another. It is particularly effective in maintaining low inbreeding coefficients and thus high levels of genetic variation in very small populations. In such cases it should be used in conjunction with an overall strategy to increase population size as rapidly as possible.

Table 11





4.5.5 Sublines

Once groups are larger a more effective method of maintaining maximum genetic variation over a longer period of time, may be to sub-divide the population and use a cyclic breeding system.

When a population is divided into separate sublines each of the sublines will, by definition, be smaller than the original group. Each group will then have a higher rate of inbreeding, and a higher rate of loss of genetic variation due to drift, than the total population group as a whole. However, the random chance that the same genetic variation will be lost in all the sublines is very low. It is, therefore, postulated that a population can successfully be divided into sublines. A maximum avoidance breeding strategy can then be adopted within each line. Periodically there can be an exchange of males, probably in a cyclic rotation between the sublines. In this way any degree of dividing into sublines, will ultimately reduce the final rate of decline of heterozygosity.

It has been postulated that a practical method for achieving this might be to inbreed within subdivided lines for 8 to 10 generations and then outcross between populations. The important feature of all these proposals remains the actual size of the population and therefore the rate of genetic loss, and the level of inbreeding the population can withstand. There are also practical restraints associated with unequal sex ratios and the overlap of generations (see appendix 5.4).

The strategy results in the conservation of a number of inbred lines with very little genetic variation within each one, but assumes that the total variation will survive in the total population of sublines. However, inbred lines are often inferior to non-inbred ones in terms of resistance to disease, reproductive success and lifespan. The strategy has been postulated for zoo populations where the method of maintaining the entire captive population under a minimum inbreeding programme has been compared to alternating mild inbreeding within zoos, combined with outcrossing between zoo populations. The latter strategy has the advantage of less movement of animals which helps in lower costs, animal welfare and the control of disease between the various breeding groups (see appendix 5.4).

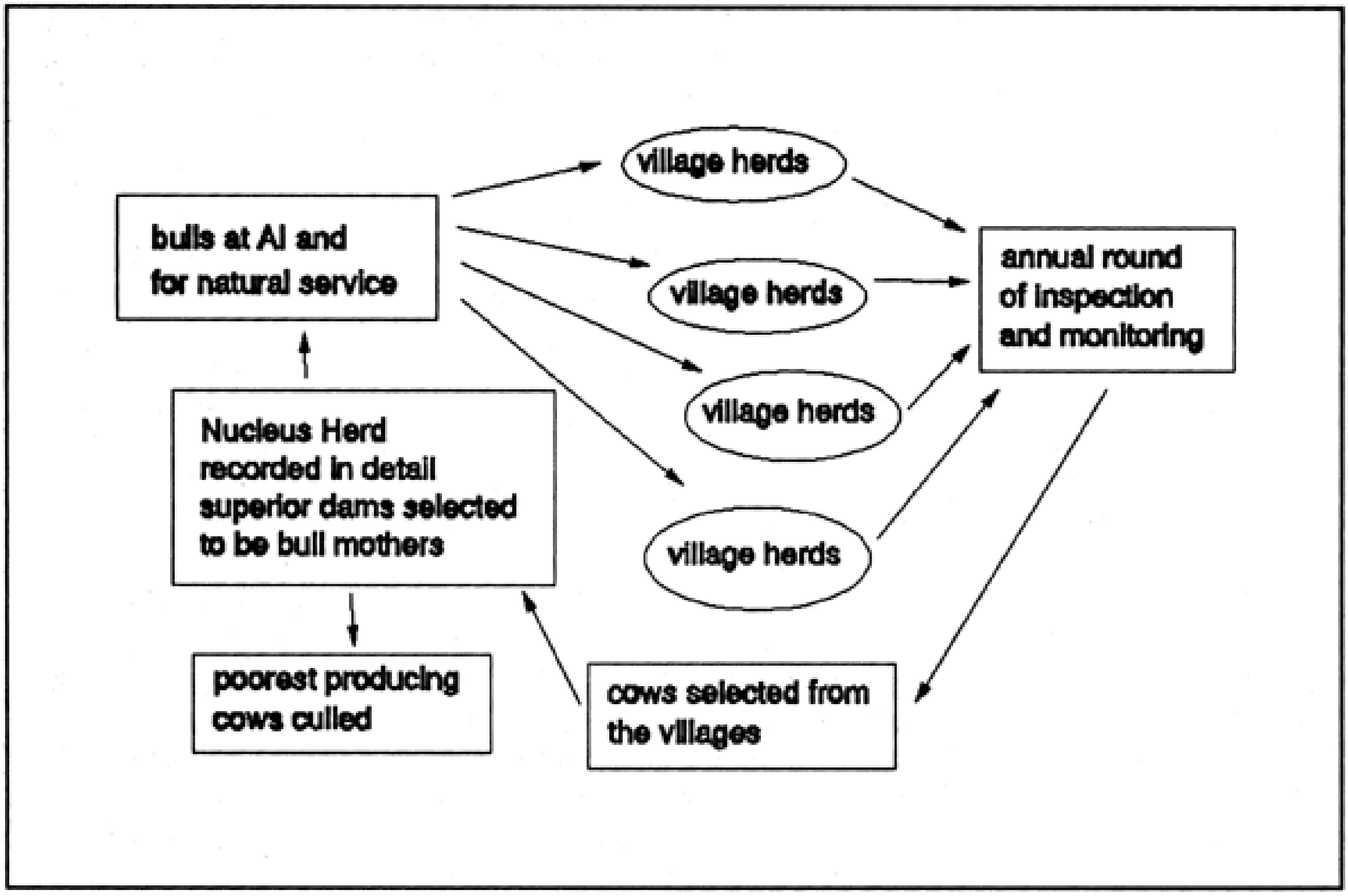
Dividing into sublines is not recommended for very small populations where the size of the sublines would be so small that the inbreeding coefficients would rise too quickly and jeopordize the survival of the sublines due to reductions in fertility and viability of offspring.In practice sub-dividing Cattle in Hungary and the Lipizzan Horse in Austria (Bodo & Pataki,. 1984).

4.6 Conservation for Utilization

The most effective method of conservation is that which involves the full utilization of a breed. There are many instances where breeds have become endangered, but through proper characterization and evaluation a role has been identified. In some cases the new role has been in another country, for example the prolific Finnish Landrace sheep which are now more numerous outside Finland than within the source country. In other cases it has been a regenerated home market resulting from proper research and improvement of a locally adapted breed. For example the Criollo cattle of Bolivia which were being systematically replaced by Zebu crosses. Research into the real production characteristics and survivability of the breed has resulted in a renewed interest in the Criollo which has a long term commercial role in the cattle industry of that country (Wilkins, 1984).

Conservation and utilization programmes require careful and accurate evaluation of breeds in their own local situation as compared to exotic breeds and their crosses in the same sustainable conditions. Where breeds emerge as having a real local potential they should be incorporated into proper evaluation and improvement programmes either on station or in the field situation.

Table 12



The most important factor of all improvement of conservation groups is that selection is carried out in the environment to which the breed is adapted and that it is for traditionally valued characteristics. These characteristics might be foraging ability, mothering ability, ease of parturition, draught ability which might include stamina, strength, food conservation for draught or tractability, it might be for rich milk for cheese or butter making, or fat meat to supplement a low fat vegetable diet, or for soap making. Western European selection criteria should not be imposed on populations unless they are clearly appropriate. Most important of all, selection must be under the local sustainable conditions. The herds must be managed within the natural environment for that breed and need to be exposed to the conditions prevalent in the field situation. Thus treatment for a disease or parasite to which the breed has some natural resistance should not be given unless the same treatment is freely and practically available in the field. Disease and parasite resistance is biologically expensive. Thus if these heavy selection pressures are lifted, and production pressures imposed the population will very quickly shift such that they will produce more milk or meat but will lose the genetically controlled resistance for which they were valued. The same is true of heat tolerance, drought resistance or the ability to survive on diets with a very low nutritional value.

There are a number of African programmes designed to conserve and improve disease resistant strains, including those with trypanotolerant N'Dama cattle in the Republic of Guinea (Devilliard, 1983). There are also village based projects beginning around the world including the Jamnapari goat project in India (Bhattacharya, 1990) and work with the heartwater resistant Tswana sheep, goats and cattle of Botswana (Setshwaelo, 1989) both of which are discussed in chapter 5 of this manual.

Projects for conservation, utilization and improvement of breeds should attempt to lay down periodic samples of cryogenically stored material as a long term insurance policy. They must clearly define their objective which should incorporate the conservation of those characteristics for which the breed has been traditionally valued. They may then take the form of a number of cooperating farms in a male progeny testing scheme, as with the Sahiwal cattle project in India discussed in chapter 5. More frequently they are associated with open nucleus type breeding strategies.

For a nucleus herd of 200 cows the best 20 females will be selected from the villages each year and some 20 will die or be culled from the nucleus herd. This system will produce a moderate rate of improvement although in practice the village farmers are not often willing to give up their best females to the programme and the nucleus herd does not produce any better than the average for the village herds. This is in part due to the fact that the village farmers don't give up or sell their best cows, but may also be due to a difference in management. It has been found in India that breeds developed over centuries in a very small herd situation with very close interaction between farmer and animal do not take well to a large herd situation with little or no association between individual animals and people. There was therefore an initial reduction in production level from the institutional farm over the average for the village herds.

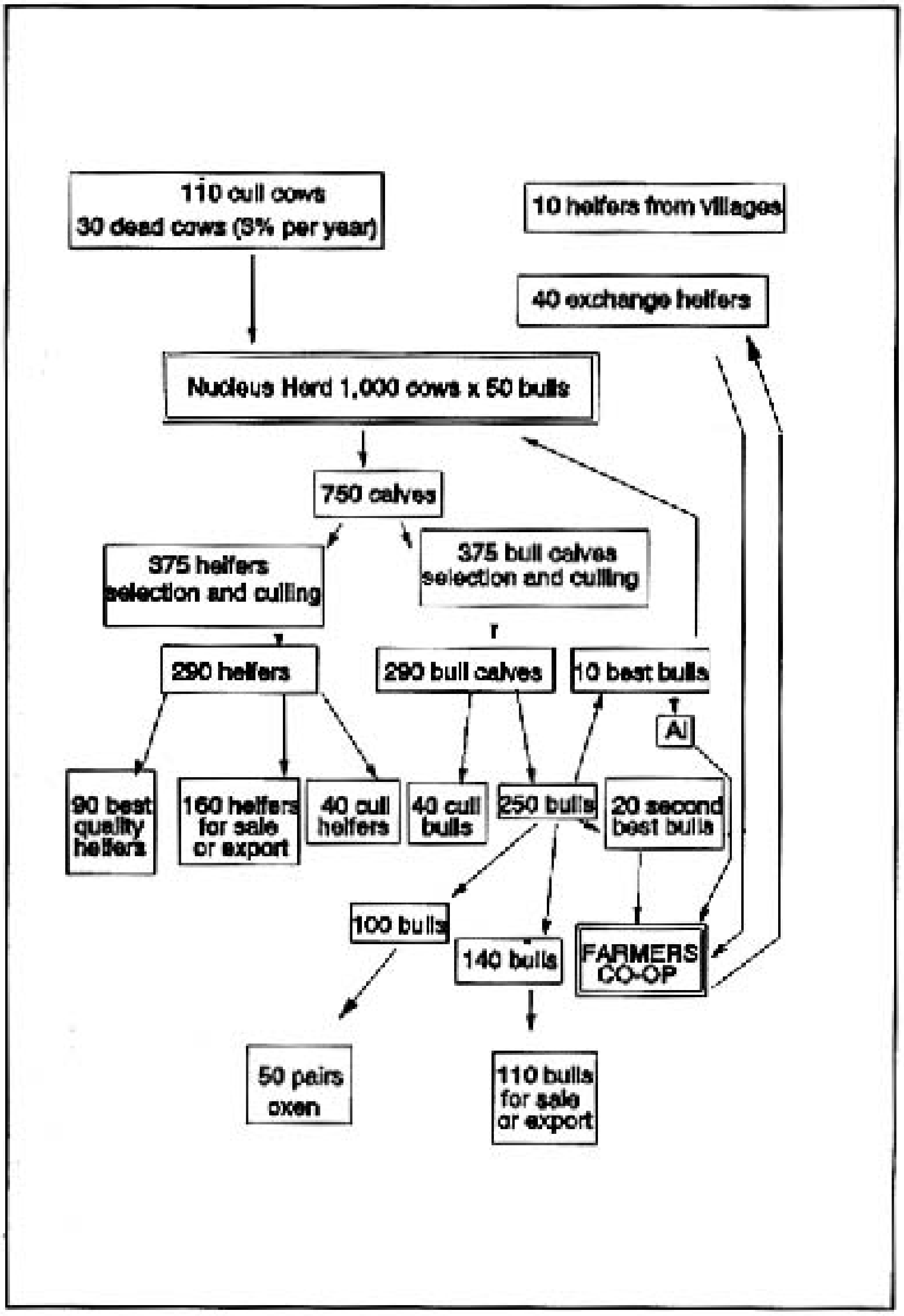
A larger nucleus of 1,000 trypanotolerant N'Dama cattle has been proposed for the republic of Guinea (Devillard, 1983) which would produce a far greater expected rate of genetic improvement and produce superior males and females for the co-operating farmers as well as surplus stock for sale to farmers within Guinea or for export to neighbouring countries.

