CONSERVATION BY MANAGEMENT

ESTIMATED COSTS OF GENETIC CONSERVATION IN FARM ANIMALS

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SUMMARY

Current UK costs have been obtained or are estimated for the different farm species for collecting, freezing and storing semen (50 doses from each of 25 sires) and embryos (25 embryos from each of 25 donors) and for maintaining a live breeding stock (in numbers to limit inbreeding to 0.2 percent per year). Estimated collection costs for frozen embryos (possibly only for sheep and cattle) are high (£50 000 and £75 000 per stock conserved). The costs are still also appreciable for frozen semen for the different species (£9000 to £25 000). However the annual storage costs for frozen stocks are very small. The costs per year of maintaining a live breeding stock are lower (£3000 to £12 000), but they are cumulative over time. For periods over five years semen storage becomes the cheapest form of conservation. Benefits from conservation cannot be predicted, but it is shown that conservation would be justified, even with a very low probability of use, if there were some gain in the economic efficiency of production through use of the conserved stock in the future.

There is considerable interest and feeling about the need for conservation of rare breeds of livestock, both by laymen and officials and at local, national and international levels (e.g. Maijala *et at.* 1983). The genetics and conservation have been examined previously (e.g. Smith 1983; Simon 1983) and the merits of different systems discussed. The objective of this paper is to try and derive costs of conservation by different methods and so indicate the resources needed to conserve breeds in danger of being lost. An attempt is also made to quantify the justification for breed conservation.

1. METHODS

Each rare breed will present a different set of circumstances with regard to numbers, distribution, ownership, performance levels and health, and these will affect the cost and need for conservation. While appreciating this, the intention here is to obtain or estimate a set of approximate average costs of conservation for each species. Where possible, costs have been obtained from specialist colleagues in each area, as shown in the tables. For other cases, the costs have been estimated, but the assumptions made and the methods used are shown, so that alternative figures may be substituted.

While major genes can be stored either in purelines in mixed stocks, for most performance traits breeds need to be stored in purebred form. The three main methods of conservation are (i) as breeding stocks, (ii) as frozen semen and (iii) as frozen embryos. Purebreds can be obtained with frozen semen by continuously keeping a small group of breeding females (Brem *et al.* 1983) or discontinuously by keeping a small store of frozen embryos (Smith 1983). This avoids the need for grading-up to the frozen semen stock, and allows substitution, and selection during substitution (Smith 1983).

1.1 Cost of Maintaining a Live Breeding Stock

Extra costs are incurred in maintaining a live breeding stock in several ways. Among them are (i) costs in purchase and collection of a representative sample for conservation; (ii) operating costs in identifying, recording, special matings (and incubation and hatching for chickens), and in supervising and administering the conservation procedures; (iii) costs of keeping extra males for breeding; and (iv) lover economic performance of the conserved stock, compared with current commercial stock. However there may also be extra returns, for example in the sale or display of animals from the rare breeds.

Estimates of the costs of keeping extra males are derived for the different species in Table 1. It is assumed that males need to be kept for about four months beyond slaughter age, to allow them to reach sexual maturity and to complete a short and fertile service period and be sold. The main costs are feed costs but further costs, set at 35 percent of feed costs, are added. There will also be a loss in slaughter value for the male, and this is set at 20 percent of normal sale value.

Table 1 ESTIMATED COSTS OF MAINTAINING A BREEDING STOCK

	Cattle	Sheep	Pigs	Chickens
Costs per male				
Extra days maintained beyond slaughter age	120	120	120	120
Feed per day (kg)	8	2	3	0.25
Cost per kg (£)	0.11	0.11	0.16	0.19
Fixed costs/feed costs	0.35	0.35	0.35	0.35
Extra costs (£)	143	36	78	7.7
Sale value per male (£)	450	45	65	1
Extra cost from 20% loss in sale values (£)	90	9	13	0.2
Total cost per extra mal? (£)	233	45	91	7.9
Cost per female				
Number of progeny per year	0.8	1.5	16	20
Extra costs per female and her progeny from a 15% loss in sale value	54	10	156	7.5

Extra costs per female arise from the lower economic performance of the conserved stock. This will vary greatly among stocks to be conserved depending on their merit, and will tend to increase with time as current stocks are improved further. Here, as an average, a figure of 15 percent lower performance is used, but with 5 percent lower input costs. Since purebreds rather than crossbreds are kept, the value of heterosis is lost (set at 10 percent but again with 5 percent lower input costs). The net loss has thus been set at 15 percent of sale value of the progeny. For pigs with a large progeny sale value per female, it might cost less to dispose of surplus progeny at birth, but the loss per individual would need to be. larger than the 15 percent of sale value used here. The costs are derived with meat type stocks in mind. For dairy cattle and egg-laying chickens, where breed differences in merit may be larger, the costs might well be higher. Of course, the costs for the larger species of farm poultry would be larger than those shown for chickens.

The relative costs per extra male and per breeding female affect the ratio of males and females kept. The rate of inbreeding can be minimized by keeping the conserved stock like a pedigreed genetic control line, with one son per sire and one daughter per dam. The rate of inbreeding per year is then $\Delta F/\text{year} = 1/32L\ (3/mL + 1/fL)$ (Hill 1972), where m and f are the number of males and females entering the breeding herd per year and L is the generation interval ($L = L_m + L_f)/2$). It is cost-effective to keep each male for only a short period, but to keep females for as long as possible, as shown in Table 2. The total costs of keeping the conserved stocks are then $mC_m + fgC_f$, where C_m and C_f are the costs per male and per breeding female per year, and g is the number of years a female is retained. The values of m and f which minimize the overall cost for a given level of inbreeding can be derived, given C_m and C_f (Smith 1976).

Table 2 ESTIMATED COSTS TO MAINTAIN A BREEDING STOCK*

	Cattle		Sheep		Pigs		Chickens	
	Male	Female	Male	Female	Male	Female	Male	Female
Years of breeding use (g)	1	5	1	5	1	2.5	1	1
Average parental age (years)	2	4	1	3	1	2	1	1
Generation interval (L) (years)	3		2		1.5		1	
Cost per breeding animal per year (£)	233	54	45	10	91	156	8	8
Number* of breeding animals entering per year (including 15% spares)	10	5	22	12	44	18	72	72
Size of breeding unit	10	26	22	60	44	44	72	72
Cost for each sex (£)	2330	1400	990	600	4000	6860	580	580
Operating costs (£)	1000		1000		1000		1000	
Mating-hatching costs (£)	-		-		-		1000	
Total cost per year (£)	5000		3000		12000		3000	

* Inbreeding rate = 0.2 percent per year
Optimized ratio of males and females to minimize total cost

Some tolerable level of inbreeding must be set. In many breeds of livestock, levels of about 0.5 percent per generation are common (e.g. Dalton 1980; Smith *et al.* 1978). This corresponds to about 0.1 to 0.2 percent per year. A figure of 0.2 percent per year has been used here, so that the conserved stock should be similar to the commercial breeds in the rates and effects of inbreeding on performance and genetic variation. This would be appropriate if the stock were to be used in purebred form. However, if future use is seen in crossbreeding or formation of new synthetic breeds, then inbreeding is less important, and higher levels might be tolerated (say 0.5 to 1 percent per year) and smaller numbers of conserved stock (40 to 20 percent of the numbers used in Table 2) could be maintained. However, the numbers would then get rather low, as for cattle, and the risks from losses in breeding and in mortality would become important.

The numbers of breeding individuals to maintain an inbreeding rate of 0.2 percent per year are also given in Table 2. An allowance of 15 percent for spares is included. For pigs and chickens, the constraint that there must be at least one breeding female per male was required. Due to the different generation intervals there were quite large differences in the size of the stocks that need to be maintained in the different species.

