File: 401791

112774

BIODIVERSITY CONSERVATION : NATIVE PASTURES AND DOMESTIC ANIMALS TWO NEGLECTED ISSUES

R.H. MACLEAN

JUNE, 1995

BIODIVERSITY CONSERVATION : NATIVE PASTURES AND DOMESTIC ANIMALS TWO NEGLECTED ISSUES

INTRODUCTION

The global population of 5.5 billion is forecasted to double by 2046, and demographic indicators suggest that growth will not stabilize until well into the 21st century (World Bank, 1994). The lion's share of this increase will be witnessed in the South where population is increasing at 2.33% yr^{-1} (Cunningham, 1993). As population continues to soar, so does humanity's dominance over fellow species and their native habitat. Should current trends continue, over-population will become the single greatest threat to the environment.

> The most important evolutionary adaptation that distinguishes *Homo sapiens* from *Homo erectus* and our other ancestral spp. is skull shape and increased skull size. Transformation came about as a result of natural selection acting on the genetic diversity that characterizes the human genome. Although intelligence is only loosely correlated to brain size, it is believed that our closest ancestor was much smarter than apes, yet dull in comparison to humans (Dodson, 243-45).

Biodiversity

Biodiversity, the genetic library maintained by natural ecosystems (Ehrlich and Wilson, 1991), is the basic biotic resource that sustains all human life-support systems (Kim, 1993). From algae to humankind, biodiversity embodies the unique genetic blueprint of each and every living organism on this planet, and the environment to which that organism has become adapted.

Biodiversity is divided into five hierarchical levels; 1) ecosystems, 2) communities, 3) species, 4) populations, and 5) genes (Soulé, 1991). Each level is further sub-divided into three primary components - composition, structure, and function - all organized into nested sets (Franklin, 1988; Walker, 1992). The key word is nested, as it underlines the complexity and inter-connectedness between and within levels and components of biodiversity. This redundant network of relationships is believed to confer ecosystem resilience, defined here as a system's ability absorb change, and its capacity to return to its original state, once disturbed (Walker, 1982 Savanna).

Human dominance and extinction

As we continue to exert our dominance over the biological and physical components of the environment, each level of biodiversity is affected. Ecosystems become fragmented and/or degraded, communities become stressed and ecological relationships disrupted, population genetic structure becomes altered potentially threatening species and their inherent gene pool. This has sparked many conservation biologists to forecast a period of mass extinction of unprecedented proportions (Ehrlich and Daily, 1993; Ehrlich and Wilson, 1991; Ehrlich and Ehrlich, 1981; Myers, 1990 a,b; Myers, 1993 a, b; Wilson, 1992; Kim, 1993).

> Our knowledge of how, and to what extent, ecosystem resilience is affected by our activities, and at which point our activities trigger resilience collapse, remains scant at best (Myers, 1993; Wilson, 1992; Kay and Schneider, 1994).

Extinction however, is not a new phenomenon. The fossil record indicates that well-defined extinction periods of varying intensities have occurred in the past, during which time many large vertebrates vanished (Jablonski, 1991). Many remain vulnerable today. Large vertebrates are uncommonly prone to extinction because generally, their population sizes and densities are low, range requirements vast, generation times long, and trophic requirements large (Jablonski, 1991). Those species, whose very survival hinges on any one or all of these fundamental ecological requisites, will be adversely affected by the additional burden of human encroachment. Given the present rate of human intrusion into and the fragmentation of native habitats, many vulnerable species are destined to extinction. 'Once a species is gone, it's gone for good' (Myers, 1993).

> The most recent extinction period began an estimated 27,000 years ago and lasted 9000 years (Jablonski, 1991).

The causes for human-induced extinction are bio-physically and socio-politically rooted. Bio-physical causes include habitat modification and fragmentation; over-exploitation in agriculture, forestry, and fisheries; soil, air, and water pollution; native breed and landrace substitution with exotic species; spread of disease; and climate change (Soule, 1992). The socio-political causes for biodepletion are " ... power, information, and resource concentration; unsustainable levels of global resource demand; the effects of global market forces that undervalue natural resources; externalization of environmental costs associated with development; lack of understanding of indigenous resource management systems; and lack of an ethical and financial commitment to sustainability" (McNeely, 1992). In an effort to overcome these problems, governments, the international community, and scientists worldwide have recognized how vital a component of sustainable research and development biodiversity is, and are now beginning to take the necessary steps to ensure that biodiversity is conserved.

Intergenerational equity and the precautionary principle

The cornerstone to biodiversity conservation is inter-generational equity, the assurance that future generations gain equal access to the biological resources that have enabled recent generations to improve their standard of the living. Tomorrow's genetic library is dangerously eroding however (Myers, 1993), hence, a new urgency for action to conserve the planet's genetic endowment.

> Cameron and Abouchar (1991) define the precautionary principle as 'a guiding principle which ensures that even if no conclusive scientific proof linking a given substance or activity to environmental damage exits, that the potential threat of that substance or activity to the environment be sufficient grounds to prevent either from adversely affecting the environment'.

The international community has recognized this urgency by stiffening environmental legislation and policy with the endorsement of the 'precautionary principle'. Interpretations of the precautionary principle range from acknowledging environmentally detrimental activities and implementing corrective measures, to ordering 'polluters to establish by some appropriate burden of proof that their activities are not releasing potentially eco-reactive substances into the environment and thereby causing damage' (Cameron and Abouchar, 1991). In other words, the onus to demonstrate that an activity is environmentally benign must lie with those responsible for the activity, rather than with the public at large to prove otherwise. It is also imperative that research and data remain factual and unbiased, thus genuinely reflecting the real situation. In many cases however, scientific evidence is not necessary to determine if human activity is adversely affecting the environment or not, but only to assess the extent of the damage incurred (Myers, 1993).

The precautionary principle has been incorporated into the legal framework of several international agreements and protocols endorsed by nations worldwide (Cameron and Abouchar, 1991). The Bergen Declaration commits its signatories to 'anticipate, prevent and attack where the threat of serious or irreversible damage exists and that, a lack of full scientific certainty is not sufficient cause for postponing the implementation of cost-effective measures to prevent environmental degradation (Bergen Declaration in Cameron and Abouchar, 1991).

Conservation strategies and consequences

In the Convention on Biological Diversity, the two main classifications of conservation are *in-situ* and *ex-situ* conservation, where *in-situ* conservation is defined as the "recovery and maintenance of species or races in the surroundings in which they developed" (FAO, 1994). In contrast, *ex-situ* conservation is designated as the "maintenance of small, closely managed captive populations in artificial or semi-artificial settings and cryopreservation and storage of semen, embryos, and to a very limited extent, ova" (FAO, 1994). Within the science of conservation, three major approaches targeting different levels of biodiversity can be identified: the ecosystem, species, and gene approaches.

Ecosystem approach

The ecosystem approach emphasizes the need to conserve habitats and the assemblages of species living within those habitats. This *in-situ* approach is based on species inventories and population surveys as well as area identification, protection, and monitoring of ecosystem processes and dynamics (Soule, 1992). Protected areas range from terrestrial and marine parks and wildlife reserves to world heritage sites, biosphere reserves, and internationally recognized wetlands (Geisler, World Bank Report 1993). Left undisturbed, these designated areas maintain critical watersheds, serve as research and educational facilities, and provide desirable recreation grounds.

The earliest ecosystem conservation efforts centred around national parks and wildlife reserves, established in regions characterized either with high species diversity, high local endemism, and/or displayed magnificent beauty. Today, unique environments under severe human encroachment are also included.

> Worldwide, an estimated 7000 legally protected areas have been established in some 130 nations, encompassing roughly 5% of Earth's surface area (McNeely, 1992 in Ambio p162).

Ideally, safeguarding ecosystems ensures that all levels of biodiversity are preserved (Soule, 1991). Serious ecological, socio-economic, and cultural concerns however, have been raised regarding the effectiveness of ecosystem conservation policies. Among others, these include the ecological impact of habitat fragmentation, and the issue of local community access to natural resources.

Habitat fragmentation

Habitat fragmentation implies that a section of land is disconnected from a larger whole in an effort to conserve the fragment in its natural state. Land is often divided as such, when the area in question is chosen for 'development' or when human settlements are within a newly designated protected area. The impact of habitat fragmentation on the survival of resident animal and plant species is

> "Few protected areas are more than fragments of natural ecosystems, and most are not large enough to function in the same self-regulating manner. Most protected areas have boundaries dictated by administrative limits and do not conserve the integrity of ecological processes" (UNESCO, 1994).

a critical issue, particularly for migratory animal and insect populations. Wilcove (1987) identified four causes of species loss as a result of habitat fragmentation:

1) the loss of species due to initial exclusion from the fragment;
2) the loss of species due to lack of habitat heterogeneity within the fragment;
3) the loss of species due to the effect of habitat fragmentation on reproductive dynamics of small populations;
4) the loss of species due to ecological imbalances within the fragment.

These interrelated causes hasten rather than deter the process of extinction.

Community access

Historically, protected areas have been administered by appointed officials who enforce prohibitive guidelines set by national authorities who fail to weigh the value of the natural resources within the designated area to local residents. Many of these imposed restrictions are perceived as an intrusion to local welfare (Wells and Brandon, 1993 Ambio p. 157). Since biodiversity is highly concentrated in the tropics, and biodiversity conservation is beneficial to all of humanity, one must appreciate the disproportionate share of the opportunity costs shouldered by citizens of tropical countries when traditional resources are targeted for conservation and access to them denied (McNeely, 1992). Efforts to conserve biodiversity must be intensified where the risk of biodepletion is greatest, particularly where political purpose is bent around exploitative economic development, and where exploding landless populations must compete with wildlife for space (Soule, 1992).

> 'Habitat destruction and extinction will occur most rapidly in the tropics, where lack of economic opportunity, demographic momentum, and restrictions on reproductive choice are the engines that power the destruction of life' (Soule, 1991).

The negative repercussions of denying local communities access to traditional and essential resources within protected areas has in many instances proven counter-productive. The need for resource extraction rights within buffer zones surrounding core reserves has recently been acknowledged by policy makers as an effective tool to overcome previously imposed restrictions,

> '... biodiversity protection gains local acceptance only to the extent that it is compatible with economic goals' of the community (Poole, 1993 World Bank Parks).

and as a method of harnessing local cooperation. Positive recognition of the participatory role local communities can and must play in protected area design, research, and management began with UNESCO's Man and the Biosphere (MAB) Programme in 1979 (Wells and Brandon, 1993). Efforts to promote this approach have been undertaken by the International Union for the Conservation of Nature (IUCN) and the World Wildlife Fund (WWF), among others. In addition, the Global Environment Facility (GEF) has recently confirmed that social impact assessments will serve as a formal mechanism for 'putting people first' in protected area projects (Geisler, 1993, WB).

Species approach

The species approach to conservation is based on the precept that species survival in changing environments is a function of both short and long-term population adaptive fitness, conferred by the level of heterozygosity characterizing that species (Frankel, 1983 in Soule, 1992). The primary objective to species conservation is to maintain targeted populations at levels where the risks of genetic bottlenecks and inbreeding are minimized, and consequently, where genetic variation within the population is preserved (Soule, 1992).

Frequently championed by the outcry of public opinion, several conservation campaigns for endangered or threatened charismatic species have been mounted. In spite of numerous success stories, the species action strategy has repeatedly been labelled a 'crisis management science' and 'reactive rather than proactive', as it addresses symptoms associated with species extinction rather than causes. Furthermore, although the worldwide endangered species lists continues to grow, few effective conservation plans have been conceived, let alone implemented (Myers, 1993). For the estimated 570 species officially listed under the Endangered Species Act in the US, recovery plans have been formulated for less than half of listed species (Soule, 1992). Lack of appropriated funds to undertake the research required to decipher a specie's complex, yet fundamental biology, and, to implement and enforce legislated management, leaves these recovery plans as '...nothing more than a promise cloaked in a prayer' (Soule, 1992). Although funding justification is often based on the specie's economic and ecological values, these arguments have often failed to persuade policy makers to undertake the necessary action (WB GEF).