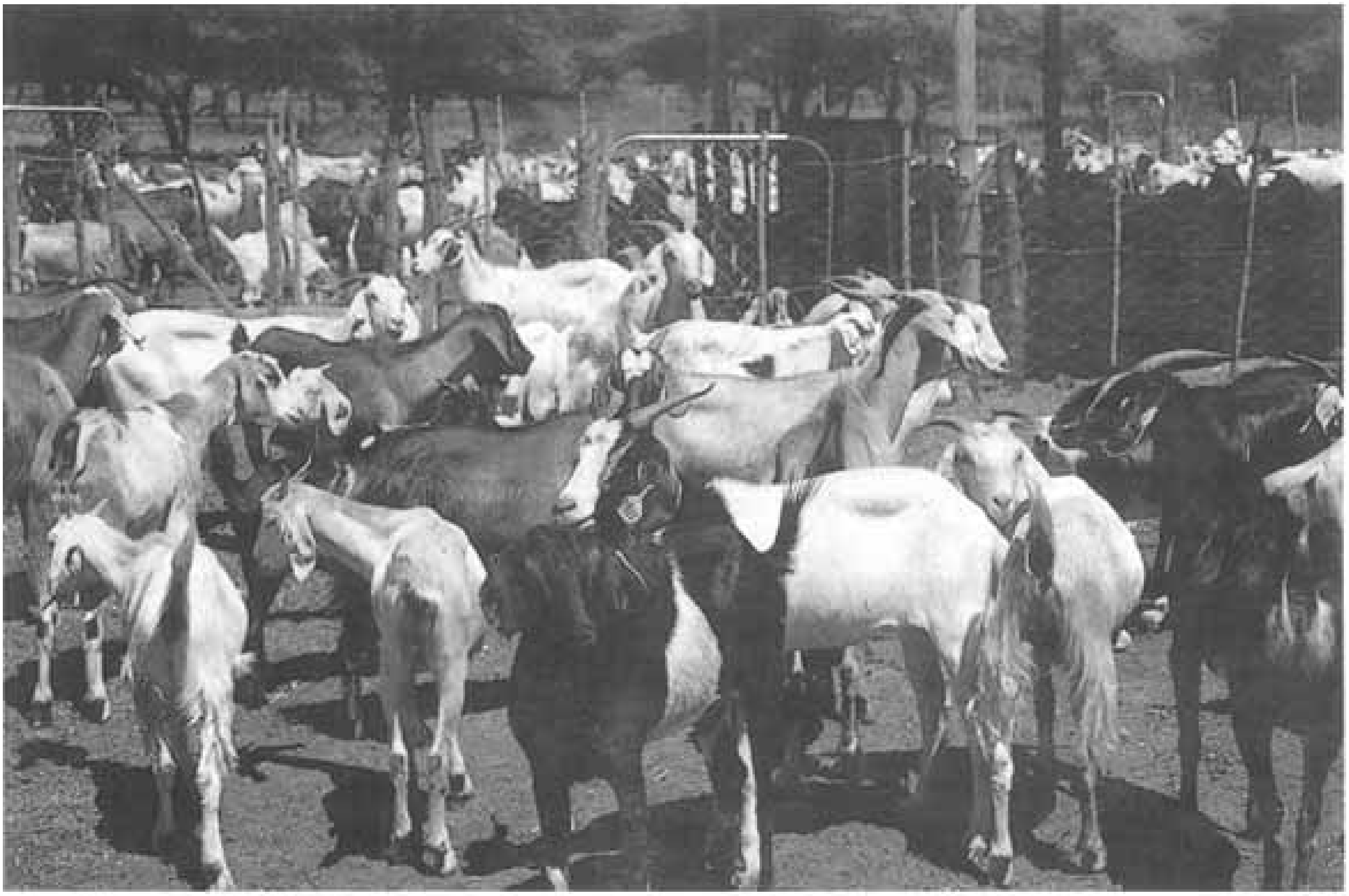
The problems lie in the maintenance of such a large herd under sustainable village conditions, and convincing the Fulani herdsmen to sell or lease their best cows to the project. There are also some problems associated with obtaining accurate details of the production in the field situation. For example when monitoring milk production and growth rate of calves, it is essential to know if the cow is also being milked for family milk consumption, and if so, at what level.

There is an argument to use research stations to research into possible management improvements that could be practically used by the farmers, optimal dipping period, feeding regimes, feeding supplements, weaning times and so on. Selection and monitoring of breeds can then be done using national resources and large numbers of co-operating farmers.

Similar farmer co-operative methods are being used to monitor and improve the production of indigenous stocks throughout the world. Some examples may be found in chapter 5.

Table 13





7. A national conservation and improvement programme for Tswana goats, which are resistant to the tick borne heartwater disease has been established in Botswana.

8. Panteneiro cattle, adapted to the extremely hot and humid conditions of the Pantenal region of Brazil. This breed is now being researched and characterised by the National Agricultural Research Institute in Brazil.

5. Conservation in Practice

In practice the conservation of live populations of endangered breeds rarely follows the text book patterns of minimum inbreeding coefficients and model breeding strategies. In the field, in an *in situ* project the constraints and priorities are shifted as the lines between breeds and populations, and between conservation and utilization become less obvious.

One of the great strengths of *in situ* conservation projects lie in their own diversity. Unlike cryogenic projects which require a minimum level of technological equipment and knowledge, *in situ* conservation can be carried out at any level, in any country with the skills and resources already available.

Programmes can be administered by national government agencies, by non government organizations, by private organizations, by cooperative groups of farmers and by private individuals. Examples of all of these currently exist in diverse nations throughout the world and each will be discussed in turn.

5.1 National Government Projects

5.1.1 Endangered Species Important for Domestication

The need to conserve endangered species already used in agriculture or, those with a potential for domestication has already been discussed in previous chapters. Generally such projects require large scale conservation efforts involving the conservation of sufficient habitat for the species to continue to thrive and develop in its natural environment.

For example, in Southern India and Sri Lanka the Indian Elephant is an important draught animal, besides having great cultural and religious significance. The captive breeding of elephants is very difficult because the males become extremely aggressive during their breeding period known as the ‘musk’. In order to overcome this females are often turned into the jungle to mate with males in wild or feral herds and are either recaptured or their youngsters are taken when still small enough to train. In this situation the conservation of wildlife areas large enough to support wild herds of elephant are essential if the important domestic stock are to survive.

One of the most successful conservation programmes for the conservation of livestock with a potential for domestication has been the programme to save the South American camelids. The domesticated Llamas and Alpacas are not endangered but between 1950 and 1970 the international population of Vicuna had fallen from an estimated 400,000 to 10,000 in Peru and less than 2,000 elsewhere. In 1968 the International Union for the Conservation of Nature and Natural Resources (IUCN) declared the Vicuna to be an ‘endangered’ species. National natural breeding reserves were established in Peru and Chile and all countries involved signed an agreed embargo for trade in Vicuna animals and skins. The population began to recover very quickly and the programme was deemed to have been so successful that by 1981 the Vicuna was moved from the IUCN ‘endangered’ to the ‘vulnerable’ list. Larger reserves were then created and a strategy of planned and sustainable harvesting was initiated.

Table 14

Country	Domestic		Wild		Total
	Llama	Alpaca	Vicuna	Guanaco	
Peru	900	3,020	60	5	3,985
Bolivia	2,500	300	4.5	0.2	2,804.7
Chile	85	0.5	16	20.2	121.5
Argentina	75	0.2	9	550	634.2
Ecuador	2	-	-	-	2
Columbia	0.2	-	-	-	0.2
Total	3,562.2	3,320.7	89.5	575.2	7,547.6

(after Novoa 1989)

In Brazil research is being carried out into the potential use of both alligators and the rodents capibara as animals for domestication. In the case of alligators there is a serious threat of extinction due to poaching of the wild animals for their skins. Trade in alligators skins is therefore currently prohibited, but it is felt that if alligator farming could become a realistic option it might help to conserve the wild population while creating a new agricultural resource.

5.1.2 Breeds with Potential for Use

There are a number of countries in which indigenous stocks have been identified as being endangered through dilution or replacement, but for which an important role has been recognized. Disease resistance or tolerance is particularly important including, for example, that found in the trypanotolerant livestock of West Africa and the heartwater resistant stock of Botswana. Climatically adapted breeds including Criollo cattle in South America adapted to extremes of cold, heat and humidity; the Kuri cattle of Lake Chad whose large hollow horns enable them to swim from one lake island to the next in search of forage; or the seaweed eating sheep of North Ronaldsay island in Scotland are just three examples. Finally there are stocks which are culturally adapted to their specific local markets including the egg producing ducks of Indonesia.

In each of these and many other cases it has been shown that a local breed will disappear due to pressure from replacement breeds or even replacement agricultural systems, even though the native stock has a great deal to offer to national or regional production. In these cases, national or local programmes can be established to carry out further research into the breed, establish improvement programmes, and work with local farmers to re-establish local interest and respect for the breed.

a. Disease Resistance

In West Africa FAO, UNEP and other agencies have been active in helping to establish research centres and open nucleus breeding herds to monitor and improve those breeds of livestock able to survive and reproduce in the trypanosomiasis areas. These populations are obvious candidates for conservation and use because exotic imported stock are not able to survive in this environment. It is important to ensure, however, that all selection and improvement projects are carried out under the same level of disease challenge as the improved stock will encounter when they are reintroduced into the field situation and under sustainable levels of feeding and management.

In Botswana it was noted that a number of exotic breeds were superior when monitoring each component of production, litter size, milk production or growth rate. As a result farmers were encouraged to introduce exotic males to their herds. However, more recent research which included the measurement of fertility, mortality amongst young stock and longevity of the adults, it was found that the Tswana animals had a higher economic return for the farmers. This overall increase in production of the local stock was largely due to their tolerance to high levels of ticks and their resistance to heartwater which is endemic and prevalent throughout the country and had a very detrimental effect on the survival chances of the exotic imports (Setshwaelo, 1989).

As a result of these discoveries the Botswana national livestock programme now includes a herd of 600 Tswana cattle, 1,000 Tswana goats and 500 Tswana sheep for research, conservation and improvement with the top 10% of the males selected for production characteristics under sustainable management systems.

b. Climatic Adaptations

In many regions of the world domestic stocks have developed to extremes in climatic conditions. The Criollo cattle of South America have adapted over 400 years to extremes of heat, humidity and altitude. Some of this adaptation has now been recognized and identified as important by the national governments concerned. In particular EMBRAPA, the National Agricultural Research Institute for Brazil has begun projects to conserve a number of breeds including the now very rare Crioulo Panteneiro or swamp cattle from the Pantanal, which is a large swamp land in the state of Mato Grosso. These cattle are adapted to long periods of flooding and to very high temperatures and humidity. Research has shown that, although these cattle are much smaller, grow less quickly and look less impressive than the Zebu based Nellore which have replaced them, they produce 80 to 90% calves per cow per year, as opposed to only 45% calves per cow per year from the Nellore cattle. The EMBRAPA project involves the maintenance and monitoring of a conservation herd of 200 Panteneiro cattle and incorporates conservation, research and the production of information which they hope to use to raise the awareness of the local farmers in the Pantenal to the value of their local breed (Mariante, 1991).

c. Cultural Adaptation

In Indonesia the development of an industrialized poultry production system for hens has greatly increased total egg production. However, the farmers complained that the higher production required greater expensive imports of feed, vaccines and breeding stock and that fluctuations in production had resulted in the farmers not receiving a steady income from this increased capital investment. Over 80 million tons of Duck eggs are produced in Indonesia each year (Sparframjandet, 1990). It was decided, in the light of the problems with industrialized hens, to look at developing the duck industry using indigenous stocks. Full scale programmes were established to evaluate local breeds of duck. This was followed by selection and crossing trials to produce indigenous ducks based on local strains which could improve the national supply of duck eggs without greatly increasing national imports of breeding stock, specialist feeds or veterinary medicines and which would avoid the need for farmers to make large scale capital investments (Gunawan, 1989).

5.1.3 Breed Conservation as a Part of Environmental Conservation

Mans agricultural activities have been instrumental in the formation of much of the natural environment. In may cases this adaptation of the environment has become associated over centuries with specific wildlife fauna and flora and with particular farming techniques and methods. In some regions the conservation of ancient habitats has incorporated the conservation of farming skills and the ancient breeds with which they are associated. The most famous, and probably most effective of these is the Hungarian programme of Hortobagy National Park in Eastern Hungary where herds of Hungarian Grey Steppe Cattle, Mangalica Pigs, Racka Sheep, Water Buffalo and poultry are carefully conserved in a large scale government programme. This programme seeks to maintain the ancient grazing lands known as the Puszta, along with its wildlife, rich botanical diversity, cultural heritage and traditional livestock breeds. The project has its own state funded budget through the National Park authority and has very close links with university personnel who control the breeding programmes and use the animals in wide ranging research.

In France, the ecologically important area of the Carmargue in the Rhone Delta is designated as a National Park dedicated to the conservation of the natural environment, its plants and wildlife. This conservation also includes the ancient semi-feral populations of Carmargue horses and cattle. These animals are maintained on a feral system with minimal management, recording or intervention in the natural breeding cycle.

Similar projects also exist in the state parks of Florida, in the USA, where the Florida

Pineywoods or Cracker Cattle have been associated with the ecology of the area for a very long period, and where their conservation has been incorporated as an integral part of the Park's aims, in conjunction with research support from the state university. This idea has also been used in other European countries with feral or semi-feral populations. For example, the feral herds of Pajuna Cattle and Galician Ponies are maintained, respectively, in the National Park of Andalusia in Spain, and the Peneda Geres National Park in the extreme north west of Portugal.

The conservation of Rove goats in France has taken the management of a rare breed in conjunction with a natural area a stage further and incorporated these rare goats into the management and conservation of the associated forests of the Parc Naturel Regional du Luberon in Provence. The plan is to use the goats in place of expensive mechanical machinery to keep the fire breaks free from scrub.

The Government of Greece has extended its preservation of cultural and historical artifacts and buildings to incorporate a project to ensure the survival of the ponies of Skyros Island. The ancestors of these small, but strong and hardy ponies were the war horses of the Greek Empire and appear in relief in the Elgin marbles. This small national project recognizes the cultural and historical importance of this breed and seeks to conserve the population as part of the Greece's national heritage. Tourists are invited to visit the project and could potentially supply much of the funding needed for its maintenance.

5.2 Non-Government Organizations

Some of the most successful conservation programmes for live populations have been carried out by national non-governmental organizations. In some cases these are organizations dedicated to the conservation of rare breeds but, in others, rare breed conservation has been a convenient and complementary adjunct to their work in environmental or historical conservation and education.

5.2.1 Habitat Conservation

Many countries now have very active non government organizations involved in the conservation of wildlife and the protection of natural habitats. These organizations are often working in direct opposition to agriculture because they are attempting to protect land from the influences of mankind. There are however, examples where habitat conservation is enhanced by grazing and in such cases it may be possible to incorporate rare breeds into habitat conservation projects.

In particular within Europe the indigenous wild grazing animals, the Aurochs, Bison, Prezwalski Horse, Mouflon and wild goats have long ago been driven to extinction or survive only in tiny pockets or in zoos. In these countries it is therefore reasonable to use rare breeds of domestic or feral livestock as the large grazing animals, although in some areas they may also be endangered. In such areas indigenous wild animals will and should be used to fill the grazing niches on wildlife reserves.

The Nature Conservancy Council in Britain is involved in the conservation of natural wildlife habitats. It has used a number of rare breeds of sheep to graze coastal areas and other grassland meadows whose flora need to be grazed in order to maintain botanical equilibrium, and where there are rare butterflies and other insects who need grazed plants to complete their own life cycles. In particular the small light weight breeds, like the primitive Soay sheep, have proved to be very useful in areas of fragile soil structures which are more susceptible to soil erosion, where small light weight sheep with extensive grazing behaviour and low management requirements are an advantage.

Similarly, the Dutch State Forestry Service, which is responsible for conservation, has recently imported Scottish Highland Cattle to graze their nature reserves established to conserve Dutch wildlife. These areas would have originally been grazed by Aurochs which are now extinct, and later by extensive and hardy semi-feral breeds which, due to the extreme specialization of Dutch agriculture, are also now extinct. Luckily, comparable breeds do still exist in Britain and the importation of hardy Scottish Highland cattle into Holland has been successful. The cattle graze the herbage to the correct level, do not need winter housing or intensive management while still producing a harvest of lean meat.

In Brazil the national genetic resources programme (EMBRAPA-CENARGEN) has become involved in the conservation of the semi-wild/feral horses known as Lavradeiro Criollo from Roraima in Northern Brazil. This population is adapted to sparse grazing conditions and has had no management to control parasites suggesting some levels of resistance or tolerance. In the past 20 years the numbers of these horses has fallen from 2,000 to less than 200 due to hunting and mining activities in the region. EMBRAPA believes that the Lavradeiro Criollo horses could be important in developing the horse breeding programmes in the central savanna region of the country and have therefore established a small nucleus herd. They are also involved in attempting to establish a reserve for the ‘wild’ herd which would combine the conservation of an indigenous stock which has local adaptation, with the conservation of the native grassland (Mariante, 1990).