Compared with commercial stocks, there will be extra costs also in identification, in recording, in controlled matings and in supervising and administering the conserved stocks. A sum of £1000 per stock per year has been added for the extra labour, and recording and supervisory time, assuming one person can look after several conserved stocks. For chickens there are further costs in individual mating cages, or in AI, and in incubating small batches of eggs (requiring special small incubating facilities) and a further £1000 per year has been set against this. Costs of purchase and transport of stocks are not included.

The estimated costs for maintaining stocks for the different species for males and for females and overall are given in Table 2. The largest costs are for pigs, due to the number of males needed, and the large value of output per sow. In practice, it may well be possible with good organization and willing cooperators to reduce these costs substantially or to have others meet them from their interest in conserving live stocks of rare breeds.

1.2 Cost of Frozen Semen

Estimates of the costs of collection and storage of frozen semen are given in Table 3. The genetic bottleneck due to freezing from N sires is equivalent to an inbreeding coefficient of 1/2N. With 25 sires (Smith 1983), the inbreeding incurred is thus 2 percent, corresponding to 10 years for the level (0.2 percent per year) set for maintaining a breeding stock. The sires (with spares) need to be held for health testing, training, collection and disposal periods. The collection (and evaluation) periods to collect a minimum of 50 doses of frozen semen are short for cattle and sheep but are still long for pigs (7 weeks) and poultry (17 weeks, or 9 weeks for strains capable of yielding in each ejaculate sufficient semen for two doses). The costs of collection and freezing per dose are low in cattle and sheep but are still high for pigs and chickens. In poultry the methods are still experimental, and include the cost of a programmable freezer which would most likely be replaced by a cheaper method of freezing with a commercial development. The total costs of freezing at least 50 doses of semen from 25 sires are appreciable for all species. The advantage is that storage costs are small, so that the stock can be stored for long periods at little further cost.

1.3 Cost of Frozen Embryos

It is not yet possible to freeze embryos collected from pigs and chickens. The requirement for frozen embryos, to parallel those for stocks and semen, is set at 25 embryos from each of 25 donors (Smith 1983), as shown in Table 4. The collection costs are very high, but as for frozen semen the annual storage costs are low.

Table 3 ESTIMATED COSTS OF CONSERVING A BREEDING STOCK BY FROZEN SEMEN

Item	Cattle	Sheep	Pigs	Chickens
Holding cost per sire per week (£)	30	4	15	0.3
Number of sires started	30	30	40	30
Number of sires collected	25	25	25	25
Holding period (weeks) Health tests, training, etc.	8	8	8	8
Fertility of frozen semen (%)	50	40	40	80
Doses of semen used per mating	1	2	2	1
Doses per collection	100	20	10	1 (2)*
Collections per week	1	4	1	3
Collection period (weeks)	1	2	10	17 (9)
Doses collected per sire	100	160	100	50
Number of fertile matings per sire	50	30	20	40
Number of viable progeny per sire	40	40	120	200
Collection cost per dose (£)	0.2	1.7	5.5	8.2(4.7)
Number of storage cylinder (£)	3	3	10	3
Cost per cylinder (£)	250	250	370	250
Total collection cost *(£)*	9200	8700	25200	11200(6800)
Annual storage cost (£)	200	200	400	200

Cattle : J. Isbister, Scottish Milk. Marketing Board
Sheep, Pigs : H.C.B. Reed, Meat and Livestock Commission
Chickens : P.E. Lake, Poultry Research Centre

*Figures in brackets are estimates, considering developments in freezing technique for practical application and using males capable of two doses per collection.

Table 4 ESTIMATED COSTS FOR COLLECTING, FREEZING AND STORING EMBRYOS (25 EMBRYOS FROM EACH OF 25 DONORS)

	Cattle*	Sheep**	Pigs	Chickens
Cost per embryo (£)	120	80		
Cost for 625 embryos (£)	75 000	50 000	Not possible	Not possible
Storage cost per year (625 embryos) (£)	500	500		

*W.B. Christie, Premier Embryos, Northumberland

**R. Newcomb, Sudbury, Suffolk

Costs include: Holding time, feed, labour, overheads, laboratory tests, drugs, freezing, wastage, etc.

Table 5 ESTIMATED COSTS OF STOCK CONSERVATION FOR DIFFERENT SPECIES

	Cattle	Sheep	Pigs	Chickens
Maintaining a breeding stock (per year) (£)	5 000	3 000	12 000	3 000
Frozen semen from 25 sires (£)	9 000	9 000	25 000	11 000 (7 000)*
Frozen embryos (625 stored) (£)	75 000	50 000	Not possible	Not possible

* See Table 3

1.4 Relative Costs

Comparison of the estimated costs of conservation, by different methods is given in Table 5. These are meant to serve as guides to the costs likely to be incurred, and depend on current technologies, on many assumptions about individual costs and on the levels of inbreeding set by the different methods. Collection of frozen embryos is still comparatively expensive, and even collection of ample frozen semen incurs appreciable costs. However these costs are only incurred once, and storage costs are low. Maintaining a live breeding stock costs least to start with, but the costs are continually incurred and accumulate over time. For periods of over five years, semen storage becomes the cheapest form of conservation.

Costs of conservation in dairy cattle are given by Brem et *al.* (1983). These are somewhat lower than the costs estimated here; 70 percent for a breeding stock and for frozen semen, and 80 percent for frozen embryos. These differences remind us that many of the assumptions and costs assigned are arbitrary and that there may be a considerable variation in the estimated costs with different stocks conserved and in different circumstances.

2. BENEFITS FROM CONSERVATION

There are aesthetic and cultural benefits from conservation of breeds of livestock, just as for conservation of buildings machinery, art, books and other items of historical, social or commercial importance. Fortunately with farm livestock there are many individuals and groups, such as the Rare Breeds Survival Trust in the UK, prepared to devote time and money in conservation. However, here concern is with posible economic benefits in the future from conservation now. Such economic benefits are often implied by conservationists, and examples are often cited (e.g. Mason 1974), but there have been few attempts to quantify them. Predictions from current conditions or trends are unlikely to be helpful, for they are part of the cause for the reduced commercial use of breeds at risk of being lost. Since the future and its requirements are unpredictable it is not possible to quantify benefits. Instead a method, outlined in Table 6, is given to estimate what probability of future use is required to justify conservation. Benefits from livestock- improvement accrue to the consumer (e.g. Smith 1978) rather than to the breeder or producer, and so a national viewpoint is taken. Any benefits from conserving a stock will depend on the total value of the national (or international) market (T), on the costs of conservation (C), on the proportion (x) of its genes used in future commercial production, on the proportional gain (y) in economic efficiency over the then current stocks, on the number of years (m) until commercial use and on the period of years (n) of use. No cost has been attached to the dissemination of the conserved stock since the normal dissemination systems can be used. However, the time involved in dissemination or substitution, or to achieve the required breed mix, may reduce the benefits obtained (Smith 1983). As would be expected, the larger the industry served and the lower the cost of conservation, the smaller the extent of use required to justify conservation. Similarly the sooner the use of the conserved stock and the longer the period of use, the easier it would be to justify conservation.

An example of the application of this approach is given in Table 7 for the UK. The value of livestock production for different sectors is shown as farm gate prices. These might be reduced to a net value if crop costs were removed, but would be increased with added value of product processing and marketing costs. As an example suppose the conserved stock is reused after 20 years, and for a further period of 20 years. An inflation free discount rate of 5 percent is used (Bird and Mitchell 1980). The estimated costs of conservation for 20 years are also shown. The values of the factor (xy), (the product of the proportion of genes used (x) and the increased economic efficiency (y)) which would justify conservation are also given.