Gene approach

At the gene level, two approaches to conservation are taken: living and suspended *ex-situ* strategies. Living *ex-situ* methods include aquaria, arboreta, botanical gardens, museums, private farms, and zoos, where captive breeding and propagation are routinely conducted. The suspended *ex-situ* strategy consists primarily of gene banks, where embryos, ova, semen, seeds, and tissues are cryopreserved for future access (Soule, 1991). Safeguarding species on the brink of extinction, ease and immediacy of techniques, low maintenance costs, long-term storage, and breeder access to indigenous germplasm are some of the recognized advantages to the gene approach. Drawbacks include the following:

1) the representative nature and narrow genetic base of collected samples;
2) the capacity to maintain viable populations;
3) the lack of facilities and habitat generated selection pressure;
4) the lack of favourable policies and long-term committed funding limit the scope of *ex-situ* conservation;
5) the frequent loss of traditional knowledge on how, when, and where the conserved germplasm is to be used (Wood, 1993).

All the above approaches have shortcomings, and none applied in isolation, can conserve the biological heritage that has evolved over time. No strategy is a panacea on its own, and consequently, successful efforts must be multi-strategy based.

Neglected resources

Strictly within an agricultural context, the most significant progress in conservation biology has been in *ex-situ* conservation of commodity crop germplasm within the Consultative Group on International Agricultural Research (CGIAR) and the Food and Agriculture Organization of the

United Nations (FAO).

> Much of the success in *ex-situ* conservation can be attributed to Vavilov, the Russian scientist who, some 60 years ago, pioneered the concept of conserving the genetic diversity of plants with economic value.

Biodiversity conservation of native pastures, of domesticated animals, and of aquatic genetic resources, has long been neglected and only recently, have these issues become a priority on the international agenda. The purpose of this paper is to document the most recent issues, methodologies, and related approaches to biodiversity conservation of native pastures, domesticated animals, and aquatic genetic resources.

REFERENCES

Cameron J. and Abouchar J. 1991. The precautionary principle: A fundamental principle of law and policy for the protection of the global environment. Boston College. International and Comparative Law Review.

Cunningham E.P. 1993.

Daily G.C. and Ehrlich P.R. 1992. Population, sustainability, and Earth's carrying capacity. Bioscience 42(10):761-771

Ehrlich P.R., Ehrlich A.H., and Daily G.C. 1992. Population, ecosystem services, and the human food supply. Morrison Institute for Population and Resource Studies Working Paper No. 44. Stanford University, Stanford, CA.

Ehrlich P.R. and Wilson E.O. 1991. Biodiversity studies: Science and policy. Science 253:753-762

Ehrlich P.R. and Ehrlich A.H. 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York, USA.

Folke C., Perrings C., McNeely J.A., and Myers N. 1993. Biodiversity conservation with a human face: Ecology, economics and policy. Ambio 23(2-3):62-63.

Franklin J.F. 1988. Structural and functional diversity in temperate forests. In: Biodiversity. Wilson E.O. (Ed.) pp.166-175. Washington, DC. National Academic Press.

(Geisler, World Bank Report 1993)

(IUCN, 1989),

Jablonski, D. 1991. Extinction: A paleontological perspective. Science 253:754-757.

Kim Chung Ke. 1993. Biodiversity, conservation and inventory: why insects matter. Biodiversity and Conservation 2:191-214.

McNeely J.A. 1992. The biodiversity crisis: challenges for research and management. In: Conservation of Biodiversity for Sustainable Development. Sandlund O.T., Hindar K. and Brown A.H.D. (Eds.) Scandinavian University Press, Norway.

Myers N. 1993. Questions of mass extinction. Biodiversity and Conservation 2:2-17.

Myers N. 1993. The question of linkages in environment and development. BioScience 43(5):302-310.

Myers N. 1990 a. The biodiversity challenge: Expanded hot-spots analysis. The Environmentalist 10:243-256.

Myers N. 1990 b. Mass extinctions: What can the past tell us about the present and the future? Global Planet Change 82:175-185.

Myers N. 1988. Threatened biotas: "Hot spots" in tropical forests. The Environmentalist 8(3):187-208.

Soulé M.E. 1991. Conservation: Tactics for a constant crisis. Science 253:744-750.

Walker, 1982 Savanna

Walker B. H. 1992. Biodiversity and ecological redundancy. Conserv. Biol. 6:18-23

Wilson E.O. 1992. The diversity of life. Cambridge, MA: The Belknap Press of Harvard University Press.

Wood D. 1993. Agrobiodiversity in global conservation policy. African Centre for Technology Studies. ACTS Press. Nairobi, Kenya

(World Bank, 1994).

NATIVE PASTURES

Definition and scope

Native pastures are defined as uncultivated lands in climatic zones characterized by a pronounced dry season where dominant plant communities are composed of native and/or naturalized perennial grass species that support a wide array of native herbivores (Risser, 1988; Martin et al., 1976). Native pastures include among others, the steppes of the former Soviet Union, the Serengeti of Africa, the dry grasslands of Australia, the cerrado of Brazil, the pampas of Argentina, and the Central Plains of Canada and the United States (Risser, 1988). The terminology used to identify native pastures is diverse and includes such labels as caatinga, chaco, miombo, mopane, mulga, brigalow and others, each with their distinctive flora and adaptive traits (Huntley and Walker, 1982). Throughout this text, native pastures broadly refer to rangelands, grasslands, savannas, and woodlands; the principal distinguishing feature being the increasing presence of trees and shrubs, the abundance of which is a function of soil type, nutrient status, and moisture (Figure 2) (Walker, 1993).

> 'Of the world's agricultural land, about one-third is devoted to crops and the remaining two-thirds is devoted to pastures for livestock grazing' (Pimentel et al., 1995). Native pastures are one of the most widespread terrestrial biomes with an estimated 3 billion hectares (Martin, 1976); 65% of Africa, 60% of Australia, 45% of South America (Huntley and Walker, 1982), and the largest vegetative ecosystem in North America (Sampson and Knopf, 1994).

In addition to conserving erodible soils and restoring the crumbly texture prized in agriculture (Mlot, 1990), native pastures are one of the principal carbon sinks on the planet, efficiently

> In the US, 55 grassland species are on the endangered list and another 728 are candidates, while in Canada, one third of all endangered species have a grassland origin (Samson and Knopf, 1994).

capturing greenhouse gas emissions that contribute to global warming (Seastedt and Knapp, 1993). Many native species adapted to arid conditions, have numerous essential oils of particular significance to humanity. Furthermore, some of the most spectacular wildlife reserves are native pastures.

The grass family

Although native pastures are often characterized by rough topography, poor drainage, cold temperatures, and insufficient moisture to support normal crop growth (Dormaar and Willms, 1990), their historical contribution to modern food production cannot be ignored.

From the above definition, the most distinctive features of native pastures are their dominant grassy composition, the pronounced dry season of their preferred niche, and their evolutionary association with herbivores. These features increase their predisposition to disturbance. These disturbances however, can, by eliminating species, create opportunities for new species to colonize the community, thus, potentially increasing that community's biodiversity (Reice, 1994). Selection pressure associated with disturbance has caused an enormous amount of genetic variability to emerge within the grass

> '...the success of the grasses lies primarily in the evolution of a versatile life-style adapted to unstable or fluctuating environments, particularly those associated with strongly seasonal rainfall regimes or the early stages of succession following disturbance. This life-form then proved readily adaptable to a partnership with fire and herbivores, creating the highly competitive grass-land ecosystem. Finally their propensity for exploiting instability has made them partner to the revolutionary changes in landscapes induced by man... Lastly there came man, to exploit the unique nutritional and keeping qualities of the grass endosperm. 'Ramassage', the opportunistic harvesting of pure stands of wild grass, was the first stage in this process, and even today, some of the minor crops of subsistence farming lie on this borderline of agriculture (Clayton and Renvoize, 1986 in Wood, 1993).

family. 'The most productive formations in terms of agricultural development were the Near Eastern woodlands, tropical savannas, and dry forests. Both formations are rich in species including trees and grasses' (Harlan, 1981 in Wood, 1993). It is likely from these environments that domestication of the grass family began. The fact that more than half of the human nutrition stems from the grass family in rice, wheat, and maize (Swaminathan, 1989) let alone sorghum, millet, rye, triticale, barley, oats, and sugarcane, speaks for itself.

Lost biodiversity - conversion, overgrazing and fire

> 'Fertilization and enrichment often lead to lost species diversity by favouring particular species' growth and reproduction at the expense of others' (Reice, 1994).

The major causes for native pasture biodiversity loss include conversion, overgrazing, and fire. Other exogenous factors noted to prompt decline in native species populations include the introduction of exotic or 'improved' pasture species, land-use practices, soil cultivation, the use of fertilizers and agro-inputs, water enrichment and drainage (McIntyre and Lavorel, 1994).

> Today, as much as 99% of the native tall grass prairie has been converted to grain agriculture (Table 2) (Samson and Knopf, 1994).

The loss of native pastures has had historical consequences, the 'dust bowl' era during the 30's, a case in point. Misconceptualized policies and the ease of conversion encouraged 'sod busters' to burn and plow down vast sections of the Central Plains of United States and Canada for grain agriculture. This resulted in one of the most serious ecological and cultural tragedies in recent past.

The degradation process of a Canadian native prairie due to 45 years of overgrazing has been reported by Dormaar and Wilmms (1990). The process began with the removal of preferentially grazed species resulting in increased bare ground patchiness, which in turn promoted the invasion of short, shallow rooted, and less productive species. This eventually precipitated an increase in evaporation, and a decrease in organic matter, thus reducing the soil's water and nutrient holding capacities. Soil structure deterioration, and increased soil surface sealing and compaction further reduced water infiltration thus, accelerating soil erosion under heavy grazing. Such a process illustrates the sequence of events which can unfold when fragile grasslands are overgrazed.

> The decimation of native herbivore populations and the introduction of domestic livestock have had enormous impact on native pastures biodiversity: not only are species being lost, but the ecotypic variation within species has, in many cases, been depleted (Risser, 1988). In Africa and the Middle East, grazing of indigenous pastures along with climatic variation has caused considerable expansion of the Sahelian desert (Margules and Gaston, 1994).

Overgrazing is a major problem associated with range management, particularly with strategies based on the Clementsian theory which promotes the view that if left undisturbed, native pastures, through ecological succession, return to a recognized climax state where native species dominate population composition. The impact of disturbance on community composition, structure, and biodiversity however, is a contentious issue presently being debated within scientific circles (Reice, 1994; Kay and Schneider, 1994; Myers, 1993). Native pastures today, remain one of the

> Recent findings suggest that complex factors such as spatial variation and dynamics, the significance of rare and extreme events, lag effects and thresholds, and multiple meta-stable states coupled with multiple trajectories of change (Walker, 1993) precipitate shifts in climax species composition and abundance, causing for dramatically different community structures to emerge (Myers, 1993; Walker and Noy-Meir, 1982).

most complex and least understood terrestrial ecosystems (Huntley and Walker, 1982).

Fire is another major disturbance to which native pastures are particularly prone and often subjected to, as a management tool. In heavily infested areas, farmers regularly burn pastures in an effort to rid or reduce tick infestations and to promote new succulent undergrowth.

Two types of factors need to be identified with respect to the impact of fire on native pastures: biological and physical. The biological factors include the following:

1) species susceptibility to fire;
2) habit (annual or perennial);
3) mode of reproduction (vegetative or sexual);
4) adaptive traits (rooting depth and seed burial).

The physical factors that influence the impact of fire include:

1) the amount of fuel (organic debris) and consequently, the intensity of the fire;
2) the season;
3) the frequency of burning (Lacey et al., 1982).