5.2.2 Breeds with Historical Interest

The case is often made that, if historically interesting or aesthetically pleasing man made artifacts, including buildings, tools and works of art are worthy of preservation, then so too are the domestic breeds man has created through selection. The conservation of these historically important endangered breeds can be associated with a wider plan for national conservation within the state park or museum system or through historical organizations.

The National Trust in the UK, which is concerned with the preservation of historical monuments and buildings has begun to use correct ‘period’ breeds in the fields around many of its properties to add authenticity, assist in the educational work, and help to ensure the survival of these breeds. Some historical parks in the USA have also taken similar steps.

The museum fort of San Miguel at Choi in Uruguay, which belongs to the Uruguay National Army has the last remaining herd of pure bred Criollo cattle in the country and an important flock of Criollo sheep. Through the rest of Uruguay the Criollo has been driven to extinction through cross breeding and dilution. The fort herd is maintained as part of an excellent exhibition of Gaucho history and Uruguayan fortress life.

5.2.3 Breeds with Cultural Importance

Many breeds have developed in association with specific cultural groups within countries and many have particular economic, artistic or religious significance and value to those people. Utah State University in the USA has been involved in helping the Navajo Indians to rescue all that is left of their ancient breed of sheep. This population was light-boned with clean legs and face and was well adapted to the extremes of heat and cold on the Navajo reservation. The sheep survived with little or no management and produced a very characteristic fleece with a dense fine undercoat with long coarse hair growing through it. The fleece was used by the Indians to produce beautiful rugs in traditional patterns which they can easily sell. The rugs are of great cultural importance to the Navajo people and have good financial potential to a community with an otherwise very low income. Sadly, the Navajo-Churro sheep which produced the fleeces needed for rug making have all but disappeared after many years of ‘upgrading’ to improve meat production. Utah State University has been active in helping to locate the last pockets of the breed, move rams between groups, multiply numbers and supply the weaving families with the wool they need. Ultimately the plan is to replenish the flocks of the weaving families with true Navajo-Churro sheep (McNeal, 1970).

In India the religious importance of the cow and cultural taboos with respect to the slaughter of cattle has resulted in the development of local organizations, called Gupsala, which provide a welfare service for old, sick and injured cows. These Gupsala are locally funded and have often acquired reasonably large farms which have been donated over a long period of time. At least one of these centres in Haryana state has become involved in the conservation of the local Hariana cattle. They have a herd of 100 to 200 cows and are able to monitor milk production and select superior animals to be the mothers of bulls. They have established a breeding programme in association with the National Bureau of Animal Genetic Resources in Karnal, and are helping to produce pure bred cows and bulls to be sold back to the farmers.

5.3 Private organizations

Private organizations involved in rare breed conservation fall into four major categories. First, are livestock breeding companies who need genetic variation as their primary resource. These are mostly poultry and pig improvement companies. Second, are organizations which are involved in conservation and research including universities. Third are the organizations involved in breed conservation, tourism and education such as the farm parks, museums and cultural or historical centres. Finally there are companies whose work is not related directly to genetic conservation but which have found a role for rare breeds and are therefore active in their conservation.

5.3.1 Conservation for Economic Use

In the most developed of the livestock industries, and particularly in the poultry industry, there are a few breeding companies who hold the bulk of the genetic material which make up the production stocks. Three primary breeders currently provide most of the world's turkey breeding stock and one has over half the world's market. There are only nine world class primary breeders of chicken broilers and nine primary breeders of egg layers supplying most of the industrial sector throughout the world. It may be further speculated that many of the grandparent lines of these companies have identical or similar origin. The result is a high level of genetic uniformity in the industrial stocks world wide.

The industrial poultry companies are dependent upon new genetic variation in order that their improvement programmes continue. Intensive selection is already resulting in a situation where they have homozygous birds with maximum genetic production for the genes at their disposal. The companies are very competitive and do not exchange many ideas or genetic stocks, although many have ‘gene banks’. However, they aim to plan their breeding programmes ten years in advance and hope to be self sufficient in genetic material for that period. Meanwhile, they are continuing to actively seek additional genetic resources outside the company, although as their influence on the industry increases and as the production differential between the landraces and the industrial stocks widens these will be increasingly difficult to find.

As genetic engineering options develop and become practically available, many breeding companies may wish to consider single gene transfers from relatively unselected landrace stocks provided these stocks still survive. For this reason the World's Poultry Science Association (WPSA) has urged FAO to vigourously pursue means of preserving poultry genetic resources (FAO, 1989b).

Several commercial swine companies are multinational, supplying an increasing proportion of breeding stock to the industry. They are currently seeking genetic material from around the world and do not appear to hold very large genetic reserves. These companies may also need the genetic variation found in the extensive landrace populations and it is in their interests that these populations do in fact survive.

5.3.2 Research and Conservation

The use of rare breeds in research has been sporadic and largely ineffective in ensuring the survival of many breeds. There are a number of examples where university or research institutes have inadvertently slaughtered the last group of animals in a breed, once they have finished their research, including the last herd of Lincolnshire Curley Coat pigs in Britain, and the last large flock of Navajo-Churro sheep in the USA. There are obvious exceptions to the trend. Research has been able to identify immediate uses for some breeds, for example, the prolific Finnish Landrace sheep and the disease resistant cattle of Africa.

There is a real case for the involvement of universities in rare breed conservation in all countries, but particularly in areas where there is large scale upgrading or replacement of breeds underway. In these areas universities and research institutions should be involved in maintaining pure bred populations of indigenous breeds as control populations and for research. Universities involved in medical or veterinary research could also be encouraged to use rare breeds where livestock are needed. For example, the cattle supplying blood for human vaccines could be rare breeds in conservation herds.

a. Breeds for Conservation and Use

In terms of maintaining live populations of rare breeds, universities and research institutes have had variable success. Florida and Louisiana state universities in the USA have both been involved in the research of the Gulf Coast Native sheep which are well adapted to the heat and humidity of the region and are resistant to the predominant gut parasites. Over the past 50 years the sheep industry in the South Eastern states has all but disappeared due to economic and market changes. Today almost all that remains of the Gulf Coast sheep populations is held in the two university flocks.

The principal conservation and improvement herds of Sahiwal cattle in India is maintained by the National Dairy Research Institute at Karnal and there is an important Murrah Buffalo breeding project at Haryana Agricultural University in Hissar, India, where management, nutrition, veterinary care, selection and improvement is being carried out to provide information and superior males for use by the local farmers.

b. Rare Breeds in Physiological Research

Many veterinary and medical research and production companies require the use of farm animal hosts. One drug research company in the USA has entered into a contract with a local rare cattle breeder, to supply them with cattle blood for research. The owner is able to maintain the herd at the low level of veterinary input which the company requires and the company is able to provide the owner with financial support. Although only a pilot scheme, this is a possible source of funding for more substantial rare breed conservation programmes in the future.

c. Human Research and Treatment

Other organizations involved in research that have used rare breeds in some small pilot schemes are those concerned with human animal interaction. Research in social psychology and medical research has revealed the importance of peoples’ interaction with animals. In particular, work with mentally disturbed patients has suggested social and behavioural benefits. In a number of cases rare breeds are being incorporated into state prisons and institutes for the mentally disturbed and mentally ill. Suffolk Borstal Prison Farm for young offenders in the UK, has made the interaction between individual boys and Suffolk Punch horses a major feature of their rehabilitation programme. Green Chimneys Farm School in New York has also included a rare breeds programme with their residential centre for maladjusted juveniles and Stocken Prison Farm in the UK has a herd of White Park Cattle for which the inmates are responsible. All of these programmes help to establish stable relationships between inmates and the animals with which they work, a sense of achievement and pride, and enables the inmates to learn new skills while helping to conserve a breed. Farms associated with such institutions can also help in supplying food for the inmates and help to make the hospital or prison partially self sufficient.

5.3.3 Conservation with Tourism and Education

The concept of a Farm Park, as a breeding centre for rare breeds and tourist and education resource, was initiated at the Cotswold Farm Park in the UK in 1970. It is a privately owned collection of British rare breeds in active breeding units. Small groups of each breed are exhibited to the public in an attractive setting, and visitors pay a fee to enter the exhibition area. The primary goal of the Park was originally to be a breeding centre. Public access was perceived as a means of funding the project and was promoted via the historical, cultural and aesthetic interest of the breeds. This concept has been very successful. The centre has never received outside financial support and yet has been able to maintain populations of over 300 rare breed ewes, 100 cattle, 30 pigs, 50 goats and 15 equines entirely supported by the 100,000 visitors to the Park each season. However, it has had, in conjunction with the other farm parks which now exist, an even more important consequence for the whole concept of rare breed conservation in Britain. Farm Parks have formed a focus for the press and television and are popular visitor centres for school groups, holiday makers and tourists.

In many countries the idea of museums, libraries and schools filled with static exhibits and information are being replaced. There is a growing interest in ‘living’ history, and interactive learning. Many children, particularly from industrialized countries are remote from primary food production and have little or no opportunity to interact with animals. In the USA the interactive experience of ‘Living History’ with historical settings brought back to life with costumed interpreters who practice their skills in front of the public, has proved very popular and effective. This is now being extended to include ‘period’ livestock and the issues of livestock breeding, agricultural change and conservation which can all be addressed using live animals as teaching tools.

These centres act primarily to draw attention to the changing face of agriculture and to the loss of historical breeds and are not large scale breeding centres. However, they help to raise interest and awareness of indigenous stocks and are effective teaching tools.

The idea of Farm Parks, Living History Museums and Exhibition Farms in nations where most people still have close links to the land, seems unlikely to succeed. However, tourism now represents 12% of the Worlds GNP and is a very important source of foreign currency in many countries (Mannion, 1991). In countries with a tourist industry, there is a real possibility of linking the idea of living history, incorporating traditional skills, breeds and plant crop varieties into an exhibition. This could be mounted alongside a parallel demonstration of modern techniques, varieties and breeds. Such an exhibition could help visitors to understand and better appreciate the culture of the country they were visiting, while supporting the indigenous agriculture and its breeds. It could also act as a valuable information, training and teaching resource for local people, who could see the advantages and disadvantages of the old and the new alongside one another.

5.3.4 Company Promotion

The issue of conservation is now an internationally important one. Some commercial companies have therefore become interested and involved in company promotion using rare breeds. Perhaps the most dramatic promotional use of rare breeds is the Budweiser Company's use of Clydesdale horses in the USA. Begun in 1933 at the end of prohibition, this advertising campaign using Clydesdale Horses became very popular and successful. However, unlike many other campaigns it became an integral part of the company's image. Budweiser are now leading breeders of Clydesdales and have been very instrumental in the survival of the breed both in the USA, Canada and Britain. This alliance has therefore been successful for both the company involved and the breed with which it chooses to associate.

English China Clays have found an essential role for a rare breed in their industry. The company managed to develop grasses that would colonize china clay spoil heaps but the grass species were slow growing and did not develop a strong enough root system to prevent rapid erosion. A suitable grazing animal was needed to strengthen the root structure while not destroying the fragile surface. Primitive Soay sheep were found to be ideal. They are light weight and small, so that they do not damage the surface soil structure. They also have the correct grazing pattern to help to establish the grasses and encourage the development of a stable green cover, which is needed to satisfy environmental concerns over rehabilitation of the unsightly industrial spoil heaps.

5.4 Private Conservation Efforts

5.4.1 Farmers

Local indigenous and adapted stocks are disappearing by dilution and replacement. Farmers and livestock breeders throughout the world are aware of the problem. Often they are also aware that something of great local value is being lost but that as individuals they cannot swim against the tide even if they would like to see more pride in, and use made of, their own local stocks.

There are many examples of individual farmers or groups of farmers who have continued to maintain and breed the last herd of a particular type or breed of livestock because they believed that they had something to offer. In many cases such farmers have ensured the survival of that breed until its value has been recognized.

In the Southern Brazilian State of Santa Catarina a strain of cattle known as the Crioulo Lageano has developed over the past 300 years, adapted to the rocky acid soils, high altitude and cold winters. They are large animals with magnificent long horns and like many Criollo cattle populations, occur in a wide range of colours and patterns. During the past 40 years the breed has been gradually replaced by cross breeding with imported Indian and European breeds. Thirty years ago Mr Antonio Camargo decided to gather together good examples of the breed from throughout the region and continues to breed them on the unimproved pastures of his farm. He maintains some 150 cows and 10–15 bulls. He valued the breed for its hardiness in the winter, its ability to do well without feeding supplements and the longevity of the cows who continued to produce calves every year for many years.

The animal genetic resources programme of the Brazilian Agriculture Corporation (EMBRAPACENARGEN) has now recognized that this is an important Brazilian breed and are working with Mr Camargo and the Federal University of Santa Catarina to evaluate the breed and develop a long term conservation strategy. They are also undertaking cross breeding trials whose initial results have shown the Crioulo Lageano to have an immediate commercial use, particularly in areas of adverse climatic conditions. This is linked to their ability to withstand the cold winters but may also be linked to differences in the forage and grazing behaviour as compared to the exotic cross breeds in an extensive management system.

The Maharaj Bir Singh maintains an important private animal breeding and agricultural research farm in the Hissar district of India. First established in the early years of this century by his late holiness Sri Satguru Pratap Singh ji, the farm has breeding herds of 300 Sahiwal and 300 Hariana cattle. All the cows are individually identified and excellent records maintained on their breeding, health and production. The current Maharaj believes that these two local breeds have many adaptive characteristics which make them ideal for the local farmers. In particular the exotic European crosses which have become widespread in the past thirty years do generally produce more milk in a single lactation in the first cross. However, their survival rates are considerably lower than the local breeds due to their failure to conceive repeatedly on the very low input diets available, their relatively high susceptibility to prevalent parasites and diseases and their intolerance of the humidity and heat. In addition the male cross bred calves are far less valuable as draught oxen than the local breeds because they will not work in the heat of day and are known to be slow and lazy. In a country where cattle are not slaughtered for meat, this inability to make use of the male calves is a serious financial consideration. Overall, despite their lower milk yield, the economic output of the Hariana or Sahiwal cows is not in fact inferior to the exotics or their crosses.

Through a programme of recording and selection the Maharaj hopes to be able to be instrumental in ensuring the survival of the Hariana and Sahiwal breeds while making superior animals available to local farmers wishing to return to these traditional breeds. He is now working with a number of university and research farm projects coordinated through the National Bureau of Animal Genetic Resources in Karnal.