Table 6 EXTENT OF USE AND GAIN IN ECONOMIC EFFICIENCY NEEDED TO JUSTIFY CONSERVATION

T	Total annual value of national production
c	Annual cost of maintaining a stock, or frozen stock
s	Cost of freezing a stock
x	Proportional use of genes of conserved stock in future commercial production
y	Proportional gain in economic efficiency from use
m	Time until use made (years)
n	Length of period of use (years)
d	Discount factor = 1/(1 + 0.05)
A net benefit from conserving a stock will accrue when: Cost of conservation < Extra returns obtained C $< T(xy)\ d^{m}\ (1-d^{n})/1-d$	
For breeding stock : C = mc	
For a frozen stock C = mc + s	

Table 7 ANNUAL VALUE OF UK LIVESTOCK PRODUCTION, AND EXTENT OF FUTURE USE OF CONSERVED STOCK TO JUSTIFY CONSERVATION

Product	(T)* Annual value (£ million)	(C) Cost of conservation for 20 years (£ 000) (xy) Size of factor to obtain a benefit from conservation ($x10^{6}$)					
		Breeding		Frozen		Frozen	
		C	xy	C	xy	C	xy
Milk and milk products	1900	100**	11	13	2	85	9
Beef and veal	1500	100	14	13	2	85	11
Sheep meat and wool	400	60	30	13	7	60	30
Pig meat	800	240	60	33	8	-	-
Chickens (meat)	400	60	30	15	8	-	-
Chickens (eggs)	500	60	24	15	6	-	-

Use made after m = 20 years, for n = 20 further years

$d^{m}(l-d^{n})/(l-d) = 5$

* 1980 value (farmgate) (CSO, Annual Abstract of Statistics 1982)

** Cost (C) = 20 (£5000)
Factor (xy) = C/5T
(x = proportion of genes used in future commerical production;
y = proportional gain in economical efficiency obtained)

The results are quite overwhelming. Benefits would be obtained even with both quite small gains in economic efficiency and with low proportions of the genes from conserved stocks used. In the example for a conserved stock of dairy cattle in the UK, the factor xy equals 0.000011 (or 0.11 x 100^2) showing that conservation would be justified with a 0.1 percent use of the stock and a 1 percent gain in economic efficiency. The figures are even lower for frozen semen conservation. Similar results hold for all the species. Thus, from a national point of view, even if there is a very small chance that a stock will be useful in the future, *it* would be worthwhile *to* maintain it because the potential returns are so large relative to the costs incurred in conservation. With the large disparity between possible returns and costs, there is scope for conserving a large number of stocks, on a gamble that they may contribute something useful in the future.

However it may not be worthwhile to use a conserved stock either as a purebred, crossbred or in a synthetic, unless the gain in economic efficiency is more than 5-10 percent, since it would be possible, during the time of testing and substitution, to select and improve the current stocks to be competitive (Smith 1984). Thus only gains of over 5-10 percent in economic efficiency would be worthwhile. If such gains were obtained the national economic benefits from them would be very large indeed.

Using a minimum gain in economic efficiency (y) of 5 percent, the figures in Table 7 can be expressed as the probability (q) needed for the use of a conserved stock to justify its conservation as: $q = (C/(x(0.05)T) \cdot (l-d)/(d^m (l-d^n))$. With complete substitution x=l, for a two breed cross or synthetic x=0.5 and for a specialized use x may be 0.1 or less. For the UK dairy production, and the situation in Table 7 (m=n=20), the probabilities needed are about 1/5000, 1/2500 and 1/500 for a conserved stock and about 1/35000, 1/17500 and 1/3500 for frozen semen, respectively for x=l, 0.5 and 0.1. Thus the probabilities of use needed are very low indeed, and similarly for the other species. With n stocks conserved these probabilities would be multiplied by n, but with more stocks conserved there would be a higher chance that one of them would be useful.

3. DISCUSSION

An important factor mitigating against the future use of conserved stocks, or of rare and minority breeds, is that the main current stocks are being continually improved genetically for commercial production. This makes it increasingly difficult for conserved unimproved stocks to compete, or to contribute through crossing. It will thus take substantial changes in the conditions or methods of production, in disease or in the product required by the market, for the conserved stocks to make up for their increasing deficiencies relative to current stocks and to be useful.

A cost not included here would be that of evaluating the conserved stocks, and comparing the performance for a range of traits, relative to each other and to the current commercial stocks. This might be done on a continuing basis, on animals surplus to breeding requirements or on special test groups, so that a reliable description of the performance levels and special merits of the stocks conserved would be built up. As before the costs of such tests are likely to be small relative to possible benefits. When conditions and markets change, then any conserved stocks known to be suited to the new situation could be picked and retested on a larger scale to assess their economic merit in the new conditions of production.

In developed countries with continuing genetic improvement of current stocks, it will take substantial changes in production conditions before currently uneconomic rare breeds are likely to be useful. Conservation is thus a gamble, with a high probability of no pay-off and a low probability of large benefits if the conserved stock is used. Conservation to retain some genetic diversity may be worthwhile, but to conserve all rare breeds and stocks seems unnecessary. There is, however, often considerable interest and enthusiasm by individuals and groups, such as the Rare Breeds Survival Trust in the UK (Steane 1983) and this may suffice.

The situation is more serious in developing countries. Money for conservation is scarce and many local breeds are in danger of disappearing as the more productive breeds from temperate climates are introduced. Often there are insufficient comparative tests over a range of production environments to evaluate the local breeds. Their special traits in acclimatization, in disease resistance and their tolerance of poor nutrition and environments may be lost. Here the probability of the use of conserved stocks (perhaps in new synthetic breeds or in crossing programmes with the exotic breeds) will be much higher as improved performance may depend on disease resistance and acclimatization of the local breed. This seems to be the main area for input of international resources in conservation. While the costs of conservation may well differ for developing countries (e.g. Parez 1984), it is hoped that the costs derived here may act as a rough guide to the size of the resources required, and form the basis for an international plan for conservation. Teams of technicians could then travel to developing countries and freeze semen from local breeds, storing the material at national and international semen storage centres. Monies might also be raised by allowing individuals or companies to identify with the conservation of a particular breed.

The conclusions from this paper are simple. The costs of conservation are small relative to possible future economic gains in national production. In developed countries enough conservation is probably already being done and this should continue. In developing countries the loss of locally adapted breeds is more serious and is occurring more rapidly. The time has come for international organizations to fund conservation in these countries, or to set up teams to carry out the conservation for them before it is too late.

ACKNOWLEDGEMENT

The help and advice of specialist colleagues in estimating costs is gratefully acknowledged.

REFERENCES

1980 Bird P.J.W.N. and Mitchell G. The choice of discount rate in animal breeding investment appraisal. Anim. Breed Abstr. 48:499-505.

1983 Brem G., Graf F. and Krausslich H. Genetic and economic differences between alternative methods of gene conservation (small population, frozen semen and frozen embryo). Livestock Prod. Sci. (In press).

1980 Dalton D.C. An introduction to practical animal breeding. Granada, London. 162 p.

1972 Hill W.G. Estimation of genetic change. 1. General theory and design of control populations. Anim. Breed. Abstr. 40:1-15.

1983 Maijala K., Cherekaev A.V., Devillard J.M., Reklewski Z., Rognoni G., Simon D. and Steane D.E. Conservation of animal genetic resources in Europe. Final Report of European Association of Animal Production Working Party. Livestock Prod. Sci. (In press).

1974 Mason I.L. Conservation of animal genetic resources. 1st World Congress of Genetics Applied to Livestock Production, Madrid. 2:13-21.

1984 Parez M. Harvesting, processing, storage and subsequent use of animal cells in developing countries. FAO/UNEP Joint Expert Panel on Animal Genetic Resources Conservation and Management, Rome, October 1983.

1983 Simon D.L. Conservation of animal genetic resources. Livestock Prod. Sci. (In press).

1976 Smith C. Alternative forms of genetic controls. Anim. Prod. 23:403-412.

1978 Smith C. The effect of inflation and form of investment on the estimated value of genetic improvement in farm livestock. Anim. Prod. 26:101-110.

1983 Smith C. Genetic aspects of conservation in farm livestock. Livestock Prod. Sci. (In press).

1984 Smith C. Rates of genetic change in farm livestock. J. Agric. Research and Development (Submitted).

1976 Smith C, Jordan C.H.C., Steane D.E. and Sweeney M.B. A note on inbreeding and genetic relationships among British tested pigs. Anim. Prod. 27:125-128.