Regardless of how fires are ignited, their effect on community composition, structure and stability can be consequential. Since fire is so closely associated with native pasture management, its multiple effects must be more fully understood. Although not widely practiced in technology-based agricultural systems of the North, burning has both pros and cons. *** EXPLAIN ***

Conservation of native pastures

How do native pastures differ from other crops and how would native pasture conservation strategies differ from those for any other crop ? With conventional crops, farmers harvest and save those varieties which yield and taste best, prove most disease and pest resistant, and are well adapted to local conditions. In contrast, pasture seed is neither planted nor saved as many species are perennial in habit, and grow in associations with other species. Furthermore, small-scale farmers in developing countries most often tether their animals either on natural grasslands, fallowed land, previously harvested cropland, or roadsides. Moreover, since native pastures are generally harvested by animals, they represent an intermediate source of income, and consequently, the economic incentive to conserve pastures is not as apparent. These differences must be considered in conservation strategy design and implementation.

Habitat fragmentation and variegation

> A variegated landscape is where original vegetation matrices are in various states of modification (McIntyre, 1994).

The extent to which native pastures have been disturbed will dictate conservation strategy. For example, in regions where intensive land-use systems have modified the landscape such that what remains are isolated remnants of native vegetation, appropriate conservation strategies will be inherently different from those in regions say, where the native flora is still more or less intact, but somewhat modified due to minor disturbances. This latter scenario has been described as a variegated landscape (McIntyre, 1994). In fragmented habitats, many species are physically confined within the remnant by the highly modified surrounding environments to which they are not adapted (McIntyre and Barrett, 1992). In variegated landscapes, species dispersal is often a function of tolerance to the modified adjacent environment and species exhibiting broad tolerance levels will be widely distributed throughout the landscape (McIntyre and Barrett, 1992). These are some of the distinctions which must be considered when prescribing conservation measures.

Within an agricultural setting, fragmented habitat conservation focusses around rehabilitation in an effort to expand and re-integrate remnants into the landscape (McIntyre, 1994). In contrast, restoration is an attempt to regenerate native pasture. This is a complex process, the dynamics of which we are only beginning to understand. Although a long-term proposition, recent projects have proven successful (Mlot, 1990). Rehabilitation involves reviving degraded pastures by recreating pre-settlement conditions with controlled grazing, rest, and fire, the key disturbances under which native prairie evolved (Ducks Unlimited, 1993).

> Since by definition, variegated landscapes support a diverse range of native species, management options are essentially maintenance-oriented (McIntyre, 1994).

Constraints to restoration and rehabilitation

Biological constraints associated with native pasture restoration and rehabilitation include poor seed germination and stand establishment, lack of above ground initial vigour resulting in weed infestation, and low seed set. These physiological responses are often climate and day-length controlled. Because many native pastures species have well-defined range requirements, seeds collected from one region may not perform well elsewhere. In addition, most native grasses have small seeds with limited energy reserves, and massive root

> In Canada and the US, species planted beyond their estimated 300-500 kms native range suffer from reduced winterhardiness, lack of vigour, low seed production, and poor stand establishment (Smith, 1994).

systems, and consequently, as energy reserves are consumed on root establishment, weeds invade. These are some of the obstacles facing restorationists of native pasture remnants.

Within fragmented or variegated landscapes, the major rate limiting step to native pasture conservation is adequate seed availability. Without seeds, conservation efforts are futile. Canadian and American farmers wanting to re-establish or expand native pasture acreage have encountered serious difficulties in securing seed mixtures of locally adapted complementary species in adequate quantities. Prohibitive seed costs associated with limited supply are also a major deterrent to pasture conservation. Consequently, if significant progress in pasture conservation is to be realized, increased seed production and distribution are absolutely essential. Ecovar development may just be the critical leap forward needed to achieve this objective.

Ecovars and genetic diversity

Ecovars or 'ecological varieties' differ from standard cultivars in that they are 'improved varieties generated by breeding methods that emphasize maintenance of genetic diversity rather than improved growth characteristics' (Smith, 1994). Compromises in uniformity, agronomic performance, and forage yield for greater hardiness and longevity within their respective geographic range, are fundamental to this breeding strategy (Ducks Unlimited, 1993). Farmers benefit directly from long-lived native pastures as replanting is minimized. Furthermore, native pasture species adapted to marginal soils do not require fertilizers (McIntyre and Lavorel, 1994). Less intensive management will translate into greater profitability, and could represent the incentive needed to promote native pasture biodiversity conservation.

In addition, ecovar breeding is based on fewer breeding cycles and less intense selection pressure. A grid type selection technique insures greater representation of superior performers within each replication (Smith, 1994). This breeding approach targets those traits which impede successful restoration and rehabilitation efforts, primarily seed germination, stand establishment, and seed production. While favourably modifying these targeted traits, such an approach preserves the broad genetic fabric required for ecovar populations to adapt to changing environmental conditions. Another advantage to ecovar breeding is the average time lapse from collection to registration, estimated at five years or one third of the time spent on cultivar development (Joyce, 1993).

> Collaborative research on ecovar breeding and development is presently being conducted by Agriculture Canada, the University of Manitoba, and Ducks Unlimited Canada. Considerable progress has also been achieved at the Soil Conservation Service (SCS) department of the USDA (Jacobson et al., 1994).

The possibility of fine-tuning ecovar breeding to encompass tropical native pasture species should be explored. Research on warm-season C4 native grasses is underway and could be expanded to species of tropical origin.

> In Thailand in the late eighties, *Sesbania rostrata* seed availability was limited. Many Thai farmers changed their cropping patterns to produce sesbania seed for sale to the farming community (Furoc, pers. comm.).

Secondly, the strategy and methodology could be tailored to community-oriented capabilities and objectives, thus enhancing farmer participation and potential adoption. This sound ecological approach to native pasture development and utilization could also prove to be financially lucrative. Efforts should be made to create North-South linkages between formal and informal breeding institutions such that the technology be jointly developed and made appropriate for developing countries.

Sculptured seeding

How tolerant a species is to climate, day-length, low soil fertility, drought, floods, frost, or fire will delineate that species habitat range and niche specificity. Cultivars are often environment-neutral and can be successfully grown over a wide range of habitats. Day-length response or photoperiodism is a commonly targeted trait in cultivar breeding. Although a variety's native range may be expanded by being day-length neutral, its genetic base may also be narrowed. Ecovar sensitivity demands that greater attention be paid to micro-habitat selection in restoration and rehabilitation efforts. Sculptured seeding is a promising revegetation technique presently being developed which undertakes that task.

The principle aim of sculptured seeding is to match, as closely as possible, plant communities to their specific native habitat (Jacobson et al., 1994). The process begins by identifying community components within nearby remnants, recording each vegetative unit's position within that remnant, and preparing a detailed landscape profile of that position. Because native pasture topography is typically rolling, knolls are sub-divided into top, middle, and bottom segments, and the vegetation associated with each segment is described.

> The purpose of delineating the landscape according to topography is to differentiate drainage regimes, water holding capacities, and the physical and chemical soil properties between segments, thus ensuring that species are planted in micro-habitats they are adapted to.

Until native seed production is undertaken on a commercial scale, interested farmers must collect and segregate seed mixtures of the different vegetative units observed in nearby remnants. Wild seeds however, are often highly variable with poor germination, and consequently, techniques to break seed dormancy are required. In addition, seed mixtures that correspond with the population densities observed in the remnant and with the size of the new area to be planted, must be prepared. These prepared seed mixtures are then planted in areas with properties similar to those of the original habitat. Such replication of the original habitat greatly increases the probability of successful re-establishment.

Weeds represent another major obstacle in newly planted areas, as competition from invading weeds can hamper pasture establishment. Results from restoration projects undertaken in the US suggest that weeds are effectively suppressed only once the massive root network of native species is established (Mlot, 1990). CIAT (1992) reported that Colombian farmers often combine pastures with upland rice. The rice serves to recover some of the costs associated with pasture establishment and to suppress weed growth (Fujisaka, pers. comm.). Depending on seed availability, another alternative may be pasture overseeding.

This common sense approach combined with the site-specific knowledge required, make sculptured seeding a potentially viable system for farmers who pride themselves in developing intricate cropping systems based on specific field properties. The problems associated with germination, weeds, and other agronomic parameters are not new. Many farmers in developing countries have overcome and mastered these hurdles with a myriad of other plant species which they have included in their complex farming systems.

Management considerations

Regardless if native pastures are fragmented or variegated, the main objective is to return them as close as possible to their original state. Although the process begins at different levels of degradation, the end result remains the same (McIntyre, 1994). Specifically with fragmented habitats, the following precautions must be taken:

1) To minimize species exclusion from the fragment, extensive population sampling is critical, and fragment replication within the original habitat range is desirable. Factors to consider include the size and location of the remnant being sampled, as well as the distribution range and patchiness of the targeted species (Wilcove, 1987).

2) Successful niche establishment within a fragment is governed by habitat heterogeneity. Native species germination can be highly site-specific, and when suitable habitat selection becomes an obstacle, 'land management prescriptions should be oriented around the needs of the most area-sensitive species' (Wilcox, 1984 in Wilcove 1987). In addition, buffer zones should be diverse and as representative of the original habitat as possible.

3) Small populations are vulnerable to natural catastrophes, demographic stochasticity, genetic deterioration, and social dysfunction (Wilcove, 1987). Economic realities however, often constrain the feasibility of large populations. Fragment integration via habitat corridors into networks may be a practical solution.

4) Disruption of the ecological balance that prevails in predator-prey, parasite-host, plant-pollinator relationships can trigger losses of additional species (Wilcove, 1987). Dealing with fragmented habitats demands an in-depth understanding of the complex biology of the targeted species.

Management of variegated landscapes is premised on the following basic assumptions:

1) that low intensity pastoral use is compatible with maintenance of local native species richness;
2) that land-use intensity stratification is compatible with economic priorities; and
3) that spatial optimization of land-use intensity can maintain or increase diversity (McIntyre, 1994).

The following spatial planning guidelines are outlined:

1) safeguarding sites of high-species richness should be the priority within low-intensity management areas;
2) proximity to high-intensity management areas should be avoided as loss of species richness has been correlated to such practices;
3) adequate buffers zones must be identified between low- and high-intensity management areas;
4) where native pastures and trees have clear associations (savannas and woodlands), low-intensity pasture management may be combined with silvi-pastoral systems;
5) the development of conservation networks is recommended;
6) within low-intensity targeted areas, limited disturbance is required to maintain and/or increase diversity; and
7) management diversification will promote native species diversity (McIntyre, 1994).

These are some of the issues related to native pastures. The proposed options are user- and management-oriented, and as such, actively promote native pasture biodiversity conservation. In addition, these approaches are scale-neutral, at the 'low end' of the technology spectrum, and build on the experience farmers have acquired over the years with other crops. An absolutely critical element to conservation is the sustainable utilization of the targeted resource.

REFERENCES

CIAT (1992)

Dormaar J.F. and Willms W.D. 1990. Sustainable production from the rough fescue prairie. Journal of Soil and Water Conservation 45(1):137-140.

Ducks Unlimited Canada. 1993. Native Prairie Plants. Oak Hammock Marsh Conservation Centre. Oak Hammock Marsh, Manitoba, Canada.

Harlan J.R. 1981. Ecological Settings for the Emergence of Agriculture. In: Pests, Pathogens, and Vegetation. Thresh J.M. (ed.). London: Pitman. pp.3-22.

Huntley and Walker, 1982).

Jacobson E.T., Wark D.B., Arnott R.G., Haas R.J. and Tober D.A. 1994. Sculptured seeding. Restoration and Management Notes 12(1):46-50.

Joyce J. 1993. Native Plants: exploring grass seed production and markets. Ducks Unlimited Canada and Agriculture Canada - Prairie Farm Rehabilitation Administration.

Kay J.J. and Schneider E. 1994. Embracing Complexity: the challenge of the ecosystem approach. Alternatives 20(3):32-39.

Martin J.H., Leonard W.H. and Stamp D.L. 1976. Principles of Field Crop Production (3rd Edition). Macmillan Publing Co., Inc. New York, USA

McIntyre S. 1994 a. Integrating agricultural land-use and management for conservation of a native grassland flora in a variegated landscape. Pacific Conservation Biology (in press).