The American Mulefoot Hog was widespread in the central region of the USA in the first half of this century. They were a hardy outdoor breed with the normal cloven hooves of a pig fused into a single toe (syndactyl). They were also reputed to be resistant to a number of pig diseases prevalent at the time. By the 1960's vaccines and treatments were available for most pig diseases and the numbers of Mulefoot Hogs declined. By 1985 only one herd remained belonging to a Mr R.M. Holliday in Missouri, USA. He continued to maintain the breed because he believed it had a unique characteristic of hardiness, and because of his own family tradition. Both his father and grandfather had reared this breed of pig on the small river islands in that part of the Mississippi river from which they would harvest the young pigs. Today, as new resistant strains of once controllable diseases begin to emerge there is some renewed interest in the American Mulefoot Hogs to re-evaluate the disease resistance claims. There is also interest in examining the foot structure of the breed to see if it might prevent lameness in commercial pigs reared on concrete floors or slats. However, if it hadn't been for the determination of this one farmer to keep this breed going, these new research opportunities would not be available.

In each of these and many other possible examples the value placed by individual farmers on their breeds has enabled unfashionable or temporarily uneconomic breeds to survive untill their potential value could be recognized. This highlights how important it is to seek information about breeds from farmers and to use farmers as a central part of conservation strategy.

The most powerful and stable from of live animals conservation programmes currently in operation are those which involve large numbers of small privately owned units. This system has two advantages; firstly it tends to result in the maintenance of very high effective population size (Ne) due to there being a large number of relatively small units each with at least one male; and secondly, it requires a very large number of decisions for significant changes to occur. Thus selection pressures are likely to be ineffective because they are not generally uniform between units, and in order for the programme to fail completely many individuals must withdraw their support.

The use of individual private flocks and herds co-ordinated by organizations committed to rare breed conservation, offers a powerful and cost effective means of rare breed conservation. It makes use of the skills and knowledge of farmers familiar with breeds, and keeps those breeds interacting and developing in the same environment to which they are adapted. Financial assistance, advice and practical help can be given to farmers in a number of ways through cultural, historical or agricultural organizations (Henson, 1989).

Programmes have been designed to use local farmers in vegetable and landrace crop plant conservation programmes in different parts of the world (Altieri, 1989; Fowler, 1990). These ideas of farmers as custodians of genetic resources at a village level can be used equally well for farmers involved in livestock programmes and through production linked subsidies the income of farmers involved in these programmes could be equal to those involved with replacement breeds. Conservation programmes should hold the same cultural and social value and the same sense of pride and responsibility as breed replacement and improvement programmes. They should be used as control herds to monitor the advantages of the imported stocks. As control herds they should have parallel opportunities to improve husbandry where this can be sustained in the long term economy of the country.

Such conservation projects can be co-ordinated through independent organizations where this is appropriate, or through universities or state agricultural agencies. It may be internationally, regionally or state funded through internal agencies or aid agencies. Ideally however, each aid project designed to replace or upgrade indigenous stocks with exotics should have a budget component to establish a control programme to conserve the indigenous strain in the same conditions.

In Jiangsu Province of China, a conservation area was established in 1985 to conserve the prolific Hu sheep. This area is in the main loquat and orange growing district and the sheep are traditionally kept indoors throughout the year with fodder carried to them. Their manure is then used to fertilize the fruit trees. The Hu sheep are very prolific and early maturing and will give birth to twins or triplets twice a year. It was realized that the pure Hu sheep were being gradually diluted and replaced by cross breeding and a conservation programme based on the local farmers was established. Dongsan township in Wu Country was designated as the conservation area and a special conservation law was passed prohibiting any farmer in this region from owning any other type of sheep. Farmers in the region were also required to maintain their flocks in the prescribed and traditional way, keep good pedigree and production records and replace all cull animals with purebred young stock. The project has 200 sheep in the core conservation area with some 10,000 Hu and Hu type sheep in a surrounding buffer zone. The total sheep project costs the government in the region of 10,000 yuan (ie, 1 yuan per sheep). The farmer also benefit from the sale of meat, pelts and wool and from the traditional use of the sheep manure on their fruit trees (Ruihe, 1990).

The Chakranagar region of Uttar Pradesh in India is a similar isolated area with a distinctive locally adapted breed, the Jamunapari goat. In this country it would not be possible to pass local laws insisting that farmers continue to keep the local breed but farmers can still be used as the central core of a conservation programme.

The Chakranagar is bordered by a number of rivers and is a very arid and sandy area. The goats are a large dairy breed with a good meat carcas and are able to survive and thrive in these barren conditions. As new roads and bridges are built into the area there has been an increase influx of goats of other breeds and the numbers of purebred Jamunapari goats has declined.

The Central Institute for Research on Goats in Makhdoom has established a research and development herd of Jamunapari goats but has also embarked upon a very important village based conservation and improvement programme. They have begun by locating all the farmers in Chakranagar region with more than three Jamunapari goats. By December 1990 it was intended that each farmer would have been visited and data collected on the number, age, sex, size and colour of all his goats. The second phase of the programme involved selecting a number of villages and families within those villages for more detailed study. Their herds would be used to measure growth rate and milk yield for one year. This would involve research agents living in the villages to co-ordinate the taking of regular and comparable measurements. In addition a full characterization of the conditions in the field, availability of food and management would also be made. Finally the programme would develop a progeny testing and improvement programme using the research farm herd as a nucleus and the village herds for test matings and data collection. In this way the farmers would be involved in all aspects of the conservation, pure breeding and development of their breed. The most impressive aspect of this programme is the commitment and enthusiasm of the village farmers involved in the project. Researchers have found that they are welcomed and encouraged to admire and work with the local goats. Farmers were also happy to assist with milk recording and other breed monitoring in exchange for veterinary and management advice with respect to shelters, parasite and disease control. The future stages of progeny testing and breed improvement using the village herds has, therefore, a good chance of success, and if that succeeds the breed will survive (Bhattacharya, 1990).

A similar project involving the co-operating of farmers through agricultural extension workers exists in Botswana. The farmers form co-operatives in order to share dipping facilities for the control of ticks and other ecto-parasites. They also work together to market their meat to the meat company, and they share the use of stud males of both sheep and goats. In one such cooperative outside the capital, Gaborone, a group of about 100 farmers have decided they do not wish to use imported Dorpa rams or Boer goats to cross with their stock but would prefer to use only local Tswana animals which are resistant to heartwater and more tolerant of heavy tick burdens. They are also interested in improving their stock and are therefore willing to work with the local research scientists to measure the production of their animals, use selected males and keep good records in exchange for chemicals to control ecto-parasites. This is an excellent example of how village based farmers can form the very inexpensive core of a conservation/improvement programme that would be prohibitively expensive if it were to be established as a project on a special conservation or research farm.

Probably the single most important feature of all these village and farmer based projects are the co-ordinators. In order for any conservation project of this type to be successful the co-ordinator must be enthusiastic about the project and must be familiar with the breed. He or she must have respect for the farmers and be in regular contact with them. In situations where women are the principal carers for the livestock the co-ordinators should also be a women. The co-ordinator must understand and be able to explain the conservation theory and practice and must be involved in the collection of data and in making information about the progress of the project available to the participating farmers. He or she should be involved in the distribution of financial support if it exists and must be honourable and trusted by the farmers. Working in a village situation requires the mutual respect and trust of both scientists and farmers. It is most important that a conservation project co-ordinator cares that the project will succeed.

5.4.2 Co-ordinating Organizations

There are a number of different ways of co-ordinating farmer breeders, but co-ordination of some kind is essential if conservation programmes are going to be successful for any length of time.

a. Breed Associations

Breed associations are groups of individual farmers who maintain and produce the same pure breed. They act as a pedigree registration and certification service to their members and as a commercially based breed promotion and marketing service. In normal circumstances they seek to ‘improve’ their stock by encouraging selective breeding. The combination of the two factors of breed improvement and breed promotion do, therefore, appear to be in direct opposition to the concept of the conservation of genetic variation. However, provided every breed has an active association and efforts are made to keep breeds separate they do act in combination to conserve overall variation

Breed associations for minor breeds are able to keep breeders in touch with each other; keep and make available pedigree information essential to prevent serious inbreeding; and help to promote the breed. Active associations are very important in ensuring that a breed can survive, but they are dependent upon member contributions, and in the case of small associations are normally member run. It, therefore, often happens that a very rare breed that really needs a breed association cannot sustain one. In this situation, network organizations like the Rare Breeds Survival Trust (RBST) in the UK, the American Minor Breeds Conservancy (AMBC) in the USA and EMBRAPA in Brazil, have been very effective in providing assistance with basic secretarial, communication and registration services until members are able to sustain their own breed organizations (Henson, 1987).

In Brazil one of the most important Crioulo breeds of cattle, the Caracu owes much of its current revival to the formations of an active breed association. The Caracu was systematically replaced by exotic imported Indian and European breeds although a conservation herd was established in the 1950's. Unfortunately the conservation herd suffered from a lack of directional selection to maintain the breeds production characteristics. However, there were a number of private herds which survived and continued to maintain good quality stock. These herds were re-evaluated in the 1980's and a number of complementary articles written. As a result a breed association was formed and the breed began to promote and market the Caracu. This has been so successful that the Caracu may soon no longer be considered to be a rare breed (Alba, 1986).

An association for the conservation of the Panteneiro horse has also been set up by the breeders who fear the detrimental affects of widespread crossing with breeds not adapted to the extremes of humidity and heat in the Pantenal region of Brazil.

A buffalo breed association has also been founded in Brazil to promote the use of buffalo for meat production in the humid swampy regions. This association subdivides its register into the various breeds of buffalo available in the country and is very active in promoting the use of buffalo as an agricultural species in Brazil.

In India an association of larger herds of Sahiwal cattle has been important in establishing the exchange of progeny tested bulls and the sharing of breed information.

These examples highlight the power of groups of farmers working together to promote and market a breed. It does not make the animals any more productive or efficient but it does ensure that other farmers know what the breed really has to offer and what it can produce.

b. Conservation Networks

Probably the best known of the non-government funded organizations in the field of rare breed conservation is the Rare Breeds Survival Trust (RBST) in the UK, whose primary activity is as a grassroots network organization for individual breeder members. The RBST seeks and receives financial support from the public, foundations, corporations and companies specifically for the work of rare breed conservation. Its primary task is to co-ordinate, advise and help individual farmer members who own and breed rare breeds of livestock.

To assist with this the RBST maintains a breed register and data bank, runs workshops and training sessions and arranges an annual sale at which over 1,000 breeding animals change hands each year. In addition the RBST has a large semen bank held in conjunction with the Milk Marketing Board. This incorporates both a long term store and working store which enable individual breeders to be involved in cattle breed conservation without needing to own a bull. The RBST also encourages the characterization of and research into breeds through universities and other research organizations.

The RBST has become directly involved with ownership and management of some animals including the principal flock of North Ronaldsay sheep. This is a small naturally short tailed breed found only on the Orkney island of North Ronaldsay where it has adapted, over some hundred years, to exist on a diet of the seaweed *Laminaria*. In 1970 the entire population were situated outside the sea wall on the beach of the island of North Ronaldsay in the North Sea. In 1973 a representative of the working party which was later to become the Rare Breeds Survival Trust, purchased the small island of Linga Holm and moved a group of 150 sheep and established a second sanctuary for the breed with the same environmental conditions and food supply as on the parent island. Today the RBST flock is gathered once a year, the fleeces are shorn and the lambs harvested. There have been a number of research projects carried out on various aspects of the breed's behaviour and physiology. It is hoped that by maintaining this second site, the breed, with its genetic adaptation to a seaweed diet, will survive, even if a disease outbreak or oil spill threatens one or other of the flocks. There are now a number of trials using North Ronaldsay ewes on other isolated islands, where they are rearing cross bred lambs with reasonable carcasses on a seaweed diet.

c. Grant Aid

In extreme cases where the survival of a breed has been seriously threatened by financial pressure on farmers from more commercially successful alternative breeds, the use of subsidies has been very effective. Subsidies can be paid based on a number of different systems; per capita, male only or production.

Payments made on a per capita system, has tended to encourage farmers to overstock their land. It has also been paid regardless of the quality of husbandry and tends to encourage ‘bad’ farmers to keep rare breeds and live off the subsidy while ‘good’ farmers move over to the new breeds and farming systems.

The male only system used in Britain pays a subsidy for pure bred males of specific blood lines kept at stud and has helped where the level of production of the rare breed is not very much lower than commercial breeds. In this situation a relatively small financial grant to help with the cost of keeping a male makes up the financial difference between the rare and the commercial replacement breed and is particularly effective in countering the effects of indiscriminate crossing with AI on the grounds of convenience.

Production linked subsidies are the most controlled and most effective system. In this case the subsidy is linked to the real production potential of the animals. The amount of the subsidy is determined by evaluating the production under normal management of the rare breed, and comparing it to the potential production of the replacement breed in the same management system. The farmer is then paid a subsidy equivalent to the difference. Under this system it is essential that the farmer continues to farm his animals well in order to make the maximum use of his livestock, land and other resources. This ensures that good farmers will still be attracted to the scheme and will continue to manage the rare breed to their maximum potential (Henson, 1986; Henson, 1989).

This system has been implemented in Canada where the regional government of the province of Quebec has instituted a system of paying a dollar subsidy to farmers rearing pure breed Canadienne cattle. The subsidy is based on the relative production for a Canadienne as compared to a black and white Holstein cross calf. Similarly, the RBST in the UK pays a headage grant for every pure bred Shetland calf born on the Shetland Islands, calculated from the difference between the market value of a pure bred calf and that of a cross bred calf.

In Sweden farmers are paid an annual subsidy to take their cows into the mountains to graze the traditional ‘chalets’ or high pastures. This grant is paid to maintain the natural flora of the region. This programme has now been extended to incorporate the cows of traditional Swedish breeds, so that a farmer is paid 300 Swedish krona for a cross bred cow and 500 Swedish krona (approximately 75 US dollars) for an indigenous cow grazed on the chalet. Similar grants are available for indigenous goats and sheep (Matzon, 1986).

These various systems of subsidy have been direct and effective methods of conservation and have been very cost effective in financial terms. Paying the difference between the production level under good management of the rare breed and that of the replacement is sufficient to induce a farmer not to change over breeds. However, it is a small cost in comparison to that of establishing independent conservation programmes.

5.5 Conclusion

In conclusion, the practical methods of conserving rare breeds in live animal programmes are very widespread and diverse. Not all of these methods transfer easily to all regions of the world due largely to competition for resources from agriculture and from the indigenous and endangered wildlife species. However, there is a real opportunity for live animal conservation programmes associated with university research, bio-medical and veterinary research and production and through a system of farmer subsidies maintained in parallel with programmes to introduce replacement breeds.

The time when living populations of rare indigenous breeds are no longer needed because they can all be satisfactorily stored in cryogenic banks has not yet arrived, if indeed it ever will. In the meantime breeds are best maintained in their own environment, tended by those who know and understand them. The need to preserve genetic variation in domestic livestock has been recognized for many years and it is now extremely urgent in a rapidly changing world. Farmers must be fired with enthusiasm to preserve the breeds evolved and shaped by their ancestors but that fire needs monetary fuel. It must be quickly and wisely applied before the fire is extinguished by the need for immediate survival rather than long term conservation.