1983 Steane D.E. European conservation: the next ten years. The Ark. September 1983.

GENETIC ASPECTS OF CONSERVATION IN FARM LIVESTOCK1

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ABSTRACT

Concern about loss of genetic diversity in farm animals can be effectively met by storage of frozen semen or embryos. Genes may be stored in gene pools, but generally breeding stocks should be kept in pure form. The possible returns from retaining genetic diversity may be large, while the costs by comparison are trivially small on a national basis. Thus any stocks at risk should be conserved without further ado. Some principles in conservation are: (i) to store small samples of many stocks; (ii) to choose diverse stocks; (iii) to store stocks with special traits; and (iv) to store locally adapted breeds (especially for developing countries). However, continuous genetic improvement in current stocks may make it increasingly difficult for unimproved conserved stocks to compete, unless there are reversals in breeding goals, or drastic changes in husbandry conditions.

1. INTRODUCTION

There are aesthetic and cultural reasons for conserving different breeds and strains of farm livestock, just as for the preservation of buildings, works of art and museum collections of diverse materials. However, concern here will be with genetic conservation for possible long-term use in production and for economic benefits in the future.

Current trends in livestock breeding may lead to appreciable reduction in the genetic variation available in the future (Mason 1974; Maijala 1974; Miller 1977; FAO/UNEP 1980). These trends include the worldwide concentration on a few specialized stocks and on continuous directional selection within these stocks. If husbandry and market requirements change in the future, as they have in the past, different types of stock may be needed. But without conservation no alternative stocks may be available, and there would be less genetic variation for changing the then current stock to meet the new requirements. Genetic conservation could offset these trends, if useful genetic variation were available and could be exploited. Alternatively, it might be argued, that if concern about genetic stocks and variation in the future were removed, current breeding policies could be pursued with more vigour and so with greater genetic response.

2. EXAMPLES

Some examples in the use of (planned or unplanned) conserved germ plasm in improving current breeding stocks are available (Mason 1974). Several relatively rare breeds have recently become important, either as purebreds or in crosses, in current production, such as the Finnish Landrace sheep, the Pietrain pig and the Gotland sheep. In poultry, Cornish game stocks are important components of current broilers. In pigs, the use of prolific native Chinese pig breeds is being considered. There are also several good examples of individual genes from special stocks now being used in current stocks, such as sex-linked slow feathering and dwarf genes in broilers, the halothane gene in pigs, the double muscling gene in cattle and the Booroola gene in sheep. These examples show that there have been benefits from having a diversity of stocks in the past, and so there may well be further benefits in the future, as the variety of stocks and breeds otherwise available gradually declines.

3. STORAGE METHODS

Until recently genetic conservation in farm animals has been largely unplanned, but small remnants of earlier stocks and breeds are found. Use of living stocks with normal reproduction is costly in facilities and supervision and is subject to several hazards, including loss due to disease, genetic bottlenecks from fluctuating numbers, accumulative genetic drift, inbreeding depression, contamination from other stocks and changes due to natural selection. Methods to minimize these effects are discussed by Smith (1976) for genetic control populations.

Storage of frozen semen or embryos is now the best way of preserving genetic stocks. One or both methods are now available for all farm species. High recovery rates are not required, since a few animals bred from stored material can produce large numbers of progeny. While collection costs may still be moderate, or even high, storage costs are low (Brem *et al.* 1983). The various hazards cited above for breeding stocks are reduced or removed with frozen stores. Experience with regenerating stocks from frozen semen and embryos has been good (e.g. Whittington *et al.*1977). To avoid accidental loss, several replicate stores of the same material should be maintained. As a further safeguard, the stores should be shielded from possible irradiation damage.

4. GENETIC DRIFT

It may be useful to review the inbreeding and genetic drift variance generated by different systems of conservation. The effective breeding size (N) of a population is defined as that which gives an inbreeding rate of F = 1/2N per generation. The genetic drift variance for a trait is then VG/N, where VG is the genetic variance for the trait.

In setting up breeding lines or frozen stores, the initial drift variance is:

$$\frac{VG}{4}\left(\frac{1}{s} + \frac{1}{sd} + \frac{2}{sdn}\right)$$

with s unrelated sires, d dams per sire and n offspring per dam. With frozen semen n = d = 1 and the drift variance is

$$VG/s$$

The subsequent inbreeding in a breeding line (with balanced pedigree mating) is (e.g. Hill 1972):

$$\frac{1}{2}\left(\frac{3}{16s} + \frac{1}{16sd}\right)$$

per generation, and is cumulative. With frozen semen, using sires rotationally on each other's daughters (Smith 1977), no inbreeding would be generated until the circle of sires was completed (s generations) and even then it would only rise to a maximum of (4/3) ($1/2^s$ +3), a quite trivial amount if s is not small. There would be no further inbreeding until the frozen semen stocks were exhausted and another set of sires had frozen semen stored when the above results would be repeated. With frozen embryos there would be no inbreeding or drift until stocks were used up, and a new set of embryos was produced. In multiplication, inbreeding could also be avoided by rotating over the original embryo lines.

These results show how very effective the frozen storage methods are in minimizing drift and inbreeding in genetic conservation compared with breeding stocks. Choice between semen or embryos will depend on the costs of collection and the number of progeny required. With frozen embryos the original stock can be regenerated at any time. Frozen semen needs a small permanent female breeding group or a small store of frozen embryos to reproduce the original stock. The alternative is a period of backcrossing to breed up the original stock; with 50, 75, 87, 94, 97, 98, 99 percent of its genes in generations 1-7 respectively.

5. GENE CONSERVATION

Distinction should be made between storage of individual genes and the conservation of stocks each with its combination of traits and genetic characteristics. The methods of storage and of extraction and use of the material will differ in the two cases.

If it is the gene itself which is required, it can be extracted from any form of storage and substituted into current stocks by repeated backcrossing. It may thus be stored in pure line, synthetic or gene pool form. The size of the store or the frequency of the gene need not be high since only a few copies of the gene are required. Genes with deleterious effects may need to be maintained by selection, the special stocks often being recorded in a registry (e.g. Somes 1978). If special or novel combinations of genes are required, simple random mating will be adequate and can provide a wide variety of genotypes which can be extracted (Weller and Soller 1981).

For individual genes the most efficient and effective storage methods are in gene pools, with frozen semen or embryos. Pure line forms will be preferred only if linkage groups, epistatic or genetic background effects are considered important.

The probability that a gene occurring in a population is not included in a store depends on the frequency of the gene and on the size and form of the store. If the frequency in the original population is p, the probability that none of N individuals in store have the gene is $(1-p)^{2N}$. This would apply to frozen semen store from N sires. With an embryo store of a large number (>10) of embryos per mating, the probability that none of the embryos contain the gene approximates to $(1-p)^{4N}$. With stores where N is not small these probabilities become very small, unless p is very low (less than 0.1). Thus the risk that a gene present in the original population is lost is very low, unless it was originally very rare.

In addition to known genes (identified either by phenotype or by quantitative effects, i.e. major genes), there will be other genes as yet not identified which may be detected and exploited on exposure to new conditions. The wider the genetic diversity of stock stored, the greater the chance of finding such genes.

6. QUANTITATIVE TRAITS

When many genes are involved in the expression of a trait, as for most quantitative traits, it will not be possible to extract them as a group and to use them independently of the rest of the genotype. Thus the genotypic value for all traits in a stock are relevant, for they will affect the overall performance both as a pure line and in combination with other lines. The genotypic value of the cross will tend to the average of the contributing lines. If the economic effects were linear and there was no heterosis, then the best pure line (at any time) would be as good or better than the best cross. However, with heterosis and non-linear economic weights (curvilinear, plateaus, thresholds, intermediate optima) which depend on the performance level for the trait, the best line or combination of lines would need to be derived for each situation. The value of a line will then depend on the requirements, and on the other lines in the array and on how well they complement one another. Storing of lines in purebred form allows full flexibility in their use, and so is preferred.