McIntyre S. 1994 b. Risk associated with the setting of conservation priorities from rare plant species lists. Biological Conservation 60: 31-37

McIntyre S. and Lavorel S. 1994 a. How environmental and disturbance factors influence species composition in temperate Australian grasslands. Journal of Vegetation Science (in press).

McIntyre S. and Lavorel S. 1994. Predicting richness of native, rare, and exotic plants in response to habitat disturbance variables across a variegated landscape. Conservation Biology (in press).

McIntyre S., Lavorel S., and Tremont R.M. 1994. Plant life history attributes: their relationship to disturbance response in herbaceous vegetation. Journal of Ecology (in press).

McIntyre S. and Barrett G.W. 1992. Habitat variegation, an alternative to fragmentation. Conservation Biology 6(1):146-147.

McIntyre S., Barrett G.W., Kitching R.I., and Reccher H.F. 1992. Species triage - seeing beyond wounded rhinos. Conservation Biology 6(4):604-605.

Mlot C. 1990. Restoring the prairie. BioScience 40(11):804-809.

Myers N. 1993. Biodiversity and the precautionary principle. Ambio 23(2-3):74-79.

Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurz D., McNair M., Crist S., Shpritz L., Fitton L., Saffouri R., and Blair R. 1995. Environmental and economic costs of soil erosion and conservation benefits. Science vol 267: 1117-1123.

Reice S.R. 1994. Nonequilibrium determinants of biological community structure. American Scientist 82:424-435.

Risser P.G. 1988. Diversity in and among grasslands. In: Biodiversity. Wilson E.O. (ed.). National Academy Press. Washington, USA

Samson F. and Knopf F. 1994. Prairie conservation in North America. BioScience 44(6):418-421.

Seastedt T.R. and Knapp A.K. 1993. Consequences of nonequilibrium resource availability across multiple time scales: the transient maxima hypothesis. Am. Nat. 141:621-633.

Smith S.R. 1994. Selection Methodology for improvement of native grass species. Dept. of Plant Science, University of Manitoba, Winnipeg, Manitoba, Canada.

Swaminathan M.S. 1989.

Walker B.H. 1993. Rangeland Ecology: understanding and managing change. Ambio 23(2-3):80-87.

Wilcove D.S. 1987. From fragmentation to extinction. Natural Areas Journal 7(1):23-29.

Wilcox B. 1984. In-situ conservation of genetic resource: determinants of minimum area requirements. In Proceeding of the World Congress on National Parks. National Parks, Conservation, and Development: the role of protected areas in sustaining society. McNeely J.A. and Miller K. (eds.). Smithsonian Institution Press. Washington, DC.

DOMESTIC ANIMALS

Introduction

> "The term domestication is well applied to those animal species whose existence has become so intertwined with human society that both have become dependent upon one another" (FAO, 1994).

Since our transition from a hunter-gatherer to an agricultural society, 30 to 40 animal species have been domesticated in our quest to secure adequate sources of food, fibre, and draught (Barker et al., 1993). These domesticated species were chosen out of an estimated pool of some 4,000 mammalian and 9000 avian species (Cunningham, 1992). Today, domestic breeds of cattle, sheep, goat, pig, chicken, horse, and buffalo serve as our major sources of meat, milk, eggs, wool, fibre and hide. For thousands of years, these chosen species were subjected to natural selection pressures such as climate, food availability, and endemic parasites and diseases (Barker et al., 1993) as well as directional selection associated with human population, culture, and markets forces.

> A breed is defined as "a group of interbreeding domestic 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" (Clutton-Brock, 1987 in Hall, 1990; Cunningham, 1992).

The historical purpose behind breed evolution was to develop individual phenotypes exhibiting traits most linked with increased productivity under specific farming systems, typical of given ecological zones. Through geographic isolation, mutation, and genetic drift, these phenotypes gradually evolved into separate breeds. Recent surveys indicate that 3000-4000 distinct breeds have emerged (FAO, 1994), each characterized by a unique genetic lineage reflecting a broad spectrum of adaptations suited to natural and agro-economic environments ranging from arid and semi-arid croplands, to rainforests, grasslands, and high ranges (Hammond, 1994; Hodges, 1992). It is the genetic variation between and within these breeds that constitutes the genetic diversity of each domestic animal species (FAO, 1994). The sub-species classification of breed further underscores the fact that all can interbreed, thus perpetuating an "extraordinary and prolific source of genetic variation" (Hodges, 1992). These animal genetic resources (AGR) make up the taxonomic and genetic diversity upon which much of our animal production rests today.

> The livestock contribution to the agricultural gross domestic product (GDP) by region is estimated as follows: 22% in South and Southeast Asia, 25% in Sub-Saharan Africa, 26% in China, 31% in West Asia and North Africa, 38% in South America and 44% in Central America (USDA, 1990 in DeBoer et al., 1994).

Within the agricultural sector, crops and livestock are inextricably linked in many ways. Livestock recycle nutrients vital for plant growth, generate income to purchase inputs to enhance soil and crop productivity, and represent an important source of traction and fuel in many developing countries. The International Livestock Centre for Africa (ILCA), (1993) estimates that traction, manure, and fuel further increase the gross value of animal products by 30-40%. In addition, animals play a crucial buffering role against climatic and economic instability (Li Pun and Estrada, 1988) as they provide a tangible, yet liquid form of capital often used as a hedge against drought and crop failure (Winrock, 1992; Carangal and Sevilla, 1993). Ruminant livestock are particularly beneficial as they convert crop residues and by-products, not utilized by humans, into food and disposable income. The value of animal products in terms of total agricultural productivity is estimated at 30% in developing countries and 55% in the developed world (Hammond, 1994; Strategic Planning Task Force (SPTF) of the Consultative Group in International Agricultural Research (CGIAR), 1994). In spite of these significant contributions to humanity, research budgets allocated for domestic animal conservation pale when compared to those for crops.

The challenge

The global human population is expected to double within the next 45 years (World Bank, 1994). More alarming however, is that 97% of this increase is forecasted to occur in developing countries (IFRPI, 1994). "The magnitude of the challenge of sustainably growing sufficient food for future generations is underscored by the estimate that at the current rate of growth, the world's population will consume in the second decade of the next century a quantity of food equivalent to the total agriculture production of the past 10,000 years" (FAO, 1994). Making matters worse is the unrelenting immigration of rural inhabitants to over-crowded cities. Rural-urban migration is expected to continue to increase as people desperately seek out more remunerative opportunities concentrated in large cities. An estimated 44% of the population in developing countries will live in urban centres by the turn of the millennium, double the percentage of 1960, and up 50% from 1980 (IFPRI, 1994).

> Projected annual population growth rates by region are the following: 3.1% in Sub-Saharan Africa; 2.1% in the Middle East and North Africa; 2% in South Asia; 1.8% in Latin America and the Caribbean; and 1.4% in East Asia (World Bank, 1990 in DeBoer et al., 1994).

It is absolutely imperative that the rate at which food production increases in developing countries match that of population growth, otherwise famine and malnutrition may further inhibit the prospect of stabilizing economic and agricultural productivity in these regions. Current indicators reveal that in developing countries, more than 700 million people lack the means and access to sufficient food to meet their daily needs (2,200 calories/person) and that the number of underweight pre-school children has risen from 164 to 184 million since 1980 (IFPRI, 1994). Food scarcity and insecurity can significantly reduce agricultural and economic growth, thus perpetuating the vicious cycle.

> Results from a U.S. Agency for International Development nutrition program indicate that "quality foods such as those derived from animal sources have major importance for optimizing human performance in chronically mild-to-moderately malnourished populations" (Diaz-Briquets et al., 1992 in DeBoer et al., 1994).

Demand for animal products is governed by shifts in demographic patterns and income growth (DeBoer et al., 1994). As real incomes grow, dietary preferences change. Current animal product consumption patterns indicate that pressures on the livestock industry will be greatest in Asia, particularly in China and Thailand (IFPRI, 1994), followed by Latin America and the Caribbean, and least in Sub-Saharan Africa, West Asia, and North Africa (DeBoer et al., 1994).

Table 1. Estimated annual growth in meat and milk production by geographical region, 1986-88 to 2025 (%).

Product	SSA	WANA	ASIA	LAC
Meat	3.4	3.7	3.3	1.7
Milk	2.8	2.2	3.1	1.6

Source: DeBoer et al., 1994.

> Income elasticity of demand is defined as a measure of the responsiveness of a quantity demanded to a change in income and is calculated as follows:
> <u>% change in quantity demanded</u>
> % change in income (Lipsey et al., 1985).

In spite of the fact that generally, per capita incomes in developing countries are low, income elasticities of demand for animal products are not. In a study on consumer behaviour in developing countries, Sarma and Yeung (1985) in DeBoer et al., 1994 reported the following elasticities for meat, milk, eggs, and cereals: meat 0.63, milk 0.57, eggs 1.00, and cereals 0.16, evidence that as incomes rise, consumers exhibit a greater propensity to consume animal products over cereals. As population and incomes in developing countries rise, demand for livestock products is expected to continue to escalate faster than demand for grains and pulses (Hammond, 1994). Should these forecasts be accurate, animal production systems in the developing world will likely have to intensify to industrial levels (SPTF, 1994).

During the 80s, livestock production increased by 53% in developing countries, which, after accounting for population growth, resulted in a 24% per capita increase (FAO, 1992 in IFPRI, 1994 a). Presently, the crop and animal components of agricultural productivity are increasing at a annual rate of 2.4% and 3.4%, respectively, and, individual meat and milk intake are increasing at a rate of almost 2% annually (FAO, 1993 in SPTF, 1994). Recent surveys however, indicate that although two thirds of the world's livestock is raised in the developing world, less than one third and one fifth of global meat and milk productivity, respectively, are generated from these regions, suggesting that production efficiency, presently estimated at 25% of that observed in developed countries, must be increased if demand is ever to be satisfied from local sources (DeBoer et al., 1994; SPTF, 1994).

Can animal production in developing countries be increased such that demand be satisfied, and if so, what are the alternatives ? What are the constraints limiting these alternatives ? What will the impact of these alternatives be on domestic animal biodiversity ? This paper will attempt to shed some light on these issues as well as provide a brief summary of current efforts to conserve domestic animal genetic resources.

Animal genetic resources - a checkered past

A brief glimpse at the evolution of AGR indicates that several well-defined phases have been crossed: domestication within centres of origin (9000-5000 BC.), uprooting of human populations and their herds/flocks to isolated agricultural frontiers (5000 BC.-1700 AD.), a selective breeding period (1700-1945), and the dawn of science and biotechnology and their application to animal production systems (1945-present) (Hodges, 1992).

> Besides the introduction of domesticated species into the Americas during colonial times, few events have altered AGR as much as those associated with advanced science (Hodges, 1992). From quantitative genetics and artificial insemination (AI) to multiple ovulation embryo transfer (MOET) and "transgenic animals with designer gene mixes", the genetic constitution of domestic animals has been irrevocably modified (Hodges, 1992).

The unparalleled post-war economic boom in Europe and North America unquestionably altered standards of living and consumer behaviour. In both regions, satisfying increased demand for animal products has dictated that production systems become increasingly technology driven. Farming systems have become progressively more intensive with the introduction of higher yielding breeds, improved feeds, sophisticated husbandry, and disease control. Management intensification has also enabled producers to reap higher incomes associated with increased production. As competition within the industry heightened however, family farms have gradually become more commercially-oriented enterprises with specialized production objectives (Cunningham, 1992). Although significant growth in production has been achieved, progress has often been at the expense of traditional breeds, substituted by their high performance counterparts.

Of the global number of domestic animal breeds identified (n=3831), 475 were classified as rare, 618 as extinct during the last 100 years, and 2738 as common (Hall and Ruane, 1993). An estimated 1219 (38%) of the world's living domesticated breeds are found in Europe alone, of which 335 (70% of global number) and 413 (66% of global number) were identified are rare and extinct, respectively (Hall and Ruane, 1993).

