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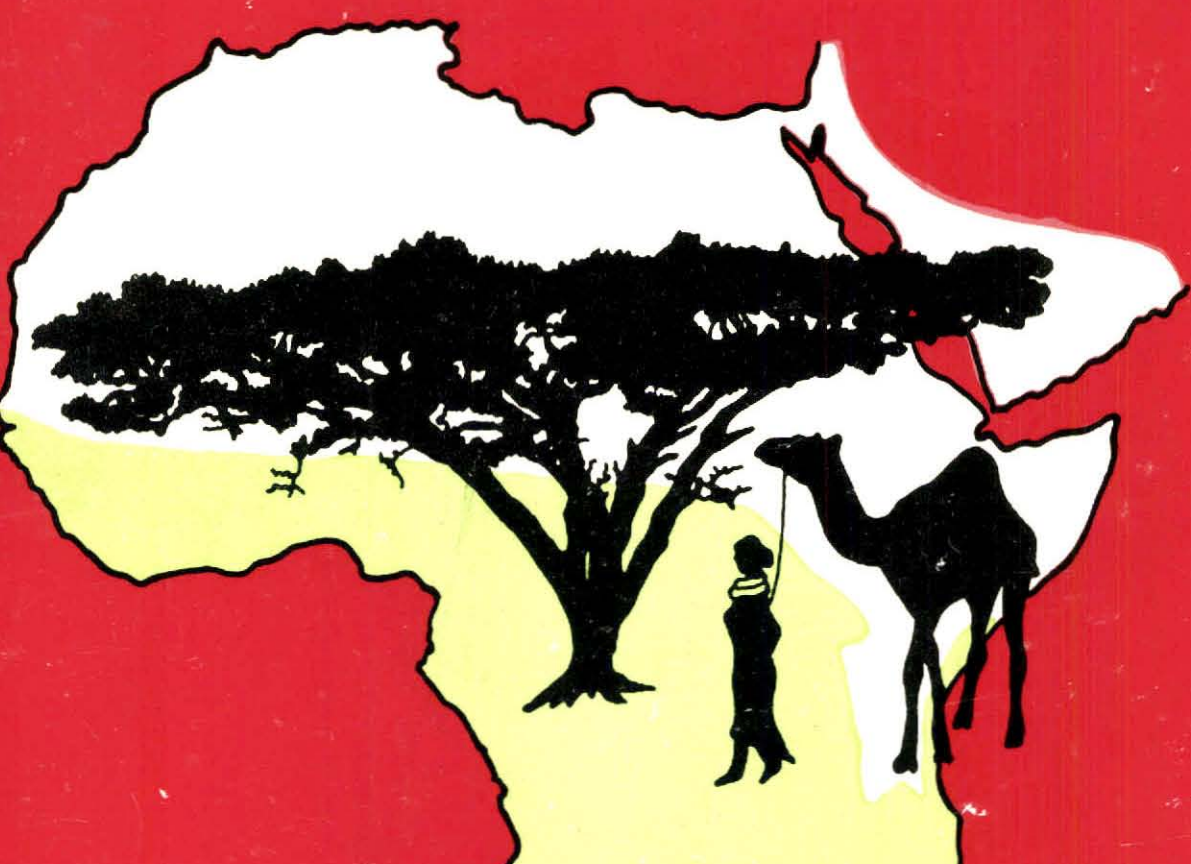
Integrated Project in Arid Lands (IPAL)

Technical Report Number E – 8



Smallstock and Cattle Productivity, Nutrition and Disease in Northern Kenya

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IPAL Technical Report E-8

SMALLSTOCK AND CATTLE PRODUCTIVITY, NUTRITION AND DISEASE IN NORTHERN KENYA

UNESCO-MAB-FRG Integrated Project in Arid Lands

CONTENTS

SUMMARY INTRODUCTION TO IPAL AND THE TECHNICAL REPORT SERIES

The Integrated Project in Arid Lands (IPAL) was established by UNESCO with financial support from UNEP in 1976 with the aim of finding direct solutions to the most urgent environmental problems associated with desert encroachment and ecological degradation of arid lands. It forms part of the international UNESCO programme, Man and the Biosphere (MAB) which has links not only with UNEP's Desertification Unit but also with FAO, in response to the Plan of Action adopted by the 1977 United Nations Conference on Desertification. It is an example of the type of pilot activity that UNESCO and UNEP, together with other organizations and a number of governments, are trying to promote to provide the scientific basis for the rehabilitation and rational management of arid and semi-arid zone ecosystems, through integrated programmes of research (including survey, observation and experimentation), training and demonstration. Phase III of the project, 1980-1983, is supported by funds in trust to UNESCO provided by the Federal Republic of Germany.

During the first phases of IPAL, a co-ordination unit was established in Nairobi and the initial field work started in the arid zone of northern Kenya in a working area of 22,500 km² situated between Lake Turkana and Marsabit Mountain. The project now operates five field stations at Mount Kulal, Olturot, Kargi, Korr and Ngurunit, with the project headquarters in Marsabit which is the administrative centre of the District. Since its establishment the project has researched several aspects of experimental management of the region, concentrating upon 'human ecology' of the nomadic pastoralists in dynamic inter-relationship with the animals, plants and the other resources of a drought-prone, uncertain environment.

During the next three years (1980-1983), the investigations in progress will be extended and intensified to develop resource management plans of models for the area, taking into account the increasing human population, the trend towards sedentarization, the degradation of primary productivity, and the increasing incidence of soil erosion, all of which are factors resulting in the necessity for constant famine relief measures in this region. Results obtained in the project are the subject of a number of training workshops and seminars in which Kenyan and regional scientists from the Sudano-Sahelian region participate.

This report is one of a series published by IPAL describing technical findings of the Project and, where appropriate, giving management recommendations relating to the central problems of ecological degradation in the arid zone. The reports are divided into the following categories distinguished by the base colours of their covers:

A. General, introductory and historical: white

B. Climate and hydrology: blue

C. Geology, geomorphology and soils: brown

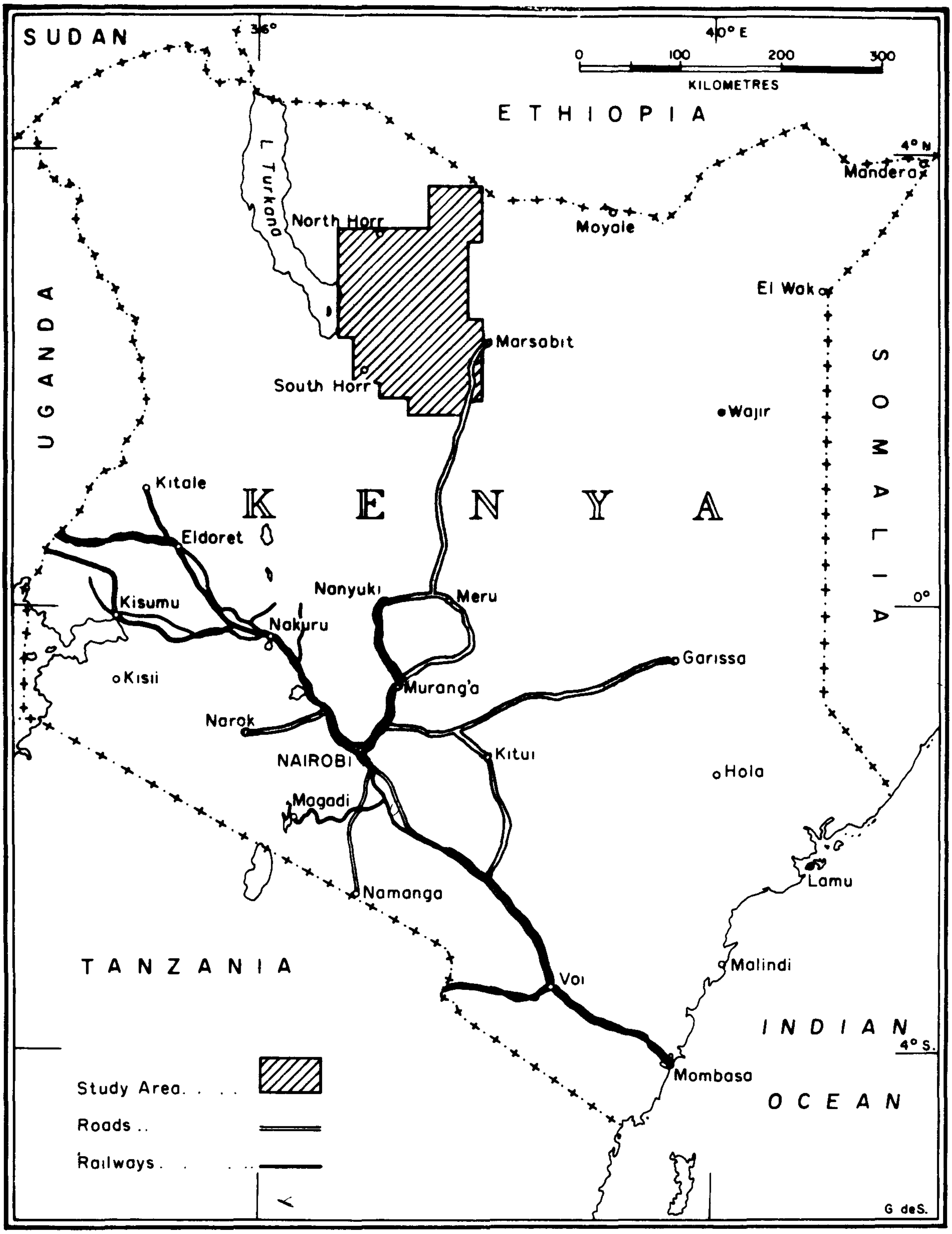
D. Vegetation: green

E. Livestock and other animal life: red

F. Social anthropological: yellow

PART ONE: SMALLSTOCK

Map 1. Location of the IPAL study area



INTRODUCTION

by

C.R. Field

The first three papers in this report concern aspects of sheep and goat ecology and productivity. We refer to these two species collectively as smallstock as they almost always occur in mixed flocks in Marsabit District where these studies were made. We prefer not to use the hackneyed term 'shoat' as on the American continent this refers to a young pig.

There were approximately a quarter of a million smallstock in the IPAL Study Area, which comprises 23,000 km^2 or 30% of the surface area of Marsabit District. There are a third of a million ungulates (both domestic and wild) in the area; therefore, numerically, smallstock comprise about three-quarters of the mammalian herbivores. However, in terms of Tropical Livestock Units (1 TLU is equivalent to a 250 kg cow) they are less than a quarter of the total and are exceeded by both camels and cattle (Field *et al.*, 1981).

The average number of smallstock owned by a Rendille household varies from 67 to 101 depending on whether the data were collected by aerial survey or by ground survey of 150 households (Field and Simpkin, 1984).

The normal ratio of sheep to goats in Rendille flocks is about 1:1.5; thus goats form 60% of the flocks, and in consequence are the most numerous ungulate species in the area.

Although the mean density of smallstock in the area is only 11 km^{-2}, about 40% of the range is not used due to insecurity and/or lack of water or forage (desert). Furthermore, smallstock must drink every three or four days in the dry season and this leads to localized densities well in excess of 100 km^{-2}.

The impact of these high densities is clearly demonstrated in and around permanent water sources and settlements where smallstock not only utilize the vegetation for food but also trample it, leading to extensive 'tracking' to and from water. An indirect effect of localized concentrations of smallstock is the elimination of woody vegetation, in particular *Acacia* thorn trees, for the construction of night enclosures for them.

Studies by Field (1978) and others have shown that both sheep and goats consume all three major categories of plants, i.e. browse, grasses and herbs. However, the proportions vary between the two species of animal, the plant communities, seasons of the year and even from one year to the next depending on the rainfall. Further details are given in the following papers, but broadly speaking sheep are primarily grazers, consuming about two-thirds of their diet as grass and a quarter as browse. Goats, by contrast, consume about three-quarters of their diet as browse, in particular in the form of dwarf shrubs, while herbs are important in the wet seasons. Thus sheep and goats may be regarded as complementary feeders and by herding the two species together a pastoralist may not only pool his limited labour resources, but also exploit the whole range of vegetation components more fully. This does not preclude situations when highly palatable species such as *Indigofera spinosa* and *Acacia tortilis* pods are eaten equally freely by both sheep and goats.

The results of aerial surveys (Field *et al.*, 1981) have revealed a very high density of smallstock, in particular in dry seasons, associated with areas of highest mean annual rainfall, highest elevation, evergreen to semi-deciduous woodland and bushland adjacent to forest and distances less than 5 km from permanent water. In short, shepherds concentrate their flocks at such times in watershed areas. Another area of importance is *Acacia tortilis* riverine woodland.

We have compared the impact and carrying capacities of smallstock and other livestock species in these two plant communities by controlled grazing trials over the past 4-7 years. Preliminary results indicate that the carrying capacity ranges from 7 TLU km^{-2} $year^{-1}$ in the *Acacia tortilis* riverine zone (mean annual rainfall 200 mm) to 60 TLU km^{-2} $year^{-1}$ in the watershed area (mean annual rainfall 700 mm). The impact of smallstock is greater than that of camels at similar stocking rates in the *Acacia tortilis* riverine zone. This is partly attributed to the considerable trampling effect of smallstock which are more active in searching for food. In the watershed area smallstock also trample more than cattle, which, combined with their extensive browsing of woody shrubs, leads to the exposure of more ground to erosion. Nevertheless, their small mouths and mobile lips enable them to select nutrient-rich leaves and leave the stems of perennial grasses, unlike cattle which consume the whole plant. Thus, with the onset of the rains, regrowth is more rapid in the smallstock paddocks than in the cattle paddocks.

Pastoralists keep sheep and goats for different purposes. It is not certain why pastoralists keep more goats than sheep, but one of the main reasons must be the greater value placed on the former due to their higher milk yield. Therefore goats are kept primarily for their milk. The majority of male animals, however, are castrated and when milk is unavailable they are slaughtered for their meat. In times of dire need goats are sometimes bled (such as in the drought of 1984), but this practice is more common among the Turkana peoples.

Goat skins are more valuable than sheep skins: the mid-1985 market price for suspension-dried Grade 1 skins in Marsabit/Samburu Districts being approximately U.S.$1.00 for the former and U.S.$0.75 for the latter.

The yield of milk from sheep is half that from goats under traditional management, although the milk is more concentrated. Thus the yield of energy and protein is more than three-quarters of that from goats' milk (Field and Simpkin, 1984).

While goats are milked twice daily, sheep are traditionally milked only once a day. Partly for this reason sheep grow 15% faster than goats.

Sheep are kept mainly for meat production and are particularly prized for their fat which accumulates in depots in the rump or tail, dewlap and behind the head, as well as around the viscera. Goats have no comparable fat depots. Fat is prized by pastoralists not only for anointing their bodies, but also because it is a rich source of energy to supplement their milk/meat diet which is relatively poor in energy but rich in protein. Indeed, the Turkana are known to sever the fat tail or rump from living sheep, which then deposit further fat in other depots in the body.

Simultaneous studies of the family herds of Rendille pastoralists have revealed that smallstock under traditional management supply 21-26% of their required energy (although, surprisingly, more than three-quarters of this is from meat) and 56% of their required protein in the diet. With good husbandry and a veterinary input these proportions may increase to 25-31% of the required energy and 65% of the required protein in the diet.

Hitherto I have referred largely to smallstock husbandry under the present conditions where recent charges have been detrimental to productivity. After this descriptive phase in our research we entered an experimental phase which forms the subject of the papers in this report. One concerns the monitoring of the effects of disease and its removal, through veterinary intervention, on the productivity of smallstock. The other two papers concern the use of basic flock parameters to model smallstock productivity and the effects of genotype (e.g. body size) and drought (i.e. nutrition) on sheep production.

Under certain conditions a strategic veterinary input would appear to be cost effective. Meanwhile, we are monitoring the performance and productivity of a larger breed of goat (the Somali Galla) which is already producing kids twice the weight of local Galla goats at birth and a higher milk yield. It would appear to be worth carrying out similar studies on a larger breed of sheep. The strategic supplementation of the diet of smallstock at critical periods also requires examination along the lines of a study already carried out on calves using *Acacia tortilis* pods.

Finally, a word of warning is necessary with regard to the interpretation of studies on smallstock carried out over relatively short periods of time. Since the completion of the work reported here, the drought of 1984 had a devastating effect on smallstock flocks, not least because most shepherds deemed it wise to slaughter all kids and lambs at birth in order to provide themselves with more milk and to give the mothers more chance of survival. They believed that young born in an extreme drought had little hope of survival. When the rains came there was a further mortality of weakened animals due to cold-stress and pneumonia. The point here is that smallstock flocks are more vulnerable to catastrophes such as droughts, floods, predation (if left out at night) and disease epidemics than camels, and in some cases, cattle also.

Clearly we have not been able to examine all these effects in the studies presented here. On the other hand, the Project's experimental flocks have been monitored for eight years. During the drought of 1984 we also reduced our flocks drastically (by 75%), through sales (46%), culling (37%) and gifts to schools (17%). In the twelve-month period since then, however, our flock has increased by 64% through natural recruitment. Thus we can see that, given adequate husbandry, smallstock populations have a remarkable capacity for recovery after a disaster.

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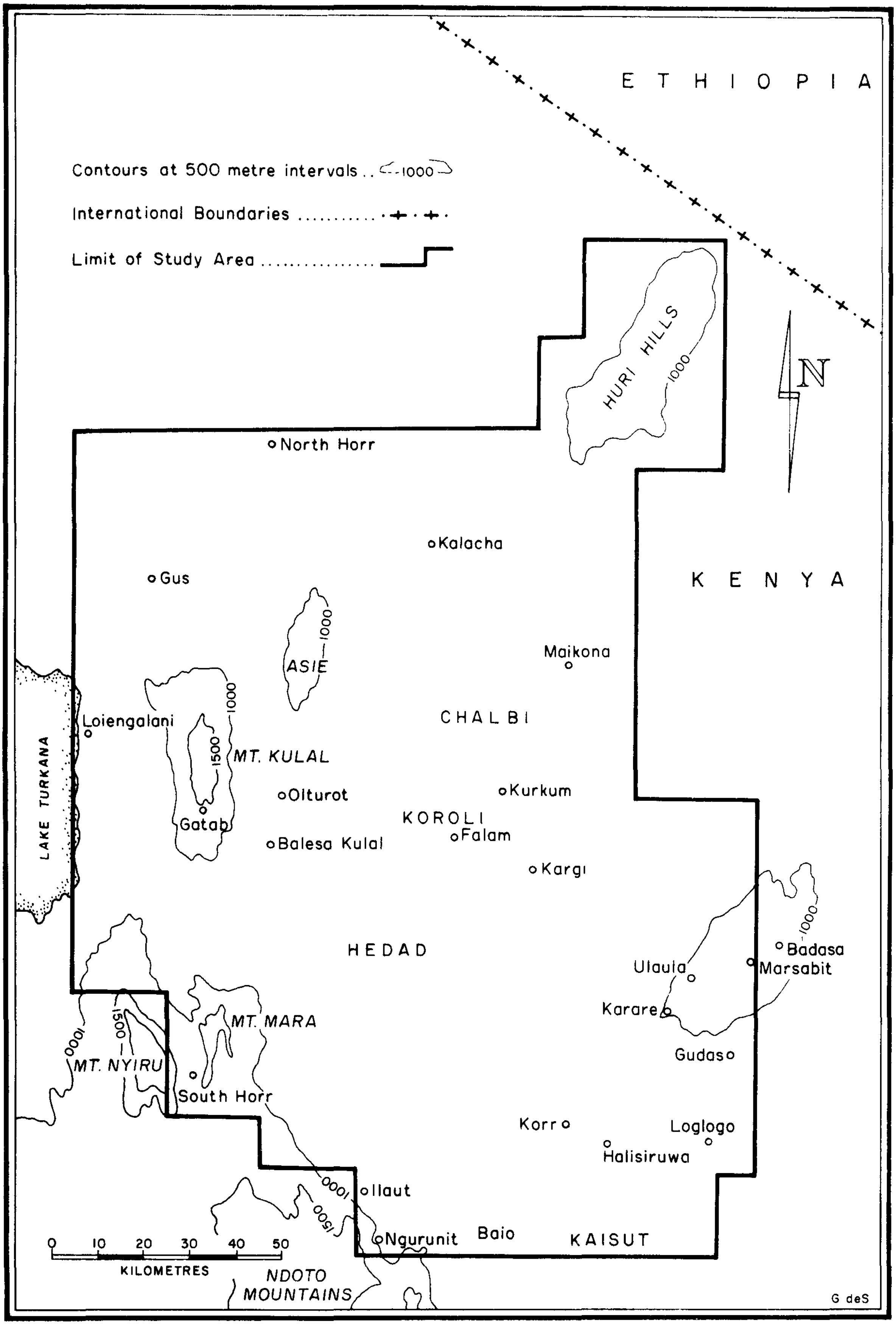
Map 2. The IPAL study area



THE PERFORMANCE OF SOMALI BLACKHEAD SHEEP AND GALLA GOATS IN NORTHERN KENYA

by

H.D. BLACKBURN and C.R. FIELD

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INTRODUCTION

There are few quantitative values for animal performance from the lesser developed countries, especially for their indigenous breeds of small ruminants. Therefore it is difficult to assess correctly the productivity of small ruminants and their relationship to range resources in these countries. In consideration of these problems, the Integrated Project on Arid Lands (IPAL) initiated a study to determine the productivity of sheep and goats in the Marsabit District of northern Kenya.

The study area is typified by its arid environment and transhumant population. It lies within a semi-desert eco-climatic zone between 1^{o} 30' and 4^{o} north of the equator. The primary vegetation areas are annual grasslands, dwarf shrubland and shrubland (Herlocker, 1979). Rainfall is low, highly variable and bimodal in distribution. Annual rainy seasons occur in late March through mid-May and in late October through early December (Edwards *et al.*, 1979).

The Somali Blackhead sheep (SB) and the Galla goat were the breeds of livestock utilized in the study. They are both indigenous to this environment (C.R. Field, 1979). Mason and Maule (1960) described the SB as a fat rumped hair sheep, with a mature weight ranging from 33 to 52 kg. Milk yield ranges from 200 to 300 g per day. The Galla is a tall slender, white goat. Males range in weight from 30 to 50 kg and does from 25 to 30 kg. Milk production was reported to be low (Mason and Maule, 1960). However, there are strains of Galla that are milked and are presumed to have a higher milk production potential.

MATERIAL AND METHODS

The data reported here were collected from late 1978 through 1980. The flock consisted of 14 ewes, 20 does and mature males of each species, which is typical of the sheep to goat ratio used by the nomadic tribesmen. Management of the flock was similar to the manner used by the local populace. That is, sheep and goats were grazed together under the constant supervision of a herdsman. Every night the animals were placed in an enclosure. There was no segregation of sexes which resulted in year round lambing and kidding. Within

24 hours of parturition the lambs and kids were weighed and separated from their dams. After separation they were placed in a small shaded enclosure. The lambs and kids were removed from this pen twice daily and allowed to nurse. While the offspring were suckling their dams, one half of the udder was milked by hand to measure milk production. With sheep this was done once daily, while goats had one side of their udder milked twice daily. Females with twins were not milked. The rationale for this procedure was that this is the traditional manner in which milk is extracted for human consumption. Estimates of total milk production were calculated by multiplying doe production by 2 and ewe production by 4.

The kids and lambs were kept in confinement until they reached a weight of 10 to 15 kg (or 60-90 days old). Once this weight was obtained the kids and lambs were placed in a flock that was grazed separately from the adult flock. A kid or lamb was weaned at approximately 5 months of age, which is the age used by Trail and Sacker (1966) and A.C. Field (1979).

Experimental protocol differed from traditional livestock management by placing the flock on a regular drenching and dipping programme. If other health problems were apparent, the animals were treated. All animals were weighed on a monthly basis.

Monthly analyses of forage consumed by each species were made. The flock was followed in its normal daily grazing area. Approximately 30 animals of each species were observed until each had completed feeding for ten minutes. Species and plant parts consumed were recorded on a time basis to the nearest minute. Food plants were expressed as a percentage of the total feeding time of the animals observed. This follows the method of Buechner (1950). Later, samples of the key food plants comprising approximately 80% of the diet were harvested by hand, according to the species and plant parts eaten, and sent for chemical analysis at the University of Hohenheim, West Germany. Plant samples were analysed (*in vitro*) for crude protein (CP) using the modified Kjeldahl technique and for digestible organic matter (DOM) using the two-stage method and sheep rumen liquor. These data coupled with the percentage of the diet that a particular plant species composed made it possible to determine a weighted average as an estimate of CP and DOM in the diet.

DATA ANALYSIS

Variables which were to be analysed were first tested for normality (Helwig and Council, 1979). The results indicated that the data were normally distributed. Least squares analysis of variance was used to determine sources of variation affecting mature female body weight fluctuations, kid or lamb growth from birth to 300 days of age, and milk production. The model used in analysis of mature female body weight included year and month within year. The analyses of lamb and kid growth utilized a model including type of birth, sex, year and season of birth (wet *vs.* dry). Year and season were the main effects included in the analyses of milk production. All possible interactions involving main effects were tested and found to be non-significant and therefore dropped from the final model. Duncan's new multiple range test was used to separate means (Steel and Torrie, 1960).

RESULTS

FORAGE ANALYSIS

The forages consumed were classified into three categories (Figures 1 and 2): browse, grasses and forbs. In both years the major constituent of the sheep diet was grass, which agrees with Bryant *at al.* (1979) and Warren *et al.* (1981). Browse was the second largest forage group consumed. Browse consumption tended to increase prior to and during the rainy seasons. The consumption of forbs remained at relatively low levels for both years.

The dietary differences between years for goats appears to be much greater than those for sheep. In 1979, the consumption of browse was higher than grasses or forbs. The 1980 diet fluctuated much more from month to month and grasses comprised a larger portion of the diet. The explanation for this yearly difference is probably associated with the fact that 1980 was a drier year.

The nutrient quality of the sheep diets ranged from 39.9 to 64.7% DOM and from 4.7 to 14.5% CP. The mean DOMs were 47.2 and 51.7, and mean CPs were 10.1 and 8.7 for 1979 and 1980, respectively.

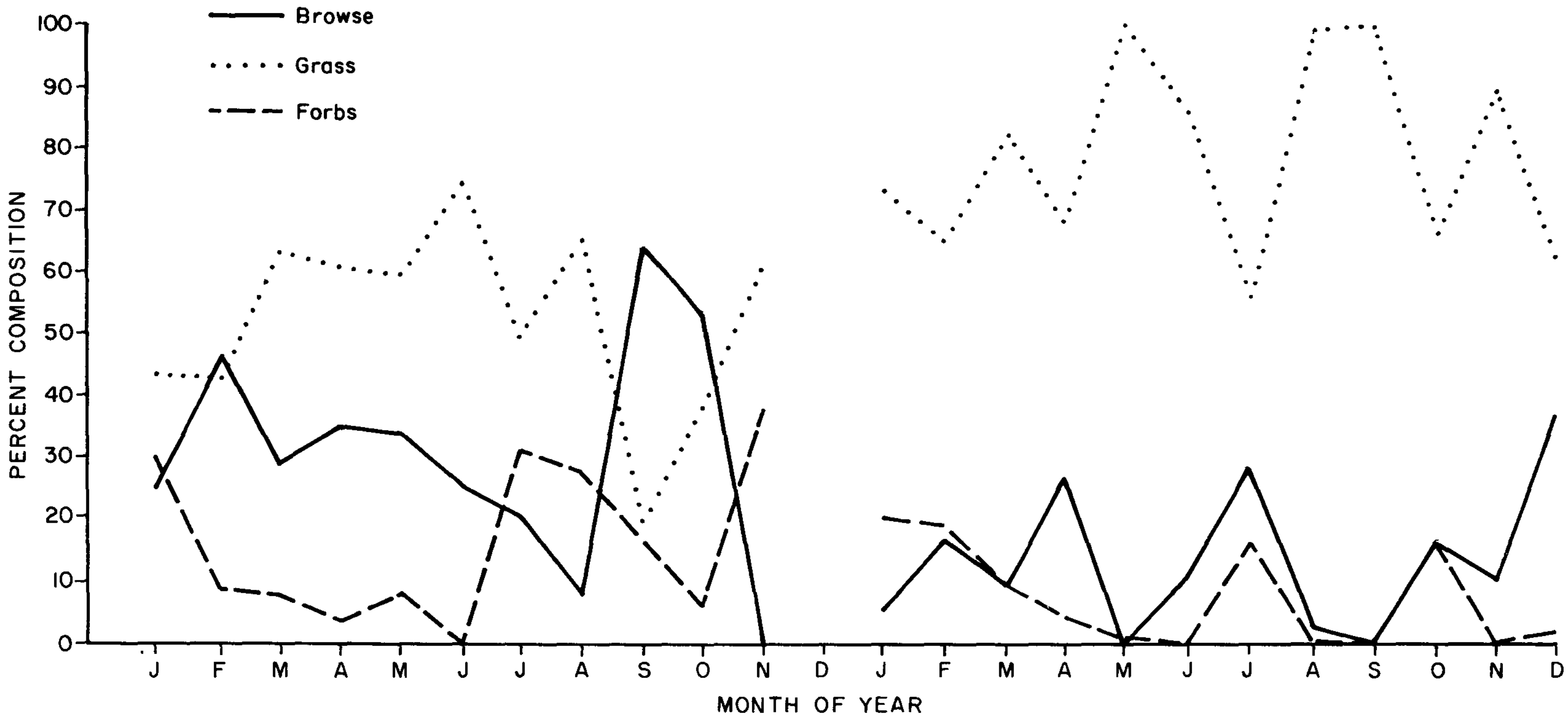


Figure 1. Diet composition of Somali Blackhead sheep for 1979 and 1980

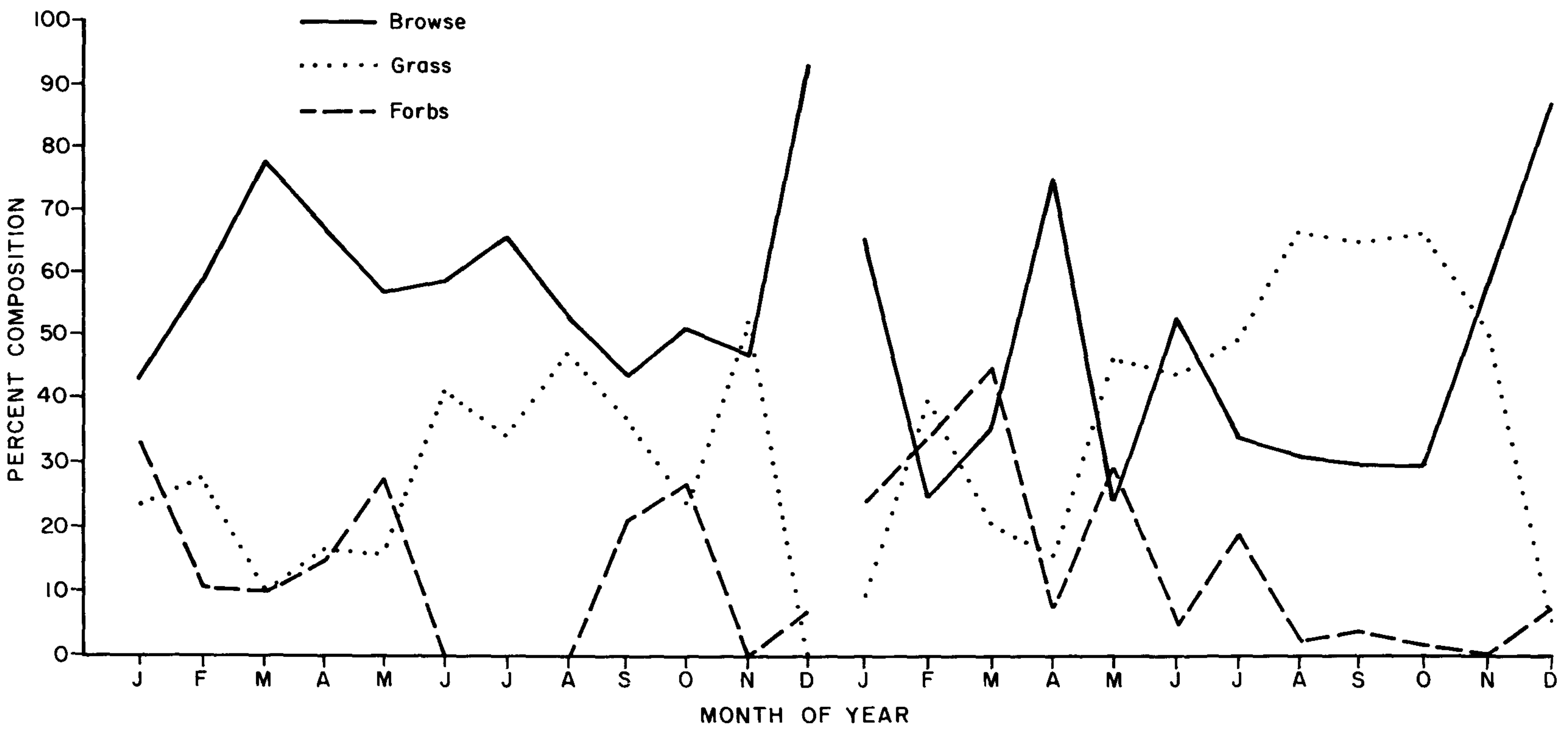


Figure 2. Diet composition of Galla goats for 1979 and 1980

The quality of the goat diets was as follows. The DOM and CP ranged from 39.0 to 54.0%, and from 5.2 to 13.9% for 1979 and 1980, respectively. The mean DOM and CP was 48.4 and 11.0% for 1979 and 46.5 and 8.8% for 1980, respectively. In 1980 the sheep selected diets which were higher in energy than the goat diets. This difference is in agreement with that found by Bryant *et al.* (1980) who felt that their observation was due to the higher levels of lignin in browse species. The higher level of lignin may have been accentuated during 1980 and may explain why the goats' diet shifted to include more grasses during the drier year.

SHEEP PERFORMANCE

Lamb Growth

Least squares means for body weight are shown in Table 1. Lambs born in the dry season tended to be heavier than wet season lambs. They were significantly heavier for 90, 120, 150 and 180 day weights. These differences appear to be due to dry season lambs being born 1 to 2 months prior to the wet season. As mentioned previously, lambs and kids were allowed to graze at 2 to 3 months of age. Therefore, dry season lambs would have access to more abundant, higher quality forage than lambs born in the wet season.

Sex differences were non-significant and smaller than those reported by Sidwell *et al.* (1964), Hohenboken (1977) and Bush and Lewis (1977). Lack of significant differences may be due to the management system which does not allow male lambs to nurse to their full potential.

Year differences were more pronounced than sex or seasonal effects. From 90 to 300 days old lambs born in 1978 were heavier than those born in 1979 and 1980. This difference may be due to the greater amount of precipitation in 1978. In the Balesa/Olturot area which was the main grazing location, annual rainfall totals were 300 mm, 1978; 273 mm, 1979; 173 mm, 1980 (Bake, 1982).

Table 1. Least squares means and standard errors for body weight of Somali lambs, kg

Item	Age in days										
	Birth	30	60	90	120	150	180	210	240	270	300
n	39	32	32	28	28	28	28	27	27	27	24
Season											
Wet	$2.2^{a}\pm0.14$	$5.2^{a}\pm0.25$	$8.1^{a}\pm0.37$	$10.6^{b}\pm0.46$	$13.0^{b}\pm0.55$	$14.5^{b}\pm0.72$	$16.5^{b}\pm0.60$	$17.8^{a}\pm0.65$	$19.2^{a}\pm0.75$	$20.4^{a}\pm0.80$	$21.3^{a}\pm0.81$
Dry	$2.2^{a}\pm0.15$	$5.5^{a}\pm0.39$	$8.3^{a}\pm0.60$	$12.5^{a}\pm0.72$	$15.0^{a}\pm0.87$	$17.0^{a}\pm1.14$	$19.3^{a}\pm0.95$	$20.1^{a}\pm1.04$	$20.5^{a}\pm1.21$	$21.7^{a}\pm1.29$	$22.8^{a}\pm1.43$
Sex											
Male	$2.2^{a}\pm0.13$	$5.2^{a}\pm0.28$	$8.0^{a}\pm0.42$	$11.7^{a}\pm0.57$	$13.9^{a}\pm0.61$	$15.8^{a}\pm0.80$	$18.1^{a}\pm0.67$	$19.9^{a}\pm0.74$	$20.8^{a}\pm0.85$	$21.8^{a}\pm0.91$	$22.4^{a}\pm1.03$
Female	$2.1^{a}\pm0.14$	$5.5^{a}\pm0.35$	$8.4^{a}\pm0.53$	$11.4^{a}\pm0.62$	$14.2^{a}\pm0.75$	$15.7^{a}\pm0.94$	$17.4^{a}\pm0.82$	$17.9^{a}\pm0.89$	$18.9^{a}\pm1.03$	$20.4^{a}\pm1.09$	$21.7^{a}\pm1.11$
Year											
1978	$2.4^{a}\pm0.29$	$5.7^{a}\pm0.62$	$8.7^{a}\pm0.94$	$13.6^{a}\pm1.08$	$17.3^{a}\pm1.30$	$20.2^{a}\pm1.70$	$23.3^{a}\pm1.42$	$24.3^{a}\pm1.54$	$23.9^{a}\pm1.77$	$25.1^{a}\pm1.89$	$26.5^{a}\pm1.93$
1979	$2.3^{a}\pm0.15$	$5.1^{a}\pm0.30$	$7.9^{a}\pm0.45$	$10.5^{b}\pm0.56$	$12.1^{b}\pm0.68$	$12.8^{c}\pm0.89$	$14.5^{c}\pm0.74$	$16.1^{b}\pm0.80$	$17.9^{b}\pm0.93$	$19.3^{b}\pm0.99$	$20.4^{b}\pm1.02$
1980	$2.0^{a}\pm0.13$	$5.3^{a}\pm0.25$	$8.1^{a}\pm0.38$	$10.6^{b}\pm0.50$	$12.8^{b}\pm0.60$	$14.2^{b}\pm0.79$	$15.4^{b}\pm0.66$	$16.5^{b}\pm0.73$	$17.7^{b}\pm0.84$	$18.8^{b}\pm0.90$	$19.3^{b}\pm1.02$

a,b,c Means within the same column of a main effect with different superscripts differ at the $P<0.05$ level.

Ewe Productivity

Significant year effects were found for ewe body weight with heavier animals in 1979 (Table 2), however, no differences for body weight between months, within years, were found. This seems unlikely when the seasonality of forage production is considered. One explanation for this lack of difference may be that as forage production increased, ewes had lambed or were going to lamb. The ewes would then utilize the higher nutritional level to produce milk and replenish body stores depleted during gestation. This would then result in body weight appearing to be relatively constant within a year. Only after prolonged environmental changes would a difference be detectable. Results from the ewe body weight analysis would indicate that this model does not account for a large portion of the variation. This model without other sources of variation (ewe age, and number of lambs/births) had an $r^2 = 0.12$.

Year differences for reproduction rate (per cent of lambs born of ewes exposed for breeding) were significant (130 *vs.* 118.8%). The increased fertility in 1979 was due to more ewes lambing twice in a year and not due to greater prolificacy. This does not necessarily indicate that the Somali Blackhead lacks the inherent ability to produce twins. In 1962, Coop studied the effects of body weight on twinning and concluded that twinning increased linearly with live weight. Our results show a non-significant fluctuation in ewe weight within year. Therefore ewe weights may be remaining at a level which is too low to cause an increase in ovulation rate.

Milk Production

Graphically (Figure 3) the lactation curve and time of peak production (two weeks postpartum) was similar to the results reported by Barnicoat *et al.* (1949), Owen (1957), Munro (1962) and Corbett (1968). Total milk production per lactation was less than the values reported by Butterworth *et al.* (1968), who studied the Persian Blackhead, an improved strain of the Somali Blackhead. Statistical comparisons were only made between years (Table 3). This factor did not influence ($P>0.05$) milk production. The lack of differences may be due to the continued severity of the environment or the sample size not being large enough to detect differences.

Table 2. Least squares means and standard errors of body weights of Somali ewes and Galla does, kg.

Species Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Sheep												
1979	$28.2^{a}\pm1.48$	$31.8^{a}\pm1.40$	$28.6^{a}\pm1.40$	$31.8^{a}\pm1.40$	$28.7^{a}\pm1.40$	$29.2^{a}\pm1.34$	$26.5^{a}\pm1.34$	$29.7^{a}\pm1.34$	$30.2^{a}\pm1.34$	$29.3^{a}\pm1.34$	$27.6^{a}\pm1.34$	$27.5^{a}\pm1.34$
1980	$27.5^{a}\pm1.23$	$26.7^{a}\pm1.19$	$26.4^{a}\pm1.15$	$26.6^{a}\pm1.15$	$27.2^{a}\pm1.15$	$28.1^{a}\pm1.15$	$27.3^{a}\pm1.15$	$25.1^{a}\pm1.11$	________	$26.9^{a}\pm1.11$	$27.3^{a}\pm1.11$	$26.8^{a}\pm1.11$
Goats												
1979	$28.2^{ab}\pm1.28$	$30.3^{ab}\pm1.28$	$28.9^{ab}\pm1.28$	$32.8^{a}\pm1.28$	$31.2^{ab}\pm1.28$	$32.2^{ab}\pm1.28$	$30.0^{ab}\pm1.28$	$32.1^{ab}\pm1.28$	$31.0^{ab}\pm1.28$	$29.3^{ab}\pm1.28$	$28.3^{b}\pm1.28$	$30.8^{ab}\pm1.28$
1980	$33.4^{a}\pm0.99$	$30.9^{ab}\pm0.99$	$30.3^{ab}\pm1.02$	$28.2^{b}\pm1.02$	$30.5^{ab}\pm1.05$	________	$33.2^{a}\pm1.08$	$32.0^{ab}\pm1.02$	________	$32.2^{ab}\pm0.99$	$32.8^{ab}\pm1.02$	$29.1^{ab}\pm1.02$

a,b,
Means within years with different superscripts differ at the $P<0.05$ level.