7. CHOICE OF STOCKS

While the intention would be to store genetic variation which may be useful in the future, it is hard to predict what this may be. Since prediction is uncertain, one course may be to store samples of all available stocks, even if these samples were very small due to limited storage facilities. However, since very large numbers of stocks and substocks could be listed for most species, this approach may be impractical.

More feasible would be to select stocks for conservation. Selection might be on their genetic diversity, as judged by genetic analysis and history (e.g. Kidd 1974). Or it might be on their high overall performance, or on special attributes in performance, including physiological or biological traits, or types, or extremes (Land 1981). It would seem obvious that the lower the genetic similarity and higher the diversity of types and traits among conserved stocks, the greater the probability of finding a gene or a stock, or a combination of stocks, with the set of properties and traits to cover the widest range of conditions possible in the future. Thus, with limited facilities, a choice among stocks based on their diversity would be recommended. This choice would require reliable genetic and performance information on candidate stocks. However, it should be stressed that it is the overall economic performance involving a combination of many traits in the future that is important, rather than extremes for specific traits.

8. SAMPLING

The main aim in sampling will be to get a representative and adequately sized sample of the stock to be conserved. The past breeding history and geographical distribution will need to be considered, so that a representative stratified sample can be collected. Within strata, relationships among sampled individuals should be avoided. In rare stocks, or those liable to contamination, parentage testing and genetic marker tests to ensure purity may be worthwhile.

The number of parents sampled and number of sperm doses or embryos stored will depend on the eventual usage of the stock. If the stock is to be used as a purebred, or as a maternal breed in a crossbreeding programme, inbreeding (leading to inbreeding depression) and loss of genetic variation (leading to lower respones to subsequent selection) should be avoided. A maximum level of inbreeding incurred by the storage process might be set at about 2 percent, equivalent to about 4, generations of inbreeding for many breeds of livestock in practice. The 2 percent would also be the percentage loss in genetic variation in forming the store, due to limited numbers. It would be equivalent to an effective population size in storage of 25, and would be met by 25 unrelated sires with frozen semen, or (conservatively, d = n = 1) by 25 parental pairs with frozen embryos. Thus moderate numbers are likely to be adequate, though these might be increased in practice for a margin of safety. The number of frozen embryos or semen doses to store from each mating or each sire depends on the reproductive success with the frozen material and on the amount of testing, multiplication and additional uses to be made of the conserved stocks.

9. ECONOMIC BENEFITS

Economic benefits from genetic conservation are hard to quantify because future needs and conditions cannot be predicted. However, the benefits from genetic improvement, on a national basis, are large. Further inputs to increase rates of response for current objectives in current stocks show diminishing rates of return and are restricted by the reproductive rate of the species (Smith 1981). By contrast small inputs in conserving stocks, as insurance, for alternative conditions and requirements may yield large returns if these conditions or requirements materialize.

The expected benefit (B) in any year might be expressed by an equation of the form

$$B = P\ (R - R_o) - nC$$

where P is the probability that one of the conserved stock has a performance greatest than for the original stock and so has an economic return R which is higher than the return R from the original stock, and n stocks are stored each at cost C. With frozen germ plasm the costs are likely to be small, so many stocks could be stored. With many stocks stored the probability of getting one stock (or a combination of stocks) better than the original is increased.

10. TESTING

Some information on performance will be available on the stored stocks at time of storage. However, before reuse in new husbandry and marketing conditions, further testing will be needed. These tests may proceed sequentially, starting with small samples of many candidate stored stocks and subsequently testing larger samples of the best stocks. Accurate performance data, relative to the current stocks, are needed for all relevant production traits, and over the range of production systems. The costs of these tests and comparisons are likely to be small relative to any achieved gains on a national scale if a better stock were identified. But any net economic advantage needs to be reliably estimated, else the benefits predicted may not materialize or may turn into losses. However, any substitution of a new stock would probably be gradual, with continuous comparisons of the different stocks until their relative economic value was well established in practice.

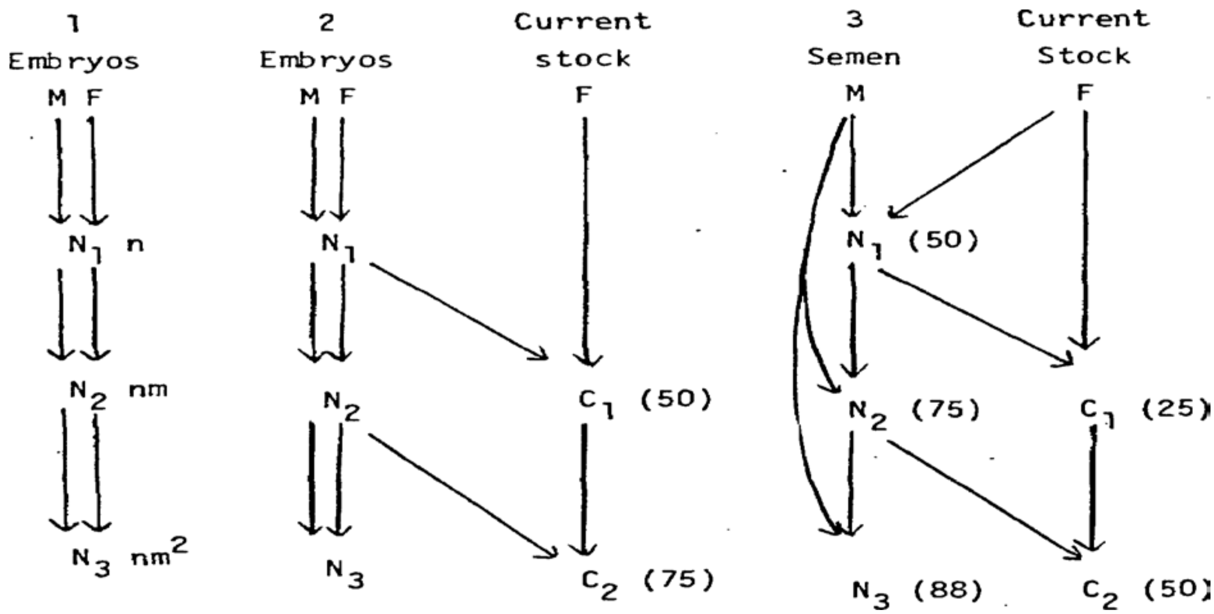
11. SUBSTITUTION

It will take time to substitute one stock for another, or to combine one with another, and to multiply and repopulate for commercial production. Three possible systems are shown in Figure 1. The first shows the multiplication of a pure stock from an embryo store, and its substitution for the current population. The rate of substitution will depend on the number of ova used (2n) and on the reproductive rate (2m) of females, which may be enhanced by embryo transfer techniques. Numbers of females would increase exponentially (n, nm, nm , nm , etc.) over the generations. The second system relies on grading up the current population, while also maintaining and multiplying the pure stock. The third shows grading up from a semen store. The relative rates of improvement by substitution over the generations are graphed in Figure 2A. The generation length might be reduced on the male side in the semen system to speed up the grading up process somewhat.

It is important to consider selection during substitution, for the time spent in substitution could also be spent in selecting the current stock for the new requirements. With no selection during substitution (taking say 4-5 generations to over 95 percent substitution), the new stock would have to exceed the current stock by more than 4-5 times the current genetic response rate in overall economic merit per generation if the substitution is to be worthwhile. In Figure 2A, a superiority of 8 times the generation improvement rate is used. Figure 2B shows the value of selection during the substitution. Selection will be possible in the purebred groups bred from embryo stores, with selected individuals forming the breeding nucleus for the eventual pyramidal breeding structure of the population. A delay of 2 generations for multiplication, followed by normal selection and response in the nucleus group (straight dashed lines) is shown in Figure 2B, with the substituted commercial population eventually lagging by one generation. With frozen semen, selection cannot proceed (on the male side) during grading up, because a fixed panel of sires is involved. Selection should replace grading up when the slope for merit on the substitution line is less than the response slope, as shown in Figure 2B. However, having lost several generations of selection, substitution by frozen semen is likely to lag behind the genetic merit of stocks from embryo stores. The value of maintaining a small pool of frozen embryos to complement the semen store and allow production and multiplication of purebreds, as for frozen embryos, would be large in this case.