SUMMARY OF RECOMMENDATIONS

1. Current agriculturalists have inherited a wealth of animal genetic variation in the form of a vast array of locally adapted and modified varieties, strains and breeds of livestock from our farming ancestors. The rate of loss of this resource through dilution and extinction is very high. Immediate action is needed to ensure that it is not squandered, but is passed on to our descendants for whom this resource may be essential to develop new livestock populations in response to changing environmental conditions and unpredictable human requirements.
2. Conservation may be by the *ex situ* preservation of cryogenically frozen genetic material (for which a separate FAO manual has been prepared) or the *in situ* conservation of live populations. The latter is particularly important for species or within geographical regions where cryogenic preservation techniques are not well developed or are not available. It also enables populations to continue to adapt, evolve and be selected for use in their natural environments.
3. Immediate action should be taken to conserve any population in imminent danger of extinction. All livestock populations should be identified and action taken to describe and characterise them so that their genetic potential, both in their native country and other regions can be known, and to locate those breeds for which conservation is needed.
4. Populations may be conserved as separate breeds or in breed pools or composites. No more than three or four breeds should be included in a breed composite or pool, and care should be taken to ensure that they are all well characterised prior to pooling. Only breeds with similar characteristics should be included in the same pool.
5. Minimum population sizes of an effective population (Ne) of 250 animals should form the basis of a conservation programme although populations may recover from much smaller founder groups. Very small populations should be increased in size as rapidly as possible. More effective conservation of breeds for use should involve the conservation and breeding of much larger population numbers involving several thousand animals.
6. Minimal conservation projects must be very carefully planned to minimize inbreeding and maximize the contribution of each individual to the next generation. In these programmes there can be no room for selection, other than against gross abnormalities. In larger scale conservation projects, selection should be within the adaptive environment and under sustainable management conditions. Selection should be for those characteristics for which the breed was traditionally valued.
7. In practice, *in situ* conservation programmes may be organised at a regional, national, or local level. They may take the form of planned breeding programmes on specified conservation farms. This requires land, personnel, capital to purchase

stock and a well planned breeding programme for which long term funding must be found and justified. It is equally possible to establish successful *in situ* projects at a local level using the land, experience and skill of local farmers. These farmer based projects can be funded nationally or locally and can be co-ordinated through centrally planned programmes or through local co-operatives. Such projects can be very effective in conserving breeds in their natural environment in which they can continue to adapt and evolve within sustainable changes in local agricultural practice, and changes in climatic and environmental conditions. They can be funded through subsidies which should be based on the difference between the potential production of the conserved strain and that of the alternative replacement breed or its crosses.

Suggested Programme for Action

Table A - Identification of populations/breeds

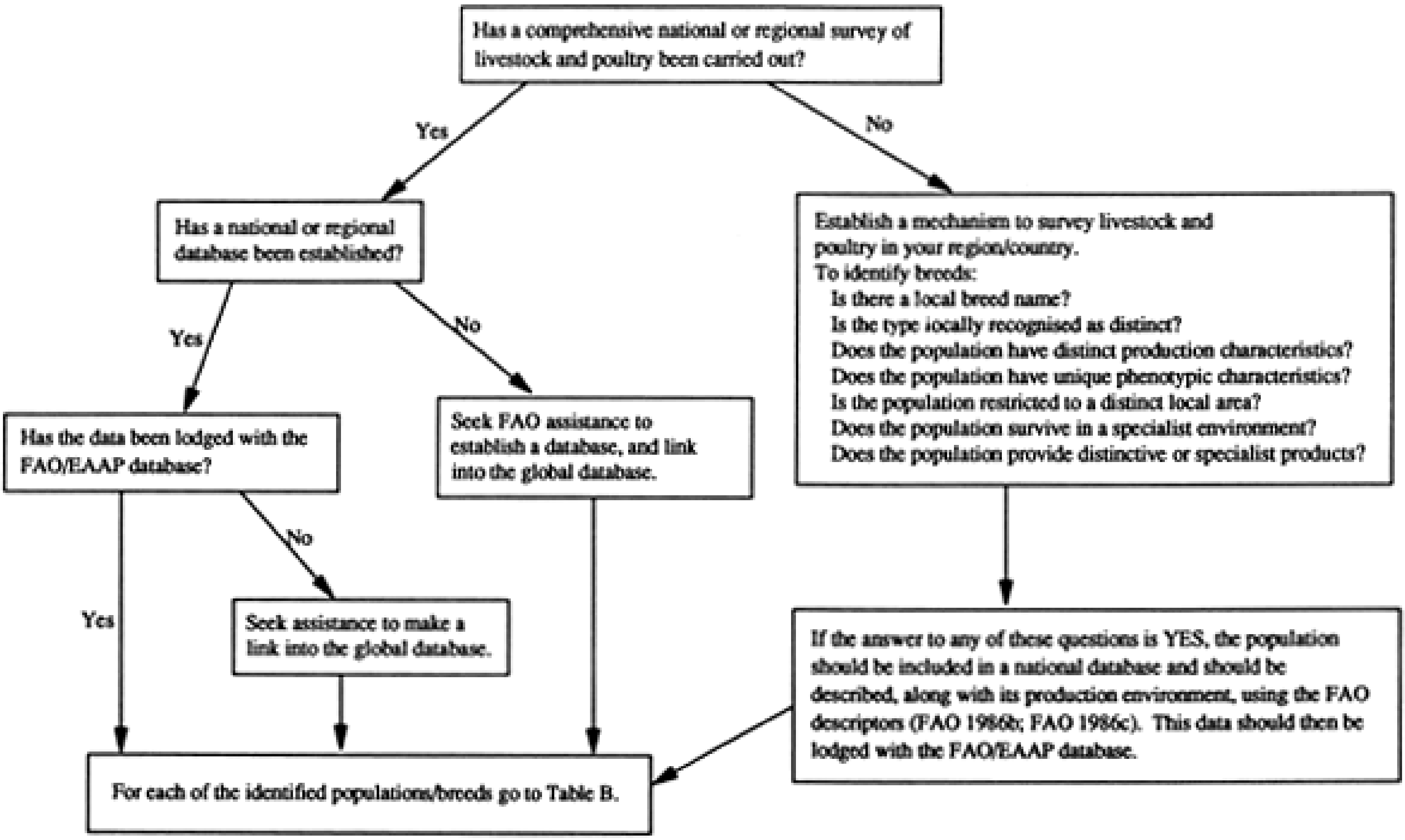


Table B - Identification of stocks in need of conservation.

(see Section 3.4)

countries.

For all breeds identified in table A above and not found in larger numbers in neighbouring

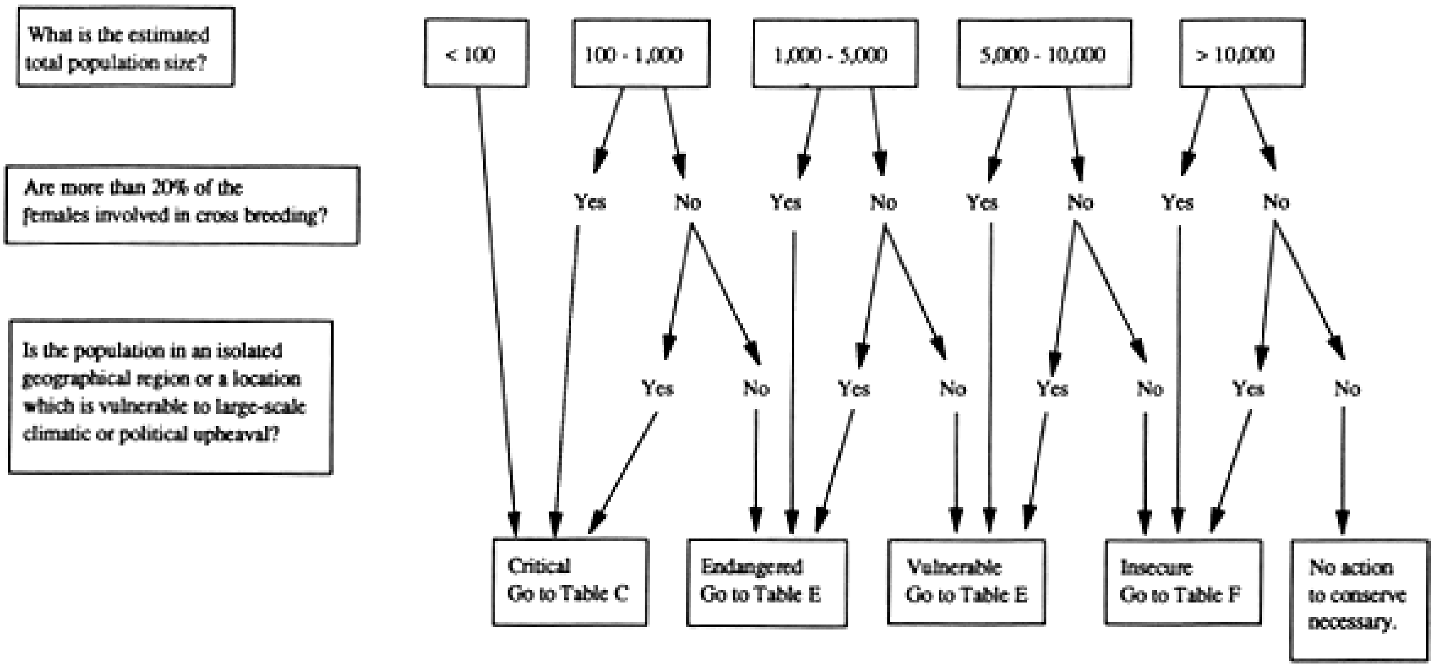


Table C - Critical Populations

Immediate action is needed to prevent extinction.

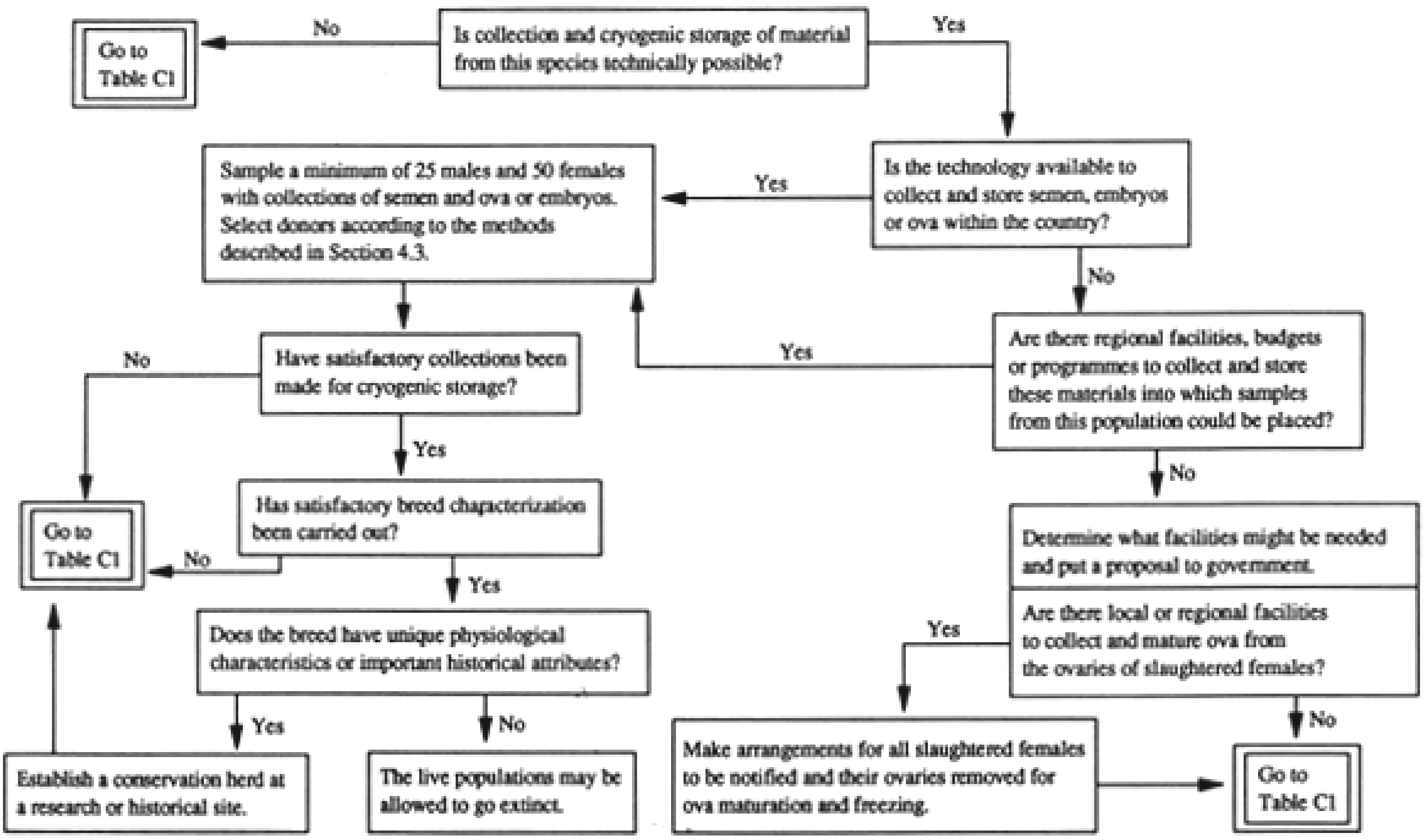


Table C1 - Critical Live Population

A live animal conservation project must be established.

Objectives

- To increase the population size as rapidly as possible to at least an effective population size (Ne) of 50.
- To maximize the genetic influence of all the founder animals.
- To minimize the loss of heterozygosity due to inbreeding, drift and selection.
- To use the conservation herds to monitor and characterize the breed.

Methods

- Sample as much of the population as possible. Ideally all animals should be included.
- Breeding groups should be as small as possible and at different locations to reduce the risk of disease.
- Each individual animal should contribute equally to the next generation, mating groups of one male : one female with each male being replaced by one son and each female by one daughter.
- Selection should only be against gross abnormalities.

Table D - Endangered Population

Action to conserve is needed to prevent further erosion of the genetic variation found within the population.