Figure 3. Daily milk production for Somali Blackhead ewes during 1979 and 1980

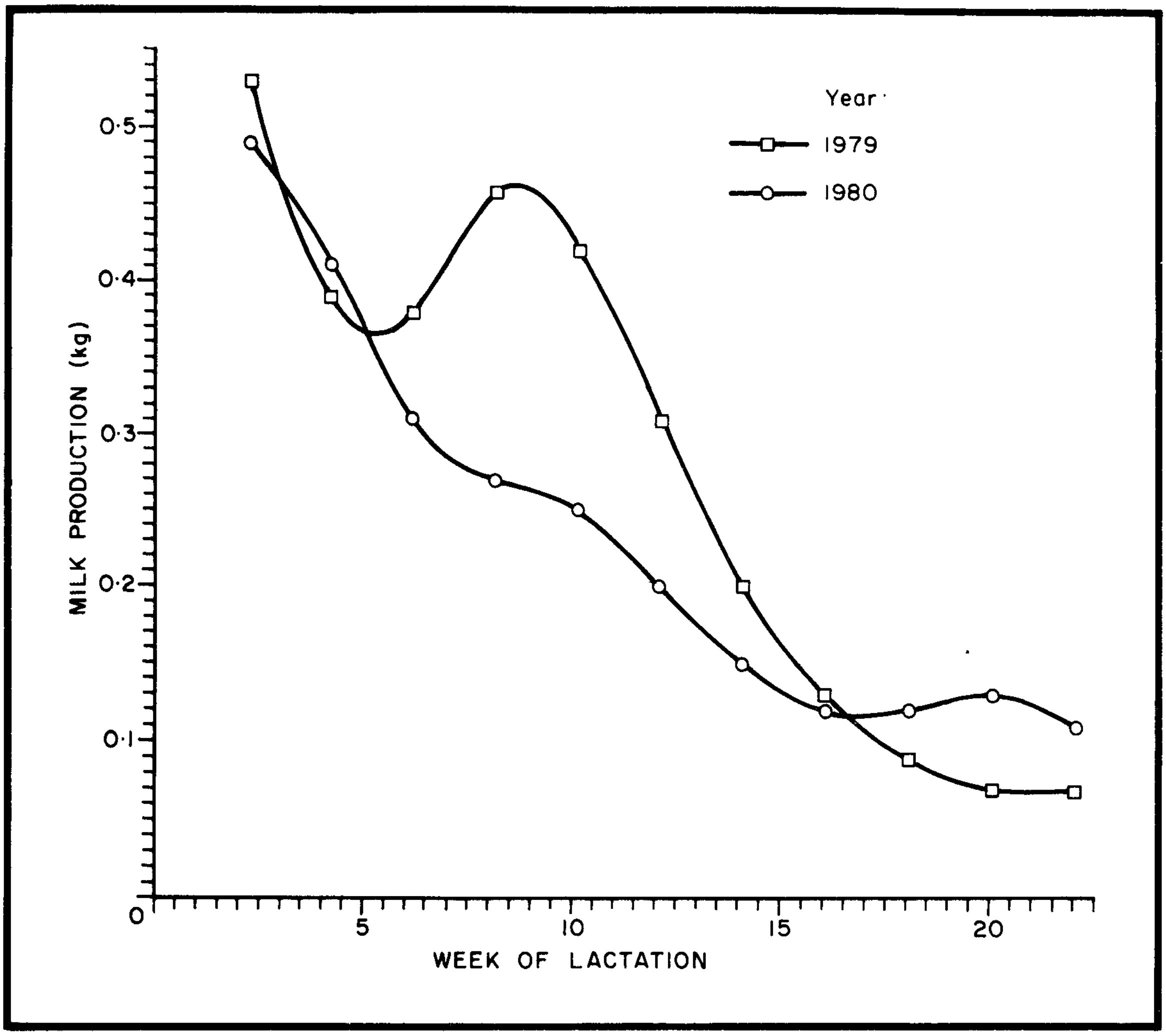


Table 3. Least squares means and standard errors for sheep and goat daily milk production, kg

Item		Weeks of lactation										
		2	4	6	8	10	12	14	16	18	20	22
Sheep	n	9	14	14	14	14	14	14	14	10	9	9
Year	1979	0.53 ±0.08	0.39 ±0.06	0.38±0.07	0.46 ±0.05	0.42 ±0.04	0.31±0.04	0.20±0.03	0.13±0.02	0.09±0.02	0.07±0.01	0.07±0.02
	1980	0.49 ±0.08	0.41 ±0.06	0.31±0.07	0.27 ±0.05	0.25 ±0.04	0.20±0.04	0.15±0.03	0.12±0.02	0.12±0.02	0.13±0.01	0.11±0.02
Goats	n	34	30	34	34	30	30	30	28	22	16	22
Season	Wet	0.39 ±0.04	0.55 ±0.07	0.55±0.07	0.53*±0.06	0.42*±0.03	0.30±0.05	0.28±0.05	0.27±0.04	0.21±0.05	0.19±0.03	0.12±0.02
	Dry	0.41 ±0.05	0.42 ±0.08	0.38±0.08	0.33 ±0.07	0.29 ±0.04	0.37±0.06	0.34±0.06	0.21±0.05	0.33±0.07	______	0.09±0.03
Year	1979	0.49*±0.05	0.65*±0.09	0.52±0.08	0.44 ±0.06	0.33 ±0.04	0.39±0.06	0.36±0.06	0.28±0.05	0.21±0.06	0.19±0.04	0.09±0.03
	1980	0.31 ±0.04	0.33 ±0.07	0.41±0.07	0.42 ±0.06	0.37 ±0.04	0.28±0.05	0.26±0.05	0.20±0.04	0.32±0.07	______	0.12±0.03

* Means within the same column of a main effect differ at the $P<0.05$.

GOAT PERFORMANCE

Kid Growth

Results from the analysis of kid data indicate that their growth patterns are similar in shape but of a lower magnitude than the growth of lambs. Kids born in the wet season tended to be heavier ($P>0.05$) than kids in the dry season. Significant body weight differences between singles and twin births (Table 4) were found for birth weight only. This finding agrees with Ashmawis' (1982) work with Baladi goats in Egypt. Weight differences due to sex were present ($P<0.05$) at 30 and 210 day weights. As with sheep, it is likely that the style of management equalized differences between type of birth and sex. Significant year differences were consistently found. Kids born in 1978 were heavier ($P<0.05$) than those born in subsequent years. Comparison of 1979 and 1980 indicated a 60-day period (120 to 180 days) where kids born in 1980 were heavier ($P<0.05$).

Doe Productivity

The analysis of doe body weight (Table 2) indicated that year differences approached significance ($P<0.10$). Year differences for body weight during August through November may be caused by the quality of the diet. During those months the DOM was higher in 1980. This is a reflection of a shift in diet composition; during this time more grass was consumed. Highly significant differences were found for month nested within year. These differences occurred after several months of a gradual decrease or increase in body weight.

Although there were no weight differences due to year effects, the drier environment appeared to have an influence on reproductive performance. In 1979, the percentage of births per female per year was significantly higher than was in 1980 (117.0 *vs.* 92.0%).

Milk Production

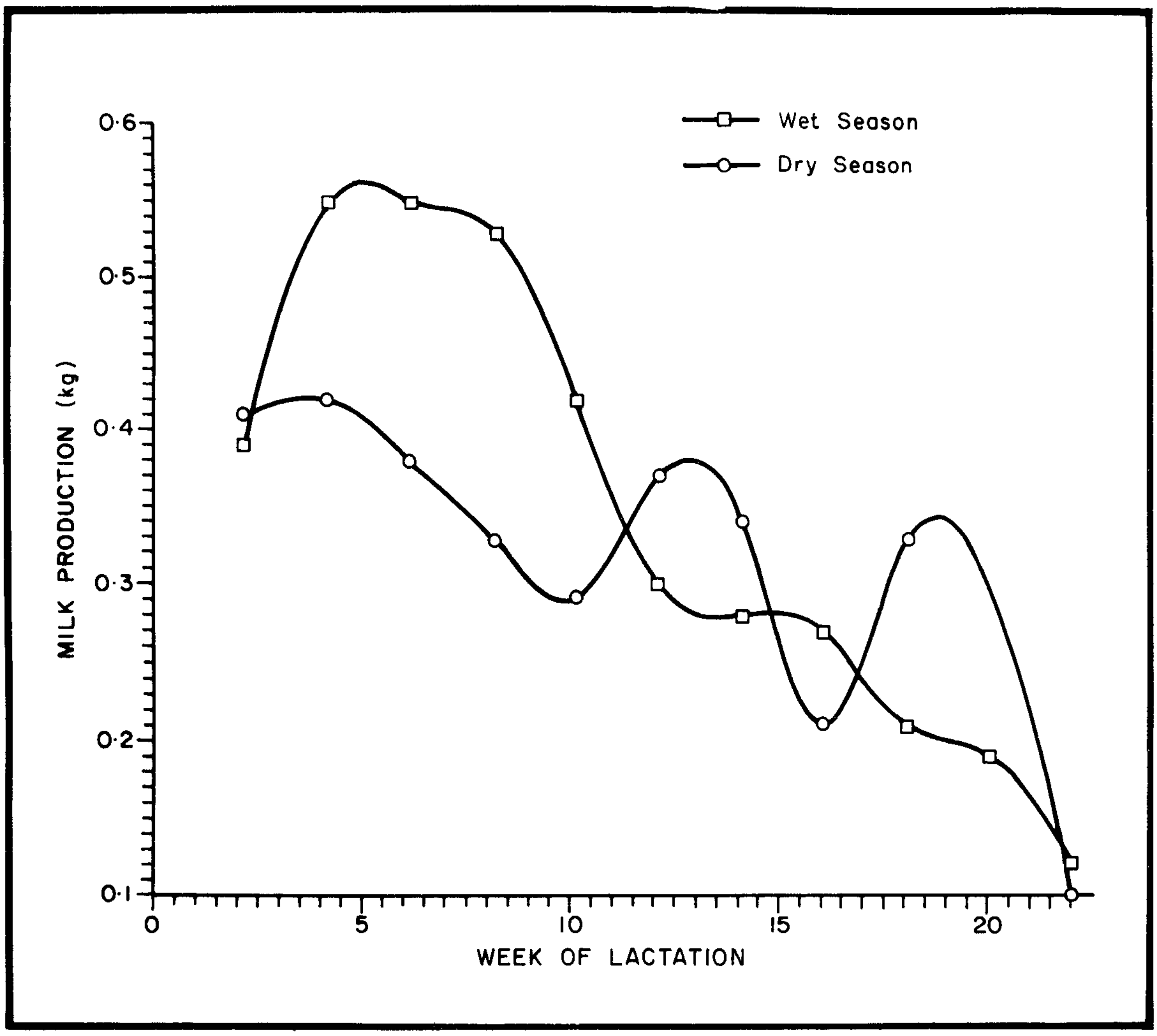
The shapes of the lactation curves can be seen in Figure 4. Milk production peaked at week 4 lactation. The average length of lactation was 154 days. There were no consistent significant trends of one year or season having a higher level of milk production (Table 3). Differences between years were found (P 0.01) for week 2 and 4 of lactation. Seasonal effects were present (P 0.05) during week 8 and 10 of lactation. This result implies that does freshening in the wet season had a higher level of nutrition and were able to sustain a higher level of milk production than does kidding in the dry season.

Table 4. Least square means and standard errors for body weight of Galla goats, kg

Item		Age in days									
	Birth	30	60	90	120	150	180	210	240	270	300
n	33	35	35	34	34	33	32	31	30	26	24
Type of Birth											
Single	$2.3^{a}\pm0.13$	$4.5^{a}\pm0.34$	$7.3^{a}\pm0.37$	$9.0^{a}\pm0.37$	$10.7^{a}\pm0.44$	$11.9^{a}\pm0.47$	$13.2^{a}\pm0.55$	$14.4^{a}\pm0.64$	$15.1^{a}\pm0.81$	$16.7^{a}\pm1.08$	$18.1^{a}\pm0.74$
Twin	$1.8^{b}\pm0.13$	$4.0^{a}\pm0.34$	$6.5^{a}\pm0.37$	$8.1^{a}\pm0.37$	$9.7^{a}\pm0.44$	$11.5^{a}\pm0.47$	$12.8^{a}\pm0.56$	$14.0^{a}\pm0.61$	$15.1^{a}\pm0.78$	$16.6^{a}\pm1.19$	$17.1^{a}\pm0.81$
Sex											
Male	$2.1^{a}\pm0.12$	$4.7^{a}\pm0.32$	$7.2^{a}\pm0.35$	$8.8^{a}\pm0.35$	$10.5^{a}\pm0.42$	$12.0^{a}\pm0.45$	$13.7^{a}\pm0.54$	$15.1^{a}\pm0.59$	$16.0^{a}\pm0.75$	$17.3^{a}\pm0.98$	$18.0^{a}\pm0.68$
Female	$1.9^{a}\pm0.13$	$3.8^{b}\pm0.34$	$6.5^{a}\pm0.37$	$8.3^{a}\pm0.37$	$9.9^{a}\pm0.44$	$11.4^{a}\pm0.47$	$12.3^{a}\pm0.55$	$13.4^{b}\pm0.63$	$14.3^{a}\pm0.79$	$16.0^{a}\pm1.23$	$17.2^{a}\pm0.85$
Year											
78	$2.1^{a}\pm0.19$	$4.4^{a}\pm0.51$	$8.5^{a}\pm0.55$	$10.3^{a}\pm0.55$	$11.8^{a}\pm0.66$	$13.8^{a}\pm0.70$	$15.8^{a}\pm0.81$	$17.3^{a}\pm0.90$	$18.3^{a}\pm1.13$	$19.4^{a}\pm1.33$	$20.3^{a}\pm0.91$
79	$2.0^{a}\pm0.11$	$4.7^{a}\pm0.28$	$6.4^{b}\pm0.31$	$7.6^{b}\pm0.31$	$8.6^{c}\pm0.37$	$9.8^{c}\pm0.39$	$10.6^{b}\pm0.48$	$12.1^{b}\pm0.55$	$13.5^{b}\pm0.70$	$15.9^{b}\pm1.22$	$17.1^{b}\pm0.85$
80	$1.9^{a}\pm0.17$	$3.7^{a}\pm0.45$	$5.7^{b}\pm0.49$	$7.7^{b}\pm0.48$	$10.2^{a}\pm0.57$	$11.4^{b}\pm0.63$	$12.6^{b}\pm0.74$	$13.4^{b}\pm0.81$	$13.5^{b}\pm1.01$	$14.6^{b}\pm1.33$	$15.4^{b}\pm0.91$
Season											
Wet	$2.1^{a}\pm0.10$	$4.8^{a}\pm0.26$	$7.2^{a}\pm0.28$	$9.0^{a}\pm0.28$	$10.7^{a}\pm0.34$	$11.9^{a}\pm0.36$	$13.5^{a}\pm0.42$	$14.8^{a}\pm0.46$	$16.1^{a}\pm0.59$	$16.8^{a}\pm0.68$	$17.7^{a}\pm0.47$
Dry	$2.0^{a}\pm0.17$	$3.7^{a}\pm0.44$	$6.5^{a}\pm0.47$	$8.0^{a}\pm0.47$	$9.7^{a}\pm0.57$	$11.5^{a}\pm0.61$	$12.5^{a}\pm0.72$	$13.7^{a}\pm0.84$	$14.2^{a}\pm1.06$	$16.5^{a}\pm1.78$	$17.5^{a}\pm1.22$

[a, b, c] Means within the same column of a main effect differ at the $P<0.05$ level.

Figure 4. Daily milk production of Galla does in wet and dry seasons



CONCLUSION

The results given in this paper provide information concerning small ruminant production under an existing production situation of northern Kenya. Although this is a first analysis of a single flock it has nevertheless produced useful information. From these data lamb and kid growth patterns were estimated. Year of birth was consistently found to have an influence upon growth. Conversely sex and type of birth seemed to have little influence upon body weight. One possible explanation is that difference in management of the sexes tended to negate the influence of sex on these characters. The literature shows that type of birth has the greatest influence on growth in early life (Olson, Dickerson and Glimp, 1976; Dickerson and Laster, 1975). However the coefficients of determination (R^2), from birth to 90 days of age, for the models used in this study were consistently below 10% for the sheep and 50% for goats. This result is due to unpartitioned sources of variation (e.g. management, age of dam) and a lack of large animal numbers which if present might have made differences more evident.

A similar problem existed in the analysis of mature female body weights. By partitioning year and month within year, approximately 12% of the variation was accounted for. However, several conclusions may be derived from these results. A noticeable difference between years for ewe weight was observed ($P<0.05$). Because the quality of forage was higher in late 1980 than in late 1979 a possible reason for this weight difference might be that availability was limiting. This seems very likely if the amount of precipitation is considered as a cause for decreased forage growth.

Doe weights did not show a distinct difference between years ($P>0.05$). Perhaps they were better able to meet their nutritional needs by having a larger vertical foraging range (20-120 cm as compared with <30 cm for sheep).

The analysis of sheep and goat milk production data indicated that the models for year and year and season accounted for approximately 12% of the total variation. As with body weight, other sources of variation are influencing the productivity of these animals. It is hypothesized that these sources are similar to those previously mentioned. The results from this portion of the study do provide an estimate of milk production in the existing environment for the two breeds involved. From these estimates it would be possible to predict the total milk production of the herd. This would be important in assessing the quantity of milk consumed by humans and the proportion of their nutritional requirements which are being met from the consumption of milk.

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THE LEVELS OF, AND CONSTRAINTS TO, PRODUCTIVITY OF GOATS AND SHEEP AT NGURUNIT AND KORR IN MARSABIT DISTRICT

by

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1. INTRODUCTION

The process of desertification in arid lands, with which IPAL is primarily concerned, is the result of the action and interaction of many components of the arid-land ecosystem. Thus a full understanding of the process, which has been IPAL's primary objective, has required work to clarify the composition and function of a representative arid-land ecosystem. For this purpose a study area was defined in Marsabit District in northern Kenya which includes some of the most arid regions of the country.

There have been many studies on isolated aspects of the performance of goats and sheep on tropical rangelands, but relatively few incorporating all major performance traits simultaneously. As there are interactions between a number of the performance traits, especially with growth, but also between lactation and fertility, as well as others, it is difficult to interpret studies on one trait in isolation. The study described here has the advantage of having incorporated all the major performance parameters and it is hoped that the value of its contribution to understanding an arid-land ecosystem will be enhanced as a result.

Large herbivores are a major component of the arid-land ecosystem and play a major role in the processes of desertification. Surveys of the study area have shown that wildlife comprise only some 3% of the biomass of these herbivores, and that the proportions of the main species of domestic stock are of the order: cattle 40%, camels 36%, and sheep and goats 18% (Field *et al.*, 1981). Within the study area a very significant trend along the aridity gradient is for cattle to decrease with increasing aridity, and in the most arid parts their contribution is negligible. Thus, in the most arid areas, sheep and goats could approach one-third of the herbivore biomass.

The utilization of sheep and goats by the pastoralist is very different to that of camels. The role of the latter is primarily to supply milk and transport. Sheep and goats are the main source of meat and skins for the household, and are the main resource in trade, whether as a commodity for barter or as a source of cash. An analysis of the sales of livestock and skins over a 12-month period amongst the Rendille of the study area revealed that of the total turnover 58% arose from sheep and goats, 42% from cattle and none from camels (Njiru, 1981).

Thus it can be seen that sheep and goats play an important role in the function of such ecosystems, and an understanding of this role will be essential in any understanding of the ecosystems as a whole.

An initial study had been made of the impact of sheep and goats on the vegetation in selected parts of the study area (Field, 1978). A second study was carried out at Olturot in *Acacia tortilis* riverine woodland to describe the production performance of Galla goats and fat-rumped black-headed Somali sheep (Blackburn and Field, this report and in press). To these was added a study intended to describe the overall performance of sheep and goats in terms of the relative contributions of the major performance parameters and of their interactions. Two subsystems were chosen - the first was a wooded dwarf shrubland with a significant amount of bushland at Ngurunit. This is typical of a habitat much favoured by goats. The second environment is principally a dwarf shrubland with much annual grassland and is more typical of the habitats used by the sheep as well as goats.

The study was also intended to identify the major constraints to performance. At an early stage a number of infectious diseases were identified as major constraints and a treatment group was added to the study for which the effects of the most important of these diseases were minimized to reveal more clearly the effects of limited energy and protein. The time schedule for these studies is summarized in Table 1.

Table 1. The schedule of studies on goats and sheep at Ngurunit and Korr

Location	Date	Phase	Activity
Ngurunit	30.7.78	1	Purchases of foundation stock started, and management routines established
	11.3.79	2	Start of 1st comprehensive monitoring period
	25.3.80		Purchase of additional foundation stock for Phase 3. Allocation of stock to traditional and health programme groups according to health status
	3.6.80	3	Start of 2nd comprehensive monitoring period
	23.2.82		Monitoring terminated
Korr	8.80		Purchase of foundation stock started and health status established
	4.11.80		Start of comprehensive monitoring
	9.2.82		Monitoring terminated, excepting lactation
	14.9.82		Last lactation completed

2. MATERIALS AND GENERAL METHODS

2.1. LIVESTOCK SELECTION AND MANAGEMENT

For each of the two study areas (Ngurunit and Korr) the foundation stock were obtained by purchasing animals from within each respective area. The majority of the stock purchased were young females ready to breed and satisfying the following criteria:

1. Presence of one pair of permanent incisors;
2. Body weight not less than 20 kg;
3. Generally healthy disposition.

A few mature bucks were purchased, and a few young castrates, primarily for use with nutritional studies but also providing data for the growth studies. Thus the herd structures (shown in Table 2) were initially very biased towards young breeding females.

The market situation was such that the acquisition of adequate numbers of foundation stock took seven months, and so this stage was designated Phase 1.

The primary objective in Phase 2 was to monitor the levels of the major performance traits under the management system currently practised by the Rendille. To achieve this the purchased animals were allocated to a local pastoralist for him to herd with his own animals. All management decisions were taken by him and he was permitted to consume any milk that he wished to. In return he agreed to all animals being individually indentified, and subjected to various regular measurements. During Phase 2 the only intervention to the Rendille system was the monthly use of an anthelmintic (fenbendazole) for a randomly selected group of females and their offspring.

Table 2. The distribution of goats and sheep in the experimental herds at Ngurunit and Korr according to entry mode, sex, and management group

Location	Species	Entry mode	Sex	Management groups 1	2	3	4	5	6	Totals	
Ngurunit	Goats	Purchase	M	24	-	2	-	1	-	27	
			F	26	13	27	4	17	29	116	143
		Birth	M	52	-	2	44	5	3	106	
			F	49	4	4	40	4	2	103	209
Korr	Goats	Purchase	M			3			1	4	
			F			38			49	87	91
		Birth	M			16			17	33	
			F			14			21	35	68
	Sheep	Purchase	M			4			6	10	
			F			47			50	97	107
		Birth	M			18			22	40	
			F			17			21	38	78
Total				151	17	192	88	27	221		696

Note: The management groups were defined as follows:

Group No.	Phase 2	Phase 3
1.	Traditional	Traditional
2.	Health programme	Traditional
3.	(absent)	Traditional
4.	Health programme	Health programme
5.	Traditional	Health programme
6.	(absent)	Health programme

The parameters monitored and the records taken during Phase 2 are summarized in Table 3.

In Phase 3 a more extensive health programme was devised which was intended to minimize the effects of the major infectious diseases identified in Phase 2, and any possible deficiencies of sodium, chlorine, copper and cobalt. The monitoring of the traditionally managed group was continued. In addition, the whole monitoring programme (for both traditional and health programme groups) was replicated at Korr, where sheep were also added. This enabled the animal performance to be monitored in a very different vegetational type, also representative of a major type in the study area. Another major difference between the two areas is that water is available daily at Ngurunit, whereas at Korr availability varied from daily to every fourth day.

The procedure for establishing and maintaining the groups with the health programme was as follows:

1. All animals were screened serologically for brucellosis and goats for contagious caprine pleuropneumonia (CCPP) - this included both animals from Phase 2 as well as additionally purchased animals. For brucellosis the screening involved two tests with a two-month interval. Only negative reactors were eligible for the health programme group (HPG).
2. All animals selected for the HPGs were vaccinated with Rev I vaccine against brucellosis, and the goats against CCPP with vaccine prepared at Kabete.
3. The HPGs were treated monthly with fenbendazole, as in Phase 2.
4. At Ngurunit a subset of 32 goats was selected at random (from weaners to adults) and the animals were given samorin cover at the rate of 0.5 mg/kg, at three-monthly intervals, to test the possible effects of trypanosomiasis.

Table 3. The performance traits and the records taken

Trait	Records
Fertility	Daily records of all matings, abortions and live births
Mortality	Daily record of all deaths Postmortem examination of as many cases as possible
Serology	Brucellosis and trypanosomiasis (See Section 7)
Strongyle eggs	Faecal levels (See Section 7)
Haematology	(See Section 7)
Growth	Body weights at birth and 14-day intervals, under standard conditions
Lactation	Estimates of total 24-hour yield were obtained every 14 days

Table 4. Rainfall at Ngurunit and Korr during the observation period (mm)

Location	Year	Months												Total
		J	F	M	A	M	J	J	A	S	O	N	D	
Ngurunit	1978									3.7	73.2	140.3	64.4	
	1979	197.1	38.8	92.0	172.0	10.0	5.0	-	0.1	-	51.8	44.1	20.1	631.8
	1980	5.4	-	1.5	78.3	60.7	-	-	2.3	-	-	72.0	-	220.2
	1981	-	-	122.5	220.4	59.8	-	-	0.5	-	5.4	9.8	46.6	465.0
	1982	-	4.4											
Korr	1980								-	-	-	18.9	-	
	1981	-	-	125.2	100.2	2.4	-	1.4	1.3	-	0.3	-	15.2	246.0
	1982	-	-	68.0	44.4	3.5	-	-	-	-	24.6	77.2	78.2	295.9

5. Attempts were made to improve the general level of hygiene by segregating sick animals, herd treatment with long-acting Terramycin if an outbreak of pneumonia was suspected (this occurred on two occasions at Ngurunit), special attention to the hygiene of the night enclosure, and attempting to minimize contact with other herds.

2.2. VEGETATION

Ngurunit is typically a wooded dwarf shrubland, with *Acacia tortilis* and *Duosperma eremophilum* being the dominant species, respectively. It also has a considerable bush component of mixed *Acacia* species. Korr is primarily a dwarf shrubland with annual grassland. *Indigofera spinosa* and *Duosperma eremophilum* are the principal species in this component.

2.3. RAINFALL

The amounts of rainfall experienced during the periods of observation at the two sites are given in Table 4.

3. GROWTH

3.1. OBJECTIVE

The primary objective was to estimate the main parameters of growth, namely mature size, mature age and growth rate, for the herds studied, and to estimate the level of effect of the main sources of variation. With individual animal estimates of these three main parameters it is possible to analyse the sources of variation more precisely than simply treating weight-for-age as the dependent variable and not making any adjustment for preceding growth (Brown, Fitzhugh and Cartwright, 1976).

3.2. ANALYTICAL PROCEDURE

Growth curves for each animal with a minimum of 20 weight records were obtained by estimating the parameters of the decaying exponential curve

$$w_t = W \left(1 - e^{-k(t - t_o)} \right)^x \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where w_t = weight at age t

W = asymptotic weight

K and t_o = constants

t= age of animal from first record of w_t, and

x = an exponent

With respect to the main objectives, it was considered that the first priority was the goodness of fit after the point of inflection, and so for these analyses the exponent was set to 1.0 (Brown, Fitzhugh and Cartwright,1976). An additional advantage of this equation is that calendar ages are not required for estimating W and k, only time differences between weight records, thus data from purchased animals of unknown birth date can be used, and are particularly suitable for estimates of W.

A number of very useful derivatives are obtainable from this equation:

1. Mature size is normally considered to be 0.98 W.
2. 1/k is a measure of the maturing time, so high values of k indicate younger ages at maturity, and vice versa.
3. Growth rates from t_o to any proportion (p) of W are obtained from equation (2), where l_n is the natural logarithm.

$$\text{Growth rate} = K\,w\,\frac{p}{-l_n\;(1 - p^x)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

in the units of k and W.

4. The age (t) at any proportion (p) of W is obtained from equation (3).

$$t = t_o - {}^1/k\;(l_n\;(1 - p^{\,x}))\ \ldots\ldots\ldots\ldots\ldots(3)$$

It should be noted that the value of k is dependent upon the section of the growth curve to which it relates. Thus, as the age at which weight observations are initiated increases (e.g. for purchased animals), so does the value of k.

The procedure used for estimating these parameters for each animal has been described by Carles, King and Heath (1981).

The variance and co-variance of W, k and t_o were analysed using the methods for non-orthogonal data, and the computer programme of Seebeck (1975).

The sources of variation that were examined were species (goats and sheep), sex (male and female), place (Ngurunit and Korr), management system (traditional and health programme - the samorin-treated subset was nested within the health programme), mode of entry (purchased or born), entry phase (phase 2 and phase 3), season of birth (0-8 weeks, 9-16 weeks and over 16 weeks after a rainy period), rainfall level during the period of birth, and from 4-6 months, and 7-9 months of age (three covariates).

For the analysis of season of birth a rainy period was defined as three consecutive fortnightly periods each receiving measurable rainfall, with the first period exceeding 9 mm. This definition arose from vegetational studies in the area that had shown such a rainfall regime produces a consistent vegetational response. The period of birth extended from one rainy period to the next.

3.3. RESULTS

The results of these analyses are presented in Tables 5, 6, 7 and 8. These tables give the estimates of the levels of effect of the different sources of variation that were found to be significant in the analyses of variance. For each factor the estimate given has been adjusted for all other effects. It was not found feasible to analyse the growth of the purchased goats at Ngurunit together with those that were born on the project due to the variances not being homogenous, and so these were separated. The analysis of the purchased animals at Ngurunit was confined to the asymptotic weight as the value of k is dependent upon the section of the growth curve from which the data are obtained, progressively increasing the later the stage of growth. For the purchased animals the point on the growth curve from which weight records began was not determinable and so it would not have been possible to interpret the estimates of k.

3.3.1. Species

The estimates of the mature size for goats is within the ranges reported for the Small East African Goat (Wilson, 1982). However the sheep are rather smaller which is consistent with the findings of Blackburn and Field (1982) from a mixed flock in another part of the study area. The indications from Wilson's studies (1982) were that in eastern Africa there is not much difference, although the results reported from the IPAL study area are probably more precise.

Table 5. Least squares means of asymptotic weight (W), the coefficient (k) and t_o for goats born at Ngurunit

Trait	Asymptotic weight (W)	Coefficient (k)
Number	39	39
Adjusted general mean	38.2 kg	0.00987
Sex Male	43.21[a] kg	0.01009
Female	33.19[b] kg	0.00965
Entry phase 2	25.80[a] kg	0.01556[a]
3	50.60[d] kg	0.00418[d]
Season of birth 1	34.16 kg	0.01135
2	45.93 kg	0.00655
	34.52 kg	0.01171
Rainfall 4-6 months x management group 1	-1.426[a] cm^{-1}	0.000572[a] cm^{-1}
2	0.414[c] cm^{-1}	-0.000058[c] cm^{-1}
3	-0.644[b] cm^{-1}	0.000113[d] cm^{-1}
Rainfall 7-9 months	-0.774*** cm^{-1}	0.000275*** cm^{-1}
t_o = - 5.80 weeks		

Notes:

1. Means within a subgroup having superscripts differ at the following levels of P: a-b, b-c, c-d, $P<0.05$; a-c $P<0.01$; a-d $P<0.005$ ***$P<0.005$.

2. Season of birth: 1= 0 - 8, 2 = 9 - 16, 3 = >16 weeks after a rainy period

3. Management group: 1 = health programme from birth
   2 = health programme from about 1 year
   3 = no health programme

Table 6. Least squares means of asymptotic weight (W, kg) for goats purchased at Ngurunit

Trait		Asymptotic weight (W)
Number		125
Adjusted general mean		41.25 kg
Sex	Male	48.42^{a} kg
	Female	34.08^{d} kg
Entry group	1	31.34^{a} kg
	2	52.77^{c} kg
	3	39.64^{d} kg
Rainfall in entry group		-0.453*** cm^{-1}

Note: Means within subgroups differ at the following level of P: c-d $P<0.05$; a-c $P<0.01$; a-d $P<0.005$; ***$P<0.005$

Table 7. Least squares means of asymptotic weight (W), the coefficient (k) and t_o for goats and sheep at Korr

Trait		Asymptotic weight (W)	Coefficient (k)
Number		155	155
Adjusted general mean		28.32 kg	0.04356
Species	Goats	29.51[a] kg	0.03794[a]
	Sheep	27.13[d] kg	0.04918[b]
Sex	Male	31.51[a] kg	0.04170
	Female	25.13[d] kg	0.04542
Entry mode	Purchase	32.88[a] kg	0.04469
	Birth	23.76[d]	0.04243
Management system			
	Traditional	28.90 kg	0.03915[a]
	Health programme	27.74 kg	0.04797[b]
t_o (for goats and sheep born on the project) =			-1.48 weeks

Note: Means within a subgroup having superscripts differ at the following levels of P: a-b, b-c, c-d $P<0.05$; a-c, b-d $P<0.01$; a-d $P<0.005$

Table 8. Growth rate (g d^{-1}) from t_o to various proportions of asymptotic weight (W) for goats and sheep

Trait		Ngurunit		Korr	
		0.25 W	0.75 W	0.25 W	0.75 W
Species	Goats	47	29	104	71
	Sheep	-	-	135	84
Sex	Male	54	34	136	84
	Female	40	25	113	70
Entry phase	2	50	31		
	3	26	16		
Season of birth	1	48	30		
	2	37	23		
	3	50	31		
Management system					
	Traditional	Dependent on rainfall		115	72
	Health programme			135	84

Note: 1. Growth rates were derived from the parameters of the growth curve.

2. 0.25 W is approximately equivalent to weaning, and 0.75 W is a fairly common stage of growth for slaughter.

Reports on the maturing time of sheep and goats in the tropics are very meagre but it is interesting to find that the sheep is earlier maturing than the goat, and that the combination of these two effects (W and k) has given the sheep a faster growth rate (Table 8).

It is important to know the relative contribution of the genotype and the environment to these phenotypic traits, i.e. the extent to which the observed levels are indicative of the genetic potential or of environmental stress.

Unfortunately the data are inadequate for such an analysis. However, while it is possible that an interaction of environmental factors has produced this effect, it would seem more likely that these differences are primarily of genetic origin, and that in this environment the sheep are smaller, earlier maturing, and have higher growth rates than the goats. This agrees with the findings of Wilson (1982) and Blackburn and Field (1982) on growth rates in mixed herds of sheep and goats. However, these workers limited the period of their studies to 150 and 300 days, respectively: at these ages the sheep were larger, but this does not preclude a reversal at a later stage of growth. The importance of this would depend upon the stage at which each species becomes productive, i.e. for slaughter or reproduction.

Interactions of the management systems and entry mode with species were tested within the model used, for analysing the Korr data, but neither were found significant. This indicates that both species responded similarly to these environmental effects. (The entry mode would have been testing for differences between periods of birth - the purchases having been born some two years earlier, and would have included other management systems as well.)

3.3.2. Location

The estimates for goats at Korr need to be adjusted to animals born on the project before comparison with estimates from Ngurunit (this gives 24.95 for W, and 0.03681 for k). It is clear that the goats observed at Korr were smaller, earlier maturing and faster growing than those at Ngurunit.

This is the first of several instances in this report where the comparison of the level of a trait between Korr and Ngurunit indicates a higher rate of turnover at the former. Due to the movement of livestock for social reasons it is almost certain that differences in genotype are small and so phenotypic differences would be primarily of environmental origin. Superficially this seems strange, as the rainfall is considerably higher at Ngurunit, but there could well be some unidentified stress restricting performance at Ngurunit. It must also be remembered that the Korr sample of observations came from a very limited period. At present the evidence is inadequate to throw further light on this.

3.3.3. Entry mode

Both at Korr and at Ngurunit the animals purchased as foundation stock were larger than subsequent animals. As the selection of the foundation stock was definitely, and intentionally, biased this is not surprising.

3.3.4. Sex

The sex differences are rather less marked than under more favourable conditions where the mature size of males is usually of the order of 1.5 times that of females. The purchased animals at Ngurunit approached this (1.4), but the others were of the order of 1.3. This may reflect the degree of stunting experienced by the animals born at Ngurunit, and those at Korr.

3.3.5 Entry phase

There was certainly a marked difference in mature size and maturing time between the goats born in the different phases at Ngurunit. The seasonal rainfall preceding and during the latter period was less than that in the former. There would have been many other systematic differences between these two periods as well, and this result is probably a combined effect of several.

3.3.6 Season of birth

Although the differences between the three seasons were not significant in the model finally selected, the season mean square was consistently on the border-line of significance for most models, and so its inclusion was considered warranted. Birth during the period well separated from the previous or the succeeding rainy period was associated with slow growth and finally giving a larger late-maturing animal. Perhaps of equal interest is the fact that birth just following or just preceding a rainy period appears to result in a similar pattern of growth, suggesting considerable flexibility of the young animal in responding to vegetational change, at least within this time-scale. However, some caution is needed here as the sample was small and all the observations for the intermediate period occurred in Phase 2.

Despite the growth data from Korr having been collected over a period of 15 months, data from birth were too restricted to permit analysis of season or period of birth effects, or of the various rainfall levels that were examined at Ngurunit.

3.3.7 Management systems

Those animals experiencing the health programme fell into two groups - those receiving it from birth, and those that started at about a year of age. The latter group comprised Ngurunit animals that were born in Phase 2 within the traditional management system and were allocated to the health programme group for Phase 3, and all purchased animals receiving the health programme.

The components of the health programme to which growth is most likely to respond are almost certainly confined to the anthelmintic measures and mineral supplementation, and principally the former.

At both Ngurunit and Korr the animals whose growth rate (k) responded most to the health programme were those experiencing it from birth as compared to those that started at about a year of age. This would be expected, and is certainly a combination of time for response and the greater susceptibility to stress of the very young (and hence the greater potential for response when the stress is alleviated).

At Korr the health programme led to an increase in growth rate and a shortening of maturing time, causing reductions of some 10% in the mature age and 4% in mature size. All these levels of change are sufficient to be important for productivity, and it is perhaps surprising that helminths are having this effect in such an arid environment. However, the evidence from the strongyle egg levels in faeces (Section 7) certainly supports this.

At Ngurunit the response to the health programme was dependent upon the level of rainfall between 4 and 6 months of age, and so will be considered in conjunction with rainfall effects.

There was no evidence that the Samorin treatment produced a significant response.

3.3.8 Rainfall

Three types of rainfall effects were analysed. The first was the level during the period in which the animal was born. The other two were levels post-weaning. There was no evidence that variation of the total rainfall during the period of birth (almost entirely confined to the very beginning of the period) produced significant variation in growth. This indicated that the relation between birth and rainfall (as analysed by season of birth) was of greater importance.

The effect of rainfall variation post-weaning was examined for two stages, from 4 to 6 months of age (immediately post-weaning), and from 7 to 9 months. Increasing rainfall during this latter period, and also during 4 - 6 months of age under traditional management, increased growth rates which again were associated with earlier maturity and smaller mature size. However, during the 4 - 6 months period it depended very much on the health programme. For those animals experiencing the health programme the response was similar to that outlined for the 7 - 9 months period, but much more marked, whereas if the management system was traditional then growth was prolonged, with an increase in mature size and age. Growth curves have been constructed to describe these responses, and these are shown in Figure 1. To present the effects of variation on the rainfall level, estimates of W and k were obtained for typical dry and wet periods (during 4 - 6 months of age), for each management system, from the coefficients given in Table 5. The levels chosen as typical were based upon an examination of the levels that occurred for these observations and were 7.5 cm above and below the mean for wet and dry periods, respectively. The end point of each growth curve is at 0.98 W, which is normally considered as the mature size. It will be seen that the ages which correspond to these are mostly in the range of 360 - 428 weeks with the two outside this range representing the curves of the two situations from the most marked interaction. The mature ages for all but the highest are considered to be realistic. The highest must be a considerable over-estimate. It is probable that in this more extreme region the relation with rainfall is curvilinear, which would have adjusted this over-estimate, whereas the final model only included a linear term. A curvilinear term had been included as a quadratic, but was finally omitted as it was not significant. It is possible the relation is indeed curvilinear, but happens to have been masked in this instance.

This situation appears rather anomalous. The prolongation of the period of growth would be similar to the normal type of compensatory growth. The other two are not consistent with compensatory growth although are following the pattern of several other responses where faster growth rates are associated with earlier maturity.

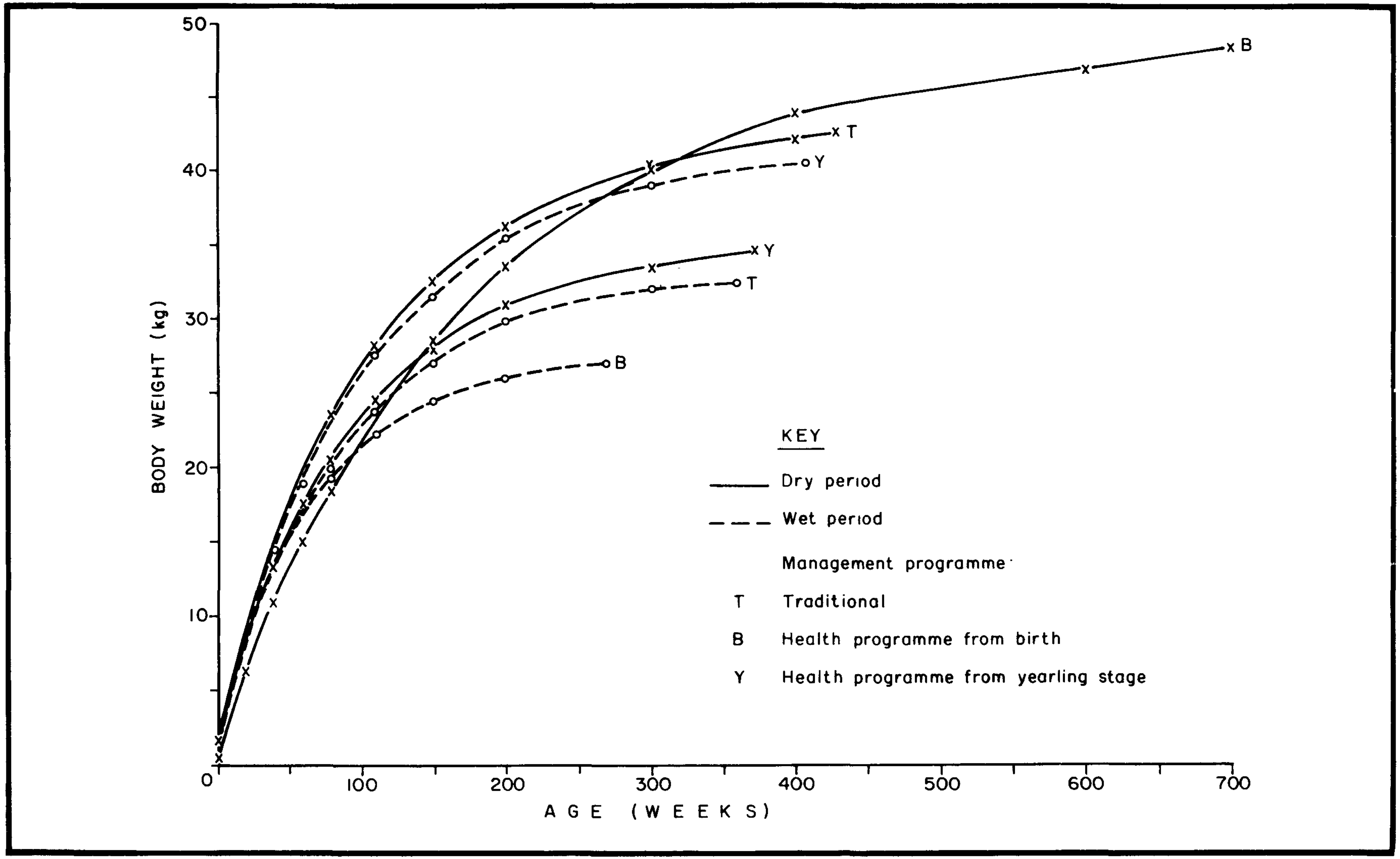


Figure 1. The effect of a dry period or a wet period at 4 - 6 months of age, and management system upon growth to mature size of goats at Ngurunit

It may be that this variation is dependent upon the extent to which, and the stage of growth at which, stress is alleviated. If the extent is large, the rapid growth that follows may trigger the onset of puberty, which in turn hastens maturity at a smaller size, whereas if the alleviation is much less then puberty is not triggered, growth is prolonged and a much larger mature size is attained. Somewhat similar patterns of growth have been observed in Texas with beef crossbred heifers suckling dairy-type dams, when puberty is hastened, and conversely with Hereford heifers on poor rangeland where puberty is delayed and large mature sizes are attained (Cartwright, personal communication).

The situation is undoubtedly further complicated by the very marked stunting that occurs during the first 6 weeks of life. In order to maximize survival the kids and lambs are kept in a small basket, raised off the ground, from birth to about 6 weeks of age. Suckling is only permitted twice a day on return of the dam from pasture in the evening and before going out in the morning. The stunting is so severe that by six weeks the weight has only doubled that at birth. It is highly likely that this also determines to a large extent the subsequent growth pattern.

3.4 CONCLUSIONS

In most cases the response to some alleviation of stress was the expected increased growth rate, but associated with a hastening of maturity and a smaller mature size: only one exception to this was observed (kids born during a dry period and receiving the health programme).

There were definite differences between the species at Korr, but no evidence of species differences in growth responses to the environment.

It appears that the Ngurunit herd had slower growth rates than the herd at Korr, contrary to expectations. It should be established whether this is typical of Ngurunit herds, or was due to some aspect of the management of this particular herd. If the former proves to be the case it suggests that there is some unidentified factor seriously limiting performance at Ngurunit below the potential of the energy and protein available.

It appears that the relation of the time of birth to a rainy period, both preceding and succeeding, has more effect upon growth than the total rainfall level at this time. However, while there is certainly variation here that has potential for exploitation, the feasibility of doing so with the existing management systems is far from clear.

One aspect that stands out is the great variation in growth patterns that has been observed with these data: a slight shift in the balance of only one or two environmental variables can produce a marked change in growth. It is well known from the many studies on compensatory growth that the current growth pattern is dependent on the previous pattern, and so it could be expected that an extreme pattern at an early age (such as the stunting during the first six weeks of life) has marked and long-term lag effects on subsequent growth. Arid environments are marked by extremes, thus almost certainly producing extreme differences in growth and certainly very complex growth patterns.

So these results indicate that the pattern of growth for small ruminants in range areas is a complex interaction between:

- the current stage of growth
- the past pattern of growth
- the levels of stress experienced (noting the great variability of these semi-arid and arid environments)
- the rates of change in the levels of stress.