The impact of husbandry intensification on breed security can best be illustrated using Europe as an example. Based on effective population size, generation interval, population trends, number of herds, herdbook registration, and percentage of purebreeding (Olivier et al., 1994), livestock breed biodiversity, and the number of rare and extinct breeds are greatest in Europe (Hall and Ruane, 1993). The striking number of European breeds may be partly attributed to the fact that breed diversification is highly correlated with human population size and geographical isolation (Hall and Ruane, 1993). Historically, population in Europe has been relatively high and agriculture relatively intensive when compared with other continental regions. After the war, changing market forces and advanced technologies transformed farming systems as producers strove to increase productivity and efficiency, conditions which favoured breed diversification. Inadvertently however, as intensification progressed, many native breeds became economically extinct and were substituted. Once a breed is no longer financially lucrative, biological extinction is often inevitable.

> "The conservation of Animal Genetic Resources is not simply a global issue, it is an international problem" (Hodges, 1993).

Given that genetic diversity is the fundamental prerequisite to breed diversification, future breed development and production potential may be forfeited as the proportion of genetically similar breeds within the genepool, increases. From an egocentric point of view, humanity stands to lose most from lost animal genetic biodiversity. The genetic treasure, valued and tended by hundreds of past generations, is now at risk, and subsequent generations will suffer the consequences. Although the Food and Agriculture Organization of the United Nations (FAO) has been pursuing the issue for some time, only recently has domestic animal biodiversity been acknowledged as a priority on the international agenda. Efforts have culminated with the Convention on Biological Diversity which came into effect on December 19, 1993.

The emerging scenario

> "The 40% increase in world population expected by 2020 will require more than a 40% increase in world food production to meet the growing demands for livestock products and other high value foods brought about by rising incomes, urbanization, and changing lifestyles" (IFPRI, 1994 b).

As large mega-cities mushroom throughout the developing world, and spectacular economic growth drives millions to seek better standards of living, substantial animal production intensification is expected, specifically in peri-urban areas. Conditions within peri-urban environments in the developing world however, will forever remain less than optimal for livestock production, unless sizable investments in infrastructure are made to overcome environmental pressures, and unless sound husbandry strategies are implemented. Without such commitments, exotic breeds raised in low- to medium-input systems will continue to be subjected to severe stress burdens with dire production consequences (Hammond, 1994).

Increasing animal productivity - the alternatives

If animal production targets are to be met, only two alternatives emerge. The first involves increasing the number of animals raised, the feasibility of which rests upon land and feed availability, among others (DeBoer et al., 1994). The second alternative is to improve each breed's production potential either by a) substituting native breeds with imported exotic breeds; b) crossbreeding or upgrading native breeds with exotic lineages; or c) selecting within native breed populations in an effort to highlight their most productive traits (Payne, 1990).

Importing exotic breeds

> "...European cattle are introduced into the tropics in development projects financed by international loans, as components of bilateral cooperation programmes, as a result of aggressive sales campaigns on the part of the exporters, and even as gifts" (Vaccaro, 1990).

To date, animal breeders have focussed primarily on production traits such as size, growth rate, yield, reproduction traits, and disease tolerance, among others. Their exploits have resulted in large, fast growing animals recognized worldwide for their exceptional production potential, under favourable conditions. It is this production potential that many developing nations strive to achieve, as they formulate strategies to increase their domestic output of animal products, and consequently, the reason why importing these prized breeds remains an alluring option. The fact that these breeds have enabled farmers and nations in the developed world to prosper, serves as additional incentive

(Simon, 1984). The productivity potential associated with exotic breeds however, has not always been realized under tropical conditions.

> "Constraints to the productivity of livestock systems are commonly listed in discrete fashion, suggesting the often erroneous simplification that elimination of a single constraint will substantially increase productivity. Usually, there are multiple interacting constraints and most, if not all, of these must be systematically resolved if substantial changes in productivity are to be realized" (Fitzhugh and DeBoer, 1981).

Production of exotic breeds in developing countries may be affected in several ways. For example, if production traits are to be maximized to their genetic potential, specific requirements must be met, each with specific physiological consequences. One determinant, directly and indirectly related to all targeted traits listed above, is heat tolerance, defined as the capacity to effectively dissipate heat, and to reduce food intake as well as basal metabolic rate (Peters, 1993). Heat dissipation is indirectly genetically controlled by such factors as hair or feather colour and structure, as well as skin pigmentation, among others. Food intake and basal metabolic rate are associated with genetically determined protein synthesis and degradation pathways, which in turn influence the amount of heat generated (Peters, 1993). Due to high maintenance requirements, large, fast growing ruminant breeds consume large quantities of forage and have rapid protein turnover rates (Peters, 1993); the greater the consumption, the greater the internal heat load (Richards, 1981). Intense heat loads, generated during conversion, must be efficiently dissipated if stress is to be minimized and productivity sustained. This is particularly true under tropical conditions, where high radiant heat, high ambient temperatures, and high relative humidity are already major productivity constraints (Horst, 1990). In addition, large appetites may not be satisfied with seasonally limited, inferior quality feeds, forcing the intake of less digestible feeds which are rapidly passed and from which nutrient absorption may be inadequate, eventually causing weight loss, health deterioration, and/or a decline in productivity (Peters, 1993).

> In evolutionary terms, fitness can be defined as " ... the number of fertile progeny an individual will generate during its lifetime in relation to other individuals within a given population" (Suzuki and Griffiths, 1976).

One of the main criticisms of the animal industry on an international scale, has been the irresponsible promotion of so few highly productive breeds per species (Hammond, 1994). Although significant improvements in rate and efficiency of have been achieved (Notter et al., 1994), the problem is that animal geneticists have yet to pinpoint the multi-trait gene complexes conferring both long- and short-term fitness and adaptability. Confounding the issue, is that many of the identified component traits of fitness (e.g. heat and disease tolerance) have low heritability values (Horst, 1990). Genetic mechanisms which synergistically confer the potential to adapt to adverse environmental conditions are extremely complex, involving dominance and epistasis, among others, whereas productivity traits are most often governed by additive effects (Notter et al., 1994).

Regardless of the mechanism, it is generally accepted that highly bred populations are less heterozygous, and in many cases, less fit and unable to cope with the challenges of tropical habitats without substantial production environment modification (Hammond, 1994; Kotze and Muller, 1994). Lack of fitness may be further heightened by the fact that temperate breeds are often exported without ever having been subjected to the array of stress challenges which thrive in tropical environments. Consequently, high yielding exotic breeds, destined for tropical regions may not always perform as well as in temperate environments.

From a non-genetic perspective, how well exotic breeds survive and produce in less favourable environments depends upon on how effectively stress factors such as temperature, feed and water quality, sanitation, and disease are managed and controlled. Stress associated with these factors may induce a myriad of specific physiological responses which can interfere with normal reproductive processes - e.g. at threshold stress levels, the endocrine and immune systems can interrupt hormonal signals which trigger the onset of reproductive cycles. Galina and Arthur, (1990) reported that when stressed, some exotic breeds tend to exhibit short or even silent oestrus cycles at night which may go completely undetected unless a male is left with the herd (Payne, 1990). Under extreme conditions, females can become anoestrous, with obvious repercussions on productivity.

> In a comprehensive review of dairy production in the tropics, Vacarro (1990) reported that abortions, stillbirths, and calf and heifer progeny deaths and culling were greater in European dairy breeds when compared to zebus and European X zebu crossbreds. In addition, an estimated 15% of the imported cattle either died prior to first calving or did not survive their first year in the tropics.

Since much of the success attributed to exotic breeds rests with their prolific reproductive rate and productive capacities, the consequences of erratic oestrous behaviour on the economic viability of any exotic animal-based farming system are significant. Vaccaro (1990) reported that over a lifetime average of three calvings, the number of replacement heifers produced and alive at first calving was 0.74 and 0.98 for European and local breeds, respectively. If herd size cannot be maintained naturally, then sustaining initial production targets will depend on the importers' capacity to replace lost individuals, a critical feat for developing countries with limited foreign

> "A high rate of reproductive efficiency is the most important prerequisite to the production of meat, milk, skins, and breeding stock" (Steinbach, 1987).

exchange reserves. Furthermore, if production of these high yielding breeds in medium- and high-stress environments is to be maintained at their genetic potential, then access to competent veterinary care and essential modern medicines becomes all the more critical, and expensive. These intensive management packages however, are generally unwarranted with local breeds, and often unavailable to the average farmer, yet indispensable if food security is to be attained by raising high input/high output pure-bred exotics within less than favourable environments (Hammond, 1994). If developing nations fail to secure adequate protein sources locally, their vulnerability and reliance on exporting countries will soar to unprecedented heights as population and demand for animal products continue to rise.

Crossbreeding strategies

In contrast to many temperate regions where record keeping, selection, and livestock breeding have a longstanding tradition, the introduction of exotic germplasm into locally adapted native breeds has only recently emerged within developing countries as a strategy to bolster livestock productivity (Peters, 1993).

> "In many developing countries, breed identity has traditionally been defined by local isolation and, perhaps certain phenotypic criteria, rather than by pedigree-based criteria inherent in the Western European concept of breed identity" (Notter et al., 1994).

Exotic germplasm may be introduced into native breeds in three different ways. The first involves crossbreeding two or more breeds such that parental crosses and F1 progeny exhibit heterosis or hybrid vigor. Heterosis is positively expressed when progeny performance for selected traits is superior to that of the parental mean (Hall, 1990). The second strategy is upgrading, where progeny production potential is increased by crossing two or more exotic and native breeds, then backcrossing the F1 over several generations to the exotic parent. The last alternative involves crossing two or more founder breeds over several generations, followed by intensive selection within the new population for production and viability traits, eventually creating a recognized synthetic or composite breed.

> Crossbreeding is defined as the repeated mating of two or more unrelated recognized breeds such that the parental merits of the selected breeds are combined (Hall, 1990). Upgrading on the other hand, is where the progeny of a native and exotic cross are backcrossed to the exotic parent over several generations such that progeny genotype increasingly reflects that of the introduced stock (Hall, 1990).

Today, crossbreeding is extensively practiced because between-breed genetic variation is more consistent than within-breeds, and as a result, introducing exotic germplasm is more expedient than seeking out the desired variability within breeds (Dickerson, 1969 in Hall, 1990). Crossbreeding is particularly important in developing countries since it enables farmers and breeders to combine the productivity traits of exotic breeds with the fitness and adaptability traits of local breeds. Furthermore, increased productivity as a result of heterosis may be achieved over a much shorter time frame than would be required should selection be applied solely among native populations (see selection) (Peters, 1993).

Maximizing heterosis will depend upon the level of heterozygosity and on the genetic complementarity for the targeted trait(s) between selected parental breeds. This sought after complementarity is particularly important for such traits as fertility and viability, among others (Payne, 1990), and it will vary with the genetic constitution of the selected parental breeds. In addition, heterosis may be influenced by population and environmental factors as well as by their interactions (Steinbach, 1987) and the degree of heterosis expressed has been linked to stressful environments (Barlow, 1981; Cunningham, 1981). Since F1 crossbred progeny are generally heterozygous for those traits unique to each parent, the greater the genetic contrast between parents, the more heterozygous, and potentially more stable, the progeny will be (Payne, 1990). However, if crossbreeding is to be successfully practiced over an extended period with the expectation that heterosis be maintained, it is imperative that the breeds to be crossed remain pure.

Effective crossbreeding strategies require well defined breeding objectives and selection criteria (Peters, 1993). One primary objective is determining optimal levels of exotic inheritance. Although yield for many targeted production traits may be increased with increasing proportions of exotic lineage, overall productivity may be suppressed due to poor reproduction, and/or reduced longevity, among others. Cunningham and Syrstad, (1987) reported that many of the traits associated with increased milk production improved linearly with up to 50% *Bos taurus* inheritance in the F1. In Latin America, local breed survival decreased with proportions of exotic lineage beyond 5/8 (Vacarro, 1990). Once optimal inheritance proportions have been determined, breeding strategies that maintain these levels can be designed and implemented.