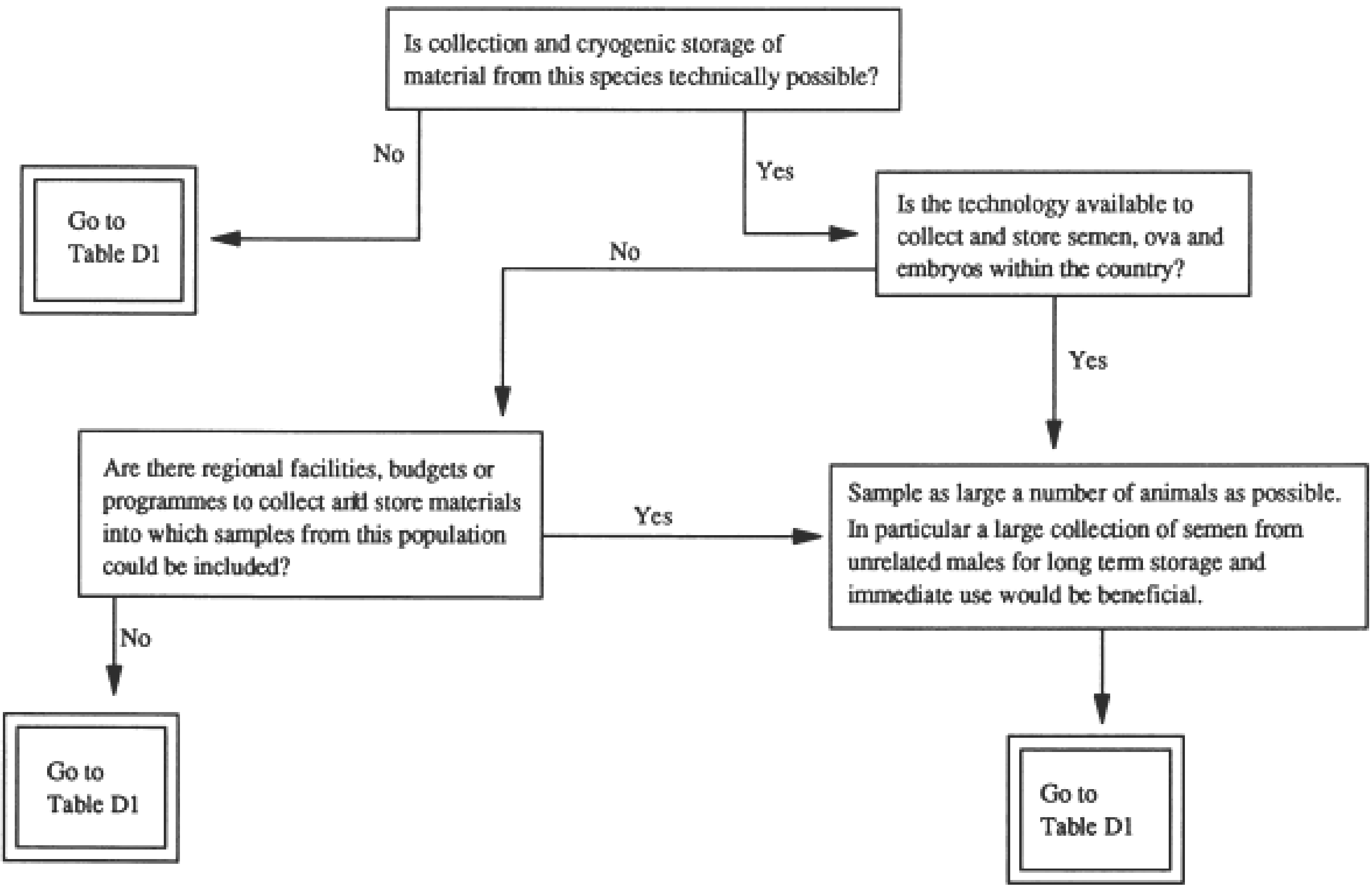


Table D1 - Endangered Live Population

(See Section 4.4)

Objectives

- To increase the population size and maintain it on an effective population size (Ne) of no less than 500 animals.
- To minimize the loss of heterozygosity due to inbreeding, drift and selection.
- To use the conservation herds to monitor and characterize the breed.

Methods

- A well planned conservation herd should be established and/or a programme to co-ordinate the farmers and institutions already using this breed.
- Selection should be against gross abnormalities and to maintain the breeds known characteristics.

Table E - Insecure Populations

Action is needed to evaluate the breed and prevent substantial loss of genetic variation.

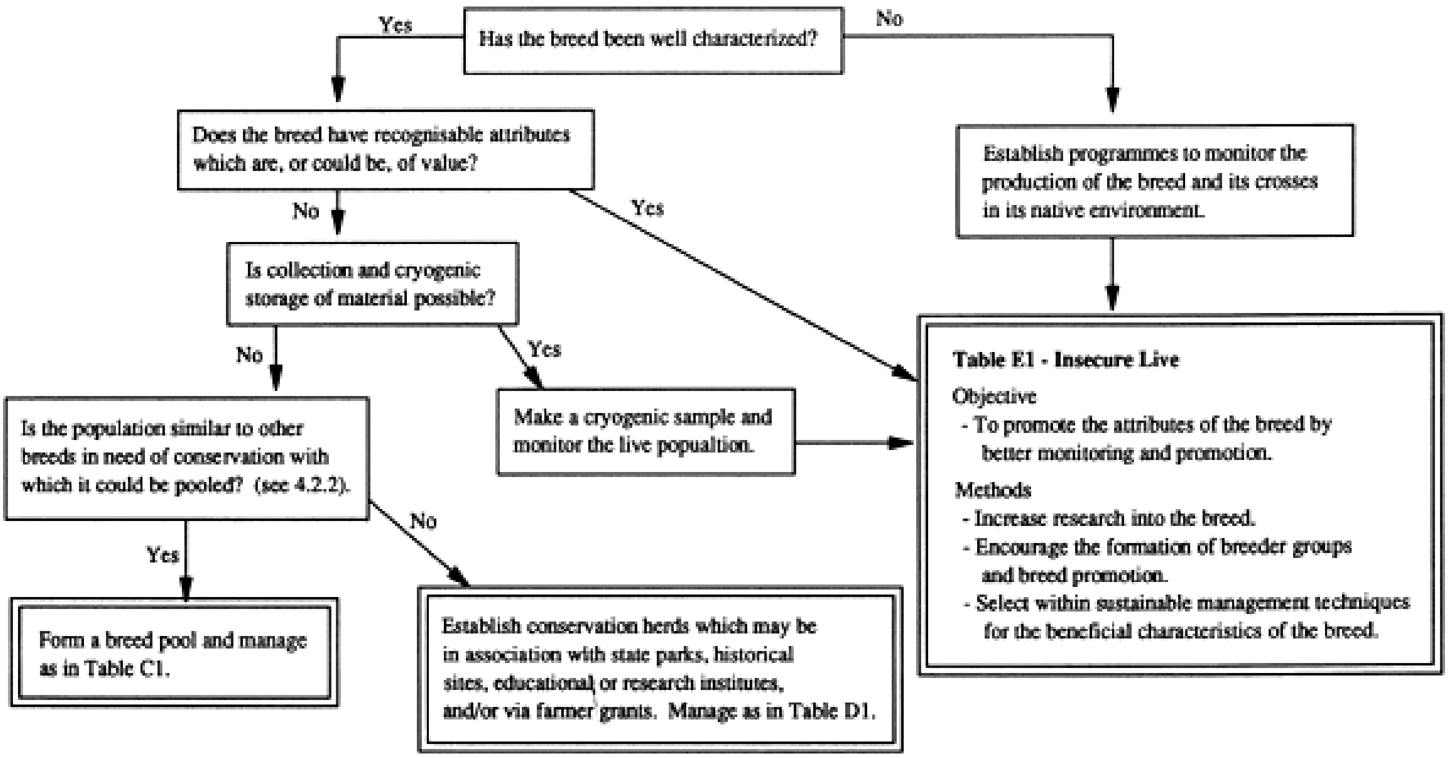
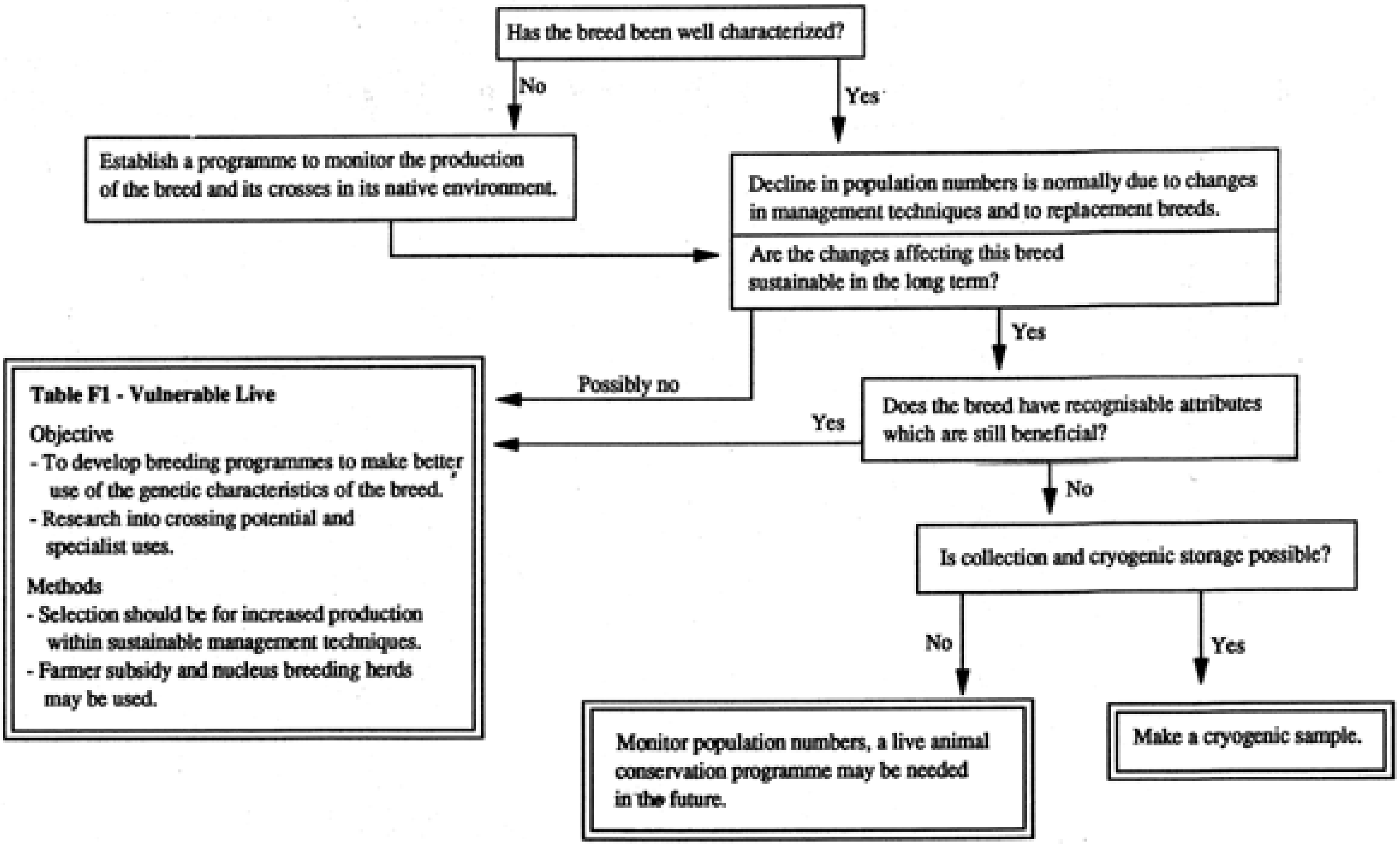


Table F - Vulnerable Populations



Has the breed been well characterized?
No
Yes
Establish a programme to monitor the production of the breed and its crosses in its native environment.
Decline in population numbers is normally due to changes in management techniques and to replacement breeds.
Are the changes affecting this breed sustainable in the long term?
Possibly no
Yes
Table F1 - Vulnerable Live
Objective
- To develop breeding programmes to make better use of the genetic characteristics of the breed.
- Research into crossing potential and specialist uses.
Methods
- Selection should be for increased production within sustainable management techniques.
- Farmer subsidy and nucleus breeding herds may be used.
Yes
Does the breed have recognisable attributes which are still beneficial?
No
Is collection and cryogenic storage possible?
No
Yes
Monitor population numbers, a live animal conservation programme may be needed in the future.
Make a cryogenic sample.

Appendix

Appendix 1

FAO Activities on Animal Resources

(taken from Hodges, 1990b)

A. Publications

1948	Breeding livestock adapted to unfavourable environments
1950	Improving livestock under tropical and sub-tropical conditions
1950	Report of the inter-American Meeting on Livestock Production
1953	Zebu cattle of India and Pakistan
1957	Types and Breeds of African Cattle
1958	Pig Breeding, Recording and Progeny Testing in European Countries
1966	European Breeds of Cattle, Vols I and II
1967	Sheep Breeds of the Mediterranean
1970	Observations on the Goat
1970	The Buffaloes of China
1974	The Husbandry and Health of the Domestic Buffalo
1977	Animal Breeding: Selected Articles from World Animal Review
1977	Bibliography on the Criollo Cattle of the Americas
1977	Mediterranean Cattle and Sheep in Crossbreeding
1978	Declining Breeds of Mediterranean Sheep
1979	The Sheep Breeds of Afghanistan, Iran and Turkey
1979	Dairy Cattle Breeding in the Humid Tropics
1980	Prolific Tropical Sheep
1980	Trypanotolerant Livestock in West and Central Africa, Vols 1 and 2
1980	Informe de la Consulta de Expertos FAO/PNUMA Sobre la Evaluacion y Conservacion de Recursos Geneticos Animales en America Latina
1981	Animal Genetic Resources - Conservation and Management
1982	Sheep and Goat Breeds in India
1982	Breeding Plans for Ruminant Livestock in the Tropics

1984	Animal Genetic Resources: Conservation by Management, Data Banks and Training
1984	Animal Genetic Resources: Cryogenic Storage of Germplasm and Molecular Engineering
1985	Livestock Breeds of China
1985	Animal Genetic Resources in Africa: High potential and Endangered Livestock
1985	Sheep and Goats in Pakistan
1985	Awassi Sheep
1986	Animal Genetic Resource Data Banks
	1. Computer Systems Study for Regional Data Banks
	2. Descriptor Lists for Cattle, Buffalo, Pigs, Sheep and Goats
	3. Descriptor Lists for Poultry
1986	Sheep and Goats in Turkey
1986	The Przewalski Horse and Restoration to its Natural Habitat in Mongolia
1987	Animal Genetic Resources - Strategies for Improved Use and Conservation
1987	Trypanotolerant Cattle and Livestock Development in West and Central Africa, Vols 1 and 2
1987	Crossbreeding *Bos Indicus* and *Bos Taurus* for Milk Production in the Tropics
1988	Biotechnology applicable to Animal Production and Health in Asia
1989	Animal Genetic Resources of the USSR
1989	Biotechnology for Livestock Production
1989	*Ex situ* Cryoconservation of Genomes and Genes of Endangered Breeds by means of Modern Biotechnological Methods
1990	Animal Genetic Resources: A Global Programme for Sustainable Development
1990	Reproduction in Camels
1990	Open Nucleus Breeding Schemes for Cattle and Buffalo

Animal Genetic Resources Information (AGRI)
This newsletter has been published during the period 1983–90 and contains update information on activities on a world scale, articles of particular relevance on endangered or highly used breeds, methodologies, book reviews and reports of meetings. It is designed to reach all who are interested and concerned with Animal Genetic Resources and is distributed free to a mailing list of 1,500 people and institutions throughout the world. Funding has been provided by UNEP.

1983–1986	A large scale pilot project to develop a new system of Animal Descriptors was carried out and resulted in the development of a system for the orderly genetic characterization of the breeds and of the environments to which they are adapted.
1983–1985	Pilot studies of alternative options for *ex situ* and *in situ* preservation of endangered breeds.
1986-	An international research project to investigate the genetic structure of Sahiwal cattle is being undertaken jointly with India, Kenya and Pakistan supported by trust funds and technical input from Sweden. The expected output is a programme for increased use of the breed in dairy programmes of developed countries, thus preserving its value germplasm.
1988-	Regional Animal Gene Banks in Latin America, Africa and Asia for the cryogenic storage of semen and embryos have been established. The banks will become operational in 1990 after training of nationals of participating countries is undertaken. An Operating Manual for Gene Banks has been prepared.
1988-	The EAAP/FAO Global Animal Genetic Data Bank was established in Hanover, FRG to hold genetic characterizations and population census data. These are stored, analyzed and available for access.