Thus it is almost certain that the genetic potential of the livestock in this environment has not yet been adequately determined. Also the complexity of the growth patterns will make the interpretation of responses to interventions extremely difficult.

It would be important to establish the pattern of growth that would result if the severe restrictions imposed during the first six weeks of life are removed. But it must be remembered that a major function of lactation is to provide milk for human consumption as well as the kid. The final recommendations must take both of these into consideration.

4. LACTATION

In the analysis of lactation yields all complete lactations were included. This was partly due to the scarcity of information on lactation of the Small East African Goat, and hence grounds for selecting 'normal' lactations were hardly adequate. Also it was considered that the inclusion of all lactations would give a clearer picture of the performance of the herd as a whole. The only lactations excluded were those that began before recording had started, or those that ended after recording was terminated.

4.1 METHODS

4.1.1 Estimation of lactation yield

In the field, records of milk production were made every 14 days over a 48-hour period. Firstly, an evening and morning record was made of the yield (by volume) from one half of the udder, and then this was repeated for the other half. These yields were obtained by hand milking - a process to which the does were well accustomed as it is traditionally practised for obtaining milk for human consumption. The recording was extended over a period of 48 hours in order not to deprive the kid (lamb). The total of these four records was considered to be the total 24-hour yield. The mean daily yield for the 14-day period was calculated as the mean of the 24-hour yield at the beginning and end of the period, and this multiplied by 14 gave the total yield for the 14-day period. The total yield for the lactation was obtained by summing the 14-day yields, and adding the first and last 24-hour yields each multiplied by 7. The lactation was considered terminated when two consecutive 14-day records gave 5 ml or less.

4.1.2 Analytical procedures

The total lactation yields and lactation lengths were analysed using the same statistical techniques and computer programme as described for the analyses of the growth parameters (Section 3), except for the lactation lengths at Korr. For this datum set it was found that the structure was too unbalanced even for the non-orthogonal analysis, and so unadjusted means were computed and direct comparisons made having obtained t values.

The following sources of variation were examined:

Lactation yield

Ngurunit: Incisor dentition at kidding (4 levels); the management system (traditional or health programme); the kidding period (total number 6, each one starting with one rainy period and ending just before the next); and the following covariates - lactation length, weight at kidding, weight loss of the doe during the first 12 weeks and also first 26 weeks of lactation, rainfall during the last month of gestation and during the first month of lactation.

Korr: In addition to the sources for Ngurunit, species (goats and sheep) was added; but kidding period was deleted as only three lactations were completed from the first period at Korr.

Lactation length

Ngurunit: One source of variation was added to those described for lactation yield at Ngurunit, namely termination (normal or death - if death of the doe occurred during lactation or two weeks following its end).

4.2 RESULTS

4.2.1 Lactation yield

The results are summarized in Tables 9 and 10.

Goats

Location: Although caution is needed when comparing results obtained from different models, nevertheless when differences are large the comparison is fully justified. In this case it is clear that the yields at Korr were considerably higher than those at Ngurunit, following the differences in growth rates that were observed in Section 3. Reports of milk yields from the Small East African Goat are exceptionally rare. An investigation of Galla goats by Field (1978) and by Blackburn and Field (1982) recorded yields of 59 kg and of 53 kg over a 20 and 23 week lactation, respectively. Comparison of the present results with those of Blackburn and Field (1982) is probably better confined to the results from Korr, on the assumption that there is some unidentified factor limiting performance at Ngurunit. Comparison can only be very general: due to major differences of environment, the observations were made over different periods. In general terms it appears that yields from goats are likely to be in the range of 40-55 litres.

Management system: At both Ngurunit and Korr appreciable increases in yield were achieved with the health programme, ranging from some 34% in the former to 10% in the latter, which are definitely high enough to warrant exploiting. It would be important to know why the increase is so much higher at Ngurunit - whether the increase at Korr was limited by an interaction with the availability of other nutrients, or whether the large increase at Ngurunit is indicative of the nature of the factor(s) limiting performance there, are matters requiring investigation. Again an examination was made for any response to the Samorin treatment, but none could be detected.

Table 9. Least squares means, ± SEs for covariates, for lactation yields of goats at Ngurunit

Trait		Lactation yield (litres)
Number		169
Adjusted general mean		24.58 litre
Management system	Traditional	21.04[a]
	Health programme	28.11[d]
Lactation length x kidding period 1		0.984[ade] $1\ wk^{-1}$
Lactation length x kidding period 2		0.306[b] $1\ wk^{-1}$
Lactation length x kidding period 3		0.560[bce] $1\ wk^{-1}$
Lactation length x kidding period 4		0.377[b] $1\ wk^{-1}$
Lactation length x kidding period 5		0.719[ac] $1\ wk^{-1}$
Lactation length x kidding period 6		1.278[d] $1\ wk^{-1}$
Weight at kidding		0.817 ± 0.150 $1\ kg^{-1}$
Weight loss during lactation 0-12 weeks		- 0.572 ± 0.245 $1\ kg^{-1}$
Weight loss during lactation 0.26 weeks		0.609 ± 0.184 $1\ kg^{-1}$
Rainfall last month of gestation		0.457 ± 0.146 $1\ cm^{-1}$
Rainfall first month of lactation		0.679 ± 0.138 $1\ cm^{-1}$

Note:

Means within subgroups with different superscripts differ at the $P < 0.05$ level or less.

Table 10. Least squares means $\pm$ SEs for covariates, for lactation yields of goats and sheep at Korr

Trait	Lactation yields (litres)
Number	123
Adjusted general mean	30.38
Management systems	
Traditional	28.98^{a}
Health programme	31.78^{b}
Species	
Goats	40.48^{a}
Sheep	20.28^{d}
Species rainfall last month gestation	
Goats	7.199^{a} 1 cm^{-1}
Sheep	0.175^{d} 1 cm^{-1}
Lactation length	0.851 ± 0.140 1 wk^{-1}
Weight loss during lactation	
0-26 weeks	0.530 ± 0.202 1 kg-^{1}

Note:

Means within a subgroup having superscripts differ at the following levels P: a - b $P<0.05$; a - d $P<0.005$.

Lactation length: This is probably the most important factor of all affecting yields and the overall effect is much the same in both environments. The interaction with kidding period at Ngurunit indicates the large variation, and not a reversal of the positive relationship. To some extent the coefficients within kidding periods follow the rainfall pattern (which was 512, 280, 123, 141, 72 and 403 mm, for periods 1 - 6 respectively). In particular the two highest coefficients are associated with the highest rainfalls, and in general vice versa, but with the exceptions of periods 3 and 5.

Body weight: Several aspects of body weight were found to have important effects upon yield. At Ngurunit the positive coefficient for weight at kidding shows that the status of the body reserves at the start of lactation affects the total yield. The effects of two types of weight change were examined - weight loss during early lactation (0-12 weeks) and throughout lactation (0-26 weeks). At Ngurunit both of these were found significant, and the negative coefficient for the first initially seems surprising. However, it is probable that the does that lose weight in early lactation were unable to sustain their performance, thus finally achieving lower yields. At both Ngurunit and Korr does with high yields had to draw significantly upon their body reserves (to approximately the same degree).

Rainfall: An examination was made of the effects of rainfall levels, both just before the onset of lactation and during the first 4 weeks of lactation. In both environments the former was found to have been important. The large difference in size of the coefficients between the two would have been due mainly to the large differences in rainfall during late gestation; at Ngurunit this ranged from 0 to 21 cm, while at Korr it was only from 0 to 1.5 cm. It was only at Ngurunit that the rainfall during early lactation was found significant, and in fact the larger coefficient shows that it was more important. The absence of a significant effect at Korr was primarily due to the short period of observations - only three values exceeded zero. In fact there was evidence from Korr that providing does had not exceeded about two-thirds of their lactation they were able to make a marked response to rainfall.

Incisor dentition: This was included as the best estimate of age that was available, as practically all does providing data on lactation had been purchased. Rather surprisingly it was not significant in either environment, even though in both there were observations from does representing all four classes. It seems likely that this is not sufficiently precise both at the youngest and oldest ages.

Sheep: The general level of yield is clearly considerably less than goats', and could have been as low as half. This was a much bigger difference than observed by Blackburn and Field (1982) where the ratio of goat to sheep for lactation yield was 1.24, although all the previous comments on the caution required in comparing these two lots of analyses apply equally here.

In most respects sheep lactation yields respond to environmental effects similarly to goats'. All possible interactions were tested and the only significant one was with rainfall during the last month of gestation, to which goat yields had quite a strong response whereas the sheep response was negligible. Perhaps this reflects the greater ability of the sheep to build up and use energy reserves in their fat depots.

4.2.2 Length of lactation

The results are summarized in Tables 11 and 12.

Goats: In general the length of lactation was longer than expected, although this would be partly due to the low levels at which observations were terminated (5 ml^{-1}). The results of Blackburn and Field (1982) are not comparable as they terminated their analyses at a much higher daily yield (about 100 $ml\ d^{-1}$).

Table 11. Least squares means, ± SEs for covariates, for lactation lengths of goats at Ngurunit

Trait	Lactation length
Number	169
Adjusted general mean	22.30 weeks
Lactation completed	32.43[a] weeks
Terminated by death	12.18[d] weeks
Kidding period 1	20.25[a] weeks
Kidding period 2	19.87[a] weeks
Kidding period 3	28.50[bd] weeks
Kidding period 4	31.39[b] weeks
Kidding period 5	23.44[ad] weeks
Kidding period 6	10.36[c] weeks
Weight at kidding	0.470 ± 0.183 weeks kg^{-1}

Note:

1. Termination by death = death during lactation or within two weeks from end of lactation.
2. Means within subgroups with different superscripts differ at the $P < 0.05$ level or less

Table 12. Means ± SDs, and t value for comparison of lactation length of goats and sheep at Korr

	Goats	Sheep
Number	57	66
Means ± SDs	26.35 ± 7.01	23.48 ± 4.63 weeks
t value	2.71*	

* P < 0.01.

<u>Location</u>: For the period observed, the lengths of normally completed lactations were longer at Ngurunit than Korr, which initially is surprising in view of the reverse situation with respect to yields. Had a detailed analysis been possible for the Korr data the explanation for this may have been available. (It almost certainly is not attributable to absence of any adjustment for termination by death at Korr, for this only applied to one lactation at Korr.)

<u>Kidding period</u>: The systematic effects represented by this term have clearly been large. (It should be remembered that for normally completed lactations 10.13 should be added to each estimate.) The lower figure for period 6 is due to all lactations over 20 weeks having been included whether terminated or not, otherwise many lactations would have been omitted due to the termination of the records. There is even less association with the rainfall levels at the beginning of the period than there was for yield. It could be that major effects were due to the season of kidding, and to rainfall levels experienced later during lactation.

Weight at kidding: Variation in the weight at kidding would have been due to both changes in body condition and stage of maturity - increases in both of these would be expected to increase lactation lengths, as observed. It could be that the major factor here was the stage of maturity as yield responded to change in body weight, having been adjusted for changes in lactation length. Apparently the general effect was of a moderate order, the difference between the higher and lower weights being some six weeks.

At Ngurunit all other effects tested in the analyses of yield were also tested for length and were found non-significant. At Korr only the management system was tested, in addition to species, and was also found non-significant.

Sheep

For these observations at Korr sheep lactations were about 11% shorter than goats' - clearly an important factor contributing to the lower yields of sheep.

4.3 CONCLUSIONS

These results have provided further evidence for the usual, but not invariable, situation that goats have higher milk yields than sheep when both phenotypes have evolved in the same environment.

Lactation length has been identified as one of the most important determinants of milk yield, but these analyses have not thrown much light on its sources of variation.

Variation of yield is matched by a number of bodyweight changes, suggesting that attention to body weight would be an important aspects of any programme for increasing yields.

There were indications that yields in goats are quite responsive to the changes induced by rainfall, at all stages of lactation (even quite late), and also at the stage of late pregnancy. The ability of the mammary system to make a significant response even late in lactation is clearly of great importance in arid environments.

It would appear that lactation may be the performance trait that is most responsive to the health programme, with increases of some 34% at Ngurunit and 10% at Korr, in relation to the traditional situation. These levels would certainly indicate that properly planned strategic use of anthelmintics would be worthwhile.

The lower yields at Ngurunit are consistent with the findings from the analyses of growth, that there is some factor(s) limiting performance at Ngurunit.

5. FERTILITY

The programme that was set up for monitoring fertility attempted to cover the whole sequence of events from mating to birth. It was hoped that not only would the programme give estimates of the levels of fertility, but also indications of the most important areas of failure.

5.1 METHODS

5.1.1 Experimental

To achieve this objective records were made of all live births, stillbirths, abortions, and matings. The first three depended upon reports from the herdsman. To make records of matings the male running with the herd had fitted on the brisket a 'Sire Sine' harness (designed by CSIRO, Australia). Coloured blocks were attached to the harness and thus mated females were colour marked on the rump. The herd was examined daily in the evening and all colour marks recorded. Analysis of these records should permit detection of anoestrus, normal oestrus without conception, abortion and normal births. The traits chosen for analysis were:

1. Proportion of barren females;
2. Age at first parturition;
3. Litter size;
4. Parturition interval.

The combination of these four enables the recruitment rate for the herd to be estimated. The proportion of barren females must be estimated for the group of breeding females, and thus a definition of the latter was required. The youngest age at which an experimental doe bred was 92 weeks, and so a breeding female was defined as all does over the age of 90 weeks.

5.1.2 Analytical

Some of the data took the form of a three-dimensional contingency table. This set of data was analysed for dependence by applying the technique of log-linear models, and using the computer package GLIM-3-12 (Baker and Nelder, 1978).

The data set for parturition intervals was adequate for an analysis of variance and covariance and the techniques required for non-orthogonal data were applied, using the computer programme SYSNOVA (Seebeck, 1975). The sources of variation that were examined were as follows:

Continuous variables:

1. The yield and length of the lactation that occurred within the kidding interval;
2. The weight loss that occurred during the 26 weeks following the onset of the same lactation as in (1);
3. The season of the first kidding, measured in two ways - the time (in weeks) from the previous rainy period to kidding, and the time from kidding to the rainy period (rainy period being defined as three consecutive fortnight periods with rain falling in each, and the level in the first period exceeding 9 mm);
4. Weight change during the month preceeding the second conception;
5. Weight at the second conception.

Classifying variables:

1. Age: defined by the number of visible permanent incisors (1 - 4 pairs), as the date of birth was unknown for 96% of the females ;
2. The period during which the first conception occurred - the period being the time from the onset of one rainy period to the onset of the succeeding one ;
3. Abortions: present or absent, during the kidding interval ;
4. Health programme: present or absent, during the kidding interval.

5.2 RESULTS

5.2.1 Matings

The analysis of the proportion of matings to births at Ngurunit revealed that 45% of all births did not have any recorded mating. Since this was the minimum proportion of matings that had been missed, it was concluded that nothing further could be done with the mating data.

5.2.2 Age at first parturition

At Ngurunit only four does of known age kidded during the experimental period. For these the ages at kidding were 94, 100, 128 and 132 weeks.

At Korr the experimental period was too short for any known-age female to have bred.

Reports of other studies on fertility are barely more than those on lactation. For the Small East African Goat kept by Maasai, Wilson (1982) reports an age of 65 weeks. In West Africa reports range from 59 weeks (Molokwu and Igono, 1980) for the goat of the Nigerian savannah zone, to 69 weeks (Wilson, 1982) for Mali. These all indicate that generally first parturition occurs at just over a year of age. However all of these reports were from more favourable environments than Ngurunit.

5.2.3 Barren females

The incidence of these, for both Ngurunit and Korr, is given in Table 13. The 11% observed for Ngurunit would appear to indicate an important source of wastage, as the time these does were available as breeding females was evenly distributed from 2 - 100 weeks.

Phase 3 at Korr was so much shorter it would be expected that the barren proportion would be greater than at Ngurunit. Even so, 16% for the goats would suggest that the long-term level is likely to be of the same order as at Ngurunit.

Perhaps the most important aspect of the Korr data is the difference between the sheep and the goats. The contingency table obtained by classifying the Korr data amongst species, management system, and class of breeding female (barren uniparous, multiparous) was analysed using log-linear models. The results showed that class of breeding female was independent of management system but highly dependent on species, giving a likelihood ratio statistic (G^2) of 15.84 ($P<0.005$). Thus the much lower barren % and much higher multiparous % is highly significant, indicating a greater proportion of sheep bred, and far more sheep bred twice.

This difference between sheep and goats was also supported by Blackburn and Field (1982), who found that the parturition intervals of their sheep were some 16% shorter than for their goats.

5.2.4 Abortion

Abortion rates for both species at both locations are given in Table 13, and indicate a general level of 8% per annum for goats, and appreciably less for sheep, at around 3%.

Brucellosis has been shown to be quite widespread in goats, and present but probably less widespread in sheep (see Section 7). However, examination of a sample of abortions for brucellosis indicates that there were also other major causes: it seems that weight loss is one of the most likely.

5.2.5 Litter size

Table 14 presents the finding on the incidence of multiple births, showing that for both species in both locations the litter size is 1.0, to all intents and purposes.

Table 13. Distribution of does and ewes amongst breeding classes at Ngurunit and Korr

Category	Ngurunit	Korr	
Length of observation period (weeks)	186	66	
Total number of females	207	250	
Immatures[1]	85	66	
Premature death[2]	1	39	
		Goats	Sheep
Breeding females	121	76	69
Proportions: Barren	11%	16%	3%
Uniparous	27%	82%	77%
Multiparous	62%	3%	20%
Abortion rates (breeding females % annum^{-1})	8.3	8.3	3.4

Notes:

1. Immatures = females under 92 weeks of age at end of phase 3.

2. Premature deaths = females of breeding age present for less than 21 weeks.

Table 14. Mean litter size of does and ewes at Ngurunit and Korr

Location	Species	No. of twin births	Total parturitions	Mean litter size
Ngurunit	Goats	0	209	1.00
Korr	Goats	2	68	1.03
	Sheep	1	78	1.01

Blackburn and Field (1982) found much the same at Olturot, but both Molokwu and Igono (1980) and Wilson (1982) report higher levels for goats, although they agree with this estimate for sheep. Again this indicates that the Rendille environment is much harsher than most of those studied so far.

5.2.6 Kidding interval

At Korr only 16 animals gave birth twice - 14 ewes and 2 does; the mean parturition intervals were 37.1 and 45.0 weeks, respectively. In terms of the whole herd these would undoubtedly be biased too low. Also the sample was too small for any further analyses.

At Ngurunit a total of 106 kidding intervals occurred. The results of the analysis of variance and covariates are given in Table 15. The adjusted mean of 66.4 weeks indicates a very slow rate of breeding.

This is very much slower than all other reports, although Blackburn and Field (1982) found a kidding interval of some 50 weeks with their goats which was appreciably longer than all the levels reported by Wilson (1982) which were of the order of 40 weeks, while Molokwu and Igono (1980) observed intervals of 32 weeks. Without data from Korr it is not possible to estimate the general level and its variability for Rendille, but with these two reports it seems clear that this environment is supporting a lower rate of increase than most others in Africa.

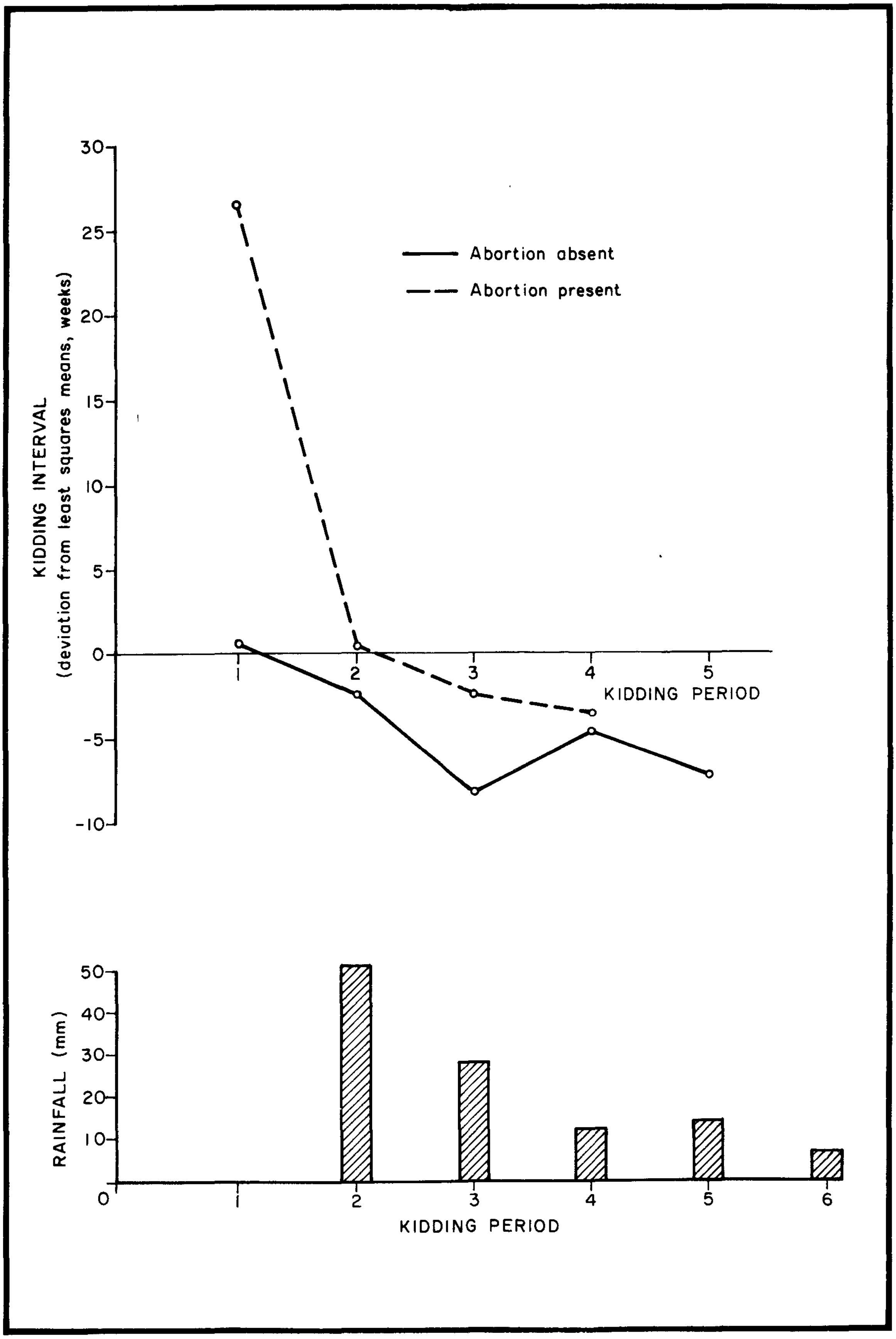
Table 15. Least squares means, ± SEs for covariates, of kidding interval at Ngurunit

Trait	Kidding interval	
Number	106	
Adjusted general mean	66.4 weeks	
	Without abortion	With abortion
Conception period 1	67.4	120.1
Conception period 2	61.2	67.0
Conception period 3	49.6	61.6
Conception period 4	56.7	59.1
Conception period 5	51.5	69.8
Lactation length x 1	1.24[a]	weeks per week of lactation
Conception period 2	- 0.57[b]	weeks per week of lactation
Conception period 3	0.88[a]	weeks per week of lactation
Conception period 4	0.11[bc]	weeks per week of lactation
Conception period 5	0.64[ac]	weeks per week of lactation
Weight loss during lactation	1.04	weeks kg^{-1}

Note:

Means within subgroups with different superscripts differ at the P<0.05 level or less.

Figure 2. The effect of abortion and kidding period upon kidding interval of goats at Ngurunit



Effects that were tested and found non-significant were age (as estimated by dentition), previous lactation yield, season of kidding previous to the second conception, weight change in the month preceeding second conception, and weight at second conception.

The coefficient for weight loss was 1.04 weeks per kilogram loss. The level of weight loss observed ($\pm$ SD) was 3.113 $\pm$ 3.732 kg, which would give a change of 15.5 weeks in kidding interval over a weight loss of the mean $\pm$ 2 SDs. As this represents a change of some 23% of the adjusted mean this would be one of the major sources of variation, which is not surprising for a semi-arid environment.

The other three significant sources of variation are all involved in interactions and these are illustrated in Figure 2. In the case of the interaction between the abortion class and conception period this is almost certainly attributable to the situation for the first period. The estimates of kidding interval for those animals aborting whose first conception occurred in this period is based on just two observations, and these were the most extreme kidding intervals for the data set. It is clear that abortions do contribute to increase in kidding interval but the sample size is too small for any general estimates to be made. Of the 106 kidding intervals analysed, 14 were affected by abortion, giving an overall rate of 13%, so it is certainly an important factor. This level is greater than that reported for all breeding females as the latter includes barren females.

The levels of kidding interval for does not experiencing abortion indicate a trend for a decreasing interval across the conception periods one to five. There does not appear to be any association with rainfall pattern, and so the most likely explanation would be the effect of increasing age as initially the does were predominantly yearlings. Adjustment for age was attempted by including dentition classes in the model but these could well have been too crude.

The interaction between lactation length and conception period is principally attributable to a high positive coefficient for the first period (1.24) and a negative coefficient for the second (- 0.57); all the other coefficients were positive and ranging from 0.1 to 0.9 weeks per week of lactation.

Both these interactions appear to be caused by extreme observations (1 and 2 for the first and second periods, respectively). For the others the positive coefficient is expected. While lactation length has been an independent variable in this analysis, it is possible that it is dependent on kidding interval.

5.2.7 Reproductive rates

At Ngurunit the multiparous females with a litter size of 1.0 and a kidding interval of 66.4 had a reproductive rate of 0.78 live births per female per annum. For all breeding females the rate would be lower still. If it is assumed that no adjustment is needed for the uniparous females (i.e. their uniparity is due to shortness of the time available for breeding either from youth or death), and that 11% is an adequate estimate for the incidence of barrenness, then the reproductive rate for all breeding females would have been 0.69 live births per female per annum.

When the late age for first breeding is taken in conjuction with this, the reproductive rate for the whole flock is depressed still further.

It should be noted that the age structure was not typical, with a bias towards young females. However, it would seem unlikely that this was a major cause of the low rates.

5.3 CONCLUSIONS

For goats, all the evidence suggests that the reproductive rates were very low, with all traits studied contributing adversely to this. Phase 3 was too short a period at Korr to provide sufficient data for Ngurunit and Korr to be adequately compared. However, for the three traits that could be compared (the proportion of barren and aborting does, and litter size) the levels were equivalent.

One of the most interesting results came from the comparison of the sheep and goats at Korr, where sheep performed more favourably in all traits analysed. This is a most important difference for consideration in developing strategies for exploiting the potential of these two species. It could be that there was an interaction with lactation levels, where goats with the higher yields would have been more adversely affected.

6. MORTALITY

The monitoring procedure that was established was intended to enable estimation of the death rate - survival being as important a performance trait as fertility, and to establish the main causes of death, and so the analyses followed this sequence.

6.1 METHODS

6.1.1 Experimental

All deaths were recorded individually on the day of death. To establish the cause of death in an area so remote from normal veterinary services posed a major problem. However, a schedule was established which proved reasonably effective. Competent members of staff at each location were trained to examine as many cases of death as possible, and with the minimum delay. A recording schedule was established in which the examiner followed a standard procedure, and a description of all findings was made, again using a standard procedure. This procedure is outlined in Figure 3. In cases where tissue was suspected of being abnormal, a sample was taken in 10% formalin and submitted to the laboratory at Kabete for examination. For most of the postmortem examinations, the abomasum and small intestine were ligatured and preserved in 10% formalin, and then subsequently the number and type of helminths present in the contents were determined in the laboratory.

Inevitably such an examination is superficial by veterinary standards. But it was considered that the level of competence of some of the staff was quite adequate to make a comprehensive examination and distinguish most abnormal tissue, and if this skill was combined with a short time interval between death and examination, then data would be obtained that would be adequate to determine the causes of death in their relative order of importance for the herd. In fact the quality of the data was expected to be better than that obtained from an examination by a veterinarian at a much longer interval after death, and this proved to be so.

Figure 3. Postmortem examination record

EXAMINER: DATE:

HERD: EAR TAG NUMBER: SEX: DATE OF BIRTH:

HISTORY: Length of sickness: Number sick: Number of Incisors:

Main signs during sickness:

TIME: Of death (Approx.): Of PM examination:

TYPE OF DEATH: Natural, Bled, Other:

Code for amount: Small+, Medium ++, Large +++

	Normal	Colour	Consistency H-ard S-oft D-iffuse L-ocalised	Size Volume L-arge S-mall	Haemo- rrhages P-inpnt S-plash	Abscesses Ulcers L-arge M-edium S-mall	Parasites Type Number	General comments	Sample
SKIN									
MUCOUS Mouth MEMBRIN									
Eye									
LYMPH GLANDS									
THORAX:Fluid									
Membranes									
Lungs left (Lobe right (number			float sink						
Heart sack fluid									
Heart									
ABDO:Fluid									
Membranes									
Kidney									
Bladder									
Genitalia									
Liver									
Spleen									
Rumen									
Abomasum									
Sml.Intestine									
Lrg.Intestine									
MUSCLES									
BRAIN									
OTHER									

COMMENTS

DIAGNOSIS

The forms and samples were then returned to the author (a veterinarian) who determined which samples warranted examination by a histopathologist. After receipt of all laboratory reports he then made the final diagnosis.

For subsequent analysis deaths were allocated amongst six classes as described in Table 16.

6.1.2 Analytical

The sources of variation that were examined were the following:

Age group

- Up to 3 weeks of age, covering the period from birth and the first half of the period in the protective basket by the night enclosure.
- 4 - 21 weeks of age, covering the major part of the suckling stage.
- 22 - 53 weeks of age, covering the most important part of post-weaning and early-immature stages.
- Over 53 weeks of age, covering the late immature stage and adulthood.

Species: Goats and sheep

Location: Ngurunit and Korr

Management system: Traditional and health programme

Death period (at Korr): two periods, each one initiated by a rainy period, defined as before (Section 2)

Sex: this was omitted because the sex structure of the herd was so atypical and non-orthogonal (due to the imbalance between the sexes for the purchases) that a number of the contingency table cells would have been obligatory zeros, introducing great difficulty in the analysis.

For both the analyses on the incidence and cause of death the classification of the data gave three-dimensional contingency tables, and so the technique of log-linear models was used, using the GLIM computer package (Baker and Nelder, 1978).

Table 16. The classification of cause of death

Title	Definition
	No postmortem examination made, and:
Unknown	Carcass was observed by herdsman
Predator	Predation observed, or complete disappearance of animal
	Postmortem examination made, and:
Doubtful	Diagnosis considered not possible
Various	Various conditions diagnosed, all of low incidence and relatively unimportant for flock mortality
Pneumonia	Pneumonia diagnosed as cause of death
Parasites	Helminths diagnosed as cause of death

6.2 RESULTS

6.2.1 Incidence of death

Goats: The distribution of all goat deaths, and the numbers surviving at the end of Phase 3, observed at both Ngurunit and Korr, is given in Table 17. This table was analysed to determine whether there was any effect upon the incidence of death in the different age groups, or the numbers surviving, from the location or management systems. This revealed that the differences between the management systems were not significant while those between age groups and locations were highly significant (G^2 = 37.09, 4 DF, $P<0.005$).

The higher death rates at Ngurunit seem to be following the patterns observed for growth, lactation and fertility. At Ngurunit the contrast between the first two age groups stresses the effectiveness of the management techniques for protecting the very young kids and their vulnerability once they leave the basket. Indeed, there almost seems to be a rebound effect between the ages of 4 and 21 weeks. At Korr the higher proportion in the first age group is probably due to the first part of Phase 3 having been exceptionally dry at Korr thus seriously depressing lactations. This was made worse for the health-programme herd because they were trekked to water every second day, whereas the traditional group watered every fourth day. In fact the former group suffered more and the practice was stopped. It would seem likely that the smaller proportion of deaths in the second age group at Korr may well have been due to the higher proportion in the preceeding age group, in the rather special circumstances outlined above, and with Phase 3 being too short a time for these effects to be balanced out.

Korr: The distribution of deaths and survivals of both goats and sheep at Korr is shown in Table 18. The analysis of this table revealed that the incidence of death and survival was independent of management-system effects, but was just dependent upon species and death period, with both maximum likelihood statistics (for the model and the species term) just on the borderline of significance. The coefficients from the model confirm that the survival rate for sheep was lower than goats; the table indicates a difference of some 10%, which would be large enough to require attention in development programmes.

Table 17. Incidence of goat deaths amongst age groups and management systems at Ngurunit and Korr

Location	Management system	Age group at death (weeks)				Survivals	Total	Death rate (%)
		3	4-21	22-53	> 53			
Ngurunit	Traditional	5	46	9	31	139	230	40
	Health programme	3	28	8	10	73	122	40
Korr	Traditional	3	1	-	8	59	71	17
	Health programme	5	5	-	12	66	88	25
Totals		16	80	17	61	337	511	
Proportions (%)		3	16	3	12	66	100	

Table 18. Incidence of deaths amongst species, age groups and management systems at Korr

Species	Management system	Death period		Survivals	Total	Death rate (%)
		1	2			
Goats	Traditional	6	6	59	71	17
	Health programme	16	6	66	88	25
Sheep	Traditional	22	12	52	86	40
	Health programme	15	8	76	99	23
Total		59	32	253	344	26
Proportion (%)		17	9	74	100	

It would appear from Table 18 that there was an interaction between species and the management system, and that the sheep benefited from the health programme. This would suggest that they suffered less from the trekking to water which appears to have masked any benefit of the health programme for the goats. However, this term was included in the model, adjusting for this effect, and the final indication was that the health programme was not associated with any effect. It is widely known that death rates of small ruminants in the African tropics fluctuate rapidly, and can reach very high proportions. However, there are few reports that are quantified, and consider the sources of variation. One that does is by Wilson *et al.* (1981), who report general preweaning mortality levels of 22.3% and 19.1% respectively, for goats and sheep from a Maasai ranch, which are obviously very similar to the general level for goats in this study (19%), but the species order is reversed. In Nigeria it was also observed from the humid zone that goats had a higher morbidity and mortality (Mack, 1982). Both these environments are much more humid than the IPAL study area, which suggests that there could be an interaction between species health and the degree of humidity.

6.2.2 Cause of death

Goats: The distribution of the various causes of death for goats, amongst age groups and location, is given in Table 19. The analysis of this table included management groups as well as age group and location, as possible sources of variation. In order to decrease the number of empty cells (due to small sample size), the age groups were condensed to just two - young and immature (upto 53 weeks old), and adults. The result of the analysis showed that cause of death was not affected significantly by either management group or location, but was very much dependent on age group ($G^2 = 17.00$, 4 DF, $P<0.005$). It seems strange that the difference between the two locations was not significant, but this may have been due to the small sample size at Korr, and particularly the great preponderance of the 'unknown' class.

Table 19. Distribution of causes of death of goats amongst age groups and location

Cause of death		Age at death (weeks) and location								Total	Proportion (%)
		0-3		4-21		22-53		> 54			
		*N	K	N	K	N	K	N	K		
Unknown		6	5	38	3	4	-	14	13	83	48
Predator		1	1	6	-	4	-	11	2	25	14
Doubtful		-	-	18	2	2	-	-	5	27	16
Various		1	2	-	1	2	-	4	-	10	6
Pneumonia		-	-	11	-	2	-	1	-	14	8
Parasites		-	-	1	-	3	-	11	-	15	9
Total	N	8		74		17		41		140	
											174
	K		8		6		0		20	34	
Proportions (%)		9		46		10		35			100

*N = Ngurunit
K = Korr

Unknown: The proportions of deaths that were not examined postmortem were 44% at Ngurunit and 76% at Korr. The former was probably reasonable, but the latter was certainly disappointing. The majority of these would have been in the very young age groups, and the proportion of these was much higher at Korr (45% of all deaths were less than 9 weeks old, as compared to 21% at Ngurunit). This is almost certainly due to the very high death rates of lambs and kids during the early part of Phase 3 at Korr, due to the very dry conditions.

Predation and various: Because of the small sample size these two were condensed together, with the former being the largest proportion. The post-weaning stage seems to be the one at greatest risk, and not the very youngest age group, a testament to the care that is taken of the very young with respect to survival. Predation seemed to be a greater risk at Ngurunit, in particular from nocturnal cats such as the Caracal, *Felis caracal*.

Doubtful: In general the younger the animal at death the more difficult is a definite diagnosis, and the distribution partially supports this. In fact, had a similar proportion of the very young deaths been examined, almost certainly the diagnosis would have been this group. The expected major contributions to this category would be acute deaths, deaths of the very young, and starvation. There were very few of the first type, and so it is most likely that the last two accounted for the majority.

Pneumonia: All cases of pneumonia came from Ngurunit and in fact almost all were attributable directly to an outbreak of contagious caprine pleuropneumonia during Phase 2. This is an episodic condition, but can be devastating when it occurs.

Parasites: A number of types of helminth infection were found causing death. The most frequent of all was the cestode larva *Coenurus cerebralis*, occurring as a cyst in the cranial cavity. Another very frequent finding was another cestode larva, *Cysticercus tenuicollis*, normally harmless, but on occasion causing massive liver damage and death. Strongyles were a frequent finding, and were considered to be the cause of death when the number exceeded 500 adults for *Haemonchus contortus* and 1,000 adults for *Trichostrongylus* spp.

At Ngurunit death caused by Cestode larvae was observed about twice as frequently as from strongyles. There would probably be two main reasons for the strong preponderance of cases in the older age group - coenuriasis is a slowly developing condition and can take upto seven months to manifest itself. In the case of strongyle infections the stresses of pregnancy and lactation probably play a major role.

Korr: The distribution of the various causes of death at Korr is given in Table 20. The analysis of this table showed that cause of death was independent of age group, species and management system. Undoubtedly the reason for this is the small number of postmortem examinations.

6.3 CONCLUSIONS

The contrast is very marked between this study in arid and semi-arid conditions and production systems in more fertile areas, where 70-80% of all deaths usually occur within the first week of life. The technology used to achieve this has clearly been very effective. However, it could well be that the obvious benefit (survival) has been achieved at the cost of the less obvious loss (better growth rate and higher life-time productivity). An additional complicating factor could be the human competition for milk at the time of peak lactation. Clarification of the effects upon life-time performance of modifying the system at this point will be very necessary but will have to be considered and developed very carefully to avoid disruption of the traditional food supply of the people.

The higher survival rate of the goats is consistent with the general observations on herd structures in the study area, where goats predominate. It is also biologically consistent with the finding that sheep had the higher fertility rate - as the long-term biological tendency is towards stable population sizes. However, these differences have great potential for exploitation, as has been observed in many areas of the world. If a suitable technology can be developed (that satisfies the socio-economic situation) for bringing the mortality rates of sheep down to the order of that for goats, then the potential for increased fertility can be exploited with great effect.

Table 20. Distribution of causes of death of goats and sheep at Korr amongst age groups and species

Cause of death	Age at death (weeks) and species						Total	Proportion (%)
	0-3		4-21		> 54			
	Goats	Sheep	Goats	Sheep	Goats	Sheep		
Unknown	5	9	3	4	13	35	69	76
Predator	1	-	-	-	2	3	6	7
Doubtful	-	-	2	2	5	3	12	13
Various	2	-	1	1	-	-	4	4
Pneumonia	-	-	-	-	-	-	0	0
Parasites	-	-	-	-	-	-	0	0
Total Goats	8		6		20		34	37
							91	
Sheep		9		7		41	57	63
Proportion (%)	19		14		67			100

The higher death rates at Ngurunit were yet further evidence that this was a less favourable environment, at least during the period of these observations. Disappointingly, the analysis of the causes of death did not give any clear guidance as to the possible reason for this. The most susceptible age group is that between 4 and 21 weeks of age, and the major types of death were in the 'unknown', and 'doubtful' categories. One possible major contributor to this situation is nutritional problems. A more detailed analysis of the body-weight changes of the deaths might clarify the position.

The fact that the health programme was not indicated as playing a significant role in any of the analyses on death (superficially) may appear surprising, especially in view of the responses that have been observed with other traits. However, the period of the study was too short for another epidemic of contagious caprine pleuropneumonia to have occurred and therefore we were unable to test the effect of vaccination. The parasites principally responsible for death were Cestode larvae, and the health programme did not contain any component that would have affected these. The frequency of these conditions does indicate the importance of attempting to break the life-cycle of those tape worms by disposing of all postmortem material so that dogs, and wild Canidae, do not have access to the infected material.

It would be expected, in an arid environment such as the study area, that inadequate nutrients would play a major role in determining general levels of morbidity, and probably making a direct contribution to mortality. The high incidences of death in the 'unknown' and 'doubtful' categories would support this.

7. INFECTIOUS DISEASE

While the primary objective of these studies was to estimate levels of performance for the most important performance traits, a secondary objective was to identify the main constraints affecting these traits. These latter studies led to the extension of the investigations into a number of infectious diseases. It has not been possible to analyse these data to the same depth as that on the performance traits. However, a general description of the data still provides some information most pertinent to the planning of smallstock management in the study area.

The majority of these infectious diseases receiving more specific attention were of a parasitic nature. Strongyle infestations were the main condition, and tick infestations were also investigated. Protozoal infections of the blood received a considerable amount of attention. The presence of brucellosis had been well established and because of the potential for causing abortions and the danger to humans a number of surveys were conducted to estimate the incidence. Finally, the clinical syndrome of anaemia received detailed attention following the early observation that it was widespread and endemic. It could have arisen from a number of conditions observed, but perhaps particularly from the strongyle burdens. It was considered that monitoring the level of anaemia in the field, in conjunction with the studies of levels of strongyle eggs in the faeces, would assist interpreting the relevance of the latter to performance.

7.1 STRONGYLES

7.1.1 Materials and methods

The investigations took two forms - primarily faecal sampling of the traditionally managed herds four times in Phase 2 and then between one and two-monthly intervals, and the estimation of the levels of strongyle eggs. This gave a general indication of the level of helminth burdens and a more direct indication of the level of infective larvae on the pasture. The second investigation was of the contents of the alimentary tract of all animals examined postmortem to establish both the spectrum of species present and also the levels of the strongyle burden.

7.1.2 Results

Ngurunit: Table 21 gives the results for faecal samples from Phase 2. The mean and SD give a measure of the general level, but the variability is so high that the proportion of the herd above the pathogenic threshold level (500 eggs) is possibly an even more important figure. It can be seen from this that throughout most of the year at least half the herd were probably adversely affected by strongyliasis. It is important to know the species of strongyles that could be present in the alimentary tract, both because this is needed for interpretation of the level of eggs found in the faeces and also for interpreting the pathogenic effects of such burdens. Table 22 gives the results of the analyses for Phase 2, and fortunately the position appears to be relatively simple, with *Haemonchus contortus* being almost the only strongyle found in the abomasum, and only the two *Trichostrongylus* spp. found in the small intestine. In over 95% of cases possessing strongyle burdens both genera were present, but the most important pathogenically was *Haemonchus contortus*. It is possible that these were biased samples having all come from deaths, and the state of health may affect the strongyle population, but so far there is no evidence that any bias was serious.

Korr: During Phase 3 at Korr it proved possible to do a more detailed analysis of the fluctuation in faecal egg output, examining the differences between goats and sheep, and the effects of seasonal change and lactation. The results of this are illustrated in Figure 4.

On the whole the levels in sheep are some 20% higher than in goats. This would be consistent with the expectation that sheep would be more exposed to infection due to their greater preference for grazing rather than browsing. Seasonal changes seem to affect both species similarly with the level steadily rising during a prolonged dry season, in this case following the failure of rains. These results indicate that this does not occur during shorter dry seasons, and it is tempting to postulate that the increased nutrient intake provide by *Acacia tortilis* seed pods under such conditions enables the animals to continue to suppress their worm population. The dramatic fall following rainfall indicates that the self-cure phenomenon observed in more humid areas is also occurring here. In this environment it appears that a relatively small amount of rain is sufficient to trigger this response. The fact that the times of high output occur towards the end of

Table 21. Strongyle egg counts in faeces from goats in the traditional management group at Ngurunit

Date	Number of goats			Mean epg
	Total	0 epg	> 500 epg	± SD
21.1.79	11	2	7	1,027 ± 1,317
28.7.79	51	8	16	380 ± 372
8.12.79	50	1	35	858 ± 679
8.2.80	45	8	19	500 ± 468
2.3.80	67	13	41	1,137 ± 1,421

Notes:

1. 0 epg = Zero eggs per gram
2. 500 epg is an approximate pathogenic threshold
3. No corrections were made for late pregancy or early lactation as the numbers of such females varied very little between samples.