Selection within native breeds

Native breeds remaining today, have, by means of differential reproductive success (Pianka, 1978), demonstrated their capacity to overcome the myriad of unrelenting challenges imposed upon them by natural selection pressures associated with local environments, as well as the diverse directional selection pressures imposed upon them by their stewards. Reproductive success can be estimated by measuring each breed's genetic contribution to the species' gene pool relative to other breeds within a delineated environment. Within each breed, there is also a range of genetic variability, which when expressed, confers a multitude of specific traits enabling bearers to emerge as superior individuals within that environment. Breeds and individuals within breeds most adapted to a given set of environmental conditions will contribute disproportionately more to the gene pool than less fit breeds.

As the agricultural frontier expanded into less favourable environments, natural selection pressure intensified. This intensification resulted in greater emphasis being placed on traits associated with survival rather than with production. Improved survival may be related to the capacity to endure harsh climates, to tolerate severe disease and heat challenges, and to persist on poor quality feeds, among others. Breeds and individuals exhibiting the widest array of survival traits will be most adapted to these unfavourable environments, and consequently, will perpetuate their genes most successfully.

> "Within-breed selection cannot produce rapid changes in performance, but may be the most appropriate strategy when expected changes in environment, management, and market demand are compatible with anticipated selection responses of 0 to 2%/year" (Notter et al., 1994).

In our quest to bolster animal productivity in stressful environments, many feel that it is within adapted native breeds that we should seek the desired genetic variability. After all, the fact that these finely tuned breeds have survived in these unfavourable environments is testimony to their fitness. Moreover, many native breeds adapted to high stress environments exhibit a broad spectrum genetic variability which potentially, could be shared and exploited with less adapted breeds raised in similar environments (Hammond, 1994). However, the degree of success we achieve and over how long a time frame, will depend upon the extent to which genes responsible for conferring productivity within native breeds have been selected against and suppressed. One example is body size, a trait commonly associated with productivity. Under harsh tropical conditions where heat stress, feed availability, and disease burden are major production constraints however, large size is undesirable and selected against (Fitzhugh, 1978).

If selection pressure in unfavourable environments has been so intense that survival attributes have been gained at the genetic expense of productivity traits, then seeking the desired genetic variability to increase production potential solely within native breeds may be a long tedious exercise without a throughout evaluation of their inherent genetic potential. Our lack of understanding of the genetic framework responsible for conferring fitness traits deemed essential to survive within high stress environments, remains a formidable handicap, and often compels us to combine attributes of both native and exotic breeds.

Consequences of importing, crossbreeding, and selection on native breed integrity

> "Traditional farming systems in the Third World were not developed under the pressure of expanding city populations and therefore current indigenous systems will need to be modified, supplemented, or even replaced" (Hall, 1990).

Since most imported exotic breeds do not possess the genetic resilience characteristic of local breeds, successfully raising exotics under tropical conditions requires that traditional farming systems undergo radical transformation. Such a fundamental departure from traditional practices however, will have a significant impact on native breed security as "individual breeds become threatened when the husbandry system to which they are adapted are modified or replaced" (Hall, 1990).

In the North, market forces dictate the evolution of farming systems, and as a result, these market forces play a determinant role in breed development as well. Directional selection pressure applied by farmers and breeders ensures that herd development follows along the lines demanded by the market. Should dietary preferences of the urban populace in developing countries shift away from local breeds, the additional threat of economic extinction would be brought to bear on native breeds, as the commercial incentive to maintain them would be lost. Farmers, in an effort to maximize returns, aspire to raise animals which conform to consumer expectations. Since consumer behaviour is somewhat fickle however, satisfying consumers with respect to animal products is predicated on how effectively the animal industry can develop breeds which comply with market forces. This in turn depends on the genetic variability farmers and breeders have at their disposal. If native breeds are displaced by imported breeds without adequate conservation measures being implemented, the genetic variability inherent to those native breeds will be lost, the consequences of which are presently immeasurable, for the spectre of challenges ahead remains unknown.

To date, crossbreeding and upgrading schemes have become increasingly prevalent in the more favourable production environments where risks are reduced, and where intensification and maximization of returns per unit animal, rather than per unit land, are sought (Peters, 1993). Indiscriminate crossbreeding and upgrading schemes with *ad hoc* objectives however, have, and will continue to reduce the number of purebred native individuals. Widespread displacement of native germplasm could conceivably wipe out a whole host of yet unidentified genetic resources responsible for conferring a wide array of traits essential to combat unforeseen adversities. As crossbreeding and upgrading become more common practice, native breeds security could be irrevocably jeopardized.

FAO projections indicate that throughout much of the next century, three quarters of global agricultural output will continue to be generated from low- to medium-input farming systems where compound stress is endemic (Hammond, 1994). If production in these environments is to improved, breeds specifically adapted to these adverse environments will have to be developed as well. As in plant breeding and animal production systems in the North, a much closer matching of genetic potential, production environment, and husbandry practices will become increasingly necessary in developing countries. Closer matching may include optimal levels of exotic inheritance, wherein a genetic compromise is struck between increased productivity and wider adaptability. Such a compromise may be particularly effective in low input, extensive production systems where resources and/or credit may not be accessible to modify adverse environmental conditions. Maintaining recommended proportions of exotic inheritance at the local herd level may prove somewhat difficult however, if farmers elect to forego traits associated with adaptability for the prospect of greater productivity accorded with higher levels of exotic lineage (Bondoc et. al., 1989). Although ample genetic diversity within existing breeds remains untapped and selection limits appear distant (Hall, 1990), the capacity to develop specific breeds for specific environments will only be realized if adequate measures are taken to catalogue, evaluate, and conserve, on a global scale, the indispensable genetic variation found in traditional native breeds.

Conservation strategies - domestic animals and wildlife

In ecological terms, a clear distinction must be made between rare domestic animals and endangered wildlife. First of all, as far as domestic animals are concerned, the threat of extinction is not at the species level, but at the breed level (Rege, 1994). A recognized breed is deemed rare with a high risk of extinction once the population of breeding males and females is less than 20 and

1000, respectively (Hammond, 1994). Criteria used to evaluate breed status in developing countries must be more rigorous than in temperate regions because the potential threat of extinction due to disease is often greater, and because population estimates may be less accurate, particularly in regions where nomadic pastoralists live.

Though the number of rare breeds (475) and endangered mammalian species (647) (World Conservation Monitoring Centre, 1992 in Hall and Ruane, 1993) are somewhat similar, the impact of either being lost on natural ecosystems is quite different. The contrast becomes apparent when we consider the ecological relationships such as predator/prey functions each wild species fulfils in the natural food chain. Secondly, most domestic animals are raised under a broad range of management intensities which differ significantly from those imposed by natural forces in the habitats wherein these animals evolved prior to domestication. In addition, those domestic species characterized with a high level of breed diversification today, are often so far removed from their native habitat that should some of these breeds disappear, many natural ecosystems would likely go unaffected. Consequently, strategies designed to conserve domestic animal resources can neither be described as ecosystem- nor as species-based strategies. Although the gene approach is relevant, it does not encompass the entire scope of activities associated with the conservation of domestic animal resources. For these reasons, among others, the approach taken to conserve domestic animal biodiversity will be notably different from those taken in wildlife preservation.

Utilizationists vs preservationists

> From a functional perspective, "... only alleles and allelic combinations have value" (Notter et al., 1994).

The main objective to any successful domestic animal conservation programme is that recognized breeds targeted for conservation remain pure in adequate numbers so as to minimize inbreeding, and that the unique traits which characterize them, not be lost. Selecting the most appropriate strategy then, is critical, since each approach will exert unique pressures on the genetic character of the targeted breeds (Rege, pers. comm.). Within conservation circles, two principal schools emerge, each with specific recommendations as to how extensive domestic animal conservation efforts should be; the utilizationists and the preservationists (Notter and Strauss, 1992 in Fitzhugh and Strauss, 1992).

> Any approach taken to manage domestic animal genetic resources on a global scale must be "... based on objective criteria, taking account not only of current utility, but also the maintenance of maximum genetic diversity in the global gene pool of each species, so as to allow for future unforeseen needs in the development of sustainable animal production systems" (Barker et al., 1993).

Utilizationists stress the importance of conserving functional diversity i.e. genetic diversity responsible for conferring traits of known or potential application for commercial or scientific purposes (Fitzhugh and Strauss, 1992). Based on present economic realities, this approach emphasizes the importance of conserving those genetic resources deemed essential for current and future livestock improvement (Barker et al., 1993). Preservationists, on the other hand, ascribe to the view that because of the uncertainties associated with forecasting future production challenges, and because of the potential for genetic erosion as a result of intensive breeding, all genetic diversity must be conserved (Fitzhugh and Strauss, 1992). In addition, preservationists recommend that each breed's historical and cultural merit also be considered (Fitzhugh and Strauss, 1992).

In-situ and *ex-situ* conservation measures

In-situ conservation, when specifically applied to domestic animals, refers to extensive genepool management of live individuals in their native environment through a range of active breeding programmes that ensure maximum utilization of each species' inherent genetic diversity in the short term, while simultaneously preserving this diversity for future generations (FAO, 1994). Live animals may also be conserved via *ex-situ* strategies however, albeit under more intensive management regimes, generally conducted outside the confines of the species' native range. Based on these definitions then, it would appear that the greatest distinction between both approaches centres around the source of selection, where *in-situ* conservation intrinsically promotes natural breed evolution, whereas *ex-situ* strategies eliminate the potential for continued adaptation via natural selection.

> "... for multiple alleles, the probability of retaining all alleles from the foundation population is higher for a specimen herd supported with frozen semen than for a conservation herd propagated by random mating" (Notter et al., 1994).

In- and *ex-situ* strategies however, need not be mutually exclusive. In fact, researchers are now recommending a balanced approach. In a recently conducted simulation study, Lomker and Simon (1994) compared cryopreserved semen (CS), cryopreserved embryos and semen (CE+CS), live animals (LA), as well as live animals and cryopreserved semen (LA+CS) with respect to initial and maintenance costs, and inbreeding accumulated over a 50 year conservation period. They found that when incurred costs for breed reactivation from cryopreserved semen were accounted, the most cost effective strategy in cattle was a combination of live animals and cryopresevd semen. Inbreeding in LA+CS was also significantly lower than in live animals alone. These findings clearly demonstrate that domestic animal biodiversity conservation will be best achieved by implementing a system embracing both *in-* and *ex-situ* strategies.

Since a large proportion of the world's domestic animal genetic resources is being tended by farmers worldwide, *in-situ* strategies which integrate farmers into the conservation process must be developed. Assuming that many of the current endangered breeds have, in the past, been subjected to market pressures and found undesirable for whatever reasons (Barker et al., 1993), additional incentive to convince farmers of the importance and value of maintaining these breeds will be necessary.

Crop-livestock integration

Crop-livestock integration is increasingly being viewed as a viable option for those regions where demand for livestock products is rising rapidly. It is particularly suited to areas where crop residues are abundant, where pasture expansion is limited, and where natural resources are under-utilized. Some of the advantages of combining crops and livestock include adequate feed sources during times of limited fodder, improved soil fertility via manure recycling, and the potential for income diversification. Additional benefits may be accrued by specifically integrating ruminants, as competition for feed sources is minimized due to their ability to subsist on crop residues not utilized by humans (Preston, 198X).

> 'Farmers have been dedicated plant and animal breeders for thousands of years, although not in the precise manner of modern genetics. They have consciously maintained diversity, planted mixed fields systematically to achieve natural crosses, practised selection and set up their own personal genebanks as well as far-flung exchange systems for acquiring genetic resources' (Rhoades, 1989 taken from Wood, 1993).

Should crop-livestock integration be considered desirable at the community level, such an undertaking could serve as the framework upon which to establish *in-situ* conservation initiatives. The prospect of increasing animal productivity via community-based breeding strategies, designed to improve native breed productivity without significantly disrupting their genetic character, may prove very effective as additional income may be generated and threatened breeds safeguarded.