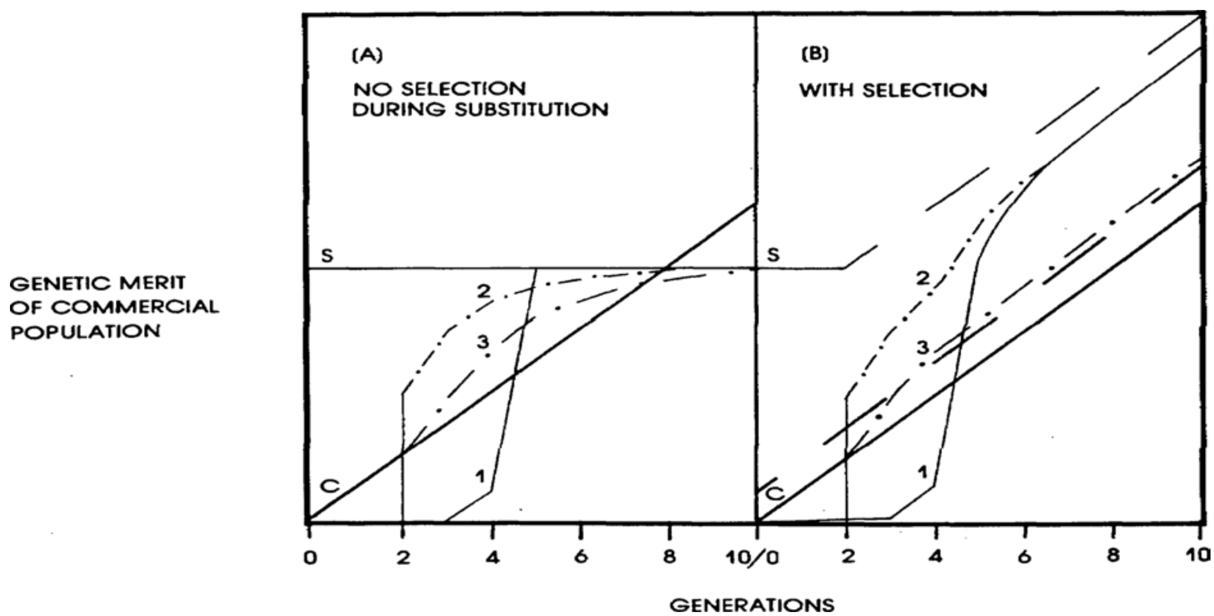
12. DISCUSSION

Intuitively, conservation at first appears a sound investment because once genes or genetic variation are lost they cannot be replaced, except by mutation or by culmulative selection. The idealist might thus advise storage of all genetic stocks since we cannot predict what will be required in the future. Quite small genetic samples (25 sires or matings) of each stock would be sufficient, but with adequate stores for future testing and multiplication. Any stocks or substocks which are closely related or similar to other stocks might be omitted. Further, with some beliefs about requirements in the future, choices among stocks could be made, though these might be mistaken and not worth the costs saved.



Method 1 represents direct substitution by multiplication from embryos (2n), for female reproductive rate (2m). Method 2 is for grading up, while maintaining and selecting a pure bred stock. Method 3 represents grading up from a semen panel. (M are males, F are females, n, nm and nm^2 are the numbers of females and the figures in brackets are the percentages of the genes from the new stock substituted.)

Fig. 1 Three methods of substitution from stored stocks



The merit of the stored stock (S) and its derivatives are shown, relative to genetic improvement in the current stock (C) . Methods 1, 2 and 3 are shown in Figure 1. A is for no selection during substitution, B is with selection. The straight dashed lines show the merit in the nucleus breeding groups in the two pure stocks. The original superiority (S-C) is 8 generations of selection response.

Fig. 2 Diagram of levels of genetic merit on substitution

Three principles in conservation might be proposed: (i) to conserve many stocks in small numbers rather than a few stocks with large stores; (ii) to choose stocks which are as genetically and phenotypically as diverse as possible; and (iii) to store the stocks as pure lines rather than as gene pools so as to allow use of the unique combinations of traits and flexibility in combination of stocks.

Some conservation will occur in farm animals in the normal course of events. There are often health and official barriers to the import and use of stocks from outside. The number of years required for substitution is greater for the larger farm livestock, compared with poultry or plants. There is also usually a greater conservation among livestock breeders and producers (with differences in requirements and locations) tending to restrain, or in some cases prevent, the full substitution process. Further there may be other bodies, such as the Rare Breeds Survival Trust in the UK, which foster the preservation of old breeds. These and smilar factors may do much to reduce the concern about conservation in practice.

Rather large changes in economic requirements or husbandry conditions will be needed to make the conserved stocks competitive. Current stocks are being continuously selected for improved performance. Moreover, many of the traits (such as fertility, survival, number of progeny, efficiency of food use and functional fitness) are likely to always have positive economic value. By contrast stored stocks are not being selected and will not benefit from improvements in these traits. These differences will accumulate over time, making it progressively harder for the stored stocks to compete. A similar result was shown for the efficiency of index selection, where reversals of sign in the economic weights of important traits are needed to reduce the efficiency of selection to zero, or to make it negative (Smith 1983). This suggests that it might be best to store stocks which are currently undesirable in traits which may only have temporary current value (such as market or grading requirements, carcass or product composition, or special behavioural adaptations to current husbandry conditions). An alternative might be to select and develop further such currently undesirable stocks, so that the full range of performance in such economically variable traits would be available in the future. For example, with changing energy costs, future requirements may be for livestock able to produce fat carcasses, as was the requirement in the past century.

Concern about conservation arises from current breeding trends, in the loss of many indigenous breeds and strains, and the possible exhaustion of useful genetic variance or balance with natural selection in selected stocks, leading to selection plateaus. Strategies for introducing genetic variation from improved stocks which have plateaued are presented, with experimental results, by Osman and Robertson (1968). Choices need to be made as to which unimproved stocks to use, on the numbers of generations of mixing before selection, on the percentage mix and on the intensity of selection used. The time taken to reach the original plateau and the further selection response obtained will depend on many of these factors.

However, Hill (1982) has recently suggested that populations of moderate effective size ($N>100$) should be able to sustain indefinitely an appreciable rate of selection response in a quantitative trait, due to the occurrence and continuous selection of favourable mutations at many loci affecting the trait. If correct, as supported by some large long term selection experiments, this would offset much of the value of conserving other stocks to preserve genetic variation.

The value of conservation may be less important in the future with the development of new technologies of molecular biology in genetics, and the possibility of manipulating genes and genetic variation and even of developing new genetic materials. On the other hand it might also be argued that all current stocks should be preserved so that the existing genetic variation can be exploited by these techniques in the future.

Perhaps the most serious concern in conservation at present is the possible imminent loss of locally adapted breeds, with their special behavioural, physiological and disease resistance properties. Conservation of samples from these stocks is important especially in developing countries, since the special genetic systems evolved by natural selection may be crucial to continued animal production in these areas. The preservation of native adapted breeds, and of stocks for special niches or conditions might be the most important role for genetic conservation.

REFERENCES

1983 Brem G., Graf F. and Krausslich H. Genetic and economic differences between alternative methods of gene conservation. Livestock Production Science.

1980 FAO/UNEP. Animal genetic resources conservation and management. Report. FAO. June.

1972 Hill W.G. Estimation of genetic change. I. General theory and design of control populations. Anim. Breed. Absts. 40:1-15.

1982 Hill W.G. Prediction of response to artificial selection from new mutations. Genetical Research (Cambridge) 40:255-278.