Figure 4. The effect of lactation and rainfall or the faecal output of strongyle eggs by adult does and ewes at Korr

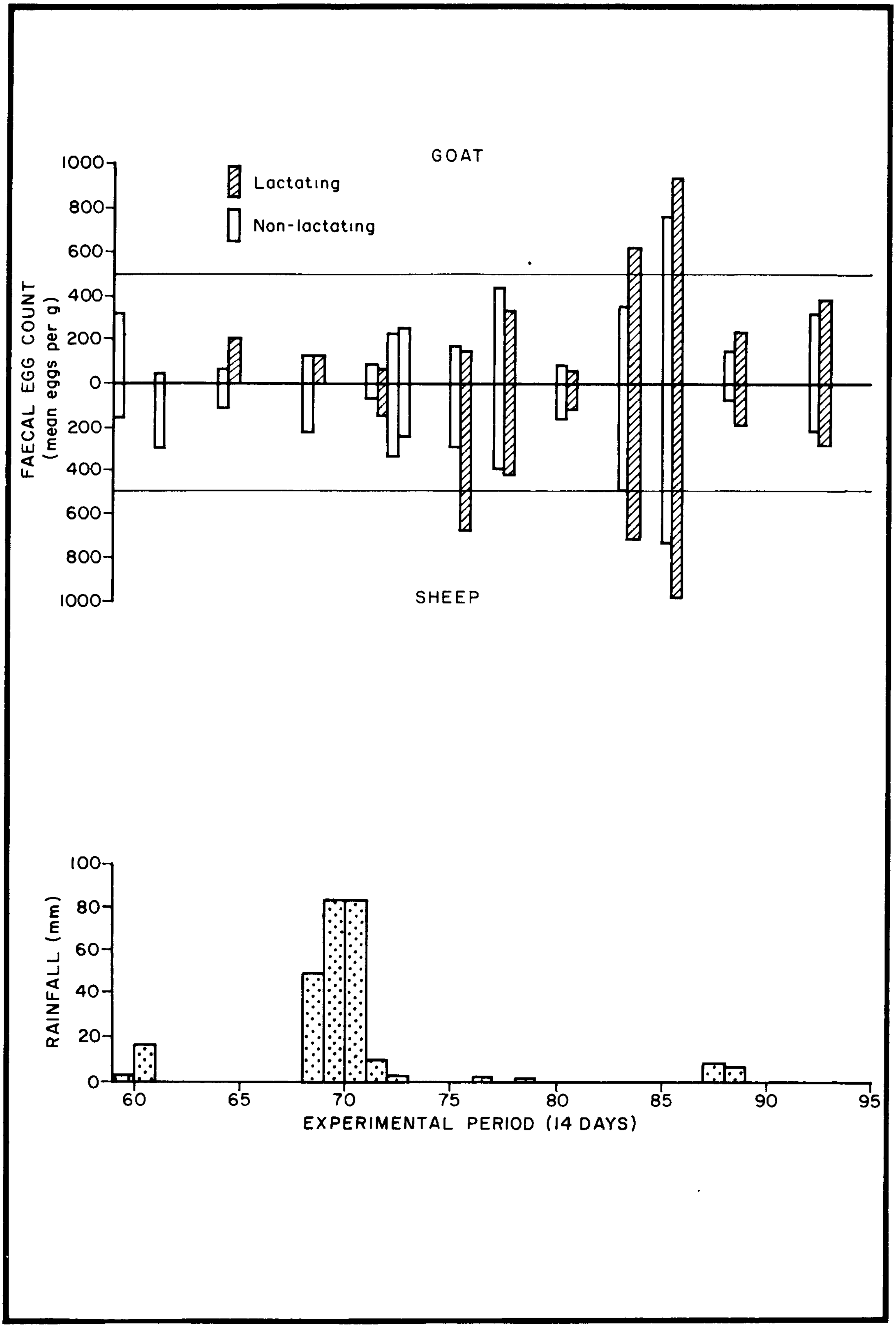


Table 22. The proportions of strongyle species in the abomasum and small intestine of goats at Ngurunit

Location	Species	Number of samples	Mean ± SD (%)
Abomasum	*Haemonchus contortus*	6	98.4 ± 3.9
	Trichostrongylus axei		1.6 ± 3.9
Small intestine	*T. colubriformis*	5	40.0 ± 54.8
	T. probolurus		59.4 ± 54.2
	Bunostomum trigonocephalum		0.6 ± 1.3

the dry season, and not during the wet season, follows the pattern observed by Allonby (personal communication) in an environment of intermediate rainfall, and certainly has important management implications. Lactating females generally have higher levels than non-lactating, as usually observed (the deviations from this were all from small samples).

7.2 TICKS

7.2.1 Materials and methods

Ticks had been found as major ectoparasites of camels at Ngurunit and Korr, and also cattle at Ngurunit. So it was considered desirable to survey the incidence on small ruminants. This was done during a dry and a wet season. Animals were sampled at random from the herd and the entire body searched. All ticks found were collected and subsequently identified in the laboratory.

7.2.2 Results

The findings of this survey are presented in Table 23. The most striking result is the extremely low burdens in both seasons. *Amblyomma* and *Hyalomma* species are potential carriers of heartwater and *Theileria* species. *Rhipicephalus pulchellus* may also be a carrier of *Theileria* but *R. pravus* and the *R. sanguineus* group have not been associated with any disease organisms of importance for goats or sheep. Unfortunately there are no known reports of tick surveys on goats and sheep in similar environments. In view of this, and the very low burdens, it seems likely that ticks do not regularly pose a threat to smallstock. Nevertheless, outbreaks of tick infestations have been noted from Mts. Kulal and Marsabit.

7.3 BLOOD PROTOZOA

7.3.1 *Anaplasma* and *Babesia*

On three occasions at Ngurunit, during both wet and dry seasons, and on one occasion at Korr, blood smears were examined for the presence of red cell marginal bodies (indicative of *Anaplasma)* and *Babesia*. The findings were totally negative for *Babesia* and there was such a low incidence of marginal bodies that these were probably artefacts (see Table 24). Taking these results in conjuction with the clinical and postmortem findings it can be concluded that neither of these infections was important.

7.3.2 Trypanosomes

On the three occasions at Ngurunit when blood films were examined the results were also negative for trypanosomes. However, since it is known that this method is very insensitive for detecting trypanosomes in goats, and as trypanosomes were known to be present in the camels at pathogenic levels, it was decided to attempt to extend the examination of the goats using the much more sensitive techniques of mouse inoculation and serology using the ELISA test. These examinations were made on two occasions in 1981, at intervals after significant

Table 23. Mean total tick loads on goats and sheep at Ngurunit and Korr in dry and wet seasons

Season	Location	Species	Age	Number sampled	Species of tick			
					R. pravus[1]	*A. gemma*	*R. sanguineus* group	Others
Dry	Ngurunit	Goats	Adults	10	5.3 ± 3.4	1.0 ± 0.94	0	*R. pulchellus*
(Oct. 1980)			Kids	5	0.2 ± 0.0	1.2 ± 0.84	0	
	Korr	Goats	Adults	10	2.0 ± 2.7	0	0	*H. impeltatum*
		Sheep	Adults	9	0.7 ± 1.4	0	0.9 ± 0.3	
Wet	Ngurunit	Goats	Adults	20	0.7 ± 0.88	2.3 ± 1.66	0	*R. pulchellus*
(May 1981)								*A. lepidum*
								H. truncatum
	Korr	Goats	Adults	20	0	0	0	
		Sheep	Adults	14	0	0	0.3 ± 0.61	

Notes:

1. *R.* = *Rhipicephalus* *A.* = *Amblyomma* *H.* = *Hyalomma*

2. Others: Ticks found very occasionally.

Table 24. The incidence of blood piroplasms and trypanosomes at Ngurunit and Korr

Location		Date	Total number examined	Number positive: Marginal bodies	Number positive: *Babesia*	Number positive: Trypanosomes	Technique
Ngurunit		8.2.79	84	3	-	-	Blood film - thick and thin
Ngurunit		28.7.79	70	5	-	-	Blood film - thick and thin
Ngurunit		8.12.79	79	1	-	-	Blood film - buffy coat
Ngurunit		15.5.81	58			-	Mouse inoculation - results at day 50
Ngurunit		16.12.81					
Ngurunit	No Samorin	16.12.81	74			4[1]	Mouse inoculation - results at day 50
Ngurunit	Samorin	16.12.81	25			-	Mouse inoculation - results at day 50
Ngurunit	No Samorin	16.12.81	74			7[1]	Serology - ELISA
Ngurunit	Samorin	16.12.81	25			7[1]	Serology - ELISA
Korr		2.3.80	33	-	-	-	Blood film - thick and thin

Notes:

1. Incidence of trypanosome species

Technique	T. vivax	T. congolense	T. brucei	T. evansi
Mouse isolate		2		2
Serology	10	3	1	

rainfall when it was expected that any parasitaemias present would have been well developed. The results are shown in Table 24.

It can be seen from the table that evidence was obtained showing that trypanosomiasis was present in a very few goats (5%) at the time of examination; and had been present in rather more (14%) previously. Furthermore, the overall incidence indicated from the serology was rather higher in the goats provided with a Sâmorin cover!

The evidence suggests that the cases of trypanosomiasis are very low grade and chronic - all titres being low and only in adults, and parasitaemias being very few. Also it indicates that the Samorin treatment at three-monthly intervals was perhaps adequate to suppress parasitaemias, but inadequate to prevent infection.

So, it has been found that goats can be infected with trypanosomes at Ngurunit, but taking the incidence in conjunction with analyses for effects of Samorin prophylaxis on growth and lactation, it can be concluded that no depression of performance occurred. This would need confirming for times of very high challenge (during a very wet period).

7.4 BRUCELLOSIS

The surveys were carried out when the stock were being gathered for either Phase 2 or 3, and also during Phase 2 three other surveys were made on the same animals to observe whether there were fluctuations with seasonal change. At each survey, all adults, and most immatures, were sampled. The serological tests comprised the complement fixation test, the serum agglutination test, and the Rose-Bengal precipitation test. Animals considered positive for brucellosis had to have significant titres in either of the first two tests. The results of all the surveys are given in Table 25.

It can be seen that the incidence fluctuates to some extent, mostly within the range of 13-29% of the herd. So the infection is quite widespread and probably occurs at about the same level in both sheep and goats. So it certainly could pose a danger to humans.

Table 25. The results of serological surveys for brucellosis at Ngurunit and Korr

Location	Species	Date	Total number sampled	Proportion of total sampled		Origin of sample
				Positive	Doubtful	
Ngurunit	Goats	23.1.79	84	6	7	Goats for Phase 2
		28.7.79	70	29	43	Goats for Phase 2
		10.12.79	79	13	19	Goats for Phase 2
		2.3.80	82	23	4	Goats for Phase 2
		28.4.80	141	17	0	Additional purchases for Phase 3
Korr	Goats	2.3.80	31	16	0	Initial purchases for Phase 3
		5.9.80	78	14	18	Additional purchases for Phase 3
	Sheep	5.9.80	53	17	19	Additional purchases for Phase 3

In order to determine the extent to which it really is affecting animal productivity (through abortions) specific tests are required for cases of abortion. Abortions due to brucellosis are only likely if the infection is active at the time of the abortion. To test for this, paired sera samples are required - the first within a few days of abortion and the second four to six weeks later. If the infection is active the antibody titre will have risen from the first to the second sample. It proved difficult to obtain these paired samples, but in the end some 20 were achieved, with most from another part of the study area (Olturot). The results are given in Table 26 and show that the majority of abortions were due to other causes (the most likely being inadequate nutrition).

Table 26. Incidence of active brucellosis among a sample of abortions from goats and sheep

Location	Number paired serum samples	Number active brucellosis[1]	Proportion active brucellosis (%)
Olturot	13[2]	4	31
Ngurunit	6	2	33
Korr	1	0	0
Total	20	6	30

Notes:

1. Active brucellosis diagnosed if both titres positive and the second had increased.
2. Included 2 sheep, both negative for active brucellosis.

Table 27. The packed cell volumes (%) for drenched and undrenched goats at Ngurunit (number, mean $\pm$ SD)

Date	Undrenched		Drenched	
8.12.79	43	24.2 $\pm$ 3.95	18	24.8 $\pm$ 3.49
9.2.80	42	25.3 $\pm$ 3.62	17	27.8 $\pm$ 4.33
30.3.80	44	24.8 $\pm$ 3.19	20	28.0 $\pm$ 4.00
26.4.80	44	24.3 $\pm$ 2.92	20	27.8 $\pm$ 3.41
30.5.80	46	25.5 $\pm$ 2.69	21	27.9 $\pm$ 2.91

7.5 ANAEMIA

7.5.1 Field analyses

The trait that was chosen for monitoring the level of anaemia in the field was the packed cell volume (PCV). Estimates were made at monthly intervals for the last part of Phase 2 at Ngurunit. All animals in the herd were sampled and the PCV estimated using a battery-driven microhaematocrit centrifuge (the COMPUR 1000, from Zeiss). The results obtained for adults are given in Table 27. They show that after the first sample each group established a fairly stable level, with the drenched group being some 10% higher than the undrenched, quite large enough to be associated with a significant response in performance. With the studies on strongyles having revealed that *Haemonchus contortus* was the major species present, it would be expected that it would be the main cause of this anaemia.

Normal levels for goats are reported as 29-30% (Schalm, 1975). These were obtained by centrifugation for 10 minutes at 14,000 G, and would certainly give lower estimates than the technique used in this case, so it is difficult to know how far off the normal value are the levels obtained for the drenched group.

7.5.2 Laboratory analyses

In order to interpret the data on PCVs more accurately a full haematological examination was carried out at the end of a wet and a dry season. For this, heparinized blood was used and brought to the Kabete Laboratory.

The results of these are shown in Table 28, with the age groups distinguished because of the normal differences between them. The levels for both the mean corpuscular volume and the mean corpuscular haemoglobin are below the normal, indicating a microcytic hypochromic anaemia.

A possible cause for this type of anaemia is copper deficiency and so serum samples for the whole herd (76 goats) were analysed for copper levels. These ranged from 0.65-0.92 ppm, which is within the normal range. Another frequent cause is chronic haemorrhage, which would be consistent with chronic haemonchosis.

Table 28. The mean corpuscular volume (MVC) and mean corpuscular haemoglobin concentration (MCHC), for drenched and undrenched goats at the end of a wet and a dry season (number, mean ± SD)

Parameter	Age group	Undrenched				Drenched			
		9.12.79		2.3.80		9.12.79		2.3.80	
MCV	0-4 m	3	30.2±2.06	4	17.6±3.36		-		-
	4m-1yr	8	16.3±1.40	7	17.2±0.95	4	16.8±0.48	4	19.1±3.46
	> 1 yr	44	17.3±1.94	41	17.8±2.02	17	17.3±1.71	16	18.2±1.45
MCHC	0-4 m	3	36.3±2.02	4	32.0±3.67		-		-
	4m-1yr	8	33.9±2.58	7	34.4±1.61	4	33.7±0.78	4	31.4±3.86
	> 1yr	44	34.6±2.28	41	34.2±2.62	17	34.5±1.26	16	34.8±2.36

8. CONCLUSIONS AND RECOMMENDATIONS

At this stage it is important to draw together the main findings of these studies, in order to determine the interventions that can be made immediately for improving performance, and the most important areas for further investigation.

8.1 GENETIC POTENTIAL OF RENDILLE GOATS AND SHEEP

It must be concluded that this has not yet been established for any of the performance traits.

It is clear that levels of all the performance traits studied were depressed as a result of a wide range of stress factors; and there were many indications that the potential was well above the levels observed, particularly for mature size and growth rate, and also lactation.

One of the greatest constraints to future productivity may well be the permanent stunting occurring during the first 4 to 6 weeks of life.

It is recommended that;

1. Other breeds of sheep and goats are not imported, except under controlled conditions, until the genetic potential is clarified and the feasibility of relieving the constraints for the existing genotypes has been tested. At present it is not possible to know whether other genotypes are different, and if they are, whether they will in fact perform any better within the constraints of the Rendille environment.
2. Research is required to determine the effects upon all performance traits, when the goats and sheep are not permanently stunted at a very young age.

8.2 DIFFERENCES BETWEEN GOATS AND SHEEP

In all four performance traits studied there were significant differences between goats and sheep. Sheep grew faster and matured earlier. When this is taken in conjunction with the higher fertility levels of sheep, there is greater potential for meat production, providing the higher morbidity levels are overcome.

Goats may have a potential for supplying milk to those sections of the community who do not have access to sufficient camels' milk.

It is recommended that:

1. The improvement of meat production from smallstock in Rendille should involve an integration of both species, with sheep being able to exploit more fully the potential of the more favourable season, and goats possibly being better suited to harsher times.
2. Research is required to establish the milk production potential of the goats, to establish whether this is a resource that is worth developing and integrating with camels, to meet the overall milk requirements of the community.

8.3 MAJOR CONSTRAINTS TO PRODUCTIVITY

Clearly the most important constraint of all is the restricted supply of nutrients that is inevitably part of such an environment. The effects of these are far reaching. In addition to immediate effects upon growth and lactation, there are anoestrus, abortions, predisposition to other stresses leading to death, etc. However, the evidence so far suggests that this may be confined to energy and protein, and possibly sodium. There was no evidence of deficiencies in other minerals or of vitamins, although when rain fails completely one would have doubts about the adequacy of vitamin A levels.

Predation is a major constraint, having accounted for the largest proportion of all diagnosed deaths, despite the precautions taken.

Haemonchosis is widespread, frequently occurring at pathogenic levels.

Coenuriasis is a common cause of death with depression of productivity being probably more than would appear due to the prolonged period of the disease preceeding death.

Epidemics of contagious caprine pleuropneumonia (CCPP) occur episodically with disastrous effects upon the kid crop and immatures.

Brucellosis is important as a cause of abortions and as a zoonosis.

It is recommended that:

1. Vaccination against CCPP and brucellosis be a regular part of any management programme.
2. Disposal of all carcasses and offal be effected so that dogs and wild Canidae are denied access, thus breaking the life-cycle of *Coenurus cerebralis*. It is very likely that this would have other beneficial effects as well.
3. The strategic use of anthelmintics is warranted. As *Haemonchus contortus* is much the most important species, the anthelmintic can be a narrow-spectrum (and cheap) one. The most critical groups of livestock would be the heavily pregnant and early lactating females, and the young pre- and post-weaning.
4. It may be worth running dogs (and perhaps donkeys), with the grazing herd, as additional protection against predators, a suggestion which has also been made by Kruuk (1980).
5. Research is required to determine:
   - The effectiveness of strategic supplementation, perhaps with *Acacia tortilis* pods;
   - The epidemiology of haemonchosis in this arid environment.

8.4 THE NGURUNIT ENVIRONMENT

In all performance traits but fertility, goats at Ngurunit performed worse than at Korr. In the case of fertility, comparison was not feasible due to the time restriction of the Korr studies. Considering the rainfall level and the general aspects of the vegetation, the expectation was the reverse. It is not known how performance of the experimental herd compared with other herds around Ngurunit but there were indications that it was as good as if not better than the latter. If it was appreciably lower, then the cause of these low levels was probably due to some aspect of the management of this particular herd and not indicative of the potential of the environment.

On the other hand, if this is a true indication of the general performance around Ngurunit, it indicates the presence of some unidentified stress seriously affecting productivity. The most likely cause would be of dietary origin.

It is recommended that:

A monitoring programme be established to determine growth or lactation levels in other herds at Ngurunit and Korr, to replicate the studies reported here.

8.5 INTERVENTIONS IN THE RENDILLE SMALLSTOCK SYSTEM

Considerable care is required in the choice of interventions, and considerable caution is required in the interpretation of their effects: this has been well demonstrated from the studies on growth reported here. This situation should be expected when changes are being proposed to an ecosystem about which so little is known.

It is recommended that:

1. Wherever possible interventions are monitored, and development programmes are sufficiently flexible to enable modifications to be made when appropriate.
2. Assistance be sought from the techniques of systems analysis and modelling, in gaining an understanding of the present system and effects of interventions within it.

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THE SIMULATED EFFECTS OF GENOTYPE AND DROUGHT ON SHEEP PRODUCTION

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INTRODUCTION

Sheep production in the arid region of northern Kenya is an important component in the food producing ability of the nomadic pastoralists. Due to increased pressures on natural resources and livestock it is essential that sheep production takes place at its maximum efficiency. To obtain the level of maximum efficiency all aspects of sheep production must be considered (i.e. nutrition, reproduction, genotype and management). The technique used to evaluate a complex set of factors, such as the biology of the sheep, is systems analysis. This approach diverges from the traditional approach to research since it attempts to interrelate all the components involved in the system.

A major role of systems analysis is as a strategic planning tool which can assist producers to avoid implementation of production alternatives which have a negative influence on production efficiency. Furthermore, it can identify those practices which are predicted (or simulated) to result in the greatest flock productivity. Systems analysis has a further advantage over the traditional approach to research in that a greater number of production practices can be examined than would be possible with live animals. Also, the long-term effects can be examined to determine if there is some long-range detriment or advantage which is not immediately known. Obviously, these are important options which administrators, planners and scientists should consider when studying complex situations where suggested changes in the system of production can have devastating effects on the people they are serving.

Models are the tools the systems analyst uses to interpret the behaviour of the system being studied (in this case the sheep) and the influence alterations will have on the production system. Forrester (1968) has stated that the usefulness of constructing a formal model is that our own mental image of the system is clearly exposed. Also, general statements of size, magnitude and influence are given numerical value, therefore providing decision makers with a more complete picture of the problem that they are to solve.

The modelling process is a relative matter. The evaluation of a model should not be on an absolute scale that condemns it for failure to be perfect, but on a relative scale that approves it if it succeeds in clarifying our knowledge and our insights into the system (Forrester, 1968). Forrester further states that the solutions from a simulation do not tell all of the possible behaviour patterns; instead a simulation gives a one-time history of the system. For more information based on different conditions another full step-by-step computation of a system time-response must be made.

To help the reader to understand the phases of model development better a sequence of six steps used in model development is presented. These were originally given in ILCA Monograph I (1978).

1. Problem definition. This is the initial step in model development, the boundaries of the system are outlined and the level at which the subject is to be modelled is defined.

2. Quantitative formulation of the model. The mathematical functions used to describe the biology contained within the model are developed.

3. Model verification. This step is a means of making certain that the equations used and the algorithms of the model are yielding results of the proper order and magnitude.

4. Model validation. This procedure involves comparing simulated results with real life data. The data which the model is validated against should not have been used to develop the model.

5. Model experimentation. This is the use of the model with varying alternatives after the verification and validation procedures have proven satisfactory.

6. Analysis of model results. The simulated results of different alternatives are compared to determine further experimentation or what policy should be practised.

SIMULATION MODEL

A major purpose of the Texas A & M University, Small Ruminant, Collaborative Research Support Programme (TAMU-SR-CRSP) model is to simulate sheep performance for a wide array of genotypes in a wide variety of environments with managerial options implemented as desired. These capabilities make it possible to evaluate the performance of different genotypes in different areas or environments employing different production practices. The model, which is programmed in FORTRAN IV, simulates all major phenotypic characteristics of a sheep (i.e. body weight, milk production, reproduction, feed intake and growth). It simulates these characters on a 15-day time step or period. A 15-day time step was used because it closely matches the reproductive biology of the sheep and it makes a 360-day year feasible. A shorter time step would not greatly increase the accuracy of the simulation but would add to computation time and computer costs.

To perform a simulation with the model a series of input parameters must be supplied to the program. These include the type or breed of sheep to be simulated: the breed is specified to the model in terms of mature weight (WMA), potential peak milk production (GMLKL), ovulation rate (OVR) and the rate of maturing (RM). The forage input for the model includes crude protein, digestibility and availability of the forage with the given diet quality. Each of the forage parameters is specified on a 15-day basis. The model allows for a very flexible set of management parameters: such parameters include the breeding season, age at weaning, culling levels, sale strategies and replacement policies. A series of health parameters is also specified to the model, and is used to calculate the probability of death of sheep of different ages and at different times of the year.

Output of the model includes milk produced for human consumption, deaths, sales or offtake of animals for home consumption and cull animals.

A conceptual overview of the model is presented in Figure 1. From this diagram the interactions among the different biological processes modelled can be observed.

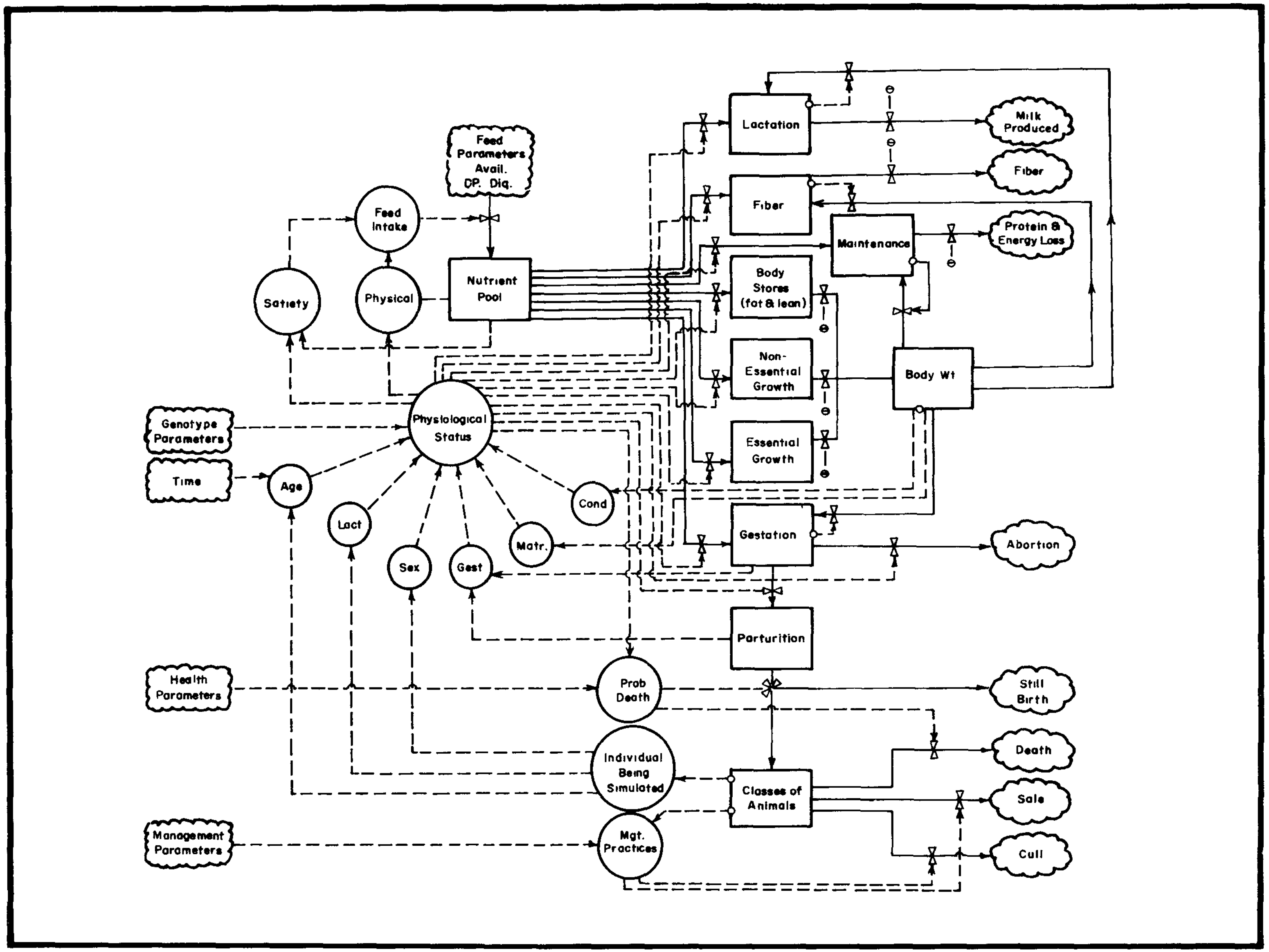


Figure 1. A conceptual overview of the information and material flow of the sheep model

VALIDATION OF THE SHEEP MODEL IN NORTHERN KENYA

A critical area of systems analysis is validation. The validation process examines how closely simulated results match actual data, thus testing both model structure and functions and input parameters. Closeness of correspondence establishes the level of confidence in the simulated results. When the simulation data match with reasonable closeness the actual production levels and fluctuations in those levels in every phase of the production system in the area of intended use, experimental simulations can be conducted with more confidence.

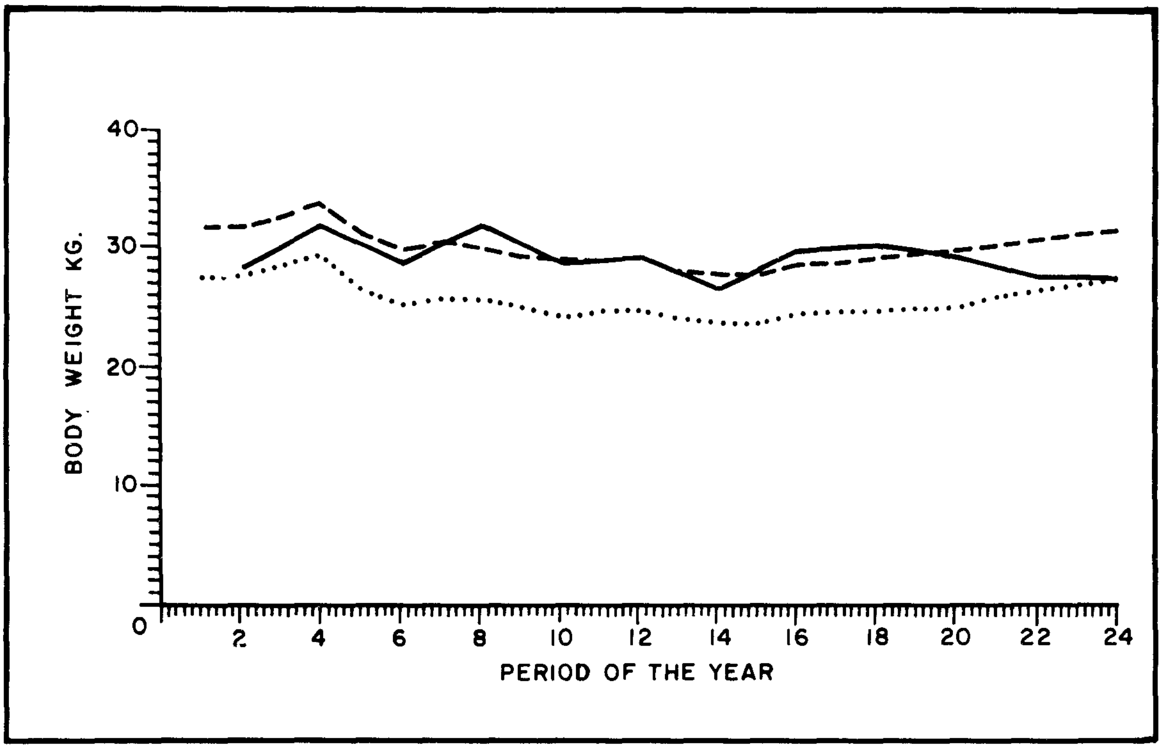
The data used for model validation were collected by the IPAL staff at Olturot Station during 1979 and 1980. The simulated results for ewe body weight, lamb growth, milk production and reproduction were compared to the actual results which were reported by Blackburn and Field (1984).

DATA FOR 1979

Ewe body weight

Body weights of actual and simulated ewes were compared for the entire year. The simulated ewe weights used were from the 4.5 year-old age group. This was the youngest group of ewes that had reached their WMA. Also, for most research results, ewes of this age group are at their peak producing ability. Empty body weight (EBW) and full weight (W) were compared to the actual ewe weights (Figure 2). It is necessary to compare all three curves in Figure 2 because actual ewe weights were recorded in the morning after being enclosed all night in the *boma* and, therefore, represent an intermediate weight.

Figure 2. Comparison of 1979 actual (solid line), simulated total (dashed line) and simulated empty body (dotted line) weights



For the greatest part of the year there is consistent agreement between the simulated and actual weights. For both sets, body weights started the year at a high level, decreased during the long dry season and then increased as the short rains began. The greatest divergence between simulated and actual results occurred in the last three months of 1979. At first inspection, the decrease in actual weight does not appear to be logical, because crude protein and digestibility were increasing. An explanation for this response is that 40% of the actual ewes gave birth and/or were lactating at this time. Therefore, lambing and lactational stress caused the reduction in actual weights. Sixteen per cent of the ewes in the simulated flock gave birth at this time; therefore the weight increase and subsequent decrease was not as great as in the actual data. To further substantiate the agreement between simulated and actual ewe weights, the weights of simulated ewes lambing in September and October were plotted against the actual data. Figure 3 clearly shows that simulated ewes in a similar reproductive phase as the actual ewes display the same pattern of weight loss.

Milk production

The average actual and simulated lactation curves are given in Figure 4. Both of these curves are averaged over the entire year. For the actual curve there were only three months in which ewes gave birth and complete lactation data were collected: April, May and November. There were four ewe records for April and May and three for November.

In general the simulated and actual lactation curves remain in close proximity of one another. Initial and ending points of the lactation curves are extremely close. However, the decrease and following increase of actual milk production did not occur in the simulated lactation curve. To determine the cause of fluctuation, the actual curves were divided and replotted as November and April and May. From these curves it is apparent that the fluctuation is the result of the April and May lactation curve. For comparison, the simulated November, April and May lactation curves were plotted with their respective counterparts. The November curves show a greater uniformity of agreement (Figure 5) than the April-May curves (Figure 6). The simulated April-May curve shows a similar decrease in milk production but it does not increase in milk

Figure 3. Comparison of 1979 actual (solid line), simulated total (dashed line) and simulated empty body (dotted line) weights. Crosshatched lines are the divergence of simulated total and empty body weights of ewes lambing in period 18 from the simulated flock average.

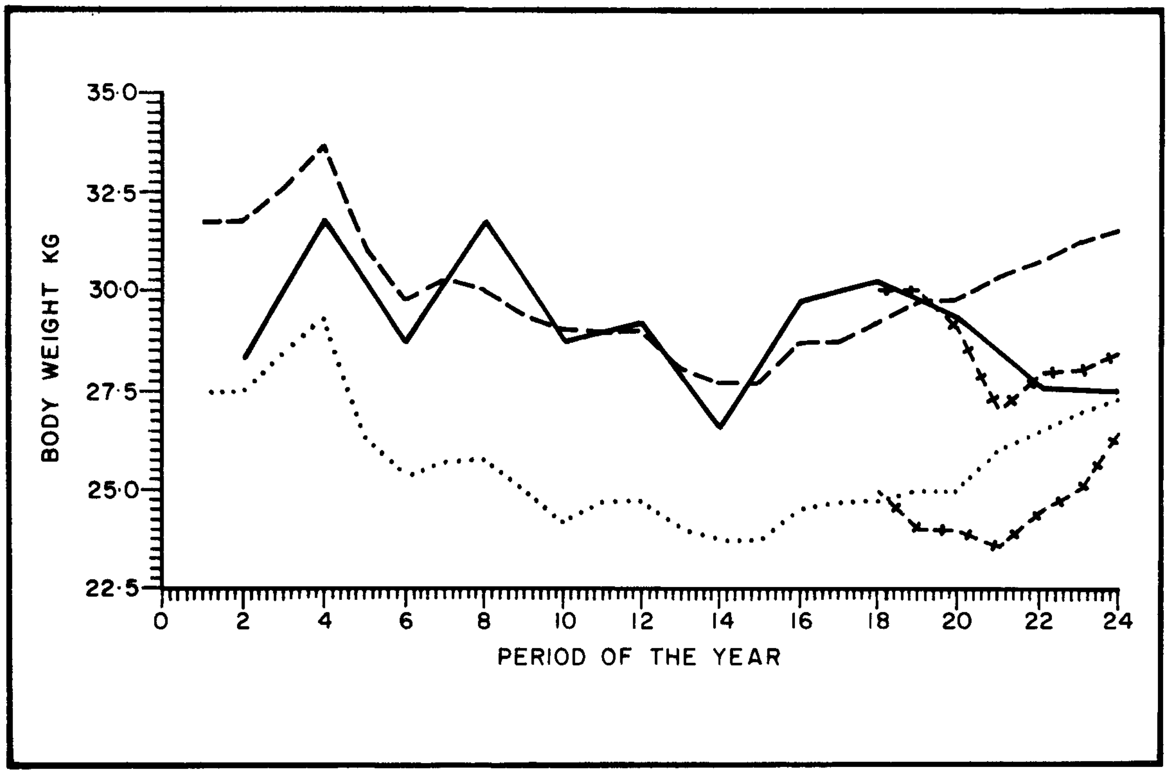


Figure 4. The 1979 average actual (solid line) and simulated (dashed line) lactation curves

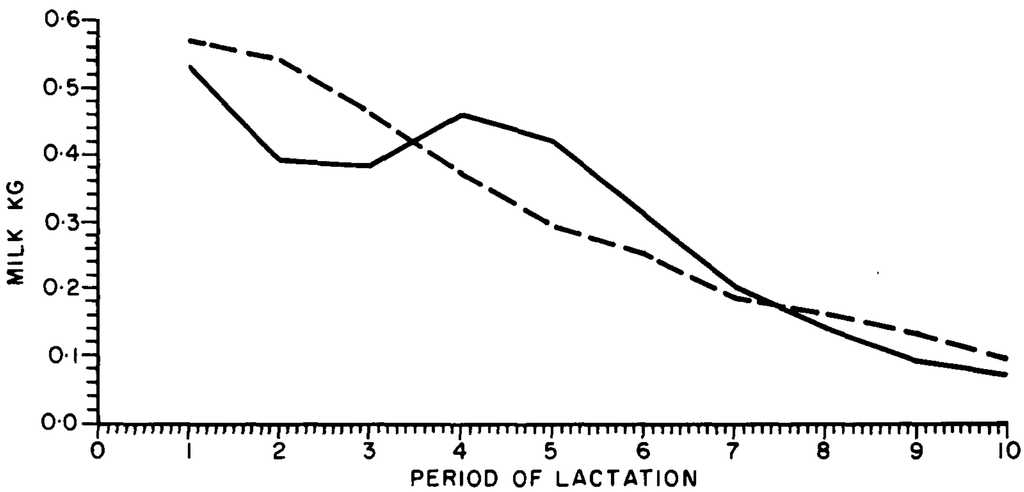


Figure 5. November lactation curves for actual (solid line) and simulated (dashed line) ewes

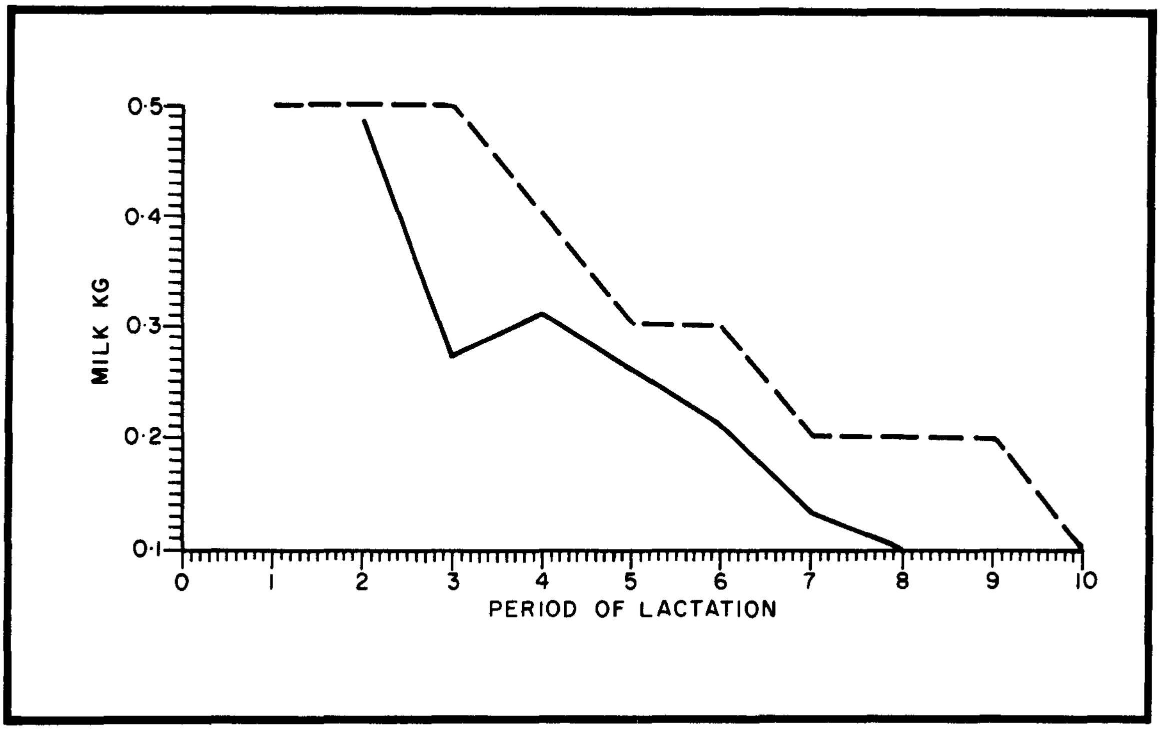
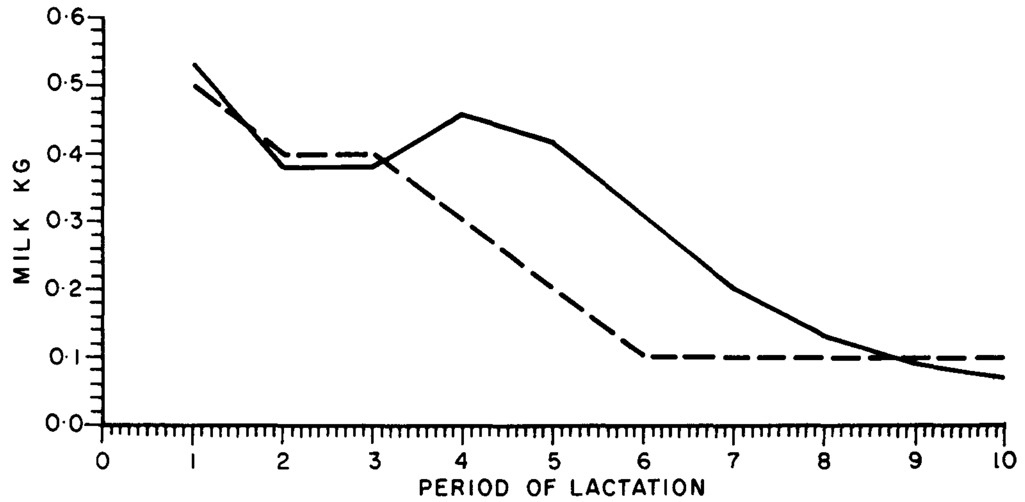


Figure 6. April and May lactation curves for actual (solid line) and simulated (dashed line) ewes



production during period 4. The cause of this increase is not clear because feed quality does not significantly change during this time. Due to the small number of lactations, it is possible that the increase was due to a peculiar artefact not counterbalanced as would be expected for a larger sample size.

Lamb growth

One of the final products of this system is lambs produced. A comparison of the least squares means of the actual lambs' weights and the simulated W and WM weights averaged over the year was made (Figure 7). There is extremely close agreement between actual and simulated weights up to 300 days. The actual and simulated curves diverged slightly after 300 days during which time the actual data were extrapolated to 360 days.

The close agreement between actual and simulated data for pre-weaning, births to 10 periods (150 days of age) of growth, has additional implications. The close agreement based on a larger sample size indicates that real milk production levels for actual and simulated ewes may have been more similar than indicated.

Reproduction

The IPAL flock had a 130% lamb crop (live lambs born/ewe) for 1979. The simulated flock had a 132% lamb crop. Further estimates of reproductive efficiency were not obtainable from the actual data. Additional simulation output indicated that lambs weaned/ewe in the flock was 100.8% , which equates to a lamb survival rate of 76.4% of the lambs weaned/lambs born. The actual reproductive rate was higher than the regional average due to IPAL ewes receiving higher levels of management (e.g. drenching and dipping). The simulated lamb survival to weaning is closer to the regional mean (Field, personal communication).