The nucleus breeding concept could conceivably achieve both of these objectives, as it specifically aims to a) screen local populations of the targeted breed; b) identify superior phenotypes; c) pool selected individuals into a central breeding nucleus; and d) distribute selected nucleus progeny as stock to contributing herds (Bondoc et al., 1989). One of the main advantages to nucleus breeding is that potentially greater gains in productivity may be realized than those possible by individual farmers. This is primarily because exceptional male progeny remain with the nucleus herd to generate sire replacements of higher genetic merit for the contributing herds than could be generated by the contributing herds independently (Bondoc et al., 1989). When germplasm from other nucleus herds or from outside sources is introduced in an effort to further increase productivity, the system is known as the open nucleus breeding strategy (ONBS). In this system, as many as 50% of the nucleus herd females may be selected annually from contributing village herds (Bondoc et al., 1989).

By consolidating farmer resources into a central pool, nucleus breeding elicits farmer participation in carefully defining breeding objectives, in critically assessing breed genetic merit upon which selection criteria are to be based, and in developing breed improvement schemes deemed appropriate for local production environments (Peters 1993). Such a strategy may also prove cost effective as productivity monitoring and record keeping are restricted to the nucleus herd (Bondoc et al., 1989).

> The nucleus breeding approach may be well-suited to developing countries which lack the skills, infrastructure, and/or foreign exchange to develop sophisticated and expensive livestock improvement programmes based on artificial insemination and/or embryo transfer technology (Bondoc et al., 1989).

Intensification and conservation

Policies aimed at promoting crop-livestock integration could in effect serve two purposes: increase the overall productivity of targeted native breeds and thus, create the necessary incentive for farmers to raise and conserve endangered animal genetic resources. Although, intensification will certainly bring about new pressures on farming systems and the natural resource base, change need not necessarily be detrimental. For example, should feed requirements for a growing animal population increase beyond traditional community sources, local farmers may be prompted to gradually shift away from subsistence cropping of annual species to more intensive mixed cropping systems with perennial components such as native pastures and leguminous fodders as well as sugarcane, cassava, sweet potato, and/or banana, all excellent animal feed sources (Preston, 198X). One direct benefit from

> "Animal agriculture production systems will undergo evolutionary changes as production becomes more intensified and shifts from less intensive pastoral systems to more intensive crop-livestock systems" DeBoer et al., 1994.

such a shift would be reduced soil erosion, the most severe and costly threat to worldwide sustainable agricultural development (Pimentel et al., 1995). Agro-silvi-pastoral systems could potentially alleviate many of the problems facing upland farmers, and enable them to achieve increased yields (MacLean et al., 1992). This whole-farm approach to conservation must be weighed against other alternatives.

Global animal biodiversity conservation - the FAO programme

FAO first became involved in domestic animal genetic resources in 1948 with their publication entitled "Breeding livestock adapted to unfavourable environments" (Hodges, 1992 a). Many of the early studies commissioned by FAO were descriptive in nature, and focussed primarily on indigenous breeds in their native environment (Hodges, 1992 a). Increased emphasis on breeding however, emerged during the 60's as breakthroughs in semen cryopreservation (storage) facilitated the international movement of germplasm, and increased the prospect of artificial insemination in developing countries (Hodges, 1992 a).

Soon after the launching of the United Nations Environment Programme (UNEP) in 1973, a joint FAO/UNEP project on the Conservation and Management of Animal Genetic Resources was initiated (Hodges, 1992 a). In 1980, a Technical Consultation (of the same name) was held to identify and prioritise those areas of research judged essential if significant losses of domestic animal genetic

Conservation by management

"That aspect of conservation by which a sample, or the whole of an animal population, is subjected to planned genetic change with the aim of sustaining, utilizing, restoring, or enhancing the quality and/or quantity of the animal genetic resource and its products of food, fibre or draught animal power" (FAO, 1994).

resources were to be averted. From the final report, a more in-depth grasp of the underlying causes for genetic erosion emerged, along with a comprehensive list of recommendations including the rationale for integrating animal genetic resource conservation and management (Hodges, 1992 a). In 1989 and 1992, a panel was appointed to devise the organizational framework and funding mechanism upon which a global programme could be structured (Hodges, 1992 a).

Programme objectives

Building on a series of regional and national project identification missions, FAO's global programme for the conservation of domestic animal biodiversity will provide a) intergovernmental policy support to developing nations as they set out to design and develop national programmes aimed at conserving domestic animal genetic resources, and b) sound technical support to member nations as they formulate effective conservation strategies (Hammond, 1994). Based on a regional umbrella format with national initiatives, the global action plan will establish the necessary infrastructure required for individual nations to conduct breed inventories, characterization studies, population monitoring, and protection of those breeds most at risk.

A major initiative for the Asia and Pacific region was recently funded by the Japanese Government with the following objectives:

a) to identify, characterize, and conserve animal genetic resources to maintain biological diversity for sustainable agriculture;
b) to enhance in-situ productivity of local breeds judged at high risk;
c) to train personnel in survey and characterization techniques and data management, as well as in *in-* and *ex-situ* conservation methods, strategic livestock development planning and breed improvement systems;
d) to regularly publish research results; and
e) to establish the Asian Network for Domestic Animal Diversity (Steane et al., 1994).

Breed inventories are the basis upon which conservation activities are established as they represent each nation's entire domestic animal genetic resource. How extensive inventories should be is a function of their potential application to a) population monitoring studies; b) breed use evaluation; and c) breed conservation (Olivier et al., 1994). Detailed breed characterization studies should include the following passport data: description of the breed's native habitat and production environment, population status and trends, genetic potential and productivity, distinctive physical traits, adaptive characteristics (resistance/tolerance to abiotic and biotic stresses), and other unique traits (Rege, 1994). This baseline data will provide conservation officials and farmers the information required to take action.

Consistent with the Convention on Biological Diversity, each signatory nation is expected to designate a lead institute for biodiversity conservation. Through formal linkage with this institute, the programme anticipates developing a detailed workplan with a series of project proposals tailored to each nation's specific situation and resources (Steane, 1994). These workplans are then dovetailed into a regional approach, building on each nation's individual strengths. Because animal genetic resources are not confined to national borders, this regional approach is essential if the widest possible range of within-species diversity is to be safeguarded (FAO, 1994). "Decisions about which breeds, strains or populations should be conserved should be based on objective criteria, as the blanket conservation of all domestic animal diversity is neither economically feasible nor technically possible" (Downswell, 1994).

In order to objectively select breeds for conservation, the two-phase approach first undertakes to discover in which breeds the widest possible range of diversity exits. In the first phase, the extent of within-species diversity will be established based on a standardized breed sampling protocol restricted to 50 breeds per species found throughout the species' entire range (Barker, 1994). The second phase will further investigate those breeds exhibiting the greatest genetic contrast in the first phase (Barker, 1994).

> "Maintenance of maximum genetic diversity could be achieved by conserving that sub-set of all breeds in a species that show the most genetic differentiation among them, including those that contain unique alleles or allelic combinations" (Barker, 1994).

The following criteria are used to determine if a breed should be sampled:

a) whether the breed has had a long history of genetic variation

b) whether the breed has evolved in a unique environment

c) whether the breed is suspected to have unique phenotypic qualities

d) whether it is practical to sample and conserve

e) the degree of threat

f) representatives of common or economically important breeds should be included, in addition to rare breeds (Barker, 1994).

Within-species genetic contrast will be determined by genetic distance evaluation of extensive DNA sequence data sampled from breeds found to be most taxonomically distinct (Barker et al., 1993). Genetic distance, a statistical procedure widely used to describe the evolutionary genetic structure and breed relationships within a species, measures differences between breed pairs at selected points on a DNA sequence (Barker et al., 1993). It is defined as the probability that a randomly selected allele will be present on one locus in one breed, but not in

> Genetic distancing enables "... breeds and populations to be ranked according to their level of phylogenetic distinction" (May, 1990 in Barker et al., 1993).

another (Barker et al., 1993). Genetic distance using extensive DNA sequence data however, is expensive and time-consuming (Nei and Takezaki, 1994). In addition, this procedure may not reliably estimate time since divergence independent of population size, and can neither weigh the importance of artificial selection on morphological and/or economic traits nor of natural selection on fitness, and consequently, genetic distance can only serve to guestimate population structures upon which conservation decisions are made (Barker, 1994). In spite of these drawbacks, genetic distancing remains a powerful research tool to ensure that conservation efforts focus on the widest possible within-species genetic diversity. To further ensure that unique breeds are not overlooked, additional criteria include "...information on traits of economic importance, specific adaptive features, presence of unique genes or phenotypes, local or regional importance of a breed in production systems, and availability of resources and infrastructure in the region where the breed is located" (Barker, 1994).

Since most of our current knowledge on the range of within-species genetic diversity is concentrated on temperate breeds, it is imperative that we document vital passport data and loss rates on tropical breeds as well, and that appropriate conservation measures be taken where warranted. This vital baseline data is gradually being gathered and incorporated into FAO's Global Databank on Animal Genetic Resources, where it is accessible to research institutions worldwide. Combining temperate and tropical breed inventories has also made it possible for FAO/UNEP to jointly publish the World Watch List for Domestic Animal Diversity (1993), the first global breed inventory designed to serve as an early warning system for domestic animal resources (Hammond, 1994). To ensure that information stored in the FAO databank is widely disseminated, and to facilitate the process of education and training in conservation genetics, the Global Information

System for Domestic Animal Diversity (DAD-IS), a computer-based initiative transmitted via the Internet, was created (Hammond, 1994). DAD-IS is also expected to serve as a cost-effective vehicle for the dissemination of a) a global bibliography on animal genetic resources, b) practical and appropriate experimental designs and data analysis techniques to assist national programmes in the implementation of conservation measures, and c) to promote the active participation of a global network of organizations committed to the conservation of domestic animal biodiversity (Hammond, 1994). By accelerating the data transfer, DAD-IS will also enable national authorities to quickly assess breed status and to take the necessary steps to ensure that breeds be safeguarded (Hammond, 1994).

> The programme recognizes the need for developing breeding strategies which "... can optimise and sustain genetic gain in the developing country environment **without** the tacit assumption of all other resources being readily available, i.e. the development of *in-situ* breeding schemes" (Steane et al., 1994).

Once a threatened breed is judged genetically unique, the programme recommends that both *in-* and *ex-situ* measures be taken to conserve it. Essentially, the *in-situ* measures proposed involve the introduction of targeted breeds into either government-runned or community-based, structured breeding programs. This utilizationist approach should ensure that genetically viable populations and their allelic diversity are conserved (Notter et al., 1994). To achieve these objectives, it is critical that a minimum effective population size (N_e) be maintained. Although the issue of N_e is somewhat controversial, Bodo (1992) recommended that programs aim to establish breeding populations of 25 to 400 individuals. Based on these figures, Notter et al., (1994) identified three population categories, each with specific conservation objectives: the specimen population, the conservation population, and the improvement population.

The specimen population approach focusses on breeds characterized by any one or a combination of the following descriptors: highly isolated, of limited immediate commercial value, average adaptability to harsh environments, a biological extreme for unacceptable traits (e.g. fattiness, dwarf etc...), and/or are of little interest to farmers (Notter et al., 1994). Because these genotypes are generally undesirable, conservation efforts may be restricted to maintaining populations at the minimum N_e, as long as precautionary measure are taken to minimize the prospect of inbreeding. Inadvertently however, specimen populations may, over several generations, undergo considerable genetic drift and lose some of the genetic variation required for restoration as viable commercial purebred (Notter et al., 1994). This may not be of great concern however, as it is highly unlikely that demand for these breeds will ever require that they be elevated to commercial status. Nevertheless, this approach does ensure that signature alleles, inherent to these undesirable breeds, yet of potential significance to other breeds, are conserved (Notter et al., 1994). Notter et al., (1994) argues that, with respect to breeds lacking "obvious economic merit", the specimen population approach allows greater diversity to be conserved, since several breeds may be maintained, rather than few.

Conservation populations aim to conserve a large proportion of the targeted breed's genetic diversity over prolonged periods (Notter et al., 1994). Breeds targeted for conservation populations would be characterized with traits of greater economic significance than those in specimen population. In addition, signature alleles of these breeds may be less pervasive throughout fellow breeds. Consequently, larger herds/flocks must be maintained.