1974 Kidd K.K. Biochemical polymorphisms, breed relationships and germ plasm resources in domestic cattle. 1st World Congress of Genetics Applied to Livestock Production. Madrid 1:321-328.

1981 Land R.B. An alternative philosophy for livestock breeding. Livestock Prod. Sci.8:95-100.

1974 Maijala K. Conservation of animal breeds in general. 1st World Congres of Genetics Applied to Livestock Production. Madrid 2:37-46.

1974 Mason I.L. Conservation of animal genetic resources. 1st World Congress of Genetics Applied to Livestock Production. Madrid 2:13-21

1977 Miller R.H. The need for and potential application of germ plasm preservation in cattle. J. Heredity 68:365-374.

1968 Osman H.E.S. and Robertson A. The introduction of genetic materials from inferior to superior strains. Genetical research (Cambridge) 12:221-236.

1976 Smith C. Alternative forms of genetic controls. Anim. Prod. 23:403-412

1977 Smith C. The use of frozen semen and embryos to measure genetic trends in farm livestock. Z. fur Tierzucht u. Zuchtungsbiologie 94:119-130.

1981 Smith C. Levels of investment in testing in the genetic improvement of livestock. Livestock Prod. Sci. 8:193-202.

1983 Smith C. Effects of changes in economic weights on the efficiency of index selection. J. Anim. Sci. 56:1057-1064.

1978 Somes R.G. Registry of poultry genetic stocks. Storrs Agr. Exp. Sta., Univ. of Connecticut, Storrs, USA.

1981 Weller J. and Soller M. Random mating and selection to produce multi-marker strains. Theor. and Applied Genetics 59:73-77.

1977 Whittington D.G., Lyon M. and Glenister P.H. Re-establishment of breeding stocks of mutant and inbred strains of mice from embryos stored at -196^{o} C for prolonged periods. Genetical Research (Cambridge) 30:287-299.

TRYPANOTOLERANT LIVESTOCK NETWORK IN WEST AND CENTRAL AFRICA1

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1. BACKGROUND

The exploitation of genetic resistance to infectious diseases is being given increasing attention in developing countries, where conventional disease control measures are often not effective, do not exist, or cannot be implemented because of lack of finance or trained manpower. However in animal breeding programmes, disease resistance can be only one of many aspects of production that have to be considered. In the vast majority of selection programmes, practical breeders usually select on overall viability, probably the poorest defined character in livestock breeding work. Major problems in making progress from such selection decisions are that the heritability of overall viability is generally low, mainly because of the large environmental variance component. In contrast the heritability of well defined resistance to specific diseases, or of traits correlated to resistance, is likely to be higher than that of overall viability. Controlled challenge conditions would also be expected to increase heritability by reducing environmental variation.

Trypanosomiasis is found over about 10 million square kilometres, or roughly one third of Africa. The disease occurs in nearly every country between the deserts of southern Africa and the Sahara. Approximately 7 million square kilometres of this area are tropical savanna which could support an estimated 125 million additional cattle without environmental stress. Many African livestock producers traditionally brought their herds and flocks into trypanosomiasis areas in search of grazing during the dry season when there were few tsetse flies and moved quickly back to drier areas which were free of disease when the rains began. As populations have increased and grazing land is used for farming, this type of herding system has become less practical and grazing pressure has increased in the drier, disease-free zones.

2. TRYPANOTOLERANT BREEDS

The exploitation of trypanotolerant breeds of cattle such as the N'Dama and West African Shorthorn offers one of the most important approaches to the utilization of tsetse-infested areas in Africa. The ILCA/FAO/UNEP report on trypanotolerant livestock in West and Central Africa (ILCA 1979) emphasized the importance of trypanotolerance by indicating that West African taurine breeds are at least as productive as other indigenous African breeds in areas of low or medium trypanosomiasis risk. In areas of high trypanosomiasis risk, comparative data are not available because only trypano-tolerant breeds can exist. This report illustrated the major effects of level of trypanosomiasis risk for which only rather subjective measurements have been available in the past; and the effect of management and nutrition as indicated by ranch or village production systems. Major interactions exist between breed type; level of trypanosomiasis risk; and other nutritional, physiological, disease and management factors.

Many small scale experiments carried out in West Africa indicate similar dramatic differences between N'Dama and zebu in susceptibility to natural infection when judged by mortality levels and associated prevalence, level and duration of parasitaemia and anaemia. Similarly, evidence is available on the effects of level of challenge on subsequent anaemia. Using animals that had never been previously exposed to trypanosomes, it has been confirmed that N'Dama are significantly more resistant than zebu to experimental challenge with wild caught infected tsetse (Stephen 1966; Roberts and Gray 1973), natural field exposure (Touré *et al.* 1978; Murray *et al.* 1981) and to trypanosomes inoculated by syringe (Murray *et al.* 1977; Saror e*t al.* 1981). The resistance of the West African Shorthorn appears to be intermediate between N'Dama and Zebu (Roberts and Gray 1973).

Further evidence that trypanotolerance has a genetic basis and is not only due to resistance acquired to local trypanosome populations has been provided by the successful establishment of cattle from West Africa in distant tsetse-infested areas of West and Central Africa, e.g. the introduction of Lagune in 1904 and N'Dama in 1920 into Zaire and more recently N'Dama into the Central African Republic, Gabon and Congo (1LCA 1979).

On the basis of this knowledge, N'Dama heifers and bulls are now being imported by several countries in west and central Africa to form the nucleus of livestock development programmes in tsetse-infested areas.

There are now several reports from Kenya and Upper Volta that differences in resistance to trypanosomiasis have been found in certain *Bos indicus* types. However, as the animals in these studies had all been previously exposed to trypanosomiasis, it is not possible to assess the relative contribution of innate and acquired resistance. While critical comparative studies on the differences in susceptibility and productivity remain to be carried out, the degree of genetic resistance in *Bos indicus* types is probably significantly less than in the recognized trypanotolerant breeds.

While there is evidence in cattle that the level of innate resistance to trypanosomiasis can be supplemented by previous exposure, it must be emphasized that trypanotolerance is reduced under certain adverse conditions. In order to realize the full potential of trypanotolerant breeds, it is essential that the main factors affecting the stability of trypanotolerance be identified and the extent of their impact quantified, e.g. it is known that as tsetse challenge increases, the productivity of N'Dama falls (ILCA 1979) as a result of stunting, wasting, abortion and even death. Therefore, the ability to quantify tsetse-trypanosomiasis risk critically is required in order to determine at what level of risk the N'Dama ceases to be productive. Similarly, factors including the stress of overwork, pregnancy, parturition, lactation, suckling, poor nutrition and intercurrent disease have been identified as affecting the susceptibility of cattle to infection with trypanosomes (reviewed by Murray *et al.* 1982).

3. NETWORK OF TRYPANOTOLERANT LIVESTOCK SITUATIONS

Thus, a network of trypanotolerant livestock situations is being built up throughout West and Central Africa. In total cooperation with national research organizations and with the help of a number of donor agencies, ILCA is coordinating in-depth investigations on an eventual ten sites. These cover a range of trypanotolerant and trypanosusceptible livestock breeds under different levels of tsetse-trypanosomiasis risk and different management regimes. Additional work in East Africa by ILRAD and ILCA has led to similar studies being developed on sites in four countries in this region. The technical training and supervision is being provided jointly by ILCA, 1LRAD and ICIPE. By defining the parameters to be measured, through well organized training and supervision it is hoped to standardize the technology being used throughout Africa, in order that the results obtained in different study areas can be critically compared.

3.1 Objectives

The objectives are to evaluate the productivity of different breeds of domestic ruminants living under different levels of tsetse-trypanosomiasis risk, under different management systems, in different ecological zones. These results should allow a critical evaluation of genetic differences in susceptibility to trypanosomiasis between breeds throughout Africa. In addition they should permit critical evaluation of the role played by acquired resistance in field situations and enable between-breed comparisons of the rate at which it develops.