Figure 7. Comparison of 1979 lamb growth patterns for actual weight (solid line) and simulated total weight (dashed line) and simulated structural size ($\dot{W}M$; dotted line)

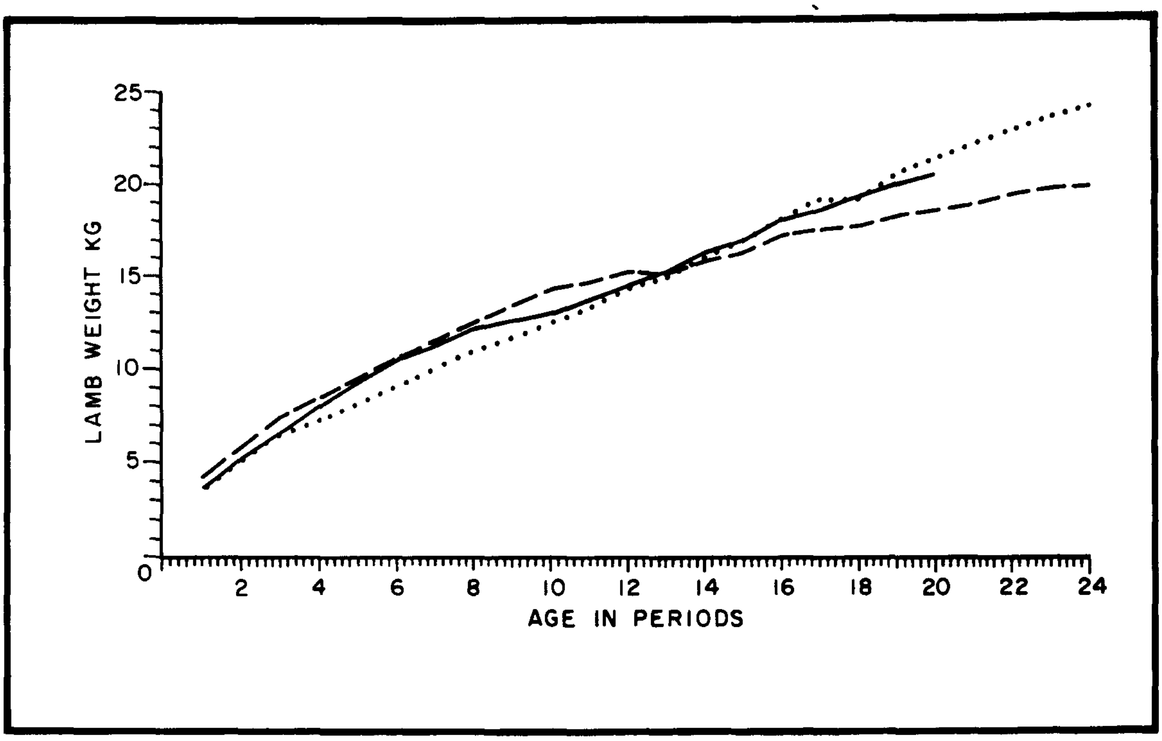


Figure 9. The 1980 average lactation curve for actual (solid line) and simulated (dashed line) ewes

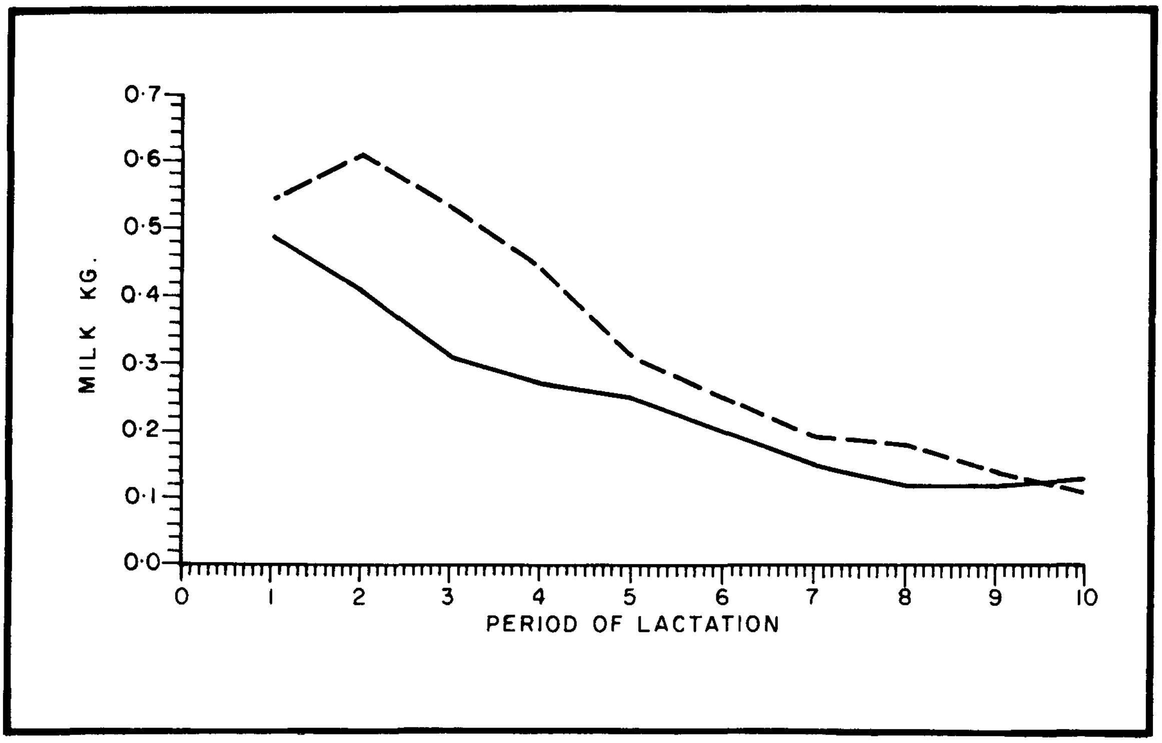
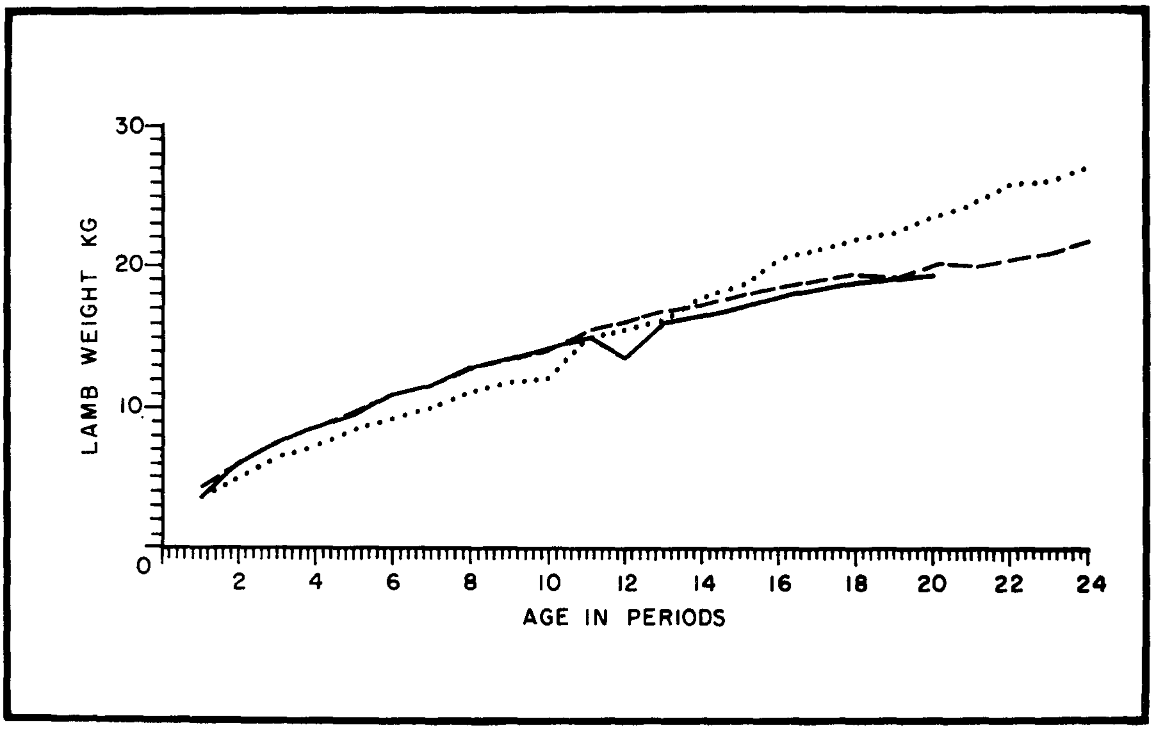


Figure 10. Comparison of 1980 lamb growth pattern for actual weight (solid line), simulated total weight (dashed line) and simulated structural size (WM; dotted line).



advantage of grazing. Secondly, in 1979 the lambing pattern was more uniformly distributed throughout the year, causing more lambs to be born in seasons of lower quality forage so that they cannot take as much advantage of grazing as in 1980.

Reproduction

The reproductive rate of the simulated *vs.* the actual was in close agreement (119 *vs.* 118%). The difference between the two years is partially explained by lower ewe body weights which would result in lower conception rates. The lambs weaned/lambs born ratio was 0.70, indicating a greater loss of nursing lambs in 1980 compared to 1979.

EXPERIMENTAL DESIGN

A number of simulations can be performed on the sheep production system in northern Kenya. An often asked question, which is difficult to answer in advance, is what impact would different breeds or types of sheep have on the production system? The sheep model is capable of simulating different breeds of sheep where differences between breeds are specified by mature size (WMA) and potential peak milk production per day (GMLKL). If new genotypes are to be evaluated as to their ability to enhance sheep productivity one must also discover how they respond to different environmental conditions. In animal breeding terms an evaluation of genetic environmental interactions (GEI) should be performed: that is, one has to determine how the selected genotypes perform in different environmental situations which may occur in the study area.

To examine the effects of genotype (G), environment (E) and G x E interaction, a 3 x 3 x 4 factorial design was used. Different mature sizes (WMA), potential peak milk production levels (GMLKL) and a changing environment were tested. Mature size and GMLKL represent characters which could have a significant impact on productivity if it was found desirable to alter the current genotype. Mature size was tested at the 30-, 35- and 45-kg level. This weight range is representative of the potential mature weights of breeds in Kenya or other semi-arid areas. Levels of milk production simulated were 0.90, 1.30 and 1.75 kg. The genotypic combination used in validation was WMA of 35 kg and GMLKL of 1.30 kg, which are intended to represent the Somali Blackhead used in the study area.

Three environments were simulated: 1979, a drought year, and two recovery years. These years differed by the forage parameters used as model inputs. The forage parameters used in 1979 were actual data collected by the IPAL staff, the drought year was a hypothesized situation where rainfall was lower than that for 1979, and forage parameters were adjusted downward to reflect this effect. The recovery years were a return to the 1979 forage parameters. Using this combination of years it was possible to determine how genotypes could respond in a relatively good year, a drought year and their subsequent recovery from the drought.

INPUT PARAMETERS

Model input parameters for genotype, forage and management are specified at the start of the simulation. The genotypes used in the study have already been described in regard to mature size and potential peak milk production. The remaining genetic parameters, seasonality of oestrus and ovulation rate, once specified, remained constant for all simulations. The sheep in northern Kenya do not experience anoestrus due to a changing day/night ratio, therefore photoperiodism was not a factor. The genetic parameter for effective ovulation rate was determined from lambing rates in the literature. For this breed and set of simulations the effective ovulation rate was set at 1.10 eggs per ovulation. Although corroborative data were not available, a mean ovulation rate of this magnitude seemed appropriate in relation to literature values for lambing rate (lambs born/ewe lambing).

FORAGE PARAMETERS

The forage parameters required by the sheep model are crude protein and digestibility of the consumed forage and the maximum daily availability of the forage on a per-sheep basis. These parameters are specified to the model on a 15-day basis. The IPAL group had collected diet quality data (unpublished) for 1979 and 1980. This information was collected by following the flock in its normal daily grazing area. Approximately 30 animals were observed until each had completed feeding for 10 minutes. Species and plant parts consumed were recorded on a time basis to the nearest minute. Food plants were expressed as a percentage of the total feeding time of the animals observed. Samples of the key food plants were harvested by hand according to the species and plant parts eaten and sent for chemical analysis at the University of Hohenheim, West Germany. Plant samples were analysed (*in vitro*) for crude protein using the modified Kjeldahl technique and for digestible organic matter using the two-stage method and sheep rumen liquor. Table 1 lists by month the estimated values for crude protein, digestibility and the percentage of the diet which was composed of analysed species.

Availability of forage was not estimated directly. Alhtough several estimates of biomass for the study area were available (Herlocker, unpublished), they could not be used because they over-estimated the amount of forage available to the sheep. Another source of information on forage availability was the observation of the resident scientists as to times when forage availability limited intake. The forage availability parameters used were based on a combination of factors which included rainfall pattern, resident scientist accounts and model responses in validation. The last category mentioned entailed supplying the model with forage availabilities and making a validation run. Actual data were compared to simulated results to determine the degree of correspondence. For periods where there were great discrepancies between actual and simulated results the forage availabilities were adjusted in the opposite direction of the discrepancy. This type of adjustment has several drawbacks and one safeguard. The safeguard is that too large an adjustment for a period or a group of periods will cause changes throughout all results of the model;

Table 1. Weighted average of crude protein and digestibility for sheep diets

Month	1979			1980		
	CP%	Dig.%	% Diet accounted for	CP%	Dig.%	% Diet accounted for
January	9.46	50.90	87.0	12.14	56.57	56.0
February	14.53	54.35	87.0	8.87	42.57	61.0
March	10.25	39.89	83.0	5.66	40.59	34.0
April	11.61	48.38	74.0	14.40	56.71	42.0
May	10.36	43.43	80.0	13.66	64.71	51.0
June	9.86	46.53	76.0	7.47	54.07	47.0
July	7.34	42.50	31.0	6.65	47.52	62.0
August	6.60	43.97	37.0	6.09	50.32	40.0
September[a]				6.50	54.90	73.0
October	8.25	45.77	91.0	5.90	54.46	68.0
November	12.50	56.50	65.0	4.67	50.49	80.0
December[a]				12.65	47.36	25.0

[a] In 1979 values for these months were not collected

therefore, if simulated results are out of phase for one or two periods, over-adjusting will cause previously in-phase results to diverge. The drawback to this type of manipulation is that the baseline validation results may be biased. The availabilities used in the baseline validation are given in Table 2.

The forage parameters used in the drought year are given in Table 3. The drought year is a hypothetical situation. Therefore, the forage values used are also hypothetical. However, their values are realistic and in a feasible range. They were established on the assumption that the drought took place in two forms. First, the long rains occurring from March to May were shortened and with less rainfall than 1979 and 1980. Second, the short rains (late October and November) were late in starting. The desired effect was to have animals in lower-than-average condition when the long dry season started and to prolong the dry season, thereby severely stressing the animals.

MANAGEMENT PARAMETERS

The inputs for the management sub-routing were obtained from the IPAL staff. These inputs comprise the management practices used on the IPAL flock. They include: year-round breeding, weaning lambs at 10 periods of age (150 days), utilizing 1/4 of the ewe's milk for dairy production and setting the minimum age of breeding-ewe lambs at one year. Model stipulations placed upon milk extraction for dairy purposes were: the ewe must be at least one year of age, the lamb body condition (EBW/WM) must be 0.85 or greater, and the maximum amount of milk extracted was set at 1/4 of the total amount produced, unless the ewe lost her lamb, then all the milk would be extracted. These stipulations emulate the basis on which herdsmen take decisions about whether to milk a ewe.

There were several classes of sheep that each sex passes through during their life-cycle. The transfers were determined by either age, weight, physiological status or a portion of the class size or total flock size. Replacement rams and excess ewe lambs were sold (or consumed) at 1 year of age. Ewes were culled from the flock twice during the year. In April, all ewes 7 years of age or those that were open and had not lambed in 1 1/2 years were culled. In September, 20% of the open ewes were randomly culled.

Table 2. Forage availability for IPAL sheep (kg head^{-1} day^{-1})

Month	1979	1980
January	1.1	1.7
February	7.5	0.4
March	7.5	3.7
April	7.5	4.0 - 0.9[c]
May	7.5	0.7
June	7.5	8.0
July	7.5	2.1
August	3.9	0.5
September[b]	1.9	0.1
October	2.7	1.0
November	1.0	12.0
December	1.0	9.3

[a] Values greater than 2.0 indicate availability is unlimited.

[b] September availability values were increased by 0.25 kg to represent the consumption of *Acacia tortilis* pods.

[c] 0.9 is the availability in the second period of April.

Table 3. Crude protein, digestibility and availability of forage for diets during the drought year

Month	CP %	Dig.%	Availability ($kg\ head^{-1}\ day^{-1}$)
January	10.0	50.0	1.00
February	7.0	43.0	0.40
March	9.0	45.0	0.70
April	8.0	45.0	0.50
May	14.0	55.0	5.00
June	10.0	50.0	5.00
July	8.0	46.0	3.00
August	6.0	44.0	0.80
September	6.0	40.0	0.55
October	6.0	42.0	0.50
November	7.0	43.0	0.60
December	10.0	50.0	5.00

RESULTS

The level of production of a nomad's flock of sheep, in response to their environment, is a composite of several factors. These include environmental changes within as well as between years, the response of each ewe within the flock (realizing that each ewe has a contribution to the overall productivity of the flock), and within each ewe the fluctuation of body condition, milk production and reproduction. Each of these factors may have an influence upon the flock's productivity at some point in time. The very complexity of this situation is a compelling reason to analyse flock productivity with a simulation model. The results have been reported in such a way as to bring to light the influences of these interactions on production.

EWE BODY CONDITION

Body condition scores (EBW/WM) are reported three times within a simulated year (Table 4). Generally the ranking of genotypes within a WMA decreased as milk production increased. In base year (BY), body condition was the lowest in August. This was a direct result of the decreased forage quality during this period of the year. Ewes exhibit their highest body condition in December, a response to increased forage quality caused by the short rains. However, as WMA increased from 30 to 35 and 45 kg, the fluctuation in EBW/WM was less. This would imply that the larger ewes with medium to high levels of milk production are not able to replenish their body stores to the same degree as lighter weight ewes.

In the drought year, ewe EBW/WM was the highest in August for all genotypic combinations. This was a reversal from the previous year. The reduction in forage quality and quantity in the first portion of the year and the additional stress during the later part of the year contributed to this result. Additionally, by August the number of ewes giving birth and lactating was reduced, also the frequency of the births increased in the last part of the drought year. These factors interact to determine EBW/WM.

Table 4. Body condition scores (EBW/WM) for breeding ewes for three periods during a year

		WMA[a] = 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
Year	Month	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
Base Year	April	0.800	0.723	0.667	0.800	0.743	0.666	0.800	0.740	0.711
	August	0.733	0.667	0.643	0.743	0.686	0.657	0.756	0.711	0.682
	December	0.833	0.790	0.777	0.829	0.771	0.723	0.815	0.749	0.711
Drought	April	0.667	0.633	0.600	0.629	0.600	0.571	0.622	0.578	0.578
	August	0.800	0.733	0.767	0.771	0.743	0.714	0.756	0.711	0.730
	December	0.667	0.633	0.633	0.657	0.629	0.600	0.622	0.600	0.600
Recovery Year 1	April	0.767	0.733	0.733	0.771	0.714	0.714	0.756	0.711	0.711
	August	0.700	0.633	0.600	0.714	0.757	0.600	0.733	0.689	0.640
	December	0.833	0.833	0.833	0.800	0.800	0.771	0.800	0.756	0.733
Recovery Year 2	April	0.800	0.700	0.667	0.800	0.714	0.686	0.800	0.733	0.689
	August	0.700	0.667	0.700	0.743	0.686	0.657	0.756	0.711	0.667
	December	0.833	0.767	0.733	0.829	0.743	0.686	0.800	0.733	0.689

[a] WMA = potential mature size, kg.

[b] GMLKL = potential peak daily milk production, kg.

During the drought year there was a tendency for the ewes with a WMA of 30 to be in better condition than ewes with larger WMAs. This result was due to the 30 WMA having a lower total maintenance requirement; therefore, they could meet their requirement easier than a heavier ewe; also the lighter sheep did not have as high a level of reproduction in the BY.

In the recovery years, EBW/WM resumes the ranking and fluctuation pattern observed in BY; however, there are several points which are different. In the first year a carry-over effect from the drought exists. The EBW/WM values for the GMLKLs of 1.30 and 1.75 are very similar. This represents an increase for the 1.75 genotypes. In year 2 of the recovery a separation of the 1.30 and 1.75 GMLKL is seen in the 35 and 45 WMA genotypes. In the 30/1.75 flock an increase in EBW/WM was observed in August. This result indicated that these ewes were not stressed to the same degree as the lower GMLKLs with the 30 WMA. A partial explanation for this increase in body condition is a lower reproductive level in recovery years 1 and 2 for the 30/1.75 flock. These results are a reflection of the interaction between nutritional requirements for milk production and reproduction along with carry over effects mediated through body condition.

REPRODUCTION

The measures of reproductive performance in the simulated flocks are given in Table 5. Two variables were used to evaluate reproduction; these were in the percentage of live lambs born (100 times live lambs born/total number of breeding ewes; LLB) and the percentage of lambs weaned (100 times lambs weaned/total number of breeding ewes; LLWN). The variable LLWN differs from LLB in the numerator by the number of lambs which died before they were weaned. The percentage of LLB gives an estimate of ewe fertility and LLWN combines ewe fertility, maternal influences and the lambs preweaning environment.

The general trend for LLB was to decrease from the BY to recovery year 1 and then increase in recovery year 2. The continued decrease in LLB in recovery year 1 was mainly due to the reproductive pattern in the flocks being disrupted.

Table 5. Flock reproductive performance as a percentage of total ewes

	WMA[a] = 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
Character/Year	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
Live lambs									
Base year	117.0	115.0	106.0	123.0	123.0	116.0	125.0	124.0	119.0
Drought	120.0	120.0	106.0	119.0	112.3	122.0	116.0	122.0	114.0
Recovery year 1	93.4	87.4	71.2	109.5	93.9	86.9	109.0	110.5	95.2
Recovery year 2	99.3	107.9	106.9	101.0	115.4	119.2	96.9	112.9	112.0
Lambs weaned									
Base year	103.0	99.0	88.0	110.0	112.0	105.0	109.0	114.0	109.0
Drought	79.2	76.5	69.6	80.9	67.1	78.9	73.0	81.1	72.6
Recovery year 1	80.8	77.3	56.3	100.9	86.8	78.8	97.4	103.1	92.0
Recovery year 2	84.8	97.0	94.4	92.6	108.2	111.3	85.5	106.6	107.9

[a] WMA = potential mature size, kg.

[b] GMLKL = potential peak daily milk production, kg.

The 20/1.75 lambs higher mortality was due to an inconsistent supply of milk. Initially these ewes produced more than adequate quantities of milk, but as lactation continued production dropped off severely, in turn causing lamb mortality to increase. The 35/0.90 and 45/0.90 decreased in LLWN during recovery year 2. This response was caused by the decrease in LLB. When examining LLWN within years and across GMLKL (Table 5), a negative relationship was seen between LLWN and GMLKL which was similar to the results seen in LLB. This would seem to be a carry-over effect from LLB because the expected result is for a positive relationship between GMLKL and LLWN.

PRODUCTIVITY PER EWE

An evaluation of performance of a genotype in the years simulated can be accomplished by putting the production characters on a per-ewe basis. Characters examined this way were lamb weight sold (LWS), total weight sold (TWS), which includes lambs and cull ewes, total milk production per year (TM/Y) and dairy milk produced per year DM/Y). Examining these production characteristics in this manner combines flock reproduction, lamb growth, ewe body weight and flock mortality.

Lamb weight sold

The weight of lamb a ewe can produce during a year is a critical factor in determining the well-being of the nomad. It is important that the offtake of LWS within a WMA be optimized and consistent.

An evaluation of LWS within a WMA and across years will determine the consistency of the production of a genotype (Table 6). The genotypes ranked closer than was observed with the other characters examined; there was not the separation of GMLKL as WMA increased. The rankings of genotypes for LWS were different from the rankings for yearling weight. For example, the LWS for 30/1.75 and 35/1.75 were the lowest ranking genotypes for their respective WMA. Although these genotypes did have higher yearling weights, their reproduction was low. Also, as a result of the low reproduction rates; these groups did not show a recovery in LWS from the drought. The converse existed with the 30/0.90 and

Table 6. Average offtake of lambs and culls per ewe, kg

Weight	WMA[a] = 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
Offtake/Year	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
Lamb									
Base year	8.8	7.3	6.1	10.3	11.3	9.9	13.1	13.8	13.6
Drought	6.6	6.1	4.4	8.5	9.0	7.1	9.5	10.9	11.5
Recovery year 1	4.1	3.7	3.3	4.8	4.7	5.3	4.5	6.0	6.7
Recovery year 2	4.9	5.1	2.6	8.9	8.8	6.2	9.2	12.2	13.2
Total									
Base year	15.0	13.5	12.3	16.9	16.9	15.7	20.8	21.0	20.3
Drought	11.6	10.7	8.9	13.8	13.4	10.6	14.8	17.5	17.5
Recovery year 1	10.2	9.6	7.7	11.3	10.9	11.3	12.3	12.0	13.4
Recovery year 2	11.5	11.7	8.9	16.7	16.5	11.5	19.0	20.2	22.2

[a] WMA = potential mature size, kg.

[b] GMLKL = potential peak daily milk production, kg.

the 35/0.90; these genotypes had relatively high reproductive rates which increased their ranking to an intermediate or high level. The most consistent ranking between genotypes can be seen in the 45 WMA where the genotypes maintain their rank throughout the study.

The relationship between GMLKL and WMA for LWS was variable. The variability was an indication that the genotypes have responded differently to the environmental stress. In BY, sheep with a WMA of 45 produced more LWS than any other genotype for size combination (Figure 11). There appears to be only a slight advantage in favour of the 45/1.30. Within the 35 WMA the 35/1.30 had a greater advantage over the other genotypes. The LSW for the 30 WMA genotypes decreased with an increase in GMLKL.

In the drought and recovery years a number of different responses, across GMLKL, occurred. The 45/0.90 and 45/1.30 produce less LWS relative to the 45/1.75. The difference between the 35/1.30 and 35/1.75 increased during the drought in favour of the 35/1.30, then evened out in the first recovery year, and in the second recovery year the 35/1.75 had the smallest recovery from the drought. A similar pattern for the last three years can be seen for the 30 WMA flocks.

It is clear from these results that reproduction and the specific matching of the WMA and GMLKL play an important role in determining LWS.

Total weight sold

The TWS responded to the environmental changes similar to LWS (Table 6). There are several years where genotypes ranked differently for TWS and LWS. A reason for the difference was that ewes with a lower GMLKL that were sold weighed more. The most notable difference occurred with the 35/1.75 genotype, which responded to the drought by dropping to its lowest level in the drought year and then showed only a slight recovery in the following two years.

An exception to the previous statement was the change of rank within the WMA. The 45/0.90 ranked very close to the highest genotype 45/1.30 for TWS in BY, but during the drought year the 45/0.90 was lower than the other two genotypes. The difference between genotypes was negated in year 1 of recovery but then increased again in recovery year 2. In recovery year 2 the rankings changed considerably from the BY and the difference became larger.

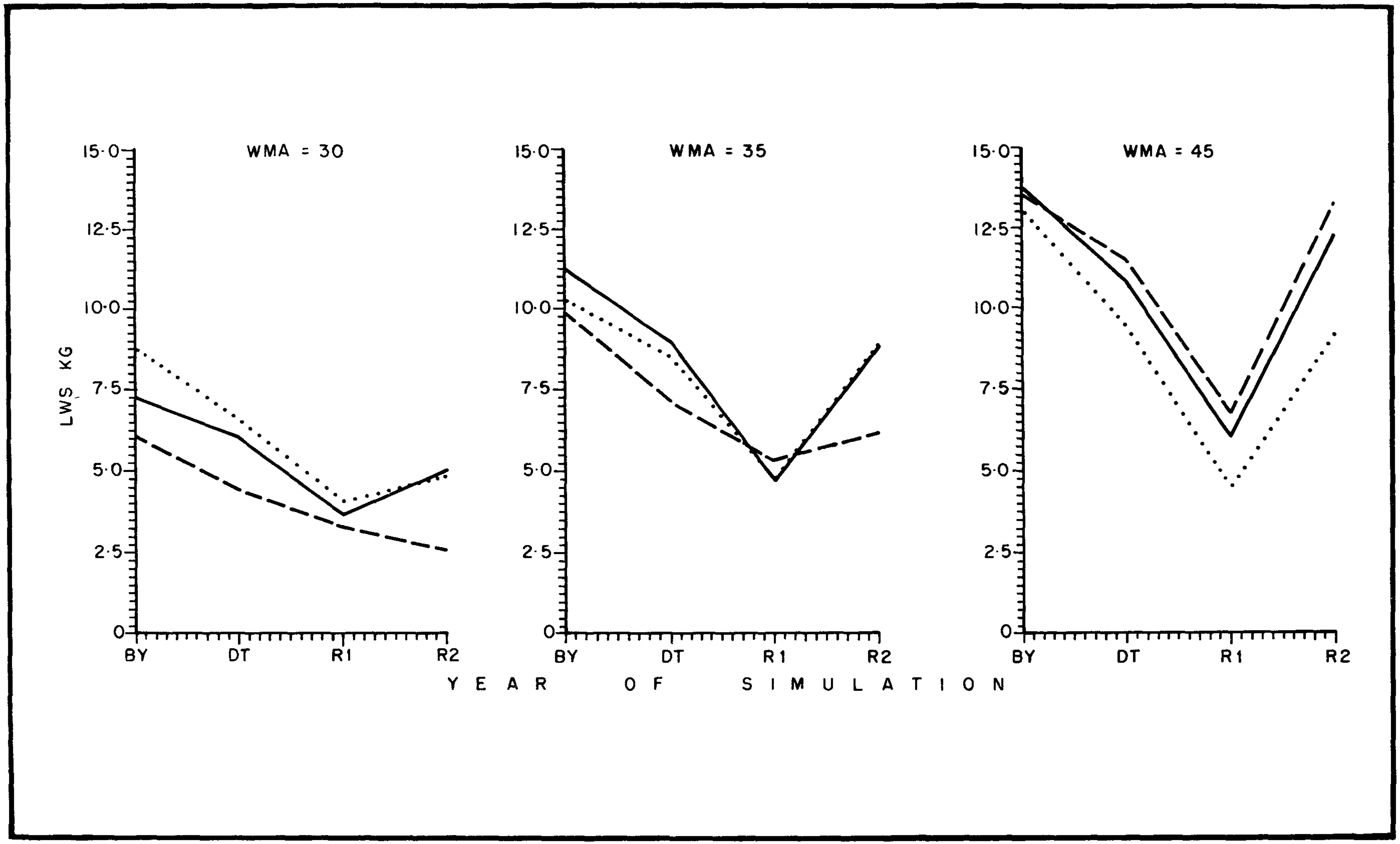


Figure 11. Effects of year and potential daily milk production (GMLKL) on the lamb weight sold per ewe (LWS) within a potential mature size (WMA). GMLKL of: .90 = dotted line, 1.30 = solid line and 1.75 = dashed line

Total milk produced per year

The TM/Y for the various genotypes is given in Table 7. The response of the TM/Y was different from the characters previously discussed. All genotypes experienced a decrease in milk production in the drought, then TM/Y remained at approximately the same level in recovery year 1 (Table 7). TM/Y increased in recovery year 2, however it did not reach its pre-drought level of production; therefore once TM/Y decreased it responded slowly to improved environmental conditions. The decrease in TM/Y was a combination of fewer ewes lactating and the time lag required for a complete recovery. Although the response of TM/Y was different from the previous characters examined, the ranking and separation of genotypes was very similar to characters previously discussed. Mature size has an important effect on TM/Y: as it increases the higher GMLKL genotypes increase their productive advantage. The 35/1.30 and 35/1.75 genotypes consistently produced more TM/Y than the 45/0.90.

Dairy milk produced per year

The yields of DM/Y had a downward trend from BY to recovery year 1 and then levelled off or had a slight increase in production in recovery year 2 (Table 7). The large decrease observed in TM/Y during the drought year did not occur with the DM/Y. This was due to a large number of lambs dying in the drought making a larger fraction of the milk available for human consumption. The DM/Y for the ewes with a WMA of 30 showed that ewes with a higher GMLKL produced approximately the same amount of milk as those with lower GMLKL levels; therefore increasing milk production in the small body size was not beneficial. Within the 45 WMA as GMLKL increased so did DM/Y, while in the 35 WMA genotypes the 1.30 produced DM/Y at a similar or higher level than the 1.75 ewes. During the BY, 35/1.30 ranked below 45/1.30; however, during the drought and recovery year 2 these genotypes were approximately equal. If recovery is measured by the amount of DM/Y, the 35/1.30 were recuperating from the drought at a faster rate than the 45/1.30. The faster recovery of the 35/1.30 may have been due to a larger number of lactating ewes in recovery year 2.

Table 7. Average yearly production of milk per ewe

Character/Year	WMA[a] = 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
Total milk									
Base year	64.3	63.9	59.3	62.3	76.2	76.5	66.0	84.6	95.7
Drought	44.1	45.3	39.7	48.4	52.3	54.3	50.2	58.9	61.8
Recovery year 1	42.5	42.1	36.3	49.5	53.8	53.2	50.1	61.7	66.1
Recovery year 2	47.4	53.0	50.2	54.5	70.3	66.7	56.4	74.8	84.9
Dairy milk									
Base year	21.6	21.5	22.3	24.8	28.4	29.6	25.9	31.3	34.7
Drought	19.7	20.1	18.8	21.6	26.2	26.5	23.2	26.0	29.6
Recovery year 1	17.0	17.7	18.2	17.7	22.3	20.8	20.5	23.9	25.8
Recovery year 2	14.7	16.3	17.7	17.8	24.0	20.9	19.7	23.5	28.4

[a] WMA = potential mature size, kg.

[b] GMLKL = potential peak daily milk production, kg.

FLOCK DYNAMICS

The simulations performed were designed to evaluate different genotypes in years of varying hardships and to determine how they recovered from the imposed hardship. How individuals and the flock respond to a drought situation is a key question to answer when evaluating the production situation in northern Kenya. Droughts are common, but there is great variability in length and severity. The genotypes would respond differently to each situation; however, the simulations performed do provide insight as to how a flock would respond to drought, and how it would re-establish itself after the drought had ceased. It is especially important to gain insight into the amount of food offtake available to the smallholders during droughts. For the purpose of this report, only sheep with a WMA of 35 kg will be discussed. For the response of the 30 and 45 kg WMAs see Blackburn (1984).

In these simulations the initial flocks in BY were in steady state, which was disrupted by the drought (a perturbation) and then the year in which the steady state had existed was re-established. A disruption was expected in the pattern of production due to the drought, followed by a re-establishment of the steady-state pattern of production. The characters chosen to examine this behaviour were the frequency of the live births and the amount of dairy milk produced per ewe per period. These two variables were chosen because frequency of birth should be drastically affected by nutritional stress and it is a key element in determining meat and milk offtake. A continuous supply of milk year round is vital to the nutrition of the smallholder of this area.

Graphs of live births (the percentage of live lambs born per period for each simulated year) for the 35 WMA genotypes in all years are presented in Figures 12 and 13. Initially, all genotypes have an extremely similar lambing pattern, which tends to be consistent throughout the year. For all genotypes the consistency was broken during period 14 and 15 which was during the dry season before the *Acacia tortilis* pods become available. Lambing in periods 14 and 15 would mean the ewes were bred in February and March which was at the end of the short dry season. Also, a small fraction of open ewes were present during period

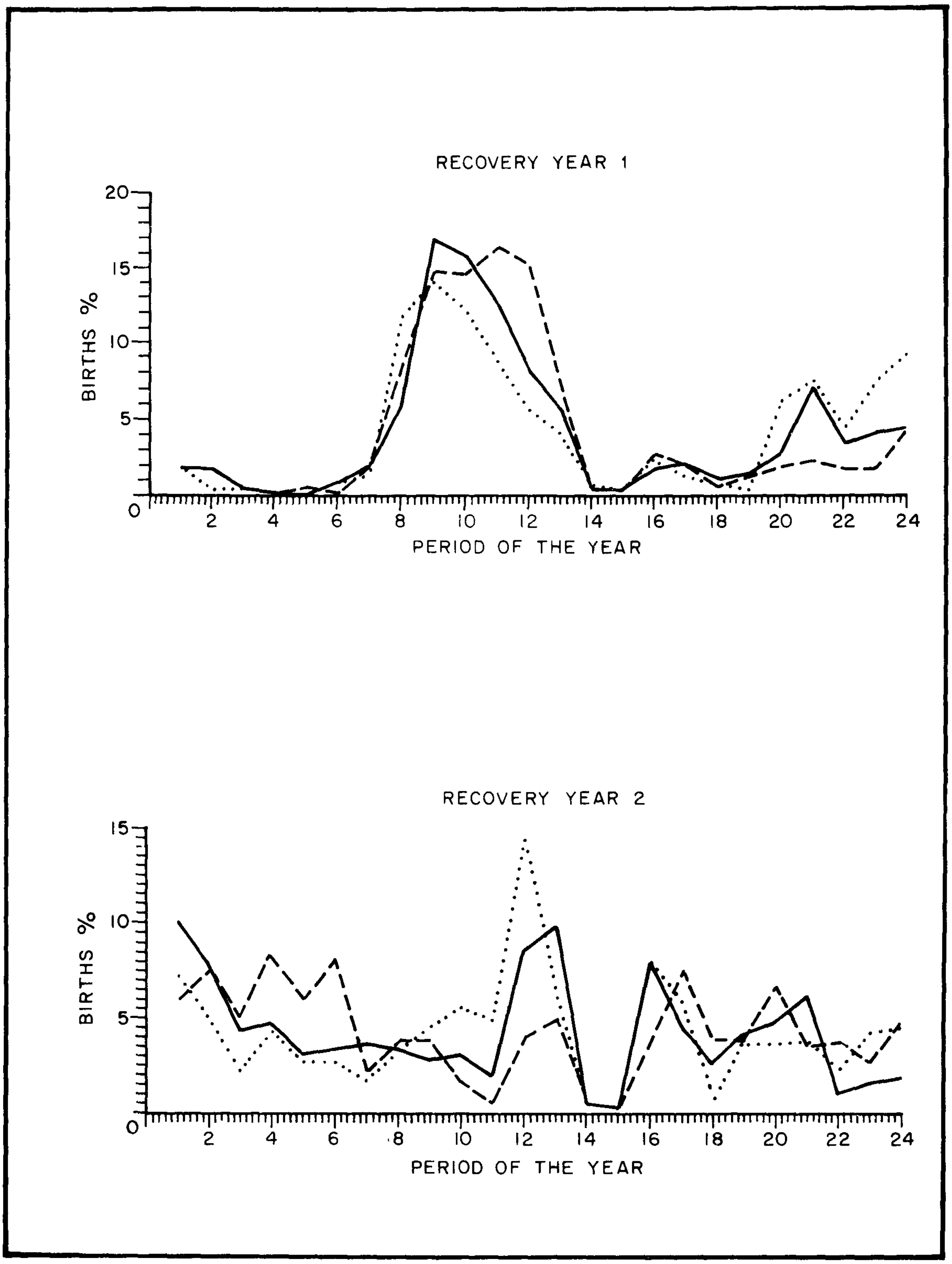


Figure 13. Effects of potential peak daily milk production (GMLKL) on the frequency of births within a year and within the potential mature size (WMA) of 35. GMLKL of: .90 = dotted line, 1.30 = solid line and 1.75 = dashed line.

8; therefore reducing the percentage of ewes lambing. There is the likelihood that ewes which are to lamb at this time have a higher incidence of abortions after carrying a foetus through all of the dry season.

When the drought was imposed, the pattern of lambing and the percentage of live births was disturbed; the percentage of live births decreases from the beginning of the year through the long dry season. During the short rains, the percentage of live births increases above pre-drought levels. The percentage of live-birth patterns was not altered drastically in the initial stages of the drought because the lambs born at this time were conceived before the drought and the ewes would have some body stores to utilize to meet their pregnancy requirement. It appears that all genotypes responded in a similar manner to the drought.

A third pattern for the percentage of live births was seen in recovery year 1. During this year a larger portion of the births occurred during the long rains. This pattern was a result of the ewes lambing late in the drought year, rebreeding and then lambing in the first year of recovery. From period 20 of recovery year 1 to the end of recovery year 1 the ewes are beginning to re-establish their original lambing pattern.

By recovery year 2, a lambing pattern similar to the base year was simulated. The difference between the second year of recovery and BY was the difference among genotypes for the percent of live births was larger. The larger variability was an indication that the genotypes had not yet reached steady state, or the initial starting point.

Several points of interest can be derived from this series of graphs (Figures 12 and 13). First, these data would imply that a continuous breeding season is an advantage in the re-establishment of the flock after a drought has occurred. By spreading births out across the year, the chance that all new-born lambs would die as a result of an environmental hardship is limited. In addition, it allows ewes to rebreed when they achieve adequate body condition. If a controlled breeding season is imposed, the prospect of greater losses and a slower rebuilding of the flock would occur, thus causing the offtake from the flock to be lower. These results demonstrate that a continuous breeding season is a survival mechanism for the flock and the pastoralists. This practice allows for the rebuilding of the flock in anticipation of the next environmental challenge.

The average dairy milk produced per ewe per day per period (DMEDP) was examined to determine how the stability of production was influenced by the drought (Figures 14 and 15). Although the amount of sheep's milk used ranks below that of goats and camels, it is important for this nutrient source to have a high degree of consistency in its availability; therefore the manner in which production would be altered by a drought is an important concern.

Initial production was fairly consistent throughout the year. This trend would seem to follow the frequency of live births. However, in the BY the level of DMEDP was distinctly different among the genotypes tested. The ranking of GMLKL for DMEDP was 1.75, 1.30 and 0.90.

In the drought, the base pattern is changed so that DMEDP follows the frequency of live births. There is a difference in the response of the genotypes for DMEDP. Within the 35 WMA the GMLKLs 1.30 and 1.75 were nearly equal during the time of increased milk production. A smoothing-out of the DMEDP curve occurred in the first year of recovery. Initially, the 0.90 GMLKL rank was considerably below the other GMLKLs; however, during the drier portions of the year this difference was reduced.

By examining the flock dynamics of the simulations it is possible to examine the behaviour of the flock on a continuous basis, the result of which is a more detailed understanding of the interactions involved. From such results a conception of the availability of protein and energy for human consumption can be obtained.