Improvement populations strive to maintain unendangered breeds with currently recognized economic traits, in large enough numbers so as to allow for appropriate selection intensities to be imposed (Notter et al., 1994). As the name implies, the primary goal of this approach is to increase the productive capacity of the targeted breeds.

"Since rates of genetic drift vary with generation interval (GI), the minimum N_e for a conservation population will vary with species. Maintenance of 90% of initial heterozygosity after 100 years requires an N_e of 60 for a GI of 8 years (e.g. 18 stallions and 90 mares for horses), of 95 for a GI of 5 years (e.g. 25 bulls and 475 cows), of 120 for a GI of 4 years (e.g. 32 rams and 480 ewes), of 237 for a GI of 2 years (e.g. 65 boars and 670 sows), and of 475 for a GI of 1 year (e.g. 140 roosters and 785 hens)" (Notter et al., 1994).

Although considerable debate regarding the how large populations need be so as to realize a satisfactory rate of genetic improvement, Notter et al., (1994) submit that "... attainment of acceptable selection intensities for males (from 1.5% in cattle to 0.1% in chicken) with acceptable rates of inbreeding (1 to 2% per year) would suggest minimum sizes for improvement populations of about 2000 cows or ewes, 500 sows and 1000 hens". Should a standardized protocol for gain evaluation, a centralized data processing system, and a breeding regime restricted to specific males be implemented, these improvement herds/flocks could be dispersed over several management units, thus incorporating farmers, breeders, and research institutions into the process (Notter et al., 1994).

The *ex-situ* measures proposed include live-genebanks of identified breeds in closely managed captive populations, and where possible, cryopreservation of semen, oocytes, embryos, and/or DNA. As repositories of last resort (Hammond, 1994), the programme aims to establish a global genebank facility with replicate germplasm at regional and national levels. To date, FAO assisted genebanks representing specific regions have been established in Argentina and Brazil for South America, Mexico for Central America and the Caribbean, India and China for Asia, and Ethiopia and Senegal for Africa (da Silva Mariante and Gerrits, 1994; Steane et al., 1994; Notter et al., 1994).

REFERENCES

Barker J.S.F. 1994. A global protocol for determining genetic distances among domestic livestock breeds. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21.501-508. Guelph, Canada.

Barker J.S.F., Bradley D.G., Fries R., Hill W. G., Nei M., and Wayne R. K. 1993. An integrated global programme to establish the genetic relationships among the breeds of each domestic animal species. Report of a working group for the Animal Production and Health Division, Food and Agriculture Organization (FAO).

Barlow R. 1981. Experimental evidence for interaction between heterosis and environment in animals. Animal Breeding Abstracts 49: 715-737

Carangal V.R. and Sevilla C.C. 1993. Crop-animal systems research experiences in Asia. In: Proceedings VII World Conference on Animal Production vol 1:367-386. Edmonton, Alberta, Canada.

Clutton-Brock J. 1987. A natural history of domesticated mammals. Cambridge University Press and British Museum (Natural History), Cambridge and London.

Cunningham E.P. 1992. Conservation and Development of animal genetic resources - FAO outline programme. FAO Expert Consultation on the Management of Global Animal Genetic Resources. FAO Animal Production and Health Paper 104. FAO, Rome.

Cunningham E.P. 1981. Selection and crossbreeding strategies in adverse environments. In: Animal Genetic Resources Conservation and Management. FAO Animal Production and Health Paper 24:279-288. FAO, Rome.

Cunningham E.P. and Syrstad O. 1987. Crossbreeding *Bos indicus* and *Bos taurus* for milk production in the tropics. FAO Animal Production and Health Paper 68. FAO, Rome.

da Silva Mariante A. and Gerrits R.J. 1994. Current development in the conservation of domestic animal diversity: The Americas. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21.447-454. Guelph, Canada.

DeBoer A.J., Yazman J.A., and Raun N.S. 1994. Animal agriculture in developing countries: technology dimensions. Winrock International Institute for Agricultural Development. Development Studies Paper Series. February, 1994.

Diaz-Briquets S., Cheny C.C., and Germano S. 1992. Nutrition CRSP feasibility and planning activity. Arlington, Virginia; Casals and Assoc.

Dickerson G.E. 1969. Experimental approaches in utilizing breed resources. Animal Breeding Abstracts. 37:191-202.

Downswell E. 1994. Implications of the Biodiversity Convention on the conservation and sustainable use of domestic animal diversity. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21.462-469. Guelph, Canada.

FAO. 1994. Implication of the Convention on Biological Diversity. Management of Animal Genetic Resources and the Conservation Domestic Animal Diversity. M. S. Strauss (ed.). Report of an Informal Working Group. Animal Production and Health Division, March, 1994. Rome.

FAO. 1993. Agriculture: towards 2010. Rome.

FAO. 1992. FAO Agrostat-PC, Population, Production, and Food Balance Sheets Domains. April 1992, Rome.

FAO. 1989. Animal genetic resources - A global programme for sustainable development. FAO Animal Production and Health Paper No. 80. FAO. Rome.

Fitzhugh H.A. 1978. Animal size and efficiency, with special reference to the breeding female. Anim. Prod. 27:393-401.

Fitzhugh H.A. and Strauss M.A. 1992. Management of global animal genetic resources - organizational and institutional structure. In: FAO Expert Consultation on the Management of Global Animal Genetic Resources. FAO Animal Production and Health Paper 104. FAO, Rome.

Fitzhugh H.A. and DeBoer A.J. 1981. Physical and economic constraints to intensive animal production in developing countries. Occasional Publications, British Society of Animal Production 4:23-52.

Galina C.S. and Arthur G.H. 1990. Review on cattle reproduction in the tropics. Part 4. Oestrous cycles. Animal Breeding Abstracts 58(8):697-707

Hall S.J.G. 1990. Genetic conservation of domestic livestock. In: Oxford Review of Reproductive Biology vol. 12. Milligan S.R. (ed.) Oxford Univ. Press. Oxford. pp. 291-318.

Hall S.J.G. and Ruane J. 1993. Livestock breeds and their conservation: a global overview. Conservation Biology 7(4):815-825.

Hammond K. 1994. Conservation of domestic animal diversity: global overview. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21.423-430. Guelph, Canada.

Hodges J. 1993. International programmes for animal genetic conservation. In: Proceedings VII World Conference on Animal Production vol 1:235-258. Edmonton, Alberta, Canada.

Hodges J. 1992 a. Review of past and present activities and prospects for the future. In: FAO Expert Consultation on the Management of Global Animal Genetic Resources. FAO Animal Production and Health Paper 104. FAO, Rome.

Hodges J. 1992 b. Issues and financial requirements of the programmes for the conservation of indigenous livestock breeds. In: FAO Expert Consultation on the Management of Global Animal Genetic Resources. FAO Animal Production and Health Paper 104. FAO, Rome.

Horst P. 1990. The concept of "productive adaptability" of domestic animals in tropical and subtropical regions. J. of the South African Veterinary Ass. 54:159-164.

International Food Policy Research Institute (IFRPI). 1994 a. Alleviating Poverty, Intensifying Agriculture, and Effectively Managing Natural Resources. Per Pinstrup-Andersen and R. Pandya-Lorch. Food, Agriculture, and the Environment Discussion Paper 1. Washington, USA.

International Food Policy Research Institute (IFRPI). 1994 b. World Food Trends and Future Food Security. Per Pinstrup-Andersen. Food Policy Report. Washington, USA.

International Livestock Centre for Africa (ILCA). 1993. Sustainable production from livestock. ILCA's medium-term plan, 1994-98. Addis Ababa, Ethiopia.

Kotze A. and Muller G.H. 1994. Genetic relationships in Southern African cattle breeds. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:413-417. Guelph, Canada.

Li Pun H. and Estrada R.D. 1988.

Lipsey, RG, Purvis, DD, and Steiner, PO (1985). Economics. 5th edition. Harper and Row Publishers Inc. NY, USA.

Lomker R. and Simon D.L. 1994. Costs of and inbreeding in conservation strategies of endangered breeds of cattle. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:393-397. Guelph, Canada.

MacLean R.H., Litsinger J.A., Moody K., and Watson A.K. 1992. The impact of alley cropping *Gliricidia sepium* and *Cassia spectabilis* on upland rice and maize production. Agroforestry Systems 20(3):213-228

May R.M. 1990. Taxonomy as destiny. Nature 347:129-130.

Nei M. and Takezaki N. 1994. Estimation of genetic distances and phylogenetic trees from DNA analysis. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:405-412. Guelph, Canada.

Notter D.R., da Silva Mariente A., Sheng Z. 1994. Modern approaches to active conservation of domestic animal diversity. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:509-516. Guelph, Canada.

Olivier L., Bodo I., and Simon D.L. 1994. Current developments in the conservation of domestic animal diversity in Europe. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:455-461. Guelph, Canada.

Payne W.J.A. 1990. An Introduction to Animal Husbandry in the Tropics. 4th Edition. Longman Scientific and Technical. New York

Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurz D., McNair M., Crist S., Shpritz L., Fitton L., Saffouri R., and Blair R. 1995. Environmental and economic costs of soil erosion and conservation benefits. Science vol 267: 1117-1123.

Peters K.J. 1993. Selection and breeding strategies for sustainable livestock production in developing countries, with particular reference to dairy cattle production. Animal Production in Developing Countries, Occasional Publication No. 16 - British Society of Animal Production. p. 119-128.

Pianka E.C. 1978. Evolutionary Ecology. 2nd Edition. Harper and Row Publishers. New York.

Preston T.R. 198X. A strategy for cattle production in the tropics. ?

Rege J.E.O. 1994. Issues and current developments in the conservation of indigenous African domestic animal diversity. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:439-446. Guelph, Canada.

Richards J.I. 1981. Methods of alleviating the deleterious effects of tropical climates on animal production. In: Proceedings of a symposium entitled Intensive Animal Production in Developing Countries. An Occasional Publication of the British Society of Animal Production No. 4. Smith A.J. and Gunn R.G. (eds.).

Rhoades R. 1989. 'The role of farmers in the creation of agricultural technology.' In: Farmer First: Farmer Innovation and Agricultural Research. Chambers R.A., Pacey A. and Thrupp (eds.)., Intermediate Technology Publication. London. England.

Sarma J.S. and Yeung P. 1985. Livestock products in the third world: Past trends and projections to 1990 and 2000. Research Report 49. International Food Policy Research Institute (IFPRI). Washington, DC.

Simon D.L. 1984. Conservation of animal genetic resources - a review. Livestock Production Science 11:23-36.

Steane D.E., Chen Yaochun, and Yamada Y. (1994). Current developments in the conservation of domestic animal diversity - the Asia and Pacific Region. In: Proceedings of the 5th World Congress on Genetic Applied to Livestock Production. Vol 21:431-438. Guelph, Canada.

Steinbach J. 1987. Evaluation of indigenous and exotic breeds and their crosses for production in unfavourable environments. ???

Strategic Planning Task Force (SPTF) of the Consultative Group in International Agricultural Research (CGIAR), 1994). Report to the Rockefeller Foundation. March, 1994.

Suzuki D.T. and Griffiths A.J.F. 1976. An Introduction to Genetic Analysis. W.H. Freeman and Company. San Francisco.

US Department of Agriculture (USDA). 1990. World agriculture: Trends and indicators, 1970-1989. Statistical Bulletin 815. Washington, DC.

Vaccaro L.P. 1990. Survival of European dairy breeds and their crosses with zebus in the tropics. Animal Breeding Abstracts 58(6):475-485.

Winrock International. 1992. Assessment of animal agriculture in Sub-Saharan Africa. Morrilton, Arkansas.

Wood D. 1993. Agrobiodiversity in global conservation policy. African Centre for Technology Studies. ACTS Press. Nairobi, Kenya

World Bank. 1994.

World Bank, 1990. World development report 1990: Poverty. Oxford: Oxford University Press.

World Conservation Monitoring Centre. 1992. Global biodiversity: Status of the earth's living resources. B. Groombridge (ed.). Chapman and Hall. London, England.