Once the essential baseline data are established and meaningful productivity indices, based on production, economic, health and tsetse data, are computed, it should then be possible: (i) to predict the productive capacity of different breeds of domestic ruminants living under different levels of tsetse-trypanosomiasis risk. This knowledge will lead to more efficient use of different breeds, and, consequently, to increased livestock production; (ii) to evaluate the cost effectiveness and impact of the introduction of current or new methods of control, e.g. the strategic use of chemotherapeutic or chemoprophylactic drugs, tsetse control, trypanotolerance, improvements in management and nutrition and, possibly in the future, immunotherapy and genetic selection.

3.2 Parameters and Techniques in Data Collection

A training manual has been produced jointly with ILRAD and ICIPE (Murray *et al,* 1983), describing the parameters and techniques used in the collection of data in the matching animal health, tsetse-trypanosomiasis risk, and animal productivity areas, and indicating how relevant information is extracted, analysed and interpreted. The manual will be reviewed after 18 months to include additional experience gathered in the field operations and during training sessions.

3.2.1 Animal health

The most reliable indication that a herd is affected by trypanosomiasis is the detection of parasites in the blood and the presence of anaemia. When evaluating the importance of trypanosomiasis in a field situation, it is also essential that other anaemia-producing pathogens are identified. thus, this manual decribes the basic techniques for estimating anaemia, detecting trypanosomes and diagnosing other anaemia-producing diseases.

3.2.2 Animal productivity

The important performance traits are reproductive performance, viability, growth and milk production. These are then amalgamated into suitable indices of overall animal productivity. To allow concurrent evaluation of animal productivity and the prevailing health and tsetse situations requires recording of all animal numbers, dates of parturition, birth, death, sale, movements in or out of herd, etc. and sampling at appropriate intervals, of body weights and milk production. Economic evaluations aim at providing useful information to development project planners and managers on production potentials and cost effectiveness of introduction of improved practices.

3.2.3 Tsetse situation

The collection of essential concurrent data on degrees of risk from tsetse infestations is essential for the appraisal of livestock production and entails general surveys of the location of foci of infestation infringing on the study areas, and the monitoring of seasonal alterations in tsetse density distribution and infection rates.

4. CURRENT NETWORK SITUATION

Approximately ten sites will be involved in in-depth investigations. Sites cover a range of trypanotolerant and trypanosusceptible breeds, under different levels of tsetse-trypanosomiasis risk, under different management regimes. In some sites, attempts are being made to improve the productivity of trypanotolerant breeds by the use of chemotherapeutic or chemoprophylactic drugs. Following staff training in Nairobi, work has commenced in situations in Zaire, Gabon, Nigeria and Ivory Coast. Further sites will include Togo, Benin, The Congo, The Gambia and Senegal.

In Zaire implementation focuses on the N'Dama breed raised both in ranches and "metayage"-village operations under various levels of trypanosomiasis risk. The field operations started in November 1982. Recording is operating at full scale in the ranches and will be operating in the metayages by the end of September 1983.

In Gabon, the ranch of the Office Gabonais d'Amelioration et de Production de Viande at Okouma maintains N'Dama and Nguni cattle and their crosses under two levels of trypanosomiasis risk, with a range of trypanosomiasis control interventions. In October 1982, herds were reorganized, and data collection according to ILCA's protocol commenced.

In Nigeria, the ILCA humid zone programme in 1981 extended its existing production recording with small ruminants to collect matching data on trypanosomiasis risk and incidence. A veterinarian from ILCA Nigeria spent four weeks in April 1982 in specialized training while three further researchers were trained in February and March 1983.

In Nigeria, the ILCA humid zone programme will monitor an importation of Gambian N'Dama cattle in cooperation with the Federal Livestock Department and Western Livestock Company, commencing September 1983. Heifers from low, medium and high trypanosomiasis risk situations in The Gambia are being maintained in low and medium ranching situations in Nigeria, with and without initial prophylaxis.Comparison is also being carried out with progeny of previous importations, born in Nigeria.

In Ivory Coast, during 1981, work on sheep in the SODEPRA Nord operations was extended with ILCA support to cover all the recording requirements in a village situation in the semi-humid savanna around Korhogo. The work is being carried out in collaboration with SODEPRA (Ministry of Animal Production), the Veterinary Laboratory of Korhogo, and a FAO project on tsetse control. A project document has also been presented to GTZ in Germany and the Ministry of Animal Production in Ivory Coast, proposing the extension of the operations to a higher tsetse challenge area and to cover both sheep and cattle (zebu, Baoule, N'Dama). Agreements have now been signed.

Togo and GTZ proposed the extension of the activities of CREAT Avetonou to carry out comprehensive work involving the station cattle and metayage operations enlarged to cover 300 N'Dama females in village herds around the station. ILCA will provide technical advice, training to local scientists and carry out the data analysis. The same recording scheme will also be applied to an ongoing village cattle project funded by Togo and GTZ in the Centre region working with Somba and Borgou cattle. Two Togolese scientists have recently completed the training course in Nairobi.

In Benin, a package of six small livestock development projects has been proposed by FAO for funding by UNDP. Two of them concern the creation and development of a unit of veterinary and animal production research, with an important goal being the study of the trypanotolerant breeds and their potential. The first phase will last three years. The operations will focus on three farms: Samiondji (Lagune), M'Betecoucou (Borgou) and Okpaha (Somba, zebu), together with surrounding village herds. It has been agreed that ILCA will organize necessary training and provide technical supervision and data analysis. The project is currently delayed for lack of funds.

In the Congo, contacts have been established with the Dihesse ranch where N'Dama are raised under low and medium trypanosomiasis risk. Currently arrangements are underway to allow the analysis of production and health data collected on the breeding herds since 1975, through a four month fellowship to a Congo scientist.

In the Gambia, a recent major development in the exploitation of N'Dama cattle is that the Government is establishing an N'Dama Centre with which ILCA and ILRAD will have major links and inputs. The main objectives of this centre are, firstly, to provide channels for marketing and export of stock, and, secondly, to undertake epidemiological studies to evaluate the productivity of N'Dama exposed to different levels of quantified tsetse-trypanosomiasis risk.

Senegal has requested ILCA to organize and support similar research work on Djallonke sheep and N'Dama cattle in Casamance and Senegal Oriental which encompass different ecological zones and tsetse challenges. This proposal has been linked to the request to EEC for the Gambia. The two research projects will therefore constitute an integrated operation.

4.1 Initial Data Analysis

Data covering the initial 12 to 18 months of operations in Gabon, Ivory Coast, Nigeria and Zaire are currently being prepared for analysis. It is anticipated that preliminary interpretation of these analyses will lead to more precise protocols being devised in all situations.

REFERENCES

1979 ILCA. Trypanotolerant livestock in West and Central Africa. Monograph 2. ILCA, Addis Ababa.

1981 Murray M., Clifford D.J., Gettinby G., Snow W.F. and Mclntyre W.l.M. Vet. Rec. 109:503.

1982 Murray M. Morrison W.I. and Whitelaw D.D. Adv. Parasit. Baker J.R. and Muller R. (eds). Vol. 21, p. 1. Academic Press, London and New York.

1983 Murray M., Trail J.C.M., Turner D.A. and Wissocq Y. (eds). Livestock productivity and trypanotolerance: Network training manual. ILCA, Addis Ababa.

1979 Murray P.K., Murray M., Wallace M., Morrison W.I. and Mclntyre W.l.M. ISCTRC.15th Meeting, Banjul, The Gambia. 1977. OAU/STRC No. 110. p. 470.

1973 Roberts C.J. and Gray A.R. Trop. Anim. Hlth. Prod. 5:220.

1981 Saror D.I., Ilemobade A.A. and Nuru S. ISCTRC. 16th Meeting. Yaounde, Cameroon, 1979. OAU/STRC. No. 111. p. 287.

1966 Stephen L.E. Ann. Trop. Med. Parasit. 60:230.

1978 Touré S.M., Gueye A., Seye M., Ba M.A. and Mane A. Rev. Elev. Med. Vet. Pays Trop. 31:293.