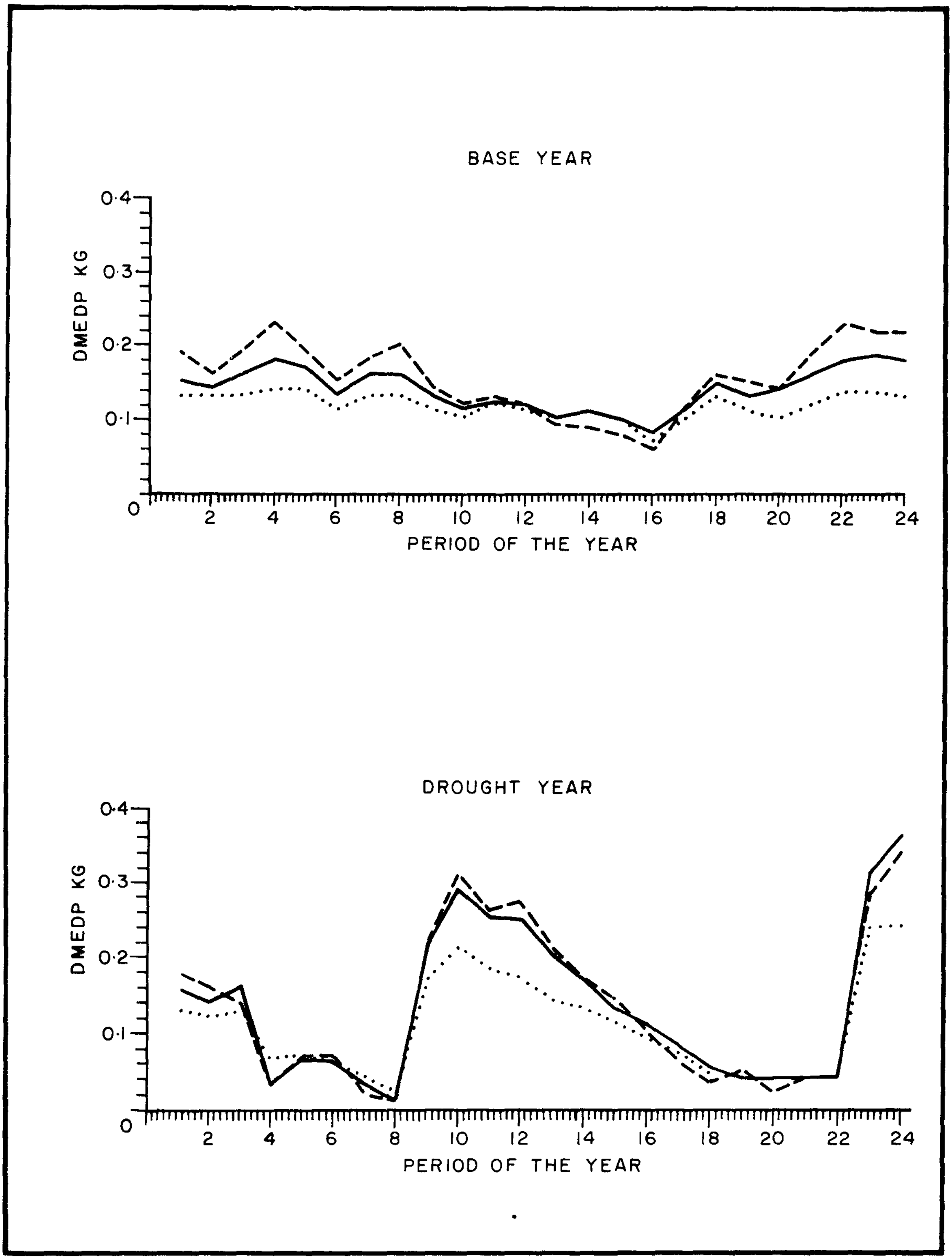


Figure 14. Effects of potential peak daily milk production (GMLKL) on the dairy milk produced ewe^{-1} day^{-1} period^{-1} (DMEDP) within a year and within a potential mature size (WMA) of 35. GMLKL of: .90 = dotted line, 1.30 = solid line and 1.75 = dashed line

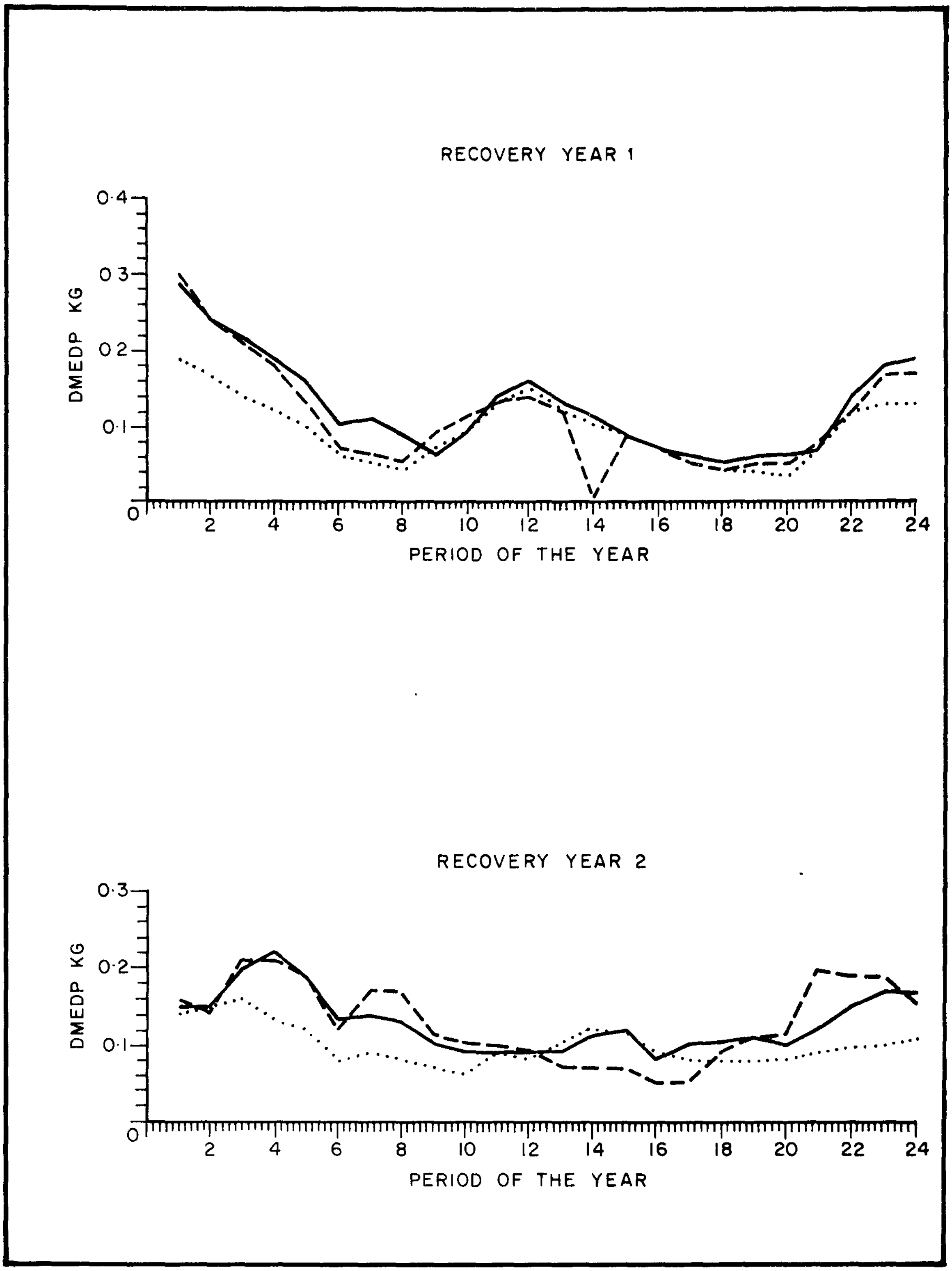


Figure 15. Effects of potential peak daily milk production (GMLKL) on the daily milk produced ewe^{-1} day^{-1} period^{-1} (DMEDP) within a year and within a year and within a potential mature size (WMA) of 35. GMLKL of: .90 = dotted line, 1.30 = solid line and 1.75 = dashed line

EFFICIENCIES OF PRODUCTION

Efficiency is defined as the ratio of output to input, and can be expressed in different physical and economic terms. In northern Kenya the critical component of the denominator is the amount of forage consumed because this will have an impact on the future range condition. The output from the system is the weight of sheep sold and the dairy milk. An evaluation of efficiency can be made using either one of these outputs; evaluating efficiency separately would be advantageous because of the form in which these products are marketed or consumed. To combine the animal weight and dairy milk, the outputs would have to be expressed in some common term such as protein or energy. By placing the output on this basis the two variables can be summed and then the efficiencies can be evaluated. The sheep model simulates the weight of lean (WL) and the weight of fat (WF) for all sheep. From the WL and WF it was possible to estimate the offtake of protein and fat from the sheep sold. The model assumes that 20% of the WL is protein; therefore, multiplying this constant by the WL will yield the weight of protein from the animals sold. Body fat was converted to Mcal of energy by the constant 9.37 Mcal/kg which was used by Ferrell and Jenkins (1984). The protein fraction of milk is assumed to be 5.6% and the energy fraction is 1.1 Mcal/kg (Graham *et al.*, 1976).

Results from the ratio of total weight sold kg/dry matter consumed kg (TWS/DM) are given in Table 8. As with other production characteristics studied, the impact of the drought was most evident in recovery year 1. The 30 WMA flocks showed less fluctuation over the 4 simulated years; however, 30/1.75 was consistently ranked as one of the least efficient genotypes. The 35/1.75 flock lost efficiency during the drought year and never made a recovery from that decrease. This response was largely due to a low reproductive rate and a loss of suckling lambs.

The GMLKL within the 30 and 35 WMA genotypes were consistent in their ranking across years. The greatest changes of rank were within the 45 WMA. Initially, the GMLKLs were ranked 0.90, 1.30 and 1.75, and at the end of the study they ranked 1.75, 0.90 and 1.30. The difference among GMLKLs during the BY were not large; however, as time progressed and the environment changed the differences

Table 8. Average annual production efficiency ratios for sheep sold and dairy milk produced

	WMA[a]= 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
Character/Year	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
Total weight									
Base year	0.0384	0.0353	0.0339	0.0373	0.0363	0.0345	0.0395	0.0383	0.0372
Drought	0.0350	0.0320	0.0288	0.0384	0.0363	0.0289	0.0362	0.0394	0.0395
Recovery year 1	0.0317	0.0300	0.0265	0.0304	0.0302	0.0308	0.0291	0.0269	0.0312
Recovery year 2	0.0347	0.0359	0.0299	0.0418	0.0394	0.0295	0.0419	0.0400	0.0445
Dairy milk									
Base year	0.0612	0.0591	0.0599	0.0530	0.0611	0.0663	0.0504	0.0564	0.0633
Drought	0.0594	0.0602	0.0607	0.0600	0.0710	0.0722	0.0567	0.0584	0.0700
Recovery year 1	0.0531	0.0553	0.0624	0.0477	0.0617	0.0566	0.0484	0.0534	0.0602
Recovery year 2	0.0443	0.0498	0.0599	0.0446	0.0574	0.0536	0.0434	0.0466	0.0570

[a] WMA = potential mature size, kg.

[b] GMLKL = potential peak daily milk production, kg.

[c] Total weight or dairy milk offtake divided by the forage dry matter consumption of the flock.

in TWS/DM became larger. In this situation the 45/0.90 cannot hold its productive advantage indicating it has limited utility.

When WMAs across GMLKL were compared in BY there was a negative relationship between GMLKL and TSW/DM. This trend was present in the remaining simulated years for the 30 WMA. Initially, all 45 WMA genotypes ranked high. During the drought and recovery year 1 the 45/0.90 and 45/1.30 dropped in rank. With the exception of the 45/1.75 genotype, flocks with a GMLKL of 1.75 did not rebound from the drought as quickly as flocks with a lower GMLKL. The heavy milking flocks had this response because body condition and reproductive rates were lower and milk production was less consistent.

The ratios of dairy milk produced and dry matter consumed (DMP/DM) for genotype and years are given in Table 8. In DMP/DM there was a larger separation of the genotypes tested than was observed for TWS/DM. The increase in DMP/DM seen for some genotypes during the drought was a result of more lamb deaths and a reduction in DM consumed. After the drought DMP/DM decreased, which was a result of greater lamb survival during the recovery years which limits the amount of milk extracted for human consumption.

The rankings of all tested genotypes changed during the simulations. As time progressed the 30/1.75, 35/1.30 and 45/1.75 increased their efficiency for DMP/DM. From the results previously discussed this result was expected for the 35/1.30 and 45/1.75. The high level of DMP/DM for the 30/1.75 in recovery year 2 was not expected; it was due to the high level of lamb mortality in recovery year 1 and 2, and a low level of feed intake.

By combining the protein produced from animals sold (PTWS) and milk extracted for human consumption (PDMP) a measure of the efficiency of protein production can be made. The efficiency of protein production is expressed as the sum of PTWS and PDMP divided by the dry matter consumption of the flock (TPROT/DM). The efficiency of protein production followed a yearly trend where recovery year 1 was the least efficient year for most genotypes and returned to pre-drought levels in recovery year 2 (Table 9). An increase in protein efficiency was observed in the drought. This increased efficiency was the result of decreased forage consumption, but the lambs sold achieved much of their growth before the drought occurred or before forage conditions degenerated to their lower levels.

As WMA increased there was a separation of GMLKL within their respective WMAs. Within each WMA there was a combination of genotypes which appeared to maintain an advantage over the other two genotypes; these were 30/1.30, 35/1.30 and 45/1.75. As WMA increased, the superiority of these combinations increased. It is important to note that during recovery year 1 the 35/1.30 and 45/1.75 had a decreased protein efficiency; however, the levels of these two flocks did not drop as low as the other genotypes. This consistency would underscore the importance of correctly matching body size and milk production levels, and imply that sheep with these genotypic combinations would be able to provide producers with more protein in harsh environmental conditions.

Rankings of genotypes between years did change. One major change in rank was 45/1.30 and 35/1.30. Initially, 45/1.30 ranked higher than 35/1.30, then during the drought and recovery years the ranking reversed. Furthermore, during recovery year 1 the 45/1.30 dropped to a level below all of the 30 WMA genotypes. During recovery year 2 the 35/1.75 did not rebound from the drought, instead it remained at a level equivalent to the 30/1.75 where in previous years 35/1.75 had a higher efficiency.

In the nomadic production system, sheep play an important role by supplying energy in the form of fat from the carcass and the fat from the milk. In the drier seasons and years, when milk production is depressed the carcass fat is a vital source of energy. In fact, it is the major source of energy which is produced in their production system. Some would argue that this is one of the primary reasons that nomads raise sheep. Due to the importance of carcass fat, the efficiency of energy production was evaluated on the basis of carcass energy divided by dry matter (CEN/DM) and the summation of CEN and energy from milk was divided by dry matter consumption (TENGY/DM).

Table 9. Average annual protein production efficiency ratios

	WMA[a] = 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
Character/Year	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
Base year	0.0072	0.0076	0.0072	0.0084	0.0087	0.0085	0.0082	0.0088	0.0095
Drought	0.0080	0.0077	0.0071	0.0087	0.0094	0.0083	0.0087	0.0093	0.0100
Recovery year 1	0.0069	0.0069	0.0068	0.0068	0.0074	0.0072	0.0068	0.0068	0.0077
Recovery year 2	0.0069	0.0073	0.0070	0.0083	0.0087	0.0070	0.0086	0.0086	0.0098

[a] Total protein produced from meat and milk divided by the forage dry matter consumption of the flock.

[b] WMA = potential mature size, kg.

[c] GMLKL = potential peak daily milk production, kg.

The results from CEN/DM (Table 10) showed that flocks with a WMA of 30 and 35 and low-to-medium milk production were more efficient in producing energy than the high-milking genotypes. They were also more consistent. In the 45 WMA the 45/1.75 was consistently the most efficient. These results follow the pattern previously discussed with the other characteristics. Ewes of lower GMLKL maintained higher condition (therefore they had a higher fat content) when they were culled from the flock, and they had higher reproductive rates which resulted in more lambs sold (the term 'sold' refers to offtake for any purpose).

The genotypes are ranked differently for the TENGY/DM than for CEN/DM (Table 10). The differences between these measures of efficiency result from the impact of energy generated through milk production. The most noticeable difference was the decreased efficiency of the lower milking genotypes. This decrease was most clearly emphasized within the 35 WMA flocks. The 35/0.90 not only has a lower efficiency but was also more variable across years. The 35/1.30 remained at a

Table 10. Average annual energy production efficiency ratios

	WMA[a] = 30, GMLKL[b]			WMA = 35, GMLKL			WMA = 45, GMLKL		
Character/Year	0.90	1.30	1.75	0.90	1.30	1.75	0.90	1.30	1.75
CEN/DM [c]									
Base year	0.0301	0.0327	0.0297	0.0363	0.0337	0.0323	0.0351	0.0369	0.0370
Drought	0.0309	0.0281	0.0306	0.0352	0.0262	0.0207	0.0282	0.0308	0.0338
Recovery year 1	0.0358	0.0322	0.0254	0.0314	0.0368	0.0364	0.0327	0.0290	0.0372
Recovery year 2	0.0374	0.0382	0.0344	0.0396	0.0404	0.0282	0.0406	0.0343	0.0452
TENGY/DM [d]									
Base year	0.0973	0.0977	0.0956	0.0947	0.1008	0.1051	0.0905	0.0990	0.1066
Drought	0.0963	0.0943	0.0974	0.1012	0.1044	0.1002	0.0906	0.0951	0.1108
Recovery year 1	0.0943	0.0931	0.0941	0.0838	0.1047	0.0986	0.0860	0.0878	0.1034
Recovery year 2	0.0862	0.0931	0.1003	0.0887	0.1035	0.0872	0.0884	0.0855	0.1079

[a] WMA = potential mature size, kg.

[b] GMLKL = potential peak daily milk production, kg.

[c] CEN/DM The ratio of energy derived from the carcass to the forage dry matter consumption of the flock.

[d] TENGY/DM The ratio of energy from the carcass and milk to the forage dry matter consumption of the flock.

higher more consistent level of efficiency. The more consistent levels of efficiency across years indicate that during environmental shifts energy from milk production and body fat are complementary, and therefore result in a more stable conversion of the feed resource. The TENGY/DM for 35/1.75 decreased over time, which was contrary to the other 1.75 GMLKLs; this decrease was due to lower levels of productivity which have been discussed previously.

The response of the genotypes within the 45 kg WMA was different from the previous genotypes discussed. The 45/1.75 group fluctuated with the changing environment but the deviation from the BY was not large. In this respect, it was similar to the 35/1.30 flock. The energy efficiencies for 45/0.90 and 45/1.30 decreased over time. The 45/1.30 showed a greater decrease in TENGY/DM than the 45/0.90 indicating that the drought had a greater impact on this flock.

As a result of genotypes responding differently to the shifting environments, numerous GEI were present for energy efficiency. Initially, for the 35 and 45 WMA flocks, there was a positive linear relationship between efficiency and GMLKL; however, in the drought and subsequent years this relationship assumed a curvilinear response. The efficiency for genotypes 35/1.75 and 45/1.30 ranked lower in the last three years than in the BY. The lower efficiency of energy production for these genotypes appeared to be due to a mismatch of milk production and body size. In the 35/1.75 group, milk production was too high and the ewes depleted their energy reserves early in lactation which resulted in a very low level of production in the later phases of lactation.

RANKINGS FOR EFFICIENCY

Genotypes were ranked to evaluate their efficiency of production. The ranks calculated were the average of the genotype's efficiency across years (Table 11).

In all categories measured, the 45/1.75 genotype ranked the highest or next to the highest. This is not surprising since the 45/1.75 flock produced more TWS and DMPE in almost all of the environments. This genotype was able to produce

Table 11. Average rankings of the genotypes (WMA/GMLKL)[a] for different measures of efficiency

Rank	TWS/DM [b]	DMP/DM [b]	CEN/DM [b]	TPROT/DM [b]	TENGY/DM [b]
1	45/1.75	35/1.30	45/1.75	45/1.75	45/1.75
2	35/0.90	45/1.75	35/0.90	35/1.30	35/1.30
3	45/0.90	35/1.75	35/1.30	45/1.30	35/1.75
4	45/1.30	30/1.75	45/0.90	45/0.90	30/1.75
5	35/1.30	30/1.30	30/0.90	35/0.90	30/1.30
6	30/0.90	30/0.90	30/1.30	35/1.75	30/0.90
7	30/1.30	45/1.30	45/1.30	30/1.30	35/0.90
8	35/1.75	35/0.90	35/1.75	30/0.90	45/1.30
9	30/1.75	45/0.90	35/1.75	30/1.75	45/0.90

[a] WMA = potential mature size and GMLKL = potential peak daily milk production, kg.

[b] TWS, total weight offtake; DMP, total dairy milk produced; CEN, energy from carcass fat; TPROT, the summation of protein from meat and milk; TENGY, the summation of energy from fat and milk; DM, dry matter consumption of the flock.

enough product to overcome the increased feed consumption and maintenance costs which accompany an increased body size. The 35/1.30 was the second most efficient genotype studied. Its high efficiency is a result of relatively high reproductive rates and a body size well matched for the existing environment. The 34/1.30 ranked high in efficiency for the products which are essential to the nomads' existence. The 35/1.30 ranked the highest for DMP/DM which indicates the genotype's usefulness in providing milk on a continual basis. Although this genotype ranked fifth in TWS/DM, it did rank third in CEN/DM, which is one of the major roles that sheep fill in this production system. The 30/1.75 flock ranked last in TPROT/DM and TWS/DM, second last for CEN/DM and intermediate for TENGY/DM and DMP/DM. The low efficiencies for the traits largely associated with lamb production were a result of low reproductive rates. The other genotypes ranked intermediate to the 35/1.30 and 30/1.75 genotypes. Generally, genotypes with GMLKLs of 0.90 and 1.30 kg ranked low in TENGY/DM while the ranking by TPROT/DM was much more a genotype-by-genotype evaluation, i.e. there are several reasons causing particular genotypes to be ranked low for TPROT/DM, which have already been discussed.

DISCUSSION AND CONCLUSIONS

The simulations reported are the first performed with the sheep model. Validation was performed with the sheep model using data collected by IPAL in northern Kenya. Characters compared for the validation were ewe body weight, milk production, lamb growth and reproduction. The results from the simulations closely matched the actual results and were within a 95% confidence interval. It was concluded that the model was validated for the northern Kenya environment and the Somali Blackhead breed of sheep.

The parameters used to specify the environments simulated were based upon one actual and three hypothetical years. They were chosen to represent a production situation that often exists in northern Kenya, environments in which any sheep placed in this production system would have to perform. In this regard the environmental fluctuations were functional, i.e. nutritional stress was placed upon the genotypes tested. Due to the environmental stress, the genotypes tested could be evaluated on their ability to perform in the drought and how they could recover from a drought. Although the results provide insight into the effects of a one-year drought, the response of the genotypes is unknown for droughts of longer duration. However, it may be assumed that for certain genotypes, such as 30/1.75 and 35/1.75, a longer drought would not enhance their level of production relative to the other genotypes evaluated. The larger genotypes may suffer a higher level of stress during a longer drought, due to the more limited, lower quality feed resource disproportionally affecting their nutrient requirements. If this were true, the 35/1.30 intermediate genotype, which ranked high for the measures of efficiency, could display an even greater advantage.

The analysis of the flock dynamics provided insight as to how genotypes were responding to the changing environment. By examining the frequency of live births, it was possible to discern how births were distributed throughout the different years. It was evident that the drought disrupted the steady-state pattern and was replaced by two different patterns during the drought year and the first year of recovery. These newer patterns were more closely grouped around the year. By the second year of recovery the flocks were returning to their initial pattern. This result led to the hypothesis that continuous breeding or year-round breeding, as practised by the nomads, is a survival mechanism in the harsh environment. By spreading births out over an extended period of time the chance that almost all new born lambs will die is limited. In the event of an environmental hardship, the clustering of births leaves the flock more vulnerable. By having year-round births the flock is able to shift its breeding season to coincide with more favourable environmental conditions due to a fraction of the ewe population always being open. This pattern was observed in the simulations. After the stress was removed or subsided, live births begin a trend toward more even distribution. The response of the breeding season during the drought may be viewed as a herd survival strategy where the objective is to maintain herd size. When births become dispersed, in better years a second phase is initiated in which the trend is to rebuild or increase flock size.

Milk production is important in subsistence agriculture; therefore, it was necessary to determine the seasonal fluctuation in milk production. The DMEDP provides a period-by-period record of milk production. In general, the DMEDP patterns followed the frequency of live births, with a time-lag interval. The DMEDP also showed that larger genotypes with higher levels of milk production had a greater increase in production than the smaller, lighter milking genotype when better foraging conditions did exist.

Ewe body condition was reported three times per year. The weight gain of the ewes and increase in body condition was the first step in the flock recovering from the drought. With an increase in body condition, ewes increased their reproductive rate and their level of milk production.

The full effect of the drought is not seen until recovery year 1 for LLB. Reproduction was not depressed as much in the drought because some of the ewes lambing were bred in the BY. There was a general trend for LLB to decrease as GMLKL increased as a direct effect of ewes with lower GMLKLs being in better condition. The negative relationship between GMLKL and LLB was reversed in recovery year 2. The reversal was caused by a carry-over effect from a relatively high level of production of the lower milking ewes in the drought year which caused a reduction in their rebreeding performance in the recovery years.

The traits LWS and TWS measure flock productivity on a per-ewe basis. The WMAs ranked 45, 35 and 30 across all years. The 45/1.75 had the highest level of offtake in the study. Within the 35 WMA, the 35/1.30 often ranked the highest for LWS, but the 35/0.90 surpassed the 35/1.30 in several years for TWS because the 35/0.90 ewes were in better body condition. The 30/1.75 consistently ranked last for LWS and TWS because of the compounding effects of low reproductive rate and low growth rate of their lambs.

The response of TM/Y was different for each WMA. The TM/Y for the 45 WMA increased as GMLKL increased, thus the 45/1.75 produced the largest amount of TM/Y in all years across all WMAs. The 35/1.30 and 35/1.75 produced more TM/Y than the 35/ 0.90 but the difference between 35/1.30 and the 35/1.75 was slight; therefore, there would be little advantage in utilizing the 35/1.75 genotype. The 30/0.90 and the 30/1.30 had higher levels of TM/Y than the 30/1.75, which indicates that the smallest body size is not capable of sustaining a high level of milk production.

Flock efficiency was evaluated by several ratios; TWS/DM, DMP/DM, CEN/DM, TPROT/DM and TENGY/DM. The responses of the genotypes tested, across time, for the different efficiencies were varied. The 30 WMA flocks showed less fluctuation across years for TWS/DM, but they were clearly the least efficient in the drought and recovery year 2. Due to low levels of reproduction and a high mortality of preweaning lambs, the 30/1.75 never showed a recovery from the drought and consequently ranked last. Initially, the 45/1.75 ranked below the 45/1.30 and the 45/0.90; however, in the recovery years, the 45/1.75 had a higher efficiency. The 35/0.90 did have a higher efficiency than the 35/1.30 and 35/1.75 throughout the simulated years. The 35/1.75, like the 30/1.75, did not show a recovery from the drought for TWS/DM.

The evaluation of the DMP/DM is a composite of lamb mortality, reproductive rate and ewe performance. The 45/1.75, 35/1.30 and 35/1.75 consistently ranked high in efficiency for DMP/DM. The 30/1.75 ranked higher in the recovery years than in the BY and drought. The increased DMP/DM of the 30/1.75 may have been due to the increased lamb mortality which allows all of the ewes' milk to be extracted for human consumption. The 45/0.90 ranked the lowest in three of four years for DMP/DM because of the combined effect of larger lambs and a low level of milk production by the ewes.

The TPROT/DM is a more complete measure of efficiency. The 45/1.75 and the 35/1.30 were the most efficient producers of protein ranked in their respective order. This ranking indicates that the type of sheep currently used is very functional in this environment as a food producer. However, the results suggest that a larger sheep with increased milk production would have a beneficial role to play in the northern Kenya production system. The 45/1.30 ranked close to the 35/1.30 in three of four years, but it was severely depressed in recovery year 1; therefore, it appeared to be more sensitive to the drought than the 45/1.75 or the 35/1.30 genotypes. As with the other efficiencies discussed, the 30/1.75 and the 35/1.75 genotypes do not recover from the drought at the same rates as the other genotypes.

Carcass fat is an important source of energy in northern Kenya. The behaviour of the genotypes across years for CEN/DM was variable. The volume of offtake from the 45/1.75 resulted in it ranking high for CEN/DM. The 35/0.90 and 35/1.30 also ranked high for CEN/DM across years. The 35/0.90 ranked high due to its cull ewes being in relatively better condition.

When all sources of energy production were considered, the 45/1.75 and the 35/1.30 were the highest ranking genotypes. The 35/1.30 was the most consistent in level of TENGY/DM; however, it had a lower total than the 45/1.75. The 35/1.75 and 30/1.75 ranked considerably higher for TENGY/DM than they had for other efficiencies. Although the 35/1.75 average was high, its TENGY/DM continued to decrease after the drought, a situation also observed for the 45/1.30 and 45/0.90.

In general, the efficiencies indicate that the 45/1.75 had a distinct advantage in the production of protein and energy. The 35/1.30 ranked high, but not highest, in all facets of production; this consistency resulted in it ranking second for TENGY/DM. The fact that this type, 35/1.30, is currently kept in the area demonstrates that consistency and productivity influenced the evolving of their characteristics in this environment.

Overall, the 35/1.75 and 30/1.75 were the least efficient genotypes. They ranked low because of a mismatch of body size and milk production. The poor performance of the 35/1.75 suggests a sensitive balance between the levels of body size and milk production interacting with an arid-land forage resource. Therefore, if there are attempts to 'improve' the sheep of this area, caution must be exercised in selecting the types or breeds of sheep introduced.

The presence of genetic-environmental interactions (GEI) were an indication that the environmental challenges were large and separated productive from unproductive genotypes. There were a number of instances where genotypes would change rank for one year and then revert back to their original order the following year. Perhaps more important is the comparison of initial with final rank, for this would be an indicator of how the genotypes responded through the transitions of the dynamic environment to which they were exposed. For most of the characters simulated, a GEI existed during the year which showed the greatest effect of drought when compared to the BY. The interaction was not always a change of rank but a decrease in the difference between ranks. The efficiencies calculated are a composite of different characters; therefore, they provide the best opportunity to determine the existence of GEIs. All of the 30 WMA plus the 35/1.75 genotypes lose efficiency and rank as time progresses. The TPROT/DM exhibits the GEI where all genotypes become closer in recovery year 1 and then separate in the last year. As time progressed the difference between 35/1.30 and 45/1.30 genotypes increased.

The simulated results suggest that the 45/1.75 genotype has promise for successful introduction to the nomads' production system and should be further tested. The results also demonstrated that an increase in body size, to 45 kg WMA, must be accompanied by an increase in milk production, otherwise the benefits of the heavier genotype will not be realized. If heavier, higher milking sheep are to be recommended for this area, several questions must be addressed. For example, if a heavier sheep is more advantageous why doesn't it already exist in this environment? There is an explanation that may provide a partial reason. There may be negative selection pressure placed upon large sheep in the nomads' flocks. The large sheep tend to be slaughtered leaving the smaller sheep for breeding.

A second possibility is that inbreeding depression may be reducing sheep size and productivity. With females being constantly exposed to their male relatives this could cause a large detriment to production.

Perhaps more probable than the existence of a high level of inbreeding is the formation of small subgroups within the Somali Blackhead population in northern

Kenya. The existence of subgroups would mean that there would be a higher rate of fixation on account of genetic drift or inbreeding. Therefore, the additive genetic variance would be reduced and the occurrence of a particular genotype more common. There is an example in Kenya of localized populations of the same breed which differ markedly in body size. The male Galla goat in the IPAL study area has an average mature weight of 50 to 60 kg; however, in the north-east corner of Kenya, along the Somali border, the Galla males weigh in excess of 80 kg. The management and environment for both groups should not differ greatly as both producers are nomads but of different tribes.

The simulation model does not simulate all biological aspects of the sheep. One is the effect of internal and external parasites on production. The parasitic load could become a limiting factor in the utilization of the 45/1.75 genotype. Although there is no apparent reason for parasite load to differentially affect larger sheep, there cannot be a complete endorsement of this genotype based on these simulations. However, in terms of forage limiting production, the 45/1.75 ranked well against the other genotypes tested. Also the levels of production for the 45/1.75 were substantially larger than the other genotypes; therefore, if the helminth load is equivalent for all genotypes, the 45/1.75 would still be competitive.

If a larger, heavier milking sheep has a potential in the nomad production system, how could the new genotype be introduced? A feasible approach would be to introduce sires of the desired genotype into the production system and mate them to the Somali Blackhead ewes. There are several breeds in Kenya and other countries of Africa which may be useful in such a project. Two of the most plausible are the Dorper and the Blackhead Persian which is an improved Somali Blackhead developed in South Africa. Both of these breeds are larger than the Somali Blackhead and, in the case of Dorper, produce more milk. A crossbreeding scheme could be designed to either up-grade the entire population or keep a desired percentage of Somali Blackhead in the offspring. These simulations would imply that a controlled breeding season is not a practice which will increase offtake.

The simulation model results provided insight as to how a flock responds to a drought and the time-lag of the impact of the drought. This type of result is useful not only to those interested in animal performance but for administrators planning drought relief. These results could be used to estimate the reduction of flock output to determine the quantity and length of drought relief. Furthermore, economists can utilize these results to evaluate the economic trade-offs involved in using different types of sheep, as well as determining the effects of removing excess animals from the flock and selling them at market.

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TRIALS ON A NEW FORMULATION OF TETRAMISOLE IN THE CONTROL OF STRONGYLIASIS IN SMALLSTOCK

by

H.J.S. Crees

CONTENTS

INTRODUCTION

A series of small trials were carried out to assess the efficacy and safety of tetramisole 3% and 3.4% as formulated by Cosmos Ltd. in their anthelmintic products Vermisol and Douvimisole, respectively. Douvimisole also contains 8% bithional sulphoxide for the treatment of liver fluke and tapeworms. The trials were conducted in an arid area in south-western Marsabit District and a semi-arid area on the adjacent border of Samburu District.

Liver fluke infestations have never been encountered in the area, Strongyloides and *Trichuris* infestation rates are generally low, as are strongyle levels in cattle, and therefore these experiments have examined only the effect of the drugs on strongyle species in sheep and goats.

METHOD

Six trials were attempted on flocks belonging to semi-nomadic pastoralists who presented animals for routine anthelmintic treatment or treatment of clinical helminthiasis. Two mixed flocks of sheep and goats kept under desert conditions were not re-examined after treatment as the initial worm egg burdens were low. Two other trials failed because the animals were not brought back for repeat sampling and treatment of the controls. A final trial was carried out on flocks belonging to UNESCO's Integrated Project in Arid Lands (IPAL) that had been the control flocks in a prolonged programme of investigation into constraints on productivity.

In each trial only late immature and adult animals were selected. Treatment and control groups were equilibrated as far as possible in respect of ages and sexes, but the herdsmen were allowed to select the individuals for the treatment group, giving a bias towards inclusion of the more clinically affected animals. Dosage rates were used according to the manufacturer's instructions, equivalent to 60-70 mg tetramisole per kilogram liveweight, the liveweights being judged by eye to the nearest 5 kilograms. Faecal samples were taken at the time of treatment and again after a few days. Except in the first trial, for diplomatic and administrative reasons it was not possible to allow a longer interval than four or five days between samplings, and there is a possibility that the interval allowed was insufficient for complete clearance of eggs from the alimentary canal.

Faecal samples were examined by a simplified McMaster technique in which only one slide chamber was counted routinely, though periodic checks on the accuracy of mixing were done by using both chambers. Because of great variation in faecal consistency and water content the aliquots for examination were measured volumetrically and the results are expressed in eggs per millilitre of fresh faeces.

RESULTS

Table 1 shows the mean strongyle egg counts (plus or minus standard deviation) of both treatment and control groups at the time of treatment and at the subsequent repeat sampling.

DISCUSSION

The products tested in these trials have proved themselves adequately effective and have shown no evidence of undesirable side-effects. Over the same period approximately 600 privately owned sheep and goats, in perhaps 20 flocks, were treated with Vermisol, at cost, but the product conspicuously failed to gain acceptance by the public of the study area, who had previously become accustomed to the use of fenbendazole. This is partly due to tetramisole's lack of effect against *Moniezia* species whose segments are visually conspicuous; and may possibly also be associated with a lesser effectiveness against immature strongyles, resulting in apparently earlier return of clinical symptoms in conditions of continuous challenge.

In the pastoral areas of Kenya a tactical programme of anthelmintic treatments offers the only practical means of controlling worm infestations. Regular de-worming can be a major expense in the present pastoral economic environment. A long-established drug such as tetramisole could fulfil a major need in the livestock industry if it were marketed at a competitive price.

Table 1. Strongyle egg counts in treatment and control groups

* Flock	Beginning of trial		End of trial	
	Control (group)	Treatment (group)	Control (group)	Treatment (group)
1.	n=6 700 (± 899)	n=6 1,517 (± 1.174)	n=6 417 (± 571)	n=6 33 (± 52)
2.	n=15 1,800 (± 1,867)	n=15 1,847 (± 1,410)	n=15 1,967 (± 1,714)	n=15 20 (± 56)
3. (a)	n=15 853 (± 456)	n=15 1,156 (± 573)	n=15 857 (± 672)	n=15 19 (± 54)
(b)	n=15 853 (± 456)	n=15 1,387 (± 870)	n=14 857 (± 672)	n=15 20 (± 41)
4.	n=15 580 (± 343)	n=15 560 (± 290)	n=15 887 (± 610)	n=15 13 (± 35)
5.	n=15 1,360 (± 809)	n=15 1,487 (± 1,234)	n=15 907 (± 663)	n=15 20 (± 56)

* Flock 1. A flock of privately owned sheep at Ngurunit, treated with Vermisol. First sampling on 9 September 1982, repeat sampling on 24 September.

Flock 2. A flock of privately owned sheep at Ngurunit, but including one goat in the treatment group, treated with Vermisol. First sampling on 9 November 1982, repeat sampling on 13 November.

Flock 3. IPAL sheep kept under desert conditions in a nomadic camp (*fora)*, (a) treated with Vermisol, (b) treated with Douvimisole. First sampling on 3 January 1983, repeat sampling on 7 January.

Flock 4. IPAL goats kept under desert conditions, treated with Douvimisole. First sampling on 3 January 1983, repeat sampling on 7 January.

Flock 5. IPAL goats at Ngurunit, treated with Douvimisole. First sampling on 4 January 1983, repeat sampling on 7 January.

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PART TWO: CATTLE

INTRODUCTION

by

C.R. Field

In the arid and semi-arid lands which cover more than three-quarters of the surface area of Kenya, and over 90% of Marsabit District, the presence of cattle is a controversial subject. This is because, under normal conditions, their physiology depends on drinking water every second or third day and is adapted for a diet of high roughage and bulk food which is best supplied by perennial grassland. In Marsabit District water supplies are few and far between and the arid and semi-arid areas are dominated by annual grassland, dwarf shrubland and *Acacia* woodland.

Nevertheless, it has been estimated that there are just under 150 million cattle in Africa, which comprise 13% of the world's population (F.A.O., 1978), while north-eastern and eastern African support just under half of the continent's cattle.

Problems lie ahead for those in the drier parts of Africa who rely too heavily on cattle. Although Africa has one-tenth of the world's human population, one-quarter of its grasslands and one-eighth of its cattle, on a unit-area basis beef production is only 20% and milk production 10% of the world's average. Cattle stocks are growing less rapidly than in the world as a whole. Beef production per head of population is already very low, and declining, although milk production is apparently keeping up with the increasing demand (Crotty, 1980).

As land use intensifies in the medium to high-potential areas, so are cattle gradually being replaced by crops and being forced into more marginal lands where their productivity falls, due, as mentioned earlier, to the unsuitability of an arid environment for the raising of cattle. During nine months of the year cattle must remain within reach of permanent wells and boreholes due to their dependence on frequent watering. This means that localized stocking rates often exceed the rather limited carrying capacity of the desert annual grasslands and a loss of cover, denudation and soil erosion follow. Under these conditions cattle are forced to walk long distances (up to 20 km) to pasture and this exhausts their fat reserves which otherwise would have been used for milk production. A vicious circle ensues as less milk is available for household consumption and frequently calves are deprived of sufficient milk and die.

In the proposed area for management in western Marsabit District which comprises 11,300 km of Rendille homelands, it is estimated from several aerial surveys, that there is an average of 24,500 cattle and that they comprise 42% of the total Tropical Livestock Units in the area (where one Unit is equivalent to a 250 kg cow). With a population of 12,900 Rendille people and a household of eight, this represents just under two cows per person or 15 cows per household (Field and Simpkin, 1985).

Slightly different results have been obtained by surveying 150 households in the area, where it was found that there were 11 cattle per household, comprising 31% of the total stock units. Furthermore, taking the age-specific composition of the herds together with data on weights at age, we concluded that an average cow in the area weighs only 165 kg and thus only seven cattle stock units are owned per household, comprising 23% of the total.

Our aerial surveys revealed that cattle are highly dependent on watershed areas, particularly during dry seasons. Indeed two-thirds of all cattle in the area were found in only 7% of the range. Inevitably this has led to a heavy and localized impact on the watershed areas which are essential for water conservation.

Experiments have been carried out on the productivity of cattle under traditional management and with a veterinary health programme. The results show that average daily milk yields per cow for human use (for all cows whether in milk or not) was a mere 355 cc for the traditional herd and 371 cc for the herd with the health programme. The corresponding nutritive values in terms of energy and protein are 235 Kcal and 11.7 g of protein under traditional management and 260 Kcal and 13 g protein for cows under the health programme.

Similar calculations have been made for meat production for the non-lactating animals. This averages 170 g per animal per day and 179 g under the health programme. These data have then been expressed on a household basis assuming that 36% of the home herds are adult females capable of producing milk (Field and Simpkin, 1985).

It has been estimated that a Rendille household requires from 15,000 Kcal to 18,300 Kcal of energy and 422 g of protein per day. Therefore the combined yields of milk and meat may contribute from 13 to 22% of energy needs and 33 to 45% of protein needs of a household. These figures are substantially lower than from the smallstock and camels in a household.

The data also reveal that under the prevailing arid conditions a health programme does not really have much effect in improving cattle productivity. It appears that the disease challenge, from parasites in particular, is low in desert conditions, possibly because cattle are relatively new arrivals in this environment and their parasites are adapted to more humid conditions.

The papers which follow address themselves to the major constraints to cattle production, namely nutrition under desert conditions and disease under sub-humid conditions, and it is interesting to note some of the conclusions. Firstly, if cattle must be kept under arid conditions, dietary supplementation is essential and in watershed areas mineral supplementation is necessary because salts tend to be leached out of the soil.

In humid areas quite a different picture emerges from that found in arid areas with respect to diseases and it seems that in the former a health programme might prove cost effective.

Since cattle contribute so little to the subsistence economy of the Rendille people, why do they keep them? The answer lies in the demand for beef in the highly populated areas of southern Kenya, while camel meat is regarded as taboo among those who are not familiar with this species. Nevertheless constraints also exist in marketing cattle. There are too many profiteers between the producer and the consumer such that the prices offered to the former are kept artificially low and provide little incentive to sell. A few traders appear to have a monopoly and can set their own prices, taking advantage of panic sales by pastoralists during droughts. It remains to be seen whether the creation of marketing and trading associations will be an effective measure to break this monopoly, but there are some promising indications from a Pilot Project in the District.

Thus, for those who are able to rise above the subsistence economy, trade in cattle may be profitable. It will stimulate cash flow and provide for some of the more modern 'necessities' of life, e.g. radios and school fees, which are only purchased with cash.

One trader has already begun to exploit the low disease challenge to cattle in the arid environment by keeping his breeding herd in the desert and sending weaners to the highland areas for fattening once they are strong enough to withstand the disease challenge.

With regard to the future, care must be taken to ensure environmental conservation for long-term sustained yields rather than looking for short-term gains. This means that the development of the cattle industry must remain within the long-term carrying capacity of the rangelands.

There is some indication that selection of drought-hardy animals which produce well could be beneficial, although presently this occurs mostly through natural selection. During the severe drought of 1984 some Rendille were able, through careful management, to train their cattle to a five-day watering regime and losses were minimized because they had more time between watering to graze their cattle on the more remote, but less used, pastures.

In highland areas a short-cut to increased yields may lie in the introduction of new but tried breeds and we are currently experimenting with improved Boran crossed with Simmenthal or Sahiwal with the intention that their bull calves will produce more meat and their cows more milk.

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FEEDING HABITS, FORAGE QUALITY AND FOOD INTAKE BY ZEBU CATTLE GRAZING NATURAL RANGELAND IN THE IPAL STUDY AREA

by

H. Kayongo-Male

CONTENTS

LIST OF TABLES

INTRODUCTION

The role of cattle as a source of livelihood for nomads cannot be overemphasized. Most pastoralists in East Africa depend on milk, blood and meat as their staple food and these items make up to 70-90% of the diet (Njiru, 1980). The quantity of blood, meat or other foods may vary but milk almost always constitutes the major part of the diet (Lusigi, 1980) and in most pastoral communities of East Africa the milk herd comprises mainly of cattle. There are an estimated 4.2 million head of cattle in the range areas of Kenya (KREMU, 1978) owned mostly by nomads. The estimated cattle population density in the IPAL study area is 2.47 km^{-2} with a total cow population of 56,810 representing 39.8% of the total Tropical Livestock Units (Field, 1980). In 1980, sale of cattle earned the Rendille tribesmen an estimated 0.5 million shillings which represented about 30.0% of the total income from livestock sales (Njiru, 1981).

In range areas, grasses grow very fast during the rainy seasons with quick development of the flowering culm, followed by rapid decline in quality by the start of the dry season (McKay, 1971; Bredon and Wilson, 1963). Seasonal fluctuation in availability and quality of forage is a major problem in ruminant stock feeding in the tropics (Abate *et al.*, 1981). Dry matter (DM) and digestible nutrient content of both mature and immature forage is relatively low (Bredon and Horrell, 1961), consequently animal production follows seasonal variability in quality and quantity of forage (Kayongo-Male *et al.*, 1978) because of insufficient DM and energy intake (Musangi, 1969; Mugerwa *et al.*, 1974).

Since about 80% of the surface area of Kenya is rangeland the animal production potential of such land would be considerable if it was well managed. In order to obtain increased animal output from rangeland there has to be a precise manipulation of the animal and its environment. Unfortunately, there is a paucity of information on constraints to productivity of migrant cattle in northern Kenya.