C. Meetings

1967	FAO study on the Evaluation, Utilization and Conservation of Animal Genetic Resources.
1969	FAO Second ad hoc Study group on Animal Genetic Resources.
1971	FAO Third ad hoc Study Group on Animal Genetic Resources (Pig Breeding).
1973	FAO Fourth ad hoc Study Group on Animal Genetic Resources (poultry breeding)
1980	FAO/UNEP Technical Consultation on Animal Genetic Resources Conservation and Management
1983	OAU/FAO/UNEP Animal Genetic Resources in Africa
1983	First FAO/UNEP Expert Panel Meeting on Animal Genetic Resources Conservation and Management
1985	FAO/UNEP Expert Consultation on Animal Genetic Resources Conservation and Management - Methodology for Data Banks
1986	Expert Consultation on Biotechnology applications
1985	FAO/UNEP Expert Consultation on the Przewalski Horse
1986	Second FAO/UNEP Expert Consultation on Animal Genetic Resources Conservation and Management
1989	Consultative Workshop for co-ordinators of Regional Animal Gene Bank Centres
1989	Workshop on Open Nucleus Breeding Systems
1989	Expert Consultation on FAO Programme for Animal Genetic Resources

D. Training Courses

1983	FAO/UNEP Training Course on Animal Genetic Resources - Conservation and Management
1988	Embryo Transfer Training Course in Czechoslovakia
1989	Embryo Transfer Training Course in Cuba
1989	Embryo Transfer Training Course in China
1989	Staff from national Bureaux or animal genetic resources in China and India trained at Global Animal Genetic Data Bank, Hanover, FRG
1990	Open Nucleus Breeding Schemes for Buffalo in Bulgaria
1990	*In vitro* fertilization (IVF) for cattle in Brazil
1991	Training Course for 2 participants from each of 12 Latin American countries on operation of Regional Animal Gene Bank in Brazil
1992	Training Course for 2 participants from each of 15 Asian countries on operation of Regional Animal Gene Bank in China

Appendix 3.1

General guidelines to decide when to intervene for conservation of natural populations

Priority	Population Status	Action
possibly	N < 100,000	At least serious surveillance of status and trends should be initiated
probably	N < 10,000	Well managed captive propagation programmes should be established, reproductive technology research should be vigorously conducted, and germinal tissues collected for storage, while there are an adequate number of animals to use as founders, subjects and donors.
certainly	N < 1,000	*Ex situ* programmes should be intensified while field (*in situ*) efforts are fortified for a 'last stand'; *ex situ* programmes are imperative.
urgently	N < 500	*Ex situ* programmes assume at least as much importance as field (*in situ*) efforts.

It would be better to predicate these guidelines on actual N_e's rather than N's. However, effective population sizes have been and will be difficult to measure for wild populations. Not only is information on sex ratios and family sizes often insufficient, but subdivision of the population and lack of data on rates of gene flow among subpopulations will complicate estimates. Nevertheless in these cases, a quick approximation may be:

$N_e = 4\ N_m\ N_f/N_m + N_f$

where N_m = the estimated number of adult males
N_f = the estimated number of adult females

(after Notter and Foose, 1987)

Appendix 3.2

Calculation of the Effective Population Size

Mathematical expressions of the effective population number (N_e) have been derived for a variety of special population structures and will be reviewed in this appendix

A. Unequal Number of Breeding Males and Females

$$N_e = (4MF)/(M + F) \qquad \textbf{(1)}$$

where M is the number of males and F is the number of females (eg, Crow and Kimura, 1970). N_e is primarily controlled by the sex (usually male) present in smallest numbers. For example, M = 10 and F = 100, the total census number is 110 but N_e = 36.

B. Fluctuation in Population Numbers Across Generations

N_e is given by the harmonic mean population number (eg, Crow and Kimura, 1970):

$$1/N_e = (\sum_{i=1}^{t} (1/N_i)/t) \qquad \textbf{(2)}$$

Where N_i is the population number in each of t generations. N_e is seriously reduced by periods of small N. If N_i = 100 in nine of 10 generations but is reduced to N_i = 10 in one generation, N_e = 53.

C. Non random Distribution of Progeny Numbers

In an ideal population, each parent is assumed to be equally likely to contribute progeny to the next generation. This implies a Poisson distribution of family sizes with the variance in family size (σ^2_k) equal to the mean family size, k (which is equal to two in a population of constant size). However, in many populations σ^2_k exceeds k.

Mathematically:

$$N_e = 2N/\left[1 + \left(\sigma_k^2/k\right)\right] \qquad \textbf{(3)}$$

where N is the actual population number (Crow and Morton, 1955). Note also that in managed populations, if each mated pair contributes exactly two offspring to the next generation, $\sigma^2_k = 0$ and $N_e = 2N$.

D. Joint Effects of Sex Ratio and Distribution of Family Size

Hill (1972) demonstrated that in this situation:

$$(1/N_e) = (1/16M)\left[2 + \sigma_{mm}^2 + (2M/F)\sigma_{mm,mf} + (M/F)^2\sigma_{mf}^2\right] + (1/16F)\left[2 + (F/M)^2\sigma_{fm}^2 + (2F/M)\sigma_{fm,ff} + \sigma_{ff}^2\right] \qquad \textbf{(4)}$$

where M and F are the numbers of males and females, respectively, σ^2_m is the variance among sires in number of male progeny, σ^2_{mf} is the variance among sires in the number of female progeny and $\sigma_{mm,mf}$ is the covariance among sires in numbers of male and female progeny. The quantities σ^2_{fm}, σ^2_{ff} and $\sigma_{fm,ff}$ are comparable values for dam progeny numbers.

In a simplified derivation, Gowe at al, (1959) demonstrated that if each sire produces exactly one male and F/M daughters and each dam produces exactly one daughter and a son with probability M/F, equation (4) becomes:

$$(1/N_e) = (3/16M) + (1/16F) \qquad \textbf{(5)}$$

Smith (1976) also modified equation (4) to estimate the effect of failure of sires and dams to produce appropriate replacements such that:

$$(1/N_e) = (1/16M)\ (4.17 - 2p_m) + (1/16F)\ (4.17 - 2p_f) \qquad \textbf{(6)}$$

where p is the probability that a male or female will survive and produce the required number of progeny.

(after Notter and Foose, 1987)

Appendix 5.4

A Procedure for Developing an Optimal Level of Subdivision within a Captive Population

A decision regarding the extent to which population subdivision is indicated can be based on the following logic:

A. Develop a goal for the amount of genetic diversity that is to be conserved. This can be expressed in a variety of ways, but for purposes of example, let it be described in terms of the percentage of the initial heterozygosity that is to be maintained for a given number of generations. Let us assume an arbitrary goal of maintenance of 90% of the initial heterozygosity for 100 generations. From equation (1) of the text, this would require a panmictic (non-subdivided) population of effective size $N_e = 356$.

B. Let the maximum rate of inbreeding that is consistent with the continued fitness of the species (ΔF_{MAX}) be arbitrarily set at 1.5% generation. In reality, this value would have to be determined separately for each species. If $\Delta F_{MAX} = .015/$ generation, then the minimum effective size of a subline (N_s) is given as

$$\Delta F_{MAX} = 1/2\,N_s = .015$$

such that $N_s = 33.3$. After 100 generations of random mating, only 22% of the initial heterozygosity is expected to be retained for any single line with $N_s = 33.3$.

C. For a population composed of k sublines the heterozygosity expressed in a composite population derived by crossing the sublines with subsequent random mating is directly proportional to the number of sublines. Such a population would be a reasonable one for reintroduction of a species into the wild and would have

$$1 - H'_t/H_o = (1/k)\,(1 - H_t/H_o) = (1/k)\,[1 - (1 - 1/2N_S)^t]$$

where H_o is the original heterozygosity, H_t is the remaining heterozygosity within a subline at generation t and H_t is the heterozygosity within the composite population derived by crossing the lines. For $N_s = 33.3$ and $t = 100$,

$$1 - H'_t/H_o = (1/K)\,[1 - (1/66.6)^{100}]$$

If we let $(1 - H_t/H_o)$ equal to .10 (the goal of the conservation programme), $k = 7.80$. Thus for 8 lines of size $N_s = 33.3$, the loss in heterozygosity would be restricted to 9.7%. A total effective population size of 266.4 would be required for the subdivided population and would compare to a value of $N_e = 356$ which would abe required to achieve the same result in a totally panmictic population.

(after Notter and Foose, 1987)

GLOSSARY OF TERMS

Allele - one of two or more alternative forms of a gene that determine alternative characteristics in inheritance situated at the same site (locus) on the chromosome.

Amino Acid - the building blocks of proteins, 20 different amino acids are commonly found in proteins which are each made of many thousand amino acids.

Artificial Insemination (AI) - a breeding technique commonly used in domestic animals in which live semen is introduced into the female reproductive tract by artificial means.

Biotechnology - techniques that use living organisms or substances from living organisms to make or modify a product, this includes embryo manipulation techniques and techniques to recombine DNA from one organism or cell into the genetic code of another organism or cell.

Bottleneck - a temporary period when a population is reduced to only a few individuals.

Breed - a group of animals related by descent from a common ancestor and visibly similar in most characteristics. A species may have many breeds.

Chromosome - a threadlike structure, composed primarily of DNA (deoxyribonucleic acid), found in the nuclei of cells. The chromosome contains the genes arranged in a linear sequence.

Codominant - describing alternative alleles of a gene that are both equally manifested in the individual.

Continuous Variation- variation with respect to a certain trait, among phenotypes that cannot be classified into clearly distinct classes, but rather that differ little, one from another controlled by quantitative genes.

Cryogenic Storage- the preservation of living tissue at extremely low temperatures, below -130 C, normally liquid nitrogen.

Cryopreservation- see cryogenic storage.

Deoxyribonucleic Acid (DNA) - the information storing portion of the genetic material of the cell consisting of a sequence of nucleotides on a sugar phosphate backbone coiled into a double helix structure. It may be replicated and acts as the genetic code.

Diploid - a cell that possesses two chromosome sets. This is the normal condition for most animal cells. Male honey bees and gametes are examples of “haploid cells”.

DNA - see Deoxyribonucleic Acid.

Domestication - the genetic adaptation of a population of animals, by selection, to life in intimate association with and to the advantage of man.

Dominant - an allele, or the corresponding trait, that is expressed while masking the expression of the alternative allele in the heterozygote, contrast with recessive.

Effective Population Size (Ne) - the size of an “ideal population” that would have a specified rate of increase in inbreeding or decrease in genetic diversity by genetic drift.

Embryo Transfer - an animal breeding technique in which viable and healthy embryos are artificially implanted into the uterus of recipient animals for normal gestation and delivery.

Evolution - a cumulative change in the inherited characteristics of a group of organisms, which occurs in the course of successive generations related by descent. Evolution is a process resulting from natural selection and has no predetermined endpoint.

Exotic - an animal or group of animals introduced into an environment or locality to which they are not native.

***Ex Situ*-** the maintenance of an organism or group of organisms away from the place where they naturally occur.

Extinction - the man-induced or natural process whereby a species, breed or type ceases to exist.

Feral - a domesticated species that has adapted to existence in the wild state but remains distinct from other wild species.

Fixation - describing an allele for which no alternative alleles at that locus exist in the population. This means that the allele has a frequency of 1 (or 100%) in the population.

Founder Effect - when the founders of a new population or a population sample do not represent the total genetic variability contained in the parent population.

Gamete - haploid sex cell, i.e. ovum or sperm.

Gene - the unit of heredity (or inheritance) transmitted in the chromosome. Interacting with other genes it controls the development of hereditary characteristics. The gene is a segment of the DNA molecule that bears the information specifying the amino acid sequence for a particular protein.

Gene Frequency - the proportion of an allele in a population relative to the proportion of other alleles for the same gene in the same population.

Genetic Diversity - the variety of genes within a particular species, variety or breed.

Genetic Drift - the cumulative effect of the chance loss of some genes and the disproportionate replication of others over successive generations resulting in the frequency of the alleles altering from one generation to the next in small populations.

Genetic Engineering - the manipulation and insertion of fragments of DNA into the nucleus of living cells.

Genotype - the genetic identify of an individual as distinguished from its physical appearance. The sum total of the genetic information contained in an individual both as expressed characteristics and characteristics which are not expressed. contrast with phenotype.

Habitat - the place or type of site where an organism naturally occurs.

Haploid - referring to a cell or organism possessing a single chromosome set. This is characteristic of gametes, i.e. sperm and ova cells.

Heterosis - increased vigour of growth or fertility (or other characteristics influencing survival) in an individual resulting from a cross of two genetically different lines.

Heterozygote - a cell or individual organism that possesses different alleles (of the same gene) at the same locus on homologous chromosomes.

Homologous Chromosomes - chromosomes which carry codes for the same functions (or genes) but may differ with respect to the alleles they carry.

Homozygote - a cell or individual organism that has the same alleles at the same locus on each homologous chromosome.

Hybrid - an offspring of a cross between two genetically unlike individuals.

Hybrid Vigour - the increase of biological performance of a hybrid over the parental strains that produce it.

Ideal Population - a concept used in the construction of population models. It is a theoretical diploid, sexually reproducing population in which individuals mate at random, there is no overlap of generations, and no migration, selection or mutation.

Inbreeding - the mating of closely related individuals resulting in increased genetic uniformity in the offspring.

Inbreeding Coefficient - the probability that the two alleles present at a locus are identical by descent, i.e. are derived from the same ancestor.

***In Situ*-** maintenance of an organism or population of organisms within its native environment.

***In Vitro*-** (literally “in glass”) the growing of cells, tissues or organisms in plastic vessels under sterile conditions on an artificially prepared medium.

Landrace - primitive or antique variety usually associated with traditional agriculture, often highly adapted to local conditions.

Locus - a site for a specific gene on a chromosome.

Mendelian Genes - genetic characteristics inherited according to the laws of Mendel, they may be either dominant or recessive in their expression.

Mutation - changes in the chemical constitution of the chromosome resulting in change in the genetic code.

Natural Selection - a natural process by which organisms leave differentially more/ less descendants than other individuals because they possess certain inherited advantages/disadvantages.

Ovary - female reproductive organ which produces haploid gametes or ova.

Ovum - female reproductive cell or egg, plural - ova.

Pedigree - a diagram showing the ancestral relationship among individuals of a family over two or more generations.

Phenotype - the observable appearance and properties of an individual as determined by the interaction of the genetic and environmental influences.

Population - a group of organisms belonging to the same species that occupy a well defined locality and that interbreed with some regularity, therefore, having a common set of genetic characteristics.

Population Model - a mathematical model developed to simulate the inheritance of genetic variation and theoretical genetic characteristics from one generation to the next.

Prolificacy - referring to the relative number of offspring produced by an individual or population.

Quantitative Genes - genes which combine to create continuous variation for a given trait, for example growth rate, size or milk production.