The objective of this study was to investigate key food plants, their quality and intake by cattle in the IPAL area in south-west Marsabit District.

MATERIALS AND METHODS

LOCATION

All field experiments on cattle feeding and nutrition were carried out in the study area described in IPAL Technical Reports B-1, D-1 and E-1. Studies of key food plants were carried out at Olturot, Mt. Kulal, Ngurunit and Lependera. Feed intake experiments were carried out at Olturot during wet season (May and June) and Ngurunit during the dry season (October and November). Climatic data with regard to temperature and rainfall for the different areas during the study were collected. The vegetation of Mt. Kulal consisted of evergreen to semi-deciduous bushland with perennial grasses, while at Olturot and Ngurunit the vegetation was primarily deciduous woodland mixed with deciduous bushland and annual grasses. All laboratory analyses, compilation and computation of data and statistical analyses were done at Kabete Campus, University of Nairobi, Kenya.

ANIMALS AND ANIMAL HUSBANDRY

A herd of 150 head of cattle of the Small East African Zebu, locally known as Samburu and Rendille cattle, was used for the studies. The herd was contracted to and looked after by the IPAL project personnel. The herd was subdivided into two equal groups - the 'EVEN' herd which received no veterinary inputs and the 'ODD' herd which received 'maximum' veterinary inputs. The latter involved treatment with veterinary drugs against a variety of diseases which had been identified in a six-month pre-treatment period. The two groups of cattle were treated differently, grazed separately but on the same vegetation type and night-paddocked in different bomas. The treated (ODD) herd was dewormed regularly using Panacur[R] 10% solution and sprayed weekly using Bacdip[R] acaricide. The ODD herd has been vaccinated against blackquarter and anthrax using Ngombevac[R], and trypanosomiasis using Somarin[R]. During the dry season, all cattle were watered every second day.

KEY FOOD PLANT SPECIES STUDIES

Food preference observations started in February 1981 and continued on a routine monthly basis with the exception of August. Cattle in the IPAL herd were observed while they were free ranging using the 'feeding minutes' technique (Field, 1978) and the 'feeding seconds' method developed by the Traditional Livestock Management Project. The 'feeding minutes' method involved recording the time spent feeding on each food plant by an individual animal. The animal is watched for not more than

10 feeding minutes. Thirty animals were observed in all, giving a total number of 300 observations recorded per month. For the 'feeding seconds' technique, 12 animals were observed each for a separate period of ten minutes. The amount of time spent feeding on a particular plant species was recorded in seconds and the number of times an animal changed to each new plant species was also recorded. The total feeding time in seconds spent by the 12 animals on each plant species was them summar

In both methods, the part of the plant consumed, such as leaf or s*em or flowers of fruits, was recorded and taken into account in the subsequent range and nutritional analyses. The total feeding time spent on each plant species by the 30 or 12 animals under observation was expressed as a percentage of their total grazing time. The species which comprised the first 80% of the cattle diet were selected as the key food plants whose samples were taken and processed for chemical analysis.

The availability of the identified key food plant species in the range was quantified by the IPAL Range Ecologist using the herb layer sample method for determining primary productivity (Herlocker, 1979).

FEED INTAKE STUDIES

ANIMALS

The experiment was conducted in a 3 x 2 factorial design. Eighteen animals were selected from the IPAL herd to represent calves, immatures and adults. Nine of the animals were taken from the ODD herd which received 'maximum' veterinary input. The rest were selected from the untreated (EVEN) herd. Tables 1 and 2 show the liveweights and estimated ages of the animals used for wet and dry season feed intake trials. The animals were permitted to graze, on average, from 07.00 to 18.00 hours daily and were weighed at the beginning and end of each collection period.

Table 1. Age[1] and liveweight of animals used for the intake study during the wet season (May-June 1981)

Class of stock	Treatment herd (odd)			Control herd (even)		
	Animal No.	Age (weeks)	Weight (kg)	Animal No.	Age (weeks)	Weight (kg)
Calves	49	< 103.3	73.0	60	< 103.3	90.0
	57	< 103.3	76.0	132	< 103.3	98.0
	63	< 103.3	73.0	178	< 103.3	78.0
	Mean	-	74.0	Mean	-	88.7
Immatures	133	> 103.3 < 127.6	90.0	170	> 127.6 < 151.0	162.0
	157	> 103.3 < 127.6	134.0	152	> 103.3	126.0
	167	> 106.2	169.0	158	> 103.3	144.0
	Mean	-	131.0	Mean	-	144.0
Adults	15	> 127.6 < 151.0	197.0	106	> 181.2	199.0
	109	> 181.2	300.0	108	> 181.2	238.0
	113	> 151.0 < 181.2	251.0	112	< 151.0 < 181.2	216.0
	Mean	-	249.3	Mean	-	217.7

[1] Age estimated from dentition (A.B. Carles and K.M. Lampkin. 1977. *J. Agric. Sci.* (Camb.), 88: 341-360).

Table 2. Age[1] and liveweight of animals used for the intake study during the dry season (October-November 1981)

Class of stock	Treatment herd (odd)			Control herd (even)		
	Animal No.	Age (weeks)	Weight (kg)	Animal No.	Age (weeks)	Weight (kg)
Calves	57	< 103.3	90.5	52	< 103.3	82.0
	59	< 103.3	80.5	60	< 103.3	103.5
	63	< 103.3	90.0	132	< 103.3	109.5
	Mean	-	88.0	Mean	-	98.2
Immatures	133	> 103.3 < 127.6	108.5	136	> 103.3 < 127.6	178.0
	157	> 103.3 < 127.6	150.0	152	< 103.3	132.0
	167	127.6	182.0	158	< 103.3	170.0
	Mean	-	146.8	Mean	-	160.0
Adults	15	> 127.6 < 151.0	240.0	106	> 181.2	244.0
	113	> 151.0 < 181.2	290.0	108	> 181.2	244.0
	187	> 181.2	325.0	112	> 151.0 < 181.2	230.0
	Mean	-	285.0	Mean	-	239.3

[1] Age estimated from dentition (A.B. Carles and K.M. Lampkin. 1977. *J. Agric. Sci.* (Camb.), 88: 341-360.)

(a) Administration of chromic oxide (Cr_2O_3)

Ten grams of Cr_2O_3 was fed daily to each animal. During the wet season Cr_2O_3 was premixed at a rate of 15% in dairy meal as a carrier. A total of 60g Cr_2O_3/carrier mixture was fed once daily to each individual animal between 06.00 and 07.00 hours. Carrier refusals were recorded daily. During the dry season the 10 g of Cr_2O_3 was offered wrapped up in a small sheet of toilet paper. It was dropped down the oesophagus of the animal with the help of a gag. The contents were washed down using a small amount of water. Cattle were fed Cr_2O_3 for 10 preliminary days and 12 collection days of each period. A collection period was 22 days and there were two such periods during the wet season and one 25-day collection period in the dry season. The collection days were further subdivided into four 3-day sub-periods. There were 4 sub-periods in each of the two collection periods during the wet season and 5 sub-periods in the one dry season collection period.

(b) Faecal collection and preparation

Animals that were on the trial were separated from the general herd and grazed separately. Nine animals from the ODD herd and nine animals from the EVEN herd were followed throughout the grazing time by two assistants trained to collect faecal samples from the cattle. Each person carried nine plastic bags, one for each animal in his group. Faecal collection was done during the 12 days of collection of each period. Every time an animal dropped faeces, the attendant would quickly pick a sample from the pile carefully avoiding inclusion of any soil particles. The sample was then put in that particular animal's bag. This process was continued throughout the day.

At the end of the day, for each animal, the day's faecal collection was mixed thoroughly and a 300g sub-sample was taken and preserved in toluene. After every third day, the faeces for every sub-period (3 days) were bulked for each animal and thoroughly mixed. Two sub-samples were then taken: a 100g sample in fresh condition was taken for protein analysis and a 300g sample was air-dried and processed for other analyses.

PASTURE SAMPLING

Samples of herbage from forage plants preferentially grazed by cattle during each collection period were taken, weighed, air-dried and processed for analysis.

ANALYSES

Faecal material and herbage samples were analysed for dry matter (DM), crude protein (CP) and ash (A.O.A.C. , 1975); and lignin (Van Soest,1963). Faecal material was analysed for Cr_2O_3 (Kimura and Miller, 1957). Faecal Cr_2O_3 concentrations were corrected for incomplete recovery from the gut by a factor of 90.2% (Abate, 1978). Herbage samples were also analysed for cell-wall constituents (CWC), acid detergent fibre (ADF), and acid detergent lignin (ADL) (Van Soest, 1963), minerals Ca, P, Mg, K and Na (Perkin-Elmer, 1971), and were subjected to *in vitro* digestibility tests (Tilley and Terry, 1963).

For the intake study, DM digestibility was estimated by using lignin in the indicator ratio technique (Crampton and Harris, 1969). Faecal output (FO), dry matter intake (DMI) and digestible dry matter intake (DDMI) were derived using the equations of Smith and Reid (1955), and Olaloku and Oyenuga (1974).

(1) Digestibility (%)

$$= 100 - 100 \frac{\%\ \text{Indicator in feed} \times \%\ \text{Nutrient in faeces}}{\%\ \text{Indicator in faeces} \times \%\ \text{Nutrient in feed}}$$

(2)
$$\text{FO (g DM/day)} = \frac{Cr_2O_3\ \text{consumed (g/day)}}{Cr_2O_3\ \text{concentration of faeces (g/g DM)}}$$

(3)
$$\text{DMI (g/day)} = \frac{\text{FO (g DM/day)}}{\text{Indigestibility of DM (\%)}}$$

(4)
$$\text{DDMI (g/day)} = \frac{\text{DMI (g DM/day)} \times \text{digestibility}}{100}$$

Data were subjected to simple (means and standard errors) statistical computations (Steel and Torrie, 1960).

RESULTS

CATTLE DIET COMPOSTTION

The data on food preferences are presented in Tables 3 and 4. On Mt. Kulal, six species of perennial grass comprised from 61 to 97% of the diet. On one occasion a single herb species was important when still green after rain. At Olturot following heavy rain eight species of annual grasses comprised from 54 to 92% of the diet. Perennial grasses featured in the diet on three occasions and the leafy dwarf shrub *Sericocomopsis* was important as grasses dried out.

At Ngurunit, where conditions were quite dry, grass litter in the form of standing hay comprised from 24 to 89% of the diet. The proportion of litter in the cattle diet appeared to increase as dry conditions persisted. Ten species of annual grasses comprised between 25 and 77% of the diet. Four of these were also important at Olturot. In December, two annual grass species made up upto 60% of the cattle diet at Korr. *Acacia tortilis* flowers were important in the diet of cattle during September and to a lesser extent during October. The dropped flowers were avidly sought after by the cattle. It should be noted that out of about 30 plant species identified between February and December 1981, only six species made it into the monthly cattle diets more than twice. The species and the times they appeared in the diets were as follows: *Eragrostis cilianensis* (6), *Aristida mutabilis* (5), *Brachiaria leersioides* (4), *Chloris virgata* (3), *Sporobolus fimbriatus* (3) and *Tetrapogon* species (3). Grass litter also appeared in the cattle diets five times during the same period.

CHEMICAL COMPOSITION AND DIGESTIBILITY OF KEY FOOD PLANTS

(a) Annual grasses

Annual grasses had generally low crude protein (CP) content and high fibre levels coupled with low *in vitro* dry matter and organic matter digestibility except in April which was the wettest month of the year (Table 5). High CP values were found in *Aristida mutabilis* (14.7%), *Dactyloctenium aegyptium* (17.3%) and *Tragus berteronianus* (13.7%)

Table 3. Key food plants expressed as % composition of cattle diets

Place	Kulal		Olturot			Kulal
Date sampled	27.2.81	13.3.81	21.4.81	21.5.81	28.6.81	23.7.81
Rainfall[1] in mm	34	22	115	52	0	29
Plant species						
Perennial grasses						
Bothrichloa insculpta	-	-	-	-	-	14.7
Cenchrus ciliaris	-	-	-	4.2	-	-
Chrysopogon plumulosus	19.7	14.3	-	-	-	-
Hyparrhenia sp.	-	-	-	-	-	14.3
Pennisetum mezianum	-	-	-	-	-	11.3
Setaria sphacelata	-	-	-	-	13.3	-
Sporobolus fimbriatus	77.3	8.0	8.7	-	-	-
Themeda triandra	-	50.7	-	-	-	20.7
Annual grasses						
Aristida mutabilis	-	-	12.1	37.5	10.4	-
Brachiaria leersioides	-	-	-	4.2	-	-
Chloris virgata	-	-	12.7	4.2	6.0	-
Dactyloctenium aegyptium	-	-	31.2	4.9	-	-
Enneapogon sp.	-	-	-	-	11.6	-
Eragrostis cilianensis	-	-	14.1	21.8	13.3	-
Tetrapogon sp.	-	-	-	-	13.0	-
Tragus berteronianus	-	-	9.1	-	-	-
Grass litter	-	13.3	-	-	-	-
Herbs						
Dyschoriste radicans	-	-	-	-	-	19.0
Dwarf shrubs						
Sericocomopsis hildebrandtii	-	-	-	9.8	12.6	-
Total	97.0	86.3	87.9	86.6	80.2	80.0

[1] Total recorded for one month prior to observations.

Table 4. Key food plants expressed as % composition of cattle diets

Place[1]	Ngurunit/Lependera (A)			Ngurunit/Lependera (B)		Plain	Korr
Date sampled	17.9.81*	17.9.81**	6.10.81	27.10.81	10.11.81	16.12.81	20.12.81
Rainfall[2], mm	0	0	0	5	5	0	0
<u>Plant species</u>							
<u>Annual grasses</u>							
Aristida adscensionis	4.3	-	-	-	-	-	-
Aristida mutabilis	3.0	-	-	-	-	-	42.8
Brachiaria leersioides	-	5.8	-	8.0	-	19.5	-
Cymbopogon validus	-	-	-	7.2	-	-	-
Digitaria sp.	3.0	-	12.9	10.0	-	1.2	-
Eragrostis cilianensis	5.0	12.5	14.3	-	-	20.8	17.2
Leptothrium senegalense	6.3	8.7	-	-	-	-	-
Tetrapogon tenellus	2.3	11.5	7.1	-	-	-	-
Grass litter	30.0	23.7	40.9	49.6	88.8	8.0	29.6
Sedge litter	7.0	-	-	-	-	-	-
<u>Perennial grasses</u>							
Setaria verticillata	-	-	-	-	-	27.5	-
Sporobolus sp.	-	-	-	-	-	8.6	-
<u>Trees and shrubs</u>							
Acacia tortilis flowers	21.0	20.9	8.2	-	-	-	-
Cadaba sp.	-	-	-	7.8	-	1.4	-
Total	81.9	83.1	83.4	82.6	88.8	87.0	89.6

[1] Lependera A and B are sites separated by about 4 km.

* Derived using 'feeding minutes' technique.

** Derived using 'feeding seconds' techniques.

[2] Total recorded for one month prior to observations.

Table 5. Chemical composition and digestibility of key food annual grass species for cattle

Plant species	Month sampled	CP[1]	CWC	ADF	HC %	L	Ash	DMD	OMD	Gross energy[2]
Aristida mutabilis	April	14.7	71.4	40.2	31.2	3.5	10.7	50.8	54.3	4.017
	May	6.3	77.9	47.1	30.8	5.1	6.6	24.3	34.0	4.123
	June	5.1	77.5	51.5	26.0	6.7	8.1	32.0	35.1	4.052
	Sept.	3.2	78.1	53.0	25.1	7.7	8.8	28.1	29.8	4.002
	Dec.	5.4	74.4	50.2	24.2	4.7	9.0	44.9	49.3	4.168
Brachiaria leersioides	May	10.0	62.3	41.0	21.3	4.4	13.5	50.8	52.4	4.106
	Sept.	4.4	72.7	52.0	20.7	5.8	6.1	35.9	37.8	4.116
	Dec.	3.8	68.6	46.5	22.1	4.5	11.1	52.7	53.1	4.124
Chloris virgata	April	10.8	78.1	43.8	34.3	4.4	10.2	42.8	44.8	3.997
	May	7.1	72.8	45.8	27.0	6.5	11.8	40.9	42.3	4.001
	June	6.7	69.6	42.9	26.7	4.9	10.5	46.3	47.7	4.131
Dactyloctenium aegyptium	April	17.3	63.5	37.4	26.1	3.0	18.8	50.1	53.1	4.012
	May	9.4	67.5	38.9	28.6	4.0	15.4	44.2	44.7	4.012
Digitaria sp.	Oct.	4.4	66.8	45.4	21.4	5.3	11.1	50.5	51.4	4.121
Enneapogon sp.	June	6.1	63.0	41.3	21.7	5.5	10.0	50.5	-	-
Erogrostis cilianensis	April	11.8	74.1	40.0	34.1	5.7	7.5	54.6	56.4	4.009
	May	8.0	74.8	46.5	28.3	7.1	8.5	35.6	39.9	3.981
	June	5.5	72.3	47.5	24.8	7.1	13.0	38.1	39.6	4.002
	Sept.	4.0	76.5	43.1	33.4	7.1	8.5	25.6	27.4	3.997
	Oct.	4.8	73.8	53.9	19.9	5.9	9.1	45.4	47.8	4.061
	Dec.	5.8	72.5	46.4	26.1	7.4	8.5	52.7	55.1	4.193
Leptothrium senegalense	Sept.	4.2	78.8	48.6	30.2	5.4	9.0	29.6	32.0	4.011
Tetrapogon sp.	June	5.5	74.0	45.9	28.1	6.0	8.0	43.7	46.5	4.012
Tetrapogon tenellus	Sept.	4.6	76.6	50.5	26.1	2.9	7.9	34.1	34.9	4.134
	Oct.	3.1	74.1	52.5	21.6	6.0	10.7	49.1	50.8	4.106
Tragus berteronianus	April	13.7	72.3	48.5	23.8	6.8	11.2	54.7	59.3	4.012

[1] CP = crude protein; CWC = cell-wall constituents; ADF = acid detergent fibre; HC = hemicellulose; L = lignin; DMD = *in vitro* dry matter digestibility; ODM = *in vitro* organic matter digestibility

[2] Measured as Kcal/g dry matter (DM)

during the month of April. Low CP values were found in all grass species sampled and ranged from 3.0 to 5.0% during the dry spells of the year. All annual grasses had high levels of cell wall constituents (CWC) ranging from 60 to 80%, and acid detergent fibre ranging from 35 to 55%. The lignin content of annual grass species was relatively low. Lignin values ranged from 2.9% for *Tetrapogon tenellus* to 7.7% for *Aristida mutabilis*. *In vitro* dry matter and organic matter digestibility coefficients ranged from 25 to 55% and 27 to 60%, respectively. Highest CWC, ADF and lignin values coupled with low digestibility coefficients were obtained during the driest months of the year (September and October) whereas the lowest fibre values coupled with high *in vitro* digestibility determinations were obtained during the wettest months of the year (April and May).

Calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sodium (Na) content of annual grasses is shown in Table 6. Annual grasses contained relatively high Ca and K levels, marginal Mg levels and deficient levels of P and Na. The ranges of elemental content (as percent (%) in the dry matter) for the different minerals were: Ca (0.15 - 0.56%); P (0.06 - 0.35%); Mg (0.05 - 0.50%); K (0.58 - 5.98%) and Na (0.04 - 7.50%). *Dactyloctenium aegyptium* had very high levels of all minerals studied, especially Na. Calcium was highest in *Brachiaria leersioides* and *Tetrapogon tenellus*, P and K in *Digitaria* spp., Mg in *Brachiaria leersioides* and *Dactyloctenium aegyptium* and Na in *Dactyloctenium aegyptium*.

Seasonal influence on chemical composition and *in vitro* digestibility of key annual grass species was exhibited in a gradual but steady decline in CP content accompanied by an increase in the fibre fractions with maturity. The decline in CP was more dramatic than the increase in fibre content. Increase in the lignin content was very high in *Aristida mutabilis* and *Eragrostis cilianensis*. *In vitro* digestibility coefficients of dry matter and organic matter also declined with age of plant being higher in *Aristida mutabilis* and *Erogrostis cilianensis* during the grazing season. The decline in mineral content with maturity of grass species was clearly shown in *Aristida mutabilis* and *Brachiaria leersioides*.

Table 6. Mineral composition of key food annual grass species for cattle

Plant species	Month sampled	Ca[1] %	P %	Mg %	K %	Na %
Aristida mutabilis	April	0.39	0.29	0.26	1.73	0.19
	May	0.21	0.10	0.10	1.09	0.07
	June	0.16	0.12	0.12	0.69	0.14
	Sept.	0.15	0.08	0.11	0.68	0.09
	Dec.	0.15	0.06	0.11	0.58	0.09
Brachiaria leersioides	May	0.62	0.21	0.78	3.46	0.09
	Sept.	0.52	0.28	0.40	2.37	0.04
	Dec.	0.45	0.09	0.34	1.03	0.10
Chloris virgata	April	0.24	0.24	0.12	1.68	0.03
	May	0.38	0.15	0.39	2.91	0.20
	June	0.26	0.20	0.15	1.50	0.04
Dactyloctenium aegyptium	April	0.44	0.29	0.48	1.63	7.50
	May	0.45	0.31	0.50	1.81	6.01
Digitaria sp.	Oct.	0.29	0.35	0.30	5.98	0.08
Enneapogon sp.	June	0.40	0.07	-	1.42	-
Eragrostis cilianensis	April	0.38	0.23	0.26	2.17	0.20
	May	0.50	0.23	0.21	1.43	0.12
	June	0.47	0.18	0.28	1.58	0.91
	Sept.	0.32	0.19	0.15	1.09	0.09
	Oct.	0.50	0.13	0.15	1.75	0.05
	Dec.	0.48	0.13	0.17	1.01	0.13
Leptothrium senegalense	Sept.	0.43	0.17	0.05	1.28	0.04
Tetrapogon insculpta	June	0.35	0.08	0.18	1.48	0.47
Tetrapogon tenellus	Sept.	0.56	0.13	0.14	2.37	0.06
	Oct.	0.50	0.20	0.18	1.38	0.11
Tragus berteronianus	April	0.42	0.20	0.20	1.63	0.39

[1] Ca = calcium; P = phosphorus; Mg = magnesium; K = potassium; Na = sodium.

(b) Perennial grasses

The chemical composition and *in vitro* digestibility of key perennial grass species which played an important role in the cattle diets is shown in Table 7. Perennial grasses had low CP content ranging from 3.1 to 15.5%. The highest CP values were obtained from *Sporobolus fimbriatus* (15.5%) during April which was the wettest month of the year. The lowest CP values were found in *Themeda triandra* (3.1%), *Chrysopogon plumulosus* (4.0%) and *Hyparrhenia* sp. (3.4%) during the dry months of March and July.

The fibre fractions of CWC, ADF and lignin were generally high with ranges of 61.6-82.4 for CWC; 41.1-65.0% for ADF; and 4.3-12.6% for lignin. *Chrysopogon plumulosus* had the highest CWS (84.2%) and lignin (12.6%) values whereas *Themeda triandra* had the highest ADF (63.0%) content. *Setaria sphaceleta* had the lowest CWC (61.6%) and ADF (41.1) values whereas *Sporobolus fimbriatus* contained the lowest lignin (4.3%) values. The highest and lowest values of the fibre fractions were obtained during the dry and wet months of the year, respectively.

In vitro dry matter and organic matter digestibility coefficients were very low throughout the year for most of the perennial grass species ranging from 21.3 to 52.3% for dry matter digestibility (DMD) and 25.3 to 56.0% for organic matter digestibility (ODM), respectively. The characteristic phenomenon of a decrease in CP coupled with a decline in *in vitro* digestibility coefficients due to high fibre content as a result of maturity was shown in *Chrysopogon plumulosus* and *Sporobolus fimbriatus*.

The mineral content of the perennial grasses is shown in Table 8. In general, all species contained low Ca, P, Mg, K and Na levels except *Cenchrus ciliaris*, *Setaria sphacelata* and *Sporobolus fimbriatus* during the wet period of the year. These same species had relatively high K and Na values - 1.38 and 4.50% for *Cenchrus ciliaris*; 3.26 and 3.38% for *Seteria sphacelata;* and 1.14 and 4.63% for *Sporobolus fimbriatus*.

Table 7. Chemical composition and digestibility of key food perennial grass species for cattle

Plant species	Month sampled	CP[1]	CWC	ADF	HC	L %	Ash	DMD	OMD	Gross energy[2]
Bothriochloa insculpta	July	4.8	75.8	51.3	24.5	6.6	8.1	33.7	35.3	4.094
Cenchrus ciliaris	May	7.1	67.3	43.0	24.3	6.2	9.3	44.4	46.6	4.210
Chrysopogon plumulosus	Feb.	8.7	81.3	55.5	25.8	12.6	7.2	34.7	41.2	4.011
	March	4.0	84.2	58.8	25.4	12.6	6.8	33.9	39.8	3.997
Hyparrhenia sp.	July	3.4	79.1	54.5	24.6	6.8	9.2	24.3	25.3	3.998
Pennisetum mezianum	July	5.4	82.8	55.4	27.4	10.2	9.8	31.8	33.1	4.121
Setaria sphacelata	June	9.1	61.6	41.1	20.5	5.3	14.2	51.0	51.2	4.210
Setaria verticillata	Dec.	6.7	64.8	44.0	20.8	4.9	14.9	51.3	56.0	4.004
Sporobolus sp.	Dec.	5.9	72.2	46.9	25.3	6.0	12.4	44.8	49.2	3.989
Sporobolus fimbriatus	Feb.	9.1	78.5	47.1	31.4	5.8	6.0	37.4	42.9	4.001
	March	5.7	81.2	50.2	31.0	6.0	7.9	34.7	40.6	4.121
	April	15.5	71.3	43.5	27.8	4.3	13.4	52.3	55.4	4.012
Themeda triandra	March	3.1	80.9	63.0	17.9	9.7	9.6	21.3	25.8	4.101
	July	5.0	77.3	52.7	24.6	8.3	9.3	44.6	46.8	3.895

[1, 2] As per footnotes, Table 6.

Table 8. Mineral composition of key food perennial grass species for cattle

Plant species	Month sampled	Ca[1] %	P %	Mg %	K %	Na %
Bothriochloa insculpta	July	0.34	0.21	0.15	1.09	0.09
Cenchrus ciliaris	May	0.29	0.09	0.27	1.38	4.50
Chrysopogon plumulosus	Feb.	0.15	0.08	0.12	0.34	0.02
	March	0.16	0.07	0.07	0.40	0.02
Hyparrhenia sp.	July	0.30	0.08	0.16	0.84	0.09
Pennisetum mezianum	July	0.28	0.48	0.24	1.93	0.06
Setaria sphacelata	June	0.47	0.11	0.41	3.26	2.38
Setaria verticillata	Dec.	0.33	0.10	0.27	2.51	0.09
Sporobolus sp.	Dec.	0.34	0.08	0.10	0.96	0.42
Sporobolus fimbriatus	Feb.	0.17	0.08	0.14	0.84	0.03
	March	0.16	0.08	0.10	0.87	0.03
	April	0.31	0.22	0.27	1.14	4.63
Themeda triandra	March	0.48	0.07	0.20	0.49	0.07
	July	0.45	0.08	0.18	0.59	0.08

[1] As per footnote, Table 6.

(c) Herbs, shrubs and trees

Herbs, shrubs and trees had very high CP and ash value but low CWC, ADF and lignin content (Table 9). Although the fibre fractions were low, the *in vitro* dry matter and organic matter digestibility coefficients were low. Crude protein content of 18.4% and calcium level of 2.4% in *Sericocomopsis hildebrandtii* were particularly impressive and were the highest in all the cattle forage species that were analysed chemically. Crude protein content ranged from 12.4 to 18.4%.

The mineral composition of herbs, shrubs and trees is shown in Table 10. *Acacia tortilis*, *Cadaba* sp. and *Sericocomopsis hildebrandtii* contained high levels of calcium, magnesium and potassium but low levels of phosphorus and sodium. *Cadaba* sp. had one of the highest levels of potassium (5.7 %).

Grass litter, which was very important in cattle diets during the dry spells of the year, contained particularly low CP and *in vitro* dry matter and organic matter digestibility values. The fibre content and ash levels were very high. The calcium, magnesium and potassium levels were high throughout the sampling periods except in March. The levels of phosphorus and sodium were very low throughout the study period.

(d) Cattle diets

The chemical composition of the monthly cattle diets, reconstituted from the feeding habits and chemical analytical data, is presented in Table 11. In general, the CP content of the diets was low whereas the fibre fractions were high throughout the year except in April which was the wettest month of the year. The mineral composition was very variable. The diets had very low levels of P, Mg and Na and these levels seemed to drop drastically during dry months of the year.

Crude protein and lignin ranged from 2.8 to 12.8% and 3.7 to 8.2%, respectively. The ranges for the minerals were:
Ca (0.16-0.51%); P (0.05-0.22%); Mg (0.09-0.31%); K (0.55-2.17); and Na (0.03-2.80%).

Table 9. Chemical composition and digestibility of key food plants (dwarf shrubs, herbs, trees and grass litter) for cattle

Plant species/ materials	Month sampled	CP[1]	CWC	ADF	HC %	L	Ash	DMD	OMD	Gross energy[2]
Acacia tortilis										
flowers	Sept.	15.2	25.2	18.5	7.2	5.3	8.5	45.1	59.1	4.522
	Oct.	12.4	49.5	27.5	22.0	9.2	14.1	51.2	55.2	4.143
Cadaba sp.	Oct.	13.9	70.2	35.4	34.8	15.9	16.2	46.3	49.0	4.204
	Dec.	14.3	68.9	33.2	35.7	14.8	17.6	49.1	51.0	4.216
Dyschoriste radicans	May	11.6	59.1	48.2	10.9	15.1	12.3	46.9	58.0	4.461
Sericocomopsis										
hildebrandtii	May	18.4	54.0	35.3	18.7	6.7	13.3	35.5	38.5	4.059
	June	14.2	41.1	23.4	17.7	3.8	18.8	55.3	57.3	3.998
Grass litter	March	2.5	82.3	63.4	18.9	8.7	11.1	31.6	37.7	4.007
	Sept.	8.6	56.4	20.5	35.9	7.1	16.7	43.5	44.6	4.017
	Oct.	5.5	70.0	48.5	21.5	8.0	9.4	47.8	48.2	3.817
	Nov.	3.4	72.4	48.0	24.4	6.3	13.3	47.6	53.8	3.901
	Dec.	6.2	69.0	47.7	21.3	5.8	12.4	48.5	52.0	3.872

[1, 2] As per footnote, Table 5.

Table 10. Mineral composition of key food plants (dwarf shrubs, herbs, trees and grass litter) for cattle

Plant species/ materials	Month sampled	Ca[1] %	P %	Mg %	K %	Na %
Acacia tortilis						
flowers	Sept.	0.35	0.23	0.22	1.53	0.07
	Oct.	1.39	0.23	0.29	1.45	0.09
Cadaba sp.	Oct.	2.07	0.08	0.91	5.23	0.09
	Dec.	2.13	0.08	1.04	5.70	0.12
Dyschoriste radicans	July	0.61	0.24	0.22	1.49	0.08
Sericocomopsis						
hildebrandtii	May	2.37	0.09	1.42	3.40	0.51
	June	2.47	0.13	1.20	3.36	0.59
Grass litter	March	0.24	0.04	0.06	0.10	0.03
	Sept.	0.37	0.19	0.47	2.27	0.13
	Oct.	0.57	0.12	0.19	2.29	0.08
	Nov.	0.56	0.08	0.16	1.12	0.04
	Dec.	0.46	0.09	0.20	1.61	0.01

[1] As per footnote, Table 6.

Table 11. Chemical composition of reconstituted diets of cattle for year 1981

Month of the year	% total diet [1]	Proximate			Van Soest				Minerals				
		CP%	Ash%	Gross energy	CWC %	ADF %	HC %	ADL %	Ca %	P %	Mg %	K %	Na % [2]
February	97.0	8.7	6.1	4.006	76.7	47.3	29.4	7.0	0.16	0.08	0.13	0.70	0.03
March	86.3	2.8	7.8	4.056	69.0	51.9	17.2	8.2	0.30	0.05	0.12	0.38	0.04
April	87.9	12.8	11.7	4.026	61.6	36.0	25.6	3.7	0.33	0.22	0.27	1.48	2.80
May	86.6	7.4	8.0	4.070	62.5	38.5	24.0	5.0	0.49	0.11	0.31	1.46	0.59
June	68.6	5.4	8.9	4.068	44.8	28.6	16.2	3.9	0.51	0.09	1.28	1.39	0.59
July	80.0	5.2	7.8	4.114	59.0	41.7	17.3	7.7	0.35	0.16	0.20	0.90	0.07
September	83.1	6.9	7.8	4.133	48.2	27.2	21.1	4.8	0.38	0.16	0.22	1.51	0.08
October	83.4	4.7	8.5	4.050	57.1	39.4	17.7	5.9	0.49	0.15	0.17	2.17	0.06
November	88.8	3.4	13.3	3.901	72.4	48.0	24.4	6.3	0.56	0.03	0.16	1.12	0.04
December (Korr)	89.6	4.6	7.7	4.126	67.5	46.1	21.4	4.9	0.24	0.05	0.09	0.55	0.08
December (Plains)	87.0	4.8	0.1	4.036	58.0	38.7	19.3	4.7	0.34	0.08	0.20	1.31	0.11

[1] Represents the percentage of diet that was analysed chemically.

[2] As per footnotes in Tables 5 and 6.

FEED INTAKE

Dry matter intake (DMI) and digestible dry matter intake (DDMI) by cattle during the wet season (May to June) is presented in Table 12. Immature cattle had relatively higher DMI and DDMI than either the calves or the adults when both parameters of intake were expressed as a percentage of bodyweight. However, when intake was expressed on a metabolic ($W^{0.75}$) bodyweight basis, DMI and DDMI varied very slightly between the three classes of stock. Mean absolute dry matter intake values were 2.82 kg/day for the calves; 4.82 kg/day for the immatures; and 7.11 kg/day for the adults. There was no clear indication of the effects of veterinary input on feed intake. When expressed on both percentage and metabolic ($W^{0.75}$) bodyweight basis, treated calves had a slightly higher DMI and DDMI compared to the untreated ones, there was hardly any difference between the treated and untreated groups of immatures for DMI and DDMI, and a depression of DMI and DDMI for adult cattle with veterinary inputs.

During the dry season (October to November), DMI was highest for calves and lowest for adult cattle when intake values were expressed on both percentage bodyweight and metabolic ($W^{0.75}$) body size (Table 13). Digestible dry matter intake (DDMI) was higher for young cattle (calves and immatures) than for adult cattle. Mean absolute dry matter intake values were 3.82 kg/day for the calves, 4.65 kg/day for the immatures, and 6.63 kg/day for the adult cattle. These animals were 10 kg or more heavier on average during the dry season than wet season.

Intake values for dry matter and digestible dry matter were suprisingly higher for calves during the dry season than during the wet season. For immatures and mature cattle, DMI was much lower during the dry season than during the wet season. This drop in DMI was much sharper in the adults than the immatures. The immatures and adults ingested, respectively, 9.6% and 19.5% less dry matter during the dry season. Again, there were no clear indication of the effects of veterinary inputs on feed intake. The treated calves had slightly higher DMI and DDMI values whereas the reverse was true for the mature cattle when intake was expressed on percentage and metabolic ($W^{0.75}$) bodyweight basis. The treated and untreated immatures had similar dry matter and digestible dry matter intake values during the dry season.

Table 12. Daily intake of dry matter and digestible dry matter by cattle grazing freely on range during the wet season [1] (Mean ± S.E.)

Class of stock	Calves		Immatures		Adults	
Herd	Untreated	Treated	Untreated	Treated	Untreated	Treated
Animals/herd	3	3	3	3	3	3
Average weight, kg	90.0	79.2	142.9	136.5	215.9	257.9
Parameter [2]						
DMI (kg/day)	2.73 ± 0.4	2.91 ± 0.2	4.90 ± 0.2	4.74 ± 0.3	7.22 ± 0.5	6.99 ± 0.7
DMI (g/kg $W^{0.75}$)	94.1	109.8	118.6	119.1	128.2	109.0
DMI (kg/100 kg LWT [3])	3.03	3.67	3.43	3.47	3.34	2.71
DDMI (kg/day)	1.44 ± 0.4	1.57 ± 0.2	2.50 ± 0.3	2.37 ± 0.2	3.75 ± 0.6	3.84 ± 0.6
DDMI (g/kg $W^{0.75}$)	49.7	59.2	60.5	59.5	66.7	60.0
DDMI (kg/100 kg LWT)	1.60	1.98	1.75	1.74	1.74	1.49

[1] Two collection periods were carried out.

[2] DMI = dry matter intake; DDMI = digestible dry matter intake.

[3] LWT = Liveweight.

Table 13. Daily intake of dry matter and digestible dry matter by cattle grazing freely on range during the dry season[1] (Mean ± S.E.)

Class of stock	Calves		Immatures		Adults	
Herd	Untreated	Treated	Untreated	Treated	Untreated	Treated
Animals/herd	3	3	3	3	3	3
Average weight, kg	98.0	89.5	152.2	146.1	233.9	279.8
Parameter[2]						
DMI (kg/day)	3.89 ± 0.1	3.75 ± 0.1	4.73 ± 0.2	4.56 ± 0.2	6.48 ± 0.4	6.78 ± 0.4
DMI (g/kg $W^{0.75}$)	124.9	128.9	109.2	108.5	108.3	99.1
DMI (kg/100 kg LWT[3])	3.97	4.19	3.11	3.12	2.77	2.42
DDMI (kg/day)	1.68 ± 0.2	1.78 ± 0.1	2.27 ± 0.2	2.45 ± 0.2	3.21 ± 0.5	3.21 ± 0.4
DDMI (g/kg $W^{0.75}$)	54.0	60.3	52.4	58.3	53.7	47.0
DDMI (kg/100 kg LWT)	1.71	1.99	1.81	1.68	1.37	1.15

1 One collection period was carried out.

2 DMI = dry matter intake; DDMI = digestible dry matter intake.

3 LWT = Liveweight.

DISCUSSION

Although there are other methods which could provide more accurate data on cattle dietary preferences, the direct observation of cattle when grazing was chosen for its simplicity. The key food plant species identified in the diet of cattle using this method provided an essential prerequisite for the understanding of feeding habits of cattle on the range. The plants were used in the reconstruction of the nutritional composition of the diets. For a better assessment of the quality of the range with respect to cattle, it is important that the plant species that were identified as appearing more frequently in diets of cattle should be studied further in more detail with regard to their ecology, agronomy and nutritive value or utilization. The fact that as the seasons change from wet to dry periods of the year, herbs, shrubs, trees and grass litter are dominant in cattle diets, should be taken seriously into account when recommending a grazing and utilization system for the range.

Most key food plants for cattle identified throughout the year, especially the grass species, had low crude protein content and high fibre values coupled with low *in vitro* dry matter digestibility coefficients. This is consistent with previous reports (Karue, 1974, 1975; Glover and French, 1957). The changes in CP and ADF values appeared in a short period of time which is in agreement with fast plant growth and rapid decline in quality of range plants (McKay, 1971). It is this rapid decline in quality that must be seriously considered when devising grazing systems for cattle for higher productivity and maximum utilization of the range in any management plan.

The reconstituted cattle diets showed poor nutritional composition, especially with respect to crude protein, phosphorus, magnesium and sodium values throughout the year except during the short wet period in April. These data on the chemical composition of the diets clearly indicated that cattle grazing on this range cannot be expected to obtain all their maintenance and production nutrient requirements throughout the year without some sort of supplementary feeding. The detrimental effects of phosphorus deficiency must explain the low fecundity or reproductive efficiency of the range cattle in this area. The high cattle mortality at the start of the rains may, to a certain extent, be due to hypomagnesaemia.

Sodium deficiency and low protein intake are known to cause complete cessation of growth (Underwood, 1971; Crampton and Harris, 1969). Hence a mineral and protein supplementation programme is essential if productivity of range cattle is to improve.

Feed intake values determined as dry matter intake (DMI) and digestible dry matter (DDMI) were much higher than those that have been reported by others (Abate *et al.*, 1981). High DMI and DDMI may have been due to over-estimation arising from uncontrolled field conditions coupled with the bulky nature of the herbage as indicated by the high CWC levels. Bulky feeds have low nutrient density which may have necessitated the animal to ingest more food to meet its energy requirements. Faecal Cr_2O_3 concentrations have to be corrected for incomplete recovery of all Cr_2O_3 from the gut (Streeter, 1969). The Cr_2O_3 recovery factor has to be obtained under similar ecological and grazing conditions for the whole experiment. In this study, the factor used to correct the faecal Cr_2O_3 concentrations was obtained under different ecological and field conditions. Such a factor could have contributed to the high estimates of DMI. No major differences in DMI and DDMI could have been expected between the treated and untreated animals since faecal egg and tick counts have so far revealed low parasite loads in both herds (Field, 1981).

The important point about the intake values derived and reported here is that they should be used with caution because the data were generated over a short study period. The wet season intake values were based on only two collection periods whereas during the dry season only one collection was carried out. They should therefore be used as guidelines for the time being until more data are generated using large numbers of animals over a longer period of time with more controlled field conditions.

The dry season intake figures obtained in this study were variable and reflected, in part, the husbandry practices and condition or health status of the cattle during the study period. Since DMI values are derived as a ratio between percent indigestibility and faecal dry matter output, the watering regime tended to increase apparent digestibility and reduce percent indigestibility. The effect of this was to increase DMI estimates. The availability of feed at the place of grazing, the distance travelled to grazing and the time spent to get there, and the time spent at watering points on a watering day, all caused the instability of values of feed intake obtained. The condition or health status of the animal determined its ability to fend for itself or compete effectively with the other animals for the little available feed. There was a clear drop of over 20% in intake values obtained between the beginning and end of the dry season collection period for most animals. This indicated the difference in severity of the drought with time in terms of available feed and condition of animals.

The high DMI and DDMI by calves during the dry season cannot be explained except by technical errors in the field. For the immatures and mature cattle, DMI and DDMI values were lower for the dry season than those obtained during the wet season. This decline in ingested feed during the dry season *per se* cannot explain the deterioration in condition and performance of the animals during the drought which was observed. It is important therefore that further studies be carried out to elucidate the main causes of this phenomenon. Studies involving the major nutrients, energy and protein, would seem valuable.

However, the feed intake values so far obtained from this study should play an important role in the calculation of stocking densities for the area in conjuction with the forage primary productivity data available. The information on stocking rates should be used by the project to recommend suitable annual off-take in order to avoid overgrazing with all its detrimental effects, especially desert encroachment, in this ecological zone.

MAJOR FINDINGS OF THE STUDY

Within the confines of the terms of reference for this project, and within the limits of the experiments carried out, the following major findings can now be reported.

1. During the wet season, annual and perennial grasses made up the bulk of the cattle diets. When the dry season became severe, the herbs, dwarf shrubs, trees and litter constituted the major portion of the cattle diets.

2. There were six plant species that frequently appeared to be important in cattle diets. These were *Eragrostis cilianensis*, *Aristida mutabilis*, *Brachiaria leersioides*, *Chloris virgata*, *Sporobolus fimbriatus* and *Tetrapogon* sp. Grass litter also appeared in the cattle diets five times during the year of study.

3. All grass species sampled had generally low crude protein content and high fibre levels, whereas herbs, shrubs and trees had high levels of crude protein and minerals. All plant species studied showed generally low digestibility coefficients. There was a sharp decline in quality with maturity of plant and this drop in crude protein and digestibility happened in a very short period of time.

4. The reconstituted cattle diets were of poor quality throughout the year except during the wettest month of the year (April). The diets had particularly low protein, phosphorus, magnesium and sodium levels.

5. Feed intake values, in terms of dry matter intake (DMI) and digestible dry matter intake (DDMI), obtained during the wet season study were more stable, reliable and tended to compare favourably with animal performance recorded than those obtained during the dry season.

6. A comparison of feed intake values derived during the wet and dry seasons of the year indicated a drop in intake during the dry season. However the drop was not drastic enough to explain the observed deterioration in condition of animals during drought.

RECOMMENDATIONS FROM THE CATTLE NUTRITION STUDIES

1. There should be detailed controlled studies on the plant species that appeared in the cattle diets most frequently. These are *Eragrostis cilianensis, Aristida mutabilis, Brachiaria leersioides, Chloris virgata, Sporobolus fimbriatus* and *Tetrapogon* sp. The studies should be planned along the following lines:
   (a) productivity and locational distribution in the study area;
   (b) introduction, propagation and other important factors of management;
   (c) effects of location, stage of maturity and species (in case of *Tetrapogon)* on nutritive value.