Recessive - an allele, or the corresponding trait, that is manifest only in the homozygote, contrast with dominant.

Recombinant DNA technology - techniques involving modifications of an organism by incorporation of DNA fragments from other organisms using techniques of molecular biology.

Sex-linked - describing a gene carried on one of the sex chromosomes. It may be expressed phenotypically in either or both sexes.

Sex ratio - the number of males divided by the number of females.

Species - a biological species is a group of individuals that can actually or theoretically interbreed successfully with one another but not with members of other groups or species.

Transgenic - an animal or cell which has fragments of DNA inserted into its chromosomes from another organism via recombinant DNA technology.

Uniparous - an animals which normally produces only one offspring per pregnancy.

Zygote - the cell formed by the union of egg (or ovum cell) and a sperm cell, also known as a fertilized egg.

BIBLIOGRAPHY

Adeniji, K.O. (1983). Recommendations for specific breeds and species for conservation by management and preferred techniques. *FAO Animal Production and Health Paper 44/1,* pp 89–99.

Alba, J. de (1986). Criollo cattle of Latin America. *FAO Animal Production and Health Paper 66,* pp 19–45.

Altieri, M.A. and Merrick, L.C. (1988). Agroecology and *in situ* conservation of native crop diversity in the third world. *Biodiversity*, edited by E.O. Wilson, pp 41–42. National Academy Press, USA.

Ark (1976). Breed of the Month - Dexter Cattle. *Ark Vol III, no 4,* pp 102–103. Rare Breeds Surivial Trust, NAC, Stoneleigh, Warks, UK.

Baltay, M. (1982). The Hungarian Mangalica Swine. *Proceedings of the International Conference Gene Reserves,* Debrecen, Hungary.

Bhattacharyya, N.K. (1990). *Annual Report - Central Institute for Research on Goats.* Makhdoom, PO Farah - 281122, Mathura, (UP) India.

Beardomore, J.A. (1973). Extinction, Survival and Genetic Variation. *Genetics and Conservation* edited by Schonewald-Cox, C.M; Chambers, S.M; McBryde, B & Thomas, L. Benjamin Cummings Publishing Co. Ltd., London, UK, pp 125–151.

Bodo, I. (1984). *Manual for Training Courses on Animal Genetic Resources Conservation and Management, Volume I.* Food and Agriculture Organisation of the United Nations, Rome, Italy.

Bodo, I. (1989). Methods and experiences with *in situ* preservation of farm animals. *FAO Animal Production and Health Paper 80,* pp 85–103.

Bodo, I., Kovacs, G. and Ludrovszky, F. (1990). The naked necked fowl. *Animal Genetic Resource Information Bulletin 7,* pp 91–93. Food and Agriculture Organisation of the United Nations, Rome, Italy.

Bodo, I. and Pataki, B. (1984). Special problems in the conservation of traditional horse lines in small herds. *35th Meeting of the European Association of Animal Production.* The Hague, Holland.

Brisbin, I.L. (1985). The Ossabaw Island Pig. *AMBC News Vol 2, no. 4,* pp 3. America Minor Breeds Conservancy, PO Box 477, Pittsboro, NC, USA.

Brook, C. and Ryder, M.L. (1978). Declining Breeds of Mediterranean Sheep. *FAO Animal Production and Health Paper 8.*

Clutton-Brock, J. (1981). *Domesticated Animals From Early Times.* British Museum Press, London, UK.

Crawford, R.D. (1989). Experience with *in situ* preservation of poultry breeds. *FAO Animal Production and Health Paper 80,* pp 142–153.

Dmitriev, N.G. and Ernst, L.K. (1987). Animal Genetic Resources of the USSR. *FAO Animal Production and Health Paper 65.*

Devillard, J.M. (1983). An example of national project on animal genetic resources (N'Dama cattle breed). *FAO Animal Production and Health Paper 44/1,* pp 48–54.

Falconer, D.S. (1981). *Introduction to Quantative Genetics.* 2nd Edition, Longman, London, UK.

FAO (1977a). Bibliography of the Criollo cattle of the Americas. *FAO Animal Production and Health Paper 5.*

FAO (1977b). Mediterranean cattle and sheep in crossbreeding. *FAO Animal Production and Health Paper 6.*

FAO (1980a). Prolific tropical sheep. *FAO Animal Production and Health Paper 17.*

FAO (1980b). Trypanotolerant livestock in West and Central Africa, General study and Country study. *FAO Animal Production and Health Paper 20.*

FAO (1981). Recursos geneticos animals en America Latina. *FAO Animal Production and Health Paper 22.*

FAO (1982). Sheep and goat breeds of India. *FAO Animal Production and Health Paper 30.*

FAO (1986a). Animal Genetic Resources Data Banks. Volume 1: Computer systems study for regional data banks. *FAO Animal Production and Health Paper 59/1.*

FAO (1986b). Animal Genetic Resource Data Banks. Volume 2: Descriptor lists for cattle, buffalo, pigs, sheep and goats. *FAO Animal Production and Health Paper 59/2.*

FAO (1986c). Animal Genetic Resource Data Banks. Volume 3: Descriptor list for poultry. *FAO Animal Production and Health Paper 59/3.*

FAO (1986d). The Przewalski Horse and restoration to its natural habitat in Mongolia. *FAO Animal Production and Health Paper 61.*

FAO (1989a). Small Ruminants in the Near East, Volume 3: North Africa. *FAO Animal Production and Health Paper 74.*

FAO (1989b). *FAO Programmes for the Preservation of Animal Genetic Resources - A Report of the Expert Consultation,* September 1989, FAO, Rome, Italy.

Foose, T.J. (1983). The relevance of captive populations to the conservation of biotic diversity. *Genetics and Conservation* edited by C.M. SchonewaldCox, S.M. Chambers, B. MacBryde and L. Thomas; pp 374–402.

Fowler, C. and Mooney, P. (1990). *Shattering - Food, Politics, and the Loss of Genetic Diversity.* University of Arizona Press, Tucson, Arizona, USA.

Frankle, O.H. and Soule, M.E. (1981) *Conservation and Evolution.* Cambridge University Press, UK.

Goodenough, U. (1978). *Genetics.* Holt Rinehart & Winston, London, UK.

Gunawan B. (1989). Endangered breeds of poultry and ducks. *FAO Animal Production and Health Paper 80,* pp 243–255.

Hasnain, H.U. (1985). Sheep and goats in Pakistan. *FAO Animal Production and Health Paper 56.*

Henson, E.L. (1981) A study of the congenital defect ‘split eyelids’ in the multihorned breeds of British sheep. Un-published paper for the Rare Breeds Survival Trust, NAC, Warwickshire, UK.

Henson, E.L. (1983) Comparative immunological blood types of Vaynol, Chillinghoan and other White Park cattle. Un-published paper for the Rare Breeds Surivial Trust, NAC, Warwickshire, UK.

Henson, E.L. (1986). The need for the conservation of animal genetic resources. Paper in support of *Global Strategies for the Conservation of Animal Genetic Resources.* National Academy Press, Washington DC, USA. (In print)

Henson, E.L. (1987). An assessment of the conservation of animal genetic diversity at the grassroot level. Commissioned paper in support of *Technologies to Maintain Biological Diversity.* Office of Technology Assessment, Washington DC, USA.

Henson, E.L. (1989). The organisation of live animal preservation programmes. *FAO Animal Production and Health Paper 80*, pp 103–117.

Henson, J.L. (1978). Preserving Britain's historic farm animals. *Conservation and Agriculture* edited by J.G. Hawkes. Duckworth Press, UK; pp 155–161.

Hodges, J. (1986) (editor). Animal Genetic Resources - Strategies for Improved Use and Conservation. *FAO Animal Production and Health Paper 66.*

Hodges, J. (1989). Review of the animal gene banks and recommendations from Hanover Workshop on associated topics raised by the Tenth Committee on Agriculture. *FAO Animal Production and Health Paper 80*, pp 51–59.

Hodges, J. (1990a). Manual on establishment and operation of animal gene banks. *FAO Animal Production and Health Paper.*

Hodges, J. (1990b). Animal Genetic Resources a decade of progress, 1980–1990. *FAO Animal Production and Health Paper.*

Hodges, J. (1990c). Conservation of Animal Genetic resources in developing countries. *Genetic Conservation of Domestic Livestock* edited by G.L.H. Alderson. pp 128–145. CAB International, Wallingford, Oxon, UK.

International Union for the Conservation of Nature (1980). *World Conservation Strategy.* International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Jewell, P.A. (1974). *Island Survivors - The Ecology of the Soay Sheep of the St Kilda Islands.* Athlone Press, University of London, UK.

Lasley, J.F. (1978). *Genetics of Livestock Improvement.* 3rd Edition, Prentice-Hall, New Jersey, USA.

Maijala, K., Cherekaev, A.V., Devillard, J.M., Reklewski, Z., Rognoni, G., Simon, D.L. and Steane, D. (1984). Conservation of animal genetic resources in Europe. Final report of the European Association of Animal Production Working Party. *Livestock Production Science* 11: pp 3–22.

Maijala, K. (1986). Possible role of animal genetic resources in production, natural environment conservation, human pleasure and recreation. *FAO Animal Production* *and Health Paper 66*, pp 205–217.

Maijala, K. (1990). Establishment of a world watch list for endangered livestock breeds. *FAO Animal Production and Health Paper* 80, pp 167–184.

Maijala, K., Neimann-Sorensen, A., Adalsteinsson, S., Kolstad, N., Danell, B. and Gjelstad, B. (1990). Conservation of gene resources of farm animals in the Nordic countries. *Animal Genetic Resources Bulletin 7.* Food and Agriculture Organisation of the United Nations, Rome, Italy.

Mannion, A.M. (1991). *Global Environmental Change.* Longman Group Ltd, Essex, UK.

Mariante, A. da Silva. (1991). Detailed practice and problems associated with *in situ* preservation schemes/herds in Latin America for the different animal species. Support paper. EMBRAPA-CENERGEN, Caixa Postal 10.2372, Brasilia, DF, Brazil.

Mason, I.L. (1984). *Evoluation of Domesticated Animals.* Longman Group Ltd, Essex, UK.

Mason, I.L. (1988). *World Dictionary of Livestock Breeds.* Central Agriculture Burea International, Wallingford, Oxon, UK.

Matzon, C. (1986). The use of native rare breeds in management of areas of importance for nature conservation in Sweden. *FAO Animal Production and Health Paper 66*, pp 217–219.

McNeal, L. (1970). Improvement of Navajo sheep. Agriculture Experiment Station Report 172. New Mexico State University, NM, USA.

Myers, N. (1979). *The Sinking Ark.* Pergamon Press, Oxford, UK.

National Academy of Science (1991a). *Managing Global Genetic Resources: The US National Plant Germplasm System.* National Academy Press, Washington DC, USA.

National Academy of Science (1991b). *Managing Global Genetic Resources: Forest Trees.* National Academy Press, Washington DC, USA.

National Academy of Science (1992). *A Global Strategy for the Conservation of Animal Genetic Resources.* National Academy of Sciences, Washington DC, USA. (In print)

National Cattle Breeders Association (1991) Notes on the E.C. directives on the trade of bovine semen after 1992. National Cattle Breeders Association, UK.

Nei, M. (1975). *Molecular Population Genetics and Evolution.* American Elsevier, New York, USA.

Notter, D. and Foose, T. (1987). Concepts and strategies to maintain domestic and wild animal germplasm. Commissioned paper in support of *Technologies to Maintain Biological Diversity,* Office of Technology Assesment, Washington DC, USA.

Novoa, C. (1989). Endangered South American Camelids. *FAO Animal Production and Health Paper 80.* pp 255–265.

Office of Technology Assessment (1987). *Technologies to Maintain Biological Diversity*. Office of Technology Assesment, United States Congress, Washington DC, USA.

Peilieu, Cheng. (1984). Livestock Breeds of China. *FAO Animal Production and Health Paper 46.*

Relief Society of Tigray (1986). Proposal for the establishment of a bull servicing project. Relief Society of Tigray, PO Box 8078, Khartoum, Sudan.

Ruihe, Chen. (1990). Creation of conservation areas for Hu sheep in Jiangsu province. *FAO Animal Genetic Resources Bulletin 7.* Food and Agriculture Organisation of the United Nations, Rome, Italy.

Setshwaelo, L.L. (1989). Live animal conservation projects in Africa. *FAO Animal Production and Health Paper 80*, pp 135–142.

Sharpe, P.M. (1987). Molecular genetic distances among animal populations - estimation and application. *Proceedings of the 38th Meeting of the European Association of Animal Production*, Lisbon, Portugal.

Simon, D. (1989). The Global Animal Genetic Data Bank. *FAO Animal Production and Health Paper 80,* pp 153–167.

Soule, M.E. (1983). What do we really know about extinction ? pp 111–124 *Genetics and Conservation* edited by Schonewald-Cox, C.M., Chambers, S.M., McBryde, B. & Thomas, L. Benjamin Cummings Publishing Co. Ltd., London, UK.

Smith, C. (1977). The use of frozen semen and embryos to measure genetic trends in farm livestock. *Z. fur Tierzucht u Zuchtungsbiologic.* 94, pp 119–130.

Smith, C. (1983). Genetic aspects of conservation in farm livestock. *Livestock Production Science* II, pp 37–48.

Smith, C. (1984). Estimated cost of genetic conservation in farm animals. *FAO Animal Production and Health Paper 44/1*, pp 21–30.

Sparframjandet, A.B. (1990). *World Food Supply.* Spintab, Stockholm, Sweden.

Ucko, P.J. & Dimbleby, G.W. (1969) (editors). *The Domestication and Exploitation of Plants and Animals.* Duckworth & Co., London, UK.

Vietmeyer, N.D. (1983). *Little Known Asian Animals With a Promising Economic Future.* National Academy Press, Washington DC, USA.

Vietmeyer, N.D. (1991). *Microlivestock - Little Known Small Animals With a Promising Economic Future.* National Academy Press, Washington DC, USA.

Warwick, E.J. & Legates, J.E. (1979). *Breeding and Improvement of Farm Animals.* Tate McGraw-Hill Publishing Co. Ltd., New Delhi, India.

Weiner, G. (1989) (editor). Animal Genetic Resources - A global programme for sustainable development. *FAO Animal production and health paper 80.*

Wilkins, J.V. (1984). Criollo cattle of the Americas. *Animal Genetic Resources Information Bulletin no. 1/84.* Food and Agriculture Organisation of the United Nations, Rome, Italy.

Wilson, E.O. (1988). (editor). *Biodiversity.* National Academy Press, Washington DC, USA.

Wright, S. (1977). Inbreeding in Animals: Differentiation and Depression. *Evolution and the Genetics of populations, Vol 3.* pp 44–46. University of Chicago press, Chicago, Illinois, USA.

Yalcin, B.C. (1986). *Sheep and goats in Turkey. FAO Animal Production and Health Paper 60.*

Yamada, Y. and Kimura, K. (1983). Survival probability in small livestock populations. *FAO Animal Production and Health Paper 44/1*, pp 105–111.

Zeuner, F.E. (1963). *A History of Domesticated Animals.* Harper & Row, London, UK.

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