   Data obtained should be used to scale down the list to about three of the most important plant species for introduction, propagation and eventual utilization.

2. Herbs, shrubs and trees are an important source of feed for cattle during the dry season. They seem to be a good source of protein and minerals. Thus, *Acacia tortilis, Dyschoriste radicans, Sericocomopsis hildebrandtii* should therefore be studied thoroughly along the lines suggested in recommendation (1). In the case of these plant species, the part of the plant ingested should be studied in detail.

3. Feeding management of the animals needs to be manipulated for higher productivity. This should be on the following broad lines:
   (a) Shifting animal agriculture whereby cattle are moved or migrated to areas of high food quantity and quality throughout the year depending on data obtained from the study of productivity and locational distribution of important plant species in cattle diets;
   (b) In devising effective grazing systems, the fact that annual and perennial grasses are very important in cattle diets during the wet seasons whereas herbs, dwarf shrubs, trees and grass litter form the major portion of cattle feed during the severe dry conditions should be taken into account;
   (c) Daily routine grazing management should mainly be based on peak grazing times - times when cattle are actually grazing and not resting during the day. These should be monitored for both the wet

and dry seasons. For instance, during the dry season cattle should be grazed during peak grazing times and watered during periods of resting. This would encourage 'maximum' feed intake for 'greater' productivity;

(d) Controlled lopping of shrubs and trees to supplement poor grazing during the dry season should be practised;

(e) Supplementary feeding using commercial feeds, especially during the dry seasons, should be explored. MUM (molasses, urea, minerals) is a practical supplement. In this case, it would provide readily available energy (molasses), protein (urea), and minerals - all of which seem to be deficient, especially during the dry seasons;

(f) Minerals supplementation should be encouraged using mineral premixes which are fortified with respect to phosphorus magnesium and sodium. These minerals have been shown to be deficient in cattle diets practically throughout the year. Besides other effects of such mineral deficiencies, the major problems are: low reproductive efficiency with low dietary phosphorus intake, grass tetany, especially during the wet season, with low magnesium intake, and depressed appetite and poor growth with low sodium intake.

4. There was a drop in dry matter intake by cattle during the dry season due to obvious unavailability of feed and the poor quality of whatever feed or grazing was available. However, the drop in feed intake was not sharp enough to explain the very poor condition of animals observed visually. Therefore a study of intake of digestible energy and protein - which are the major nutrients - should be undertaken.

All these recommendations should not be looked at in isolation, rather they should be integrated first of all with those from other cattle study projects such as the management, breeding and health aspects. And finally, they should be worked into the whole livestock productivity programme in the final management plans for increased productivity of the rangelands.

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IMPORTANT DISEASES OF CATTLE IN THE IPAL STUDY AREA

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INTRODUCTION

The arid and semi-arid lands of Kenya, of which the IPAL study area is a part, cover about 80% of the country's land surface but support only about 20% of its population (Wilson and Njogu, 1981). With the increase in population pressure on high-potential agricultural land, the need has arisen for opening up these marginal and low-potential areas to development. Large areas of these lands possess a development potential in so far as they are suited for grazing. At present they are either being misused due to the lack of a scientifically controlled approach to their exploitation, or they have been unutilized because of poor accessibility, lack of water and security problems. In many cases these barriers can be removed with a modest investment in the necessary infrastructure. The opportunity cost of land and labour in these areas is practically nil since the land is not suited for any use other than grazing (rainfall being deficient and erratic), and in the absence of alternative avenues of local employment of any significance pastoralism remains the way most people earn their livelihood (Konczacki, 1978).

Pastoralism is an economic activity in which man and herds of domesticated animals live in a symbiotic relationship (Konczacki, 1978). Being an economic activity first and foremost, man would want to avoid losses due to deaths and poor productivity. The main causes of deaths and poor productivity are diseases and undernutrition. The drought that affected the Sahel in the early 1970s and brought hunger to millions of people exposed our inability to prevent deaths and poor productivity of livestock in such events. In the event of drought the animals suffering from chronic diseases such as trypanosomiasis and helminthiasis are the first to die. Scientists involved in the search for a solution to the pastoral dilemma in Africa seem not to have recognized this basic fact, as revealed by their cautious approach to the supply of veterinary services until offtake is improved. Economists believe that improved marketing will stimulate the demand for veterinary input. While that view is theoretically sound, it must be noted that the pastoralists may also accelerate offtake if assured that deaths of their livestock can be arrested. Adequate disease control would ensure that animals are in a healthy condition with adequate fat deposits before a drought.

Such animals would withstand the drought longer and thus considerably reduce the effects of the drought.

The objective of this study was to identify diseases in cattle under pastoral management within the IPAL study area and thus contribute to the interdisciplinary efforts to find solutions to the economic and ecological problems faced by pastoralists in arid and semi-arid areas of the world.

Work had already been carried out on cattle diseases in lowland areas (Field, 1981); therefore emphasis was placed on cattle living in the watershed highland areas such as Marsabit and Kulal.

REVIEW OF LITERATURE

An attempt has been made to summarize available information on the important diseases of cattle in Marsabit District. Information on trypanosomiasis has been summarized in some detail because it is prominent in the local literature and also because the work of the author has led to the discovery of some parasites which Mugera (1982) has suggested may be different stages of binary fission of trypanosomes.

BOVINE TRYPANOSOMIASIS

Bovine trypanosomiasis is an infection caused by salivarian trypanosomes. The disease caused by the tsetse-borne African trypanosomes is called *nagana* (Wandera, 1979a). *Nagana* has indirectly contributed to widespread malnutrition in Africa by decreasing the amount of food available to man. The most important insects involved in the transmission of the disease are tsetse flies (genus *Glossina)* which are the biological vectors. The importance of other blood-sucking insects (notably flies of the genera *Tabanus, Atylotus, Philoliche, Stomoxys,* and *Hippobosca*) is uncertain. They are mechanical vectors and some workers consider them to be effective disease transmitters (Wiessenhutter, 1975). Congenital infection with trypanosomes has been described on a number of occasions and the reports have been reviewed by Ormerod (1970).

The importance of the tsetse fly and *nagana* has long been known to the African stockman. It was not, however, until the turn of the century that the presence of a small, highly motile flagellated protozoon in the blood of infected cattle was observed by scientists in Africa and determined as the cause of *nagana*. Careful study of their morphology and the characteristics of the disease they caused revealed that three species parasitize cattle. The three species are now known as *Trypanosoma congolense, T. vivax* and *T. brucei* and all these three species have been identified in cattle in East Africa (Wandera, 1979a).

Tsetse flies are only found on the African continent where they infest approximately 10 million km^2. Dense rain forest makes up 3 million km^2 of this and therefore livestock production is affected by tsetse flies to a greater or lesser extent in approximately 7 million km^2 of the continent (Finelle, 1974). It has been estimated that if the tsetse fly and *nagana* could be controlled, 120 million head could be added to the continent's population which might generate an annual revenue of about US $750 million (Finelle, 1974). The importance of the disease should be seen in this context.

Tsetse flies are divided into three main groups (Wilson and Njogu, 1981), namely:

(a) The morsitans group, which inhabits savannah type vegetation and is very important in disease transmission. Important Kenyan species of this group are *Glossina pallidipes*, *G. swynnertoni*, and *G. austeni*.

(b) The palpalis group, which inhabits mainly riverine vegetation but is less important than the morsitans group in trypanosome transmission as it infests a smaller area. The only species of this group in Kenya is *G. fuscipes*.

(c) The fusca group which inhabits mainly forest vegetation and is generally believed to be unimportant in trypanosome transmission. Important exceptions include *G. brevipalpis* (which can be an important disease transmitter) and *G. longipennis* (which inhabits the most arid vegetation of any tsetse species).

The main clinical signs of trypanosome infection are chronic and include emaciation, anaemia and generalized loss of production. Some strains of *T. vivax* are known to cause acute disease in cattle characterized by fulminating parasitaemia, generalized haemorrhage and sudden death. Wandera (1979a) points out that indeed, bovine trypanosomiasis is no longer a chronic infection confined to fly belts but a fulminating disease throughout vast areas of Africa.

THE RESERVOIR OF TRYPANOSOMES

From the literature it is clear that the main reservoir of trypanosomes is wild animals. Ashcroft (1959) summarized many surveys of trypanosomiasis in African wild animals going back to 1913. Some examples of high incidences of all forms of trypanosomiasis (*T. vivax*, *T. congolense* and *T. brucei*) in some species known to occur in the IPAL study area were:

52% in waterbuck (*Kobus* spp.); 45% in kudu (*Tragelaphus* spp.); 44% in reedbuck (*Redunca* spp.); 37% in giraffe (*Giraffa* sp.) and 31% in bushbuck (*Tragelaphus* sp.). In buffalo (*Syncerus caffer*), duiker (*Sylvicapra* spp.), and warthog (*Phacochoerus* sp.) infection rates were found to be between 10 and 16%. These figures have been derived mainly from examination of blood slides, but the work of Godfrey and Killick-Kendrick (1961) and Baker (1967) using rat inoculation suggests that infections with trypanosomes of the *T. brucei* sub-group could be much more common than figures derived solely from blood-slide examination would indicate. It is important to note that some of the wild animals named above exist within the IPAL study area and it is assumed they act as reservoirs of trypanosomes here as in other parts of Africa, although it has not been possible to demonstrate this.

PREVIOUS REPORTS OF TRYPANOSOMIASIS IN THE IPAL STUDY AREA

Trypanosomiasis is known to the pastoralists of Marsabit District. The Rendille call it *omar*, the Boran/Gabbra *gandi* and the Samburu *sarr*. There are few documented records of the presence of trypanosomes or tsetse flies in Marsabit District. According to its annual reports for the years 1979 to 1982 the Veterinary Department repeatedly stated that trypanosomiasis is endemic in Marsabit District. The map of distribution of tsetse species in the Atlas of Kenya (1962) also shows that east of Mt. Marsabit, South Horr, a strip along the Milgis river and Moyale are infested with *Glossina longipennis*. There is, however, no record of trypanosomes being diagnosed in cattle in the district and thus little is known about the species of trypanosomes that exist in this district. One criterion is the use of trypanocidal drugs in Marsabit District as issued by the Veterinary Department. In 1982 alone, 10,118 tablets of the drug Novidium 4,057 tablets of the drug Ethidium, 200g of the drug Samorin and 16 sachets of the drug Naganol were issued to stock owners in the district. These drugs were not issued on the basis of diagnosis of trypanosome infections. However, their use may suggest a high incidence of bovine trypanosomiasis in certain areas of the district.

PREVIOUS REPORTS OF OTHER DISEASES OF CATTLE IN THE IPAL STUDY AREA

According to its annual reports for the years 1979 to 1982, the Veterinary Department repeatedly stated that anthrax is a recurrent disease in the district, that blackquarter is common in the district, that helminthiasis is a major problem in the district and that outbreaks of foot and mouth disease are common in the district. Furthermore, according to the records at the Wellcome Laboratory at Embakasi, the following types of foot and mouth disease virus have been reported in northern Kenya: types O and C in 1976, types A and SAT_2 in 1977, type A in 1978 and type O in 1979. However, the IPAL experiments based on a contract herd of 140 cattle which were herded in the Kulal area from October 1980 to July 1981 and in the Ngurunit - Korr area from July 1981 to October 1982 failed to identify any major disease which could account for the observed reduced productivity and mortality during drought (Field, 1981). This finding was surprising when viewed in the light of the available information on the diseases of cattle in Marsabit district. The question thus arose as to whether the experimental herd was typical of cattle in the district as a whole with respect to disease. This study was an attempt to answer that question.

MATERIALS AND METHODS

THE STUDY AREA

The IPAL study area is approximately 22,000 km^2 and is located between the south-east shore of Lake Turkana and Mount Marsabit (See pages 2 and 8). It occupies about 30% of Marsabit District and about 4% of Kenya. Its vegetation and topography have been described in detail by Herlocker (1979), the climate by Edwards *et al.* (1979) and preliminary surveys of grazing livestock have been made by Lewis (1977).

THE CATTLE POPULATION

Despite its large size, the IPAL study area is only part of an ecosystem and large numbers of livestock move in and out of the area with the availability of grazing and water (Lewis, 1977). Thus there are basically two distinct populations of cattle. Firstly there are those cattle which stay permanently in the study area and which are based around highland areas: these are the animals which remain within the study area throughout the dry season. The second population is that which only comes into the study area during the wet season (Lewis, 1977). Field (1981) reported that from the aerial surveys six main cattle centres were identified in the study area with mean localized densitities (km^{-2}) over areas of 300 km^2 as follows:

Table 1. Mean cattle densities at six main centres

	Wet season	Dry season	Combined
Marsabit	35	31	33
Ngurunit	36	2	19
Kulal	14	14	14
Hurri Hills	35	0	17
Maikona	7	16	12
S. Horr	7	13	10

SAMPLING LOCATIONS

Two highland locations -- Mt. Marsabit and Mt. Kulal -- and one lowland location -- Ngurunit -- were selected as the main sampling locations because of their high combined densities of cattle (1981). However, some animals were also sampled at Loglogo, Kargi, Olturot and Kalacha, all of which are lowland locations.

COMBINED TRYPANOSOMIASIS, BRUCELLOSIS AND FOOT AND MOUTH DISEASE SURVEY

The co-operation of pastoral cattle owners was essential for disease surveys. To obtain that co-operation the principle of give and take was applied, i.e. the pastoral cattle owners were promised that all animals found infected with trypanosomes would be treated free of charge. It was therefore thought desirable to conduct the surveys for trypanosomiasis, brucellosis and foot and mouth disease at the same time.

Trypanosomiasis Survey

A total of 670 cattle were sampled on Mt. Marsabit, Mt. Kulal, Ngurunit and Loglogo. On Mt. Marsabit the sampling locations were Ulaula, Marsabit North, Badasa and Karare while on Mt. Kulal, Gatab was the sole sampling location. The breakdown of animals sampled per location is shown in Table 2.

a) Haematocrit Centrifugation Technique (HCT)

A heparinized capillary tube was filled from the ear vein of each animal early in the morning to optimize chances of detection of trypanosomes in the peripheral blood. Later samples were taken from anticoagulant blood as for mouse inoculation (see below). The tube was then sealed with plasticine and spun for six minutes on a haematocrit centrifuge after which the packed cell volume (PCV) was read. Each tube was then examined for trypanosomes at the interface between the plasma and blood cells using the technique of Woo (1969). A thin blood film was prepared from all animals from the top of the red blood cell layer incorporating the white cell layer by cutting the capillary tube at the red cell-plasma layer interface. A part of this was then examined for trypanosomes under wet film in the field. In cases where trypanosomes were detected the remainder of the film was later fixed in methanol and stained with Giemsa for further examination in the laboratory.

Table 2. Point prevalence percentages of bovine trypanosomiasis in all sampling locations

Sampling locations	No. of animals sampled	H C T			M I			E L I S A		
		T. b.	T. c.	T. v.	T. b.	T. c.	T. v.	T. b.	T. c.	T. v.
IPAL Herd at Korr	153	0.7	0.0	0.0	0.0	0.0	0.0	73.5	27.5	20.3
Ngurunit	100	8.0	0.0	4.0	8.0	0.0	0.0	64.0	32.0	48.0
Ulaula	114	0.0	0.0	0.0	0.0	0.0	0.0	43.0	7.9	51.8
Marsabit North	31	0.0	0.0	0.0	0.0	0.0	0.0	77.4	12.9	16.1
Badasa	47	2.1	0.0	0.0	0.0	0.0	0.0	48.9	31.9	23.4
Karare	78	0.0	0.0	0.0	0.0	0.0	0.0	43.6	3.8	17.9
Loglogo	26	0.0	0.0	0.0	0.0	0.0	0.0	26.9	0.0	3.8
Mt. Kulal	121	0.0	0.0	0.0	0.0	0.0	0.0	62.8	22.3	14.0
Overall PPPs	670	1.5	0.0	0.6	1.2	0.0	0.0	57.9	19.7	27.8

Key: T.b. = *Trypanosoma brucei*
T.c. = *Trypanosoma congolense*
T.v. = *Trypanosoma vivax*

b) Mouse Inoculation

From each anticoagulant blood sample 0.5ml was inoculated into two mice within six hours of the time of bleeding cattle. Blood from the tail of each mouse was examined for trypanosomes from day 3 post-inoculation until day 60. If trypanosomes were detected, a stained blood film was prepared for identification and the mouse discarded. It was of course realized that this technique has a serious setback in that *T. vivax* and some strains of *T. congolense* do not infect mice (Baker, 1970).

c) Enzyme-linked Immunosorbent assay (ELISA)

Blood samples from the jugular vein were also collected from the same 670 cattle. They were left to stand overnight at room temperature and then sera harvested by Pasteur pipettes. The serum samples so obtained were purified by spinning in a centrifuge. The serum sample from each animal was kept stored in three aliquots at $-20^{o}C$. One of the aliquots was assayed for antibodies against trypanosomiasis by ELISA using *T. brucei*, *T. congolense* and *T. vivax* as antigens. Only these three species of trypanosomes were used as antigens because they are the only pathogenic species of trypanosomes so far identified in East African cattle (Wandera, 1979a). The other two aliquots were reserved for serology for antibodies against brucellosis and foot and mouth disease. From the results of the HCT, mouse inoculation or ELISA tests, the point prevalence percentages of bovine trypanosomiasis at various sampling locations within the IPAL study area were calculated.

d) Further work on trypanosomiasis

The results of the trypanosomiasis survey using the three methods stated above are shown in Table 2. It shows that with HCT only 1.5% of the samples were positive and that with M I only 1.2% of the samples were positive. The results, however, show that with ELISA the point prevalence percentages were as follows: 57.9% *T. brucei*, 19.7% *T. congolense* and 27.8% *T. vivax*. With mouse inoculation known as the most reliable method in the detection of *T. brucei* (Godfrey and Killick-Kendrick, 1961; Baker, 1967), these findings suggest that either ELISA is unreliable or another protozoon with antigenic properties similar to trypanosomes exists within the IPAL study area.

Because, prior to this survey, the author had observed a large number of cattle with generalized loss of body condition, he chose the latter alternative as a working hypothesis. To confirm this hypothesis, studies using wet film and thin smears of blood were conducted. Because of the misty weather on Mt. Marsabit in the mornings (the only time the author had access to cattle), it was not possible to make thin smears of blood in the field. Blood samples were therefore obtained in bijoux bottles (with anticoagulant) and universal bottles and brought for analysis in the laboratory. Wet films were made and examined. Then thin blood smears were made, dried, fixed in absolute methanol for 5 minutes and stained for 30 minutes with Giemsa's stain diluted at a ratio of 1:10. The parasites were then sought by direct microscopy using a magnification of x 1,000. All observations were recorded. At first only cattle with generalized loss of body condition were sampled but when the parasites described in the results were detected the sampling was done at random and notes were made of body condition of cattle at the time of sampling. Blood samples from cattle in which the parasites described in the results were detected were also inoculated in mice and followed up in the manner described above.

Tsetse Fly Survey

The results of ELISA (Table 2) revealed that some of the cattle sampled had antibodies against *T. congolense*. Since *T. congolense* is tsetse dependent, this finding further suggests that there might be pockets of tsetse flies within or neighbouring the IPAL study area and this calls for a tsetse fly survey.

a) Traps

The main method used to detect the presence of tsetse fly was by using biconical traps (Challier and Laveissiere, 1973). The traps were placed in strategic areas which included those with a history of tsetse flies. Traps were placed for periods of 24 and 48 hours after which all tsetse flies present (if any) could be counted, and identified. Other blood-sucking insects present in the trap were also counted and identified according to genus and species using the keys provided by Oldroyd (1952, 1954, 1957).

b) Vehicle Patrols

These were made at Gudas only in the mornings because other sites where the traps could be placed were inaccessible to vehicles. At Gudas the vehicles stopped every 200 metres and attempts to catch any fly attracted were made using a hand net.

Brucellosis survey

A total of 670 cattle were sampled on Mt. Marsabit, Mt. Kulal, Ngurunit, Korr and Loglogo. On Mt. Marsabit the sampling locations were Ulaula, Marsabit North, Badasa and Karare. The breakdown of animals sampled per location is shown in Table 4.

a) Complement Fixation Test (CFT)

The CFT, which is one of the two tests recommended by Kagunya and Waiyaki (1978) as being reliable in detecting antibodies against brucellosis, was used in this survey. The description of this test is beyond the scope of this report. It suffices to say that the serum samples obtained and stored as described above were assayed for antibodies against brucellosis in the CFT. On the basis of the results of that test, the point prevalence percentages of the disease at various sampling locations within the IPAL study area were calculated.

Foot and Mouth Disease Survey

Oesophageal scrapings (OP) were obtained from 509 cattle while serum samples were obtained from 512 cattle on Mt. Marsabit, Mt. Kulal, Ngurunit and Korr where the IPAL contract herd was at the time of sampling. On Mt. Marsabit the sampling locations were Ulaula, Marsabit North, Badasa and Karare. Twenty seven samples from the lesions of FMD following outbreaks of FMD at Kalacha, Ulaula, Marsabit North and Kargi have also been obtained. The breakdown of the number of cattle sampled per location is shown in Table 5.

a) Detection Of The Carrier State

Oesophageal scrapings and later samples from lesions of FMD were assayed on calf thyroid monolayers in tubes by inoculating each sample in four tubes. The tubes were incubated at $37^{o}C$ and examined for cytopathogenic effects at 24 hours, 48 hours and 72 hours. Any suspicious samples were blind passaged in the same tissue culture to eliminate any false positives due to other toxic effects. Positive samples were type-confirmed using the microcomplement fixation test.

b) Serum Neutralization Test (metabolic inhibition test)

The serum samples obtained and stored as described above were assayed for FMD antibodies in the serum neutralization test (metabolic inhibition test) against FMD types O,A,C and SAT_2. As a background to this choice, FMD types O,A and C are the most prevalent in northern Kenya and in 1977 SAT_2 was diagnosed from this area. FMD type SAT_1 was not diagnosed at all during this period.

Survey for Helminthiasis and Coccidiosis

A total of 2,227 cattle of all age groups were sampled at random during the dry and rainy seasons on Mt. Marsabit, Mt. Kulal, Ngurunit, Kargi, Olturot and Kalacha. On Mt. Marsabit the sampling locations were Ulaula, Marsabit North, Badasa and Karare. The breakdown of cattle sampled per location is shown in Table 8. All samples were subjected to helminth and coccidia analysis as described below:

a) Preparation Of Faecal Samples By Dilution

The dilution method used was that recommended for field work by Soulsby (1968). A plastic flask graduated at 56 and 60ml was employed. The flask was filled to the 56ml mark with a saturated solution of magnesium sulphate and the faeces were added till the fluid reached the 60ml mark. This was then mixed thoroughly and the mixture was poured through a coffee/ tea strainer and the strained fluid caught in a 100ml beaker. The debris left on the strainer was discarded and the fluid in the 100ml beaker analysed as described below:

b) Identification Of Helminth Egg Burdens

For the identification of helminth egg burdens the McMaster method was chosen because of its speed and accuracy (Levine et al, 1960). The type of egg was identified and the number of helminth eggs in each counting chamber was multiplied by 100 to give the number of eggs per gram of faeces and then the egg counts recorded. However, Moniezia and Ascaris eggs and coccidial oocysts were recorded merely as +, ++ or +++ depending on load.

c) Strongyle Egg Culture

Faecal samples containing 1,000 strongyle eggs/g of faeces and above were cultured using a modified Baermann technique. A faecal sample in a universal bottle was, when necessary, adjusted in consistency such that it was neither too dry nor too wet by moistening with water or adding sterilized dry sheep faeces. Then the sample was allowed to stand at room temperature for seven days with the cap loosely fitted to allow free movement of air in and out. On the eighth day the universal bottle was filled with water and inverted in a Petri dish. The following morning the larvae were found in a few millilitres of water drawn off from the inverted mouth of the universal bottle. The larvae were then identified using the keys provided by Douvres (1957).

Ectoparasites

a) Assessment Of Tick Burden

Attempts were made to count all ticks on each animal. Tick counts were made on a total of 341 cattle on Mt. Marsabit and Mt. Kulal. No attempt was made to assess tick burdens in calves under six months of age as they were relatively free of ticks. On Mt. Marsabit tick counts were made at Ulaula, Badasa, Marsabit North and Karare while on Mt. Kulal tick counts were made at Gatab only. For lowland areas the data reported by Field (1981) were considered adequate. A breakdown of cattle on which the ticks were counted is shown in Table 10 in the results.

b) Tick Identification

Because of the heavy tick burdens on Mt. Marsabit, no attempt was made to remove all ticks on the animals for tick identification. Instead representatives of all tick species from various parts of the body were collected. All tick samples were then preserved in 70% methanol and later identified according to the keys provided by Hoogstral (1956).

c) Ticks Predilection Sites

Notes were made of preferential tick attachment sites. The notes indicated which species of ticks were attached to which part(s) of the body of an animal.

d) Survey For Tick-borne Diseases

While conducting studies described above, the opportunity was also taken to look for any tick-borne diseases. All observations were recorded.

Miscellaneous Diseases

Attempts were made to visit animals reported sick and a diagnosis made of diseases they were suffering. To the pastoralists of Marsabit District sick animals are those that show dramatic clinical signs such as being (a) recumbent, (b) stagnant and (c) with profuse salivation. Only the most frequently reported diseases will be mentioned.

RESULTS

TRYPANOSOMIASIS

Trypanosomiasis point prevalence percentage (PPP) according to Schwabe et al. (1977) was defined as:

$$\frac{\text{Number of animals positive at a point in time}}{\text{Number of animals sampled at that same point in time}} \times 100$$

This definition will be used in reporting this study.

The PPP of trypanosomiasis in all sampling locations according to detection of patent parasitaemia, trypanosome species and detection of circulating antibodies is shown in Table 2. Trypanosomes were identified according to size, type of movement, morphology as *T. brucei* and *T. vivax*. The results of HCT and MI show very low PPP of the disease in all sampling locations within the IPAL study area. Of the 10 cases detected by HCT, six were identified as *T. brucei* and four as mixed infections of *T. brucei* and *T. vivax*. No case of *T. congolense* was detected under HCT. ELISA results show that most of the cattle sampled have been exposed to trypanosome infection and that the most common species of trypanosome involved belonged to the *T. brucei* group.

ANAEMIC STATUS

The results of the mean packed cell volume (PCV) of cattle in all sampling locations at the time of sampling the cattle are shown in Table 3. The mean PCV values were lower on Mt. Marsabit (Ulaula, Marsabit North, Badasa and Karare) and at Loglogo. The IPAL herd at Korr and cattle at Ngurunit and Mt. Kulal had higher mean PCV values. Surprisingly the 10 cattle in which the trypanosomes were detected by HCT had the highest mean PCV values. Thus the effect of trypanosomiasis on anaemia was not demonstrated when the mean PCV of positive cattle was compared with total means of other locations (Table 3). One possible explanation for this result is that trypanotolerance may be a major factor in the maintenance of a relatively high PCV in the face of trypanosome infection. The lower mean PCV values at Ulaula, Marsabit North, Badasa, Karare and Loglogo cannot be attributed to trypanosomiasis but suggest the existence of other disease(s) resulting in anaemia.

Table 3. The mean packed cell volume (± SE) at all sampling locations

Sampling location	Total sample	Total positive	Mean PCV (± SE)
IPAL herd at Korr	153	1	32.33 ± 0.41
Ngurunit	100	8	32.58 ± 0.49
Ulaula	114	0	30.56 ± 0.46
Marsabit North	31	0	27.42 ± 0.91
Badasa	47	1	30.26 ± 0.64
Karare	78	0	28.42 ± 0.54
Loglogo	26	0	30.20 ± 0.70
Mt. Kulal, Gatab	121	0	32.50 ± 0.51
Total positive		10	34.50 ± 1.61

FURTHER WORK ON TRYPANOSOMIASIS

During the search for blood parasites described earlier, the author saw rosettes of colourless organisms under wet blood film. In thin blood smears fixed in absolute methanol for three minutes and stained with Giemsa's stain diluted to a ratio of 1:10 for 30 minutes, the author saw purple stained rosettes of organisms but occasionally they were also seen scattered between red blood cells: some looked like sperms while others were round. Both forms had numerous dots in them and, indeed, they appeared to be developmental stages of the same organism. The cattle in which the organisms were detected were all emaciated and had generalized loss of body condition similar to the clinical signs of the chronic form of trypanosomiasis. In addition calves harbouring the organisms commonly had swollen parotid lymph nodes. The author could not recall any blood parasites of veterinary importance with these features and thus thought that the organisms were probably unclassified. However, Mugera (1982) examined the slides and reported that they showed different stages of binary fission of trypanosomes which indicated that the animals were suffering from a chronic form of trypanosomiasis. But he also reported seeing filarial worms whose identity could not be established. When serum samples from 42 cattle with these organisms were assayed for antibodies against trypanosomiasis using *T. brucei brucei* antigen, all samples were positive and thus gave weight to both Mugera's report and the working hypothesis of the author. When blood samples from 20 cattle with the organisms were inoculated into mice in the manner described above the organisms were not detected in the blood from the tail. But it was noticed that mice died between day 10 and day 14 post-inoculation and the cause of death was not immediately clear. One such death occurred while the author was in the laboratory and he obtained unclotted blood from the heart and aorta. He examined the wet film of the blood and saw an organism which is pear-shaped and larger than a trypanosome moving in one field. In thin blood smears fixed in absolute methanol for three minutes and stained with Giemsa's stain diluted to a ratio of 1:10 for 30 minutes organisms looking like *Trichomonas* were seen. It is of interest that cattle suffering from the parasites respond to Berenil and not Novidium

TSETSE DISTRIBUTION

No tsetse fly was caught within the IPAL study area. However, W. Langridge collected *Glossina longipennis* on Mt. Kulal in 1977 (Field, pers. comm.).

DISTRIBUTION OF BLOOD SUCKING INSECTS OTHER THAN TSETSE

Blood sucking insects were caught in several places within the IPAL study area and have been identified as follows:

(i) *Tabanus taeniola*
(ii) *Tabanus leucostomus*
(iii) *Tabanus atrimanus*
(iv) *Philoliche magretti* (*sorondis* in Boran)
(v) *Philoliche elongata*
(vi) *Philoliche beckeri*
(vii) *Atylotus agrestis*
(viii) *Hippobosca camelina*
(ix) *Stomoxys* spp.

These blood-sucking flies probably play a major role in the mechanical transmission of trypanosomes within the IPAL study area.

BOVINE BRUCELLOSIS

The point prevalence percentages of bovine brucellosis in all sampling locations, according to detection of circulating antibodies to *Brucella abortus* in the CFT, are shown in Table 4. The results show that the disease is widespread within the IPAL study area. A further look at the point prevalence percentages of the disease within the adult female segment amplifies that the disease is widespread. Although it was not detected in 55 animals surveyed at Loglogo and Ngurunit it appears to be endemic. The samples from Loglogo were too few for any valid deduction to be made.

Table 4. Point prevalence percentages (PPP) of bovine brucellosis in all sampling locations

Sampling location	Total sample	Total positive	PPP	Total adult females	Total positive	PPP
Korr	155	8	5.16	41	6	14.63
Ngurunit	125	1	0.80	63	0	0.00
Ulaula	316	10	3.16	93	10	10.75
Marsabit North	93	2	2.15	55	2	3.64
Badasa	47	1	2.13	18	1	5.56
Karare	89	6	6.74	57	4	7.02
Loglogo	26	0	0.00	16	0	0.00
Gatab, Mt. Kulal	121	5	4.13	54	3	5.56
Total	972	33		397	26	
Arithmetic mean of PPP			4.28			9.73

Note:

Arithmetic mean = $\frac{\varepsilon(fx)}{\varepsilon f}$

Where ε = sum of

f = no of cattle positive at a location

x = PPP of brucellosis at a location

FOOT AND MOUTH DISEASE

Table 5 shows that attempts to isolate FMD virus from 509 oesophageal scrapings on calf thyroid monolayers all failed. Though no virus was recovered from all the oesophageal-pharyngeal samples submitted, it should be noted that in indigenous cattle (Zebus and Borans) the carrier state lasts only for a short period of time and can only show the overt disease situation in the area in the six months preceding the date of sample collection. In exotic cattle, the carrier state lasts for about 12 months and the disease is more severe in terms of lesions and economic impact. In Zebus the symptoms may limit themselves to slight salivation and occasionally foot lesions. The views expressed above were soon confirmed by several outbreaks of FMD within the IPAL study area. The 27 samples from FMD lesions collected from Kalacha, Ulaula, Marsabit North and Kargi during the outbreaks revealed the existence of type O of FMD virus within the IPAL study area (Table 5).

The results of assays for FMD antibodies from 512 serum samples collected from cattle on Mt. Marsabit, Ngurunit and Mt. Kulal are shown in Table 6. The results show that Mt. Marsabit and Ngurunit cattle have significantly high antibody titres to FMD types O, A and C. This would indicate repeated exposure and antibody production without overt disease or in the case of antibody titres $\log_{10} \geqslant 1.80$ in adults would indicate convalescence. High antibody titres ($\log_{10} \geqslant 1.350$) in 3-8 month old calves are due to maternal antibodies. It is of interest to note, however, that cattle from Mt. Kulal had very low antibody titres to the prevalent FMD types O, A, C and SAT_2.

HELMINTHIASIS AND COCCIDIOSIS

Helminth/Coccidia analysis

The results of helminth/coccidia analysis are shown in Tables 7, 8 and 9.

Table 5. Foot and mouth disease carrier state

Sampling location	Number of samples	Age group of cattle	Results
IPAL herd at Korr	88	Adults	Negative
Ngurunit	83	Adults	Negative
	7	Calves	Negative
Ulaula	48	Adults	Negative
	21	Calves	Negative
Marsabit North	23	Adults	Negative
	8	Calves	Negative
Badasa	25	Adults	Negative
	12	Calves	Negative
Karare	78	Adults	Negative
	-	Calves	-
Gatab, Mt. Kulal	78	Adults	Negative
	38	Calves	Negative
Kalacha	3	Adults	Positive (type 0)
	-	-	-
Ulaula	2	Adults	Positive (type 0)
	10	Calves	Positive (type 0)
Marsabit North	3	Adults	Positive (type 0)
	6	Calves	Positive (type 0)
Kargi	1	Adults	Positive (type 0)
	2	Calves	Positive (type 0)

Table 6. Foot and mouth disease antibody titres in cattle sera

Sampling location	No of samples	Age group of cattle	Geometric mean antibody titres ± SD			
			O	A	C	SAT 2
IPAL herd at Korr	153	2 - 3 years	2.09 ±0.83	1.85 ±0.63	1.16 ±0.45	0.82 ±0.18
Ngurunit	100	2 - 3 years	2.41 ±0.68	2.21 ±0.52	1.44 ±0.60	1.06 ±0.29
Ulaula	60	2 - 3 years	2.18 ±0.58	2.05 ±0.60	ND[1]	0.86 ±0.25
	21	calves 6 - 8	1.62 ±0.50	1.53± 0.54	ND[1]	0.75
Badasa/ Karare	65	2 - 3 years	1.78 ±0.80	1.68 ±0.53	1.86 ±0.47	1.07± 0.34
	47	6 - 8 months	1.43 ±0.72	1.41 ±0.46	1.62 ±0.37	0.93 ±0.15
Marsabit North	22	Adults	1.95 ±0.75	2.10 ±0.47	1.39 ±0.41	0.82 ±0.20
	8	calves	1.76 ±0.60	2.57 ±0.33	1.41 ±0.41	0.75
Mt. Kulal, Gatab	21	Adults	1.13± 0.44	1.05±0.4	1.17±0.40	0.86±0.2
	15	calves	1.07± 0.21	ND[2]	ND[2]	ND[2]

Notes:

Titres of $\log_{10} \geq 1.35$ are significant

ND[2] - Results not released

ND[1] - Sera too inadequate to test

a) Point Prevalence Percentages (PPPs)

The PPPs of helminths and coccidia within the IPAL study area are shown in Table 7. The table shows that the PPPs of strongyles were highest on Mt. Marsabit as represented by Ulaula, Badasa, Marsabit north and Karare. The table further shows that PPPs of strongyles were highest in immatures, followed by adults. Calves were the least affected. The table also shows that the PPPs of strongyles were higher in the dry season than in the rainy season. If one recalls the life cycle of strongyle worms, one sees that the worms whose eggs were detected during the dry season must have infected the cattle during the rainy season. This finding suggests that the ideal time to deworm cattle on Mt. Marsabit is after the rains. Pasture contamination could also be reduced by deworming cattle before the onset of the rains. The lowland areas, as represented by Ngurunit, Kargi, Olturot and Kalacha, generally had low PPPs but the pattern of a high incidence in immatures observed on Mt. Marsabit holds. Mt. Kulal, which has a similar climate pattern to Mt. Marsabit, had surprisingly low PPPs.

The eggs of strongyloides and *Trichuris* were not detected in any sampling location in cattle (and as such they have been omitted from Table 7). Thus these groups of helminths are unimportant in cattle within IPAL study area.

The table also shows that PPPs of ascaris eggs were very low except in Marsabit north during the rainy season and they were restricted to calves. It is also seen that the PPPs of moniezia eggs were very low except at Ulaula during the dry season. Finally, Table 7 shows that while coccidial oocysts could be detected virtually in all age groups, their PPPs were highest in calves from moister highland areas and the disease appears to be less important in the dry lowland areas.

b) Strongyle Egg Levels Per Sampling Location

The mean levels of strongyle eggs in all sampling locations are shown in Table 7. The table shows that on Mt. Marsabit (as represented by Ulaula, Marsabit north and Karare) the mean levels of strongyle eggs are higher during the dry season than the rainy season. The explanation of this is to be found in the life cycle of the worms: the worms whose eggs are detected in the dry season must have infected the cattle during the rainy season. This finding emphasizes the fact that the ideal time for deworming cattle is after the rainy season.

Table 7. Point prevalence percentages of eggs of strongyles, ascaris, moniezia and coccidial oocysts in faecal samples during dry (D) and rainy (R) seasons.

			Category and age		
Internal parasites	Sampling location	Season	Calves (PPP) <6 months	Immatures (PPP) >6 - <24 months	Adults (PPP) >24 months
Strongyles	Ulaula	D	27.79	96.88	52.94
		R	53.57	69.12	55.32
	Badasa	D	16.00	75.00	46.28
		R	-	-	-
	Marsabit North	D	56.74	74.51	53.01
		R	23.75	74.55	53.17
	Karare	D	40.00	95.74	62.50
		R	57.89	82.89	44.44
	Ngurunit	D	-	-	-
		R	10.53	36.11	29.37
	Mt. Kulal, Gatab	D	-	-	-
		R	32.78	48.00	34.17
	Kargi	D	2.88	75.00	32.65
	Olturot	D	0.00	64.71	50.00
	Kalacha	D	9.09	30.23	24.00
Ascaris	Ulaula	D	20.00	6.90	0.00
		R	3.57	0.00	0.00
	Badasa	D	17.65	6.15	0.00
		R	-	-	-
	Marsabit North	D	2.79	1.79	1.16
		R	46.88	0.00	0.00
	Karare	D	25.00	2.08	0.00
		R	15.79	5.26	0.00
	Ngurunit	D	-	-	-
		R	0.00	0.00	0.00
	Mt. Kulal, Gatab	D	-	-	-
		R	1.64	0.00	0.00
	Kargi	D	1.92	0.00	0.00
	Olturot	D	0.00	0.00	0.00
	Kalacha	D	0.00	0.00	0.00

Table 7 cont......

Table 7 (contd.)

			Category and age		
Internal parasites	Sampling location	Season	Calves (PPP) <6 months	Immatures (PPP) >6 - <24 months	Adults (PPP) >24 months
Moniezia	Ulaula	D	40.00	1.72	0.00
		R	0.00	5.88	0.00
	Badasa	D	0.00	0.00	0.00
		R	-	-	-
	Marsabit North	D	6.15	1.79	0.00
		R	0.63	1.82	0.00
	Karare	D	0.00	0.00	0.00
		R	0.00	3.95	0.00
	Ngurunit	D	-	-	-
		R	0.00	2.78	0.79
	Mt. Kulal, Gatab	D	-	-	-
		R	0.00	0.00	0.00
	Kargi	D	0.96	0.00	0.00
	Olturot	D	0.00	0.00	0.00
	Kalacha	D	0.00	0.00	0.00
Coccidia	Ulaula	D	60.00	22.41	6.02
		R	0.00	2.94	0.00
	Badasa	D	47.05	15.38	11.57
		R	-	-	-
	Marsabit North	D	7.26	8.93	1.16
		R	9.38	3.64	10.34
	Karare	D	25.00	18.75	9.09
		R	42.11	3.95	0.00
	Ngurunit	D	-	-	-
		R	0.00	5.56	1.59
	Mt. Kulal, Gatab	R	21.31	2.00	1.67
	Kargi	D	0.00	0.00	0.00
	Olturot	D	0.00	0.00	0.00
	Kalacha	D	18.18	2.32	4.00

Table 8. Mean levels (± SE) of strongyle eggs during dry (D) and rainy (R) seasons

Sampling location per season		No of samples	Mean (± SE)
Ulaula	D	247	243.72 ± 41.81
	R	143	225.17 ± 31.95
Badasa	D	215	163.72 ± 20.20
	R	-	-
Marsabit N.	D	321	282.24 ± 26.44
	R	255	156.86 ± 21.70
Karare	D	188	374.47 ± 44.35
	R	104	364.42 ± 40.80
Ngurunit	D	-	-
	R	180	51.11 ± 7.00
Mt. Kulal, Gatab	D	50	86.00 ± 17.89
	R	180	88.46 ± 16.38
Kargi	D	210	37.62 ± 6.27
Olturot	D	55	100.00 ± 19.42
Kalacha	D	79	44.30 ± 10.24

Notes:

1. No animals were found at Badasa during the rainy season because they all move to Marsabit north.

2. Most cattle move out of Ngurunit during the dry season (Field, 1981). No survey was conducted at this time.

Pasture contamination could also be reduced by deworming cattle before the onset of the rains. The lowland locations, as represented by Ngurunit, Kargi, Olturot and Kalacha, had low mean strongyle egg levels. Mt. Kulal, which is similar to Mt. Marsabit, surprisingly also had low strongyle egg levels.

c) Strongyle Egg Levels By Age Group In All Sampling Locations

The mean levels of strongyle eggs in the different age groups in all sampling locations are shown in Table 9. The results show that the levels of strongyle eggs were highest in immatures in all sampling locations. Much higher levels of egg output were observed in the immatures of Mt. Marsabit (as represented by Ulaula, Badasa, Marsabit north and Karare) and as observed earlier the mean levels of strongyle eggs were higher during the dry season than during the rainy season. This finding also suggests that immatures would benefit from block deworming after the rains while in other age groups deworming should be restricted to cases with clinical signs. The results suggest that helminth infection begins in the calves as they begin grazing and increases with both the rate of grazing and pasture contamination, with the peak becoming noticeable in immatures. Those which survive this critical stage appear to throw off the worms and develop some form of resistance such that subsequently only a low level of infection occurs.

d) Larval Cultures

Larval cultures of 63 faecal samples containing 1,000 strongyle eggs and above from five sampling location showed that the abomasal nematode *Haemonchus* was the only observed infection. However, the results must be accepted with caution because of the fact that some worms produce more eggs than others, e.g. *Haemonchus* 5,000 - 10,000 eggs per day per female, *Trichostrongylus* 100 eggs per day per female and *Nematodirus* 50 eggs per day per female. Since the faecal samples cultured were those containing high levels of strongyle eggs, it is possible that they were from cattle infected with *Haemonchus*. Thus these results cannot rule out the presence of the small intestinal nematode *Trichostrongylus* and the large intestinal nematodes belonging to the genus *Oesophagostomum*.

Table 9. Mean levels ($\pm$ SE) of stongyle eggs in calves, immatures and adults during dry (D) and rainy (R) seasons.

Sampling location	Season	Calves	Immatures	Adults
Ulaula	D	27.66 ± 7.79	537.31 ± 137.05	172.18 ± 27.57
	R	182.14 ± 53.22	310.45 ± 59.82	131.25 ± 24.68
Badasa	D	44.00 ± 23.38	274.63 ± 46.93	135.59 ± 24.01
	R	-	-	-
Marsabit N.	D	254.80 ± 29.76	512.50 ± 96.46	179.07 ± 36.37
	R	113.66 ± 25.30	318.97 ± 58.59	88.24 ± 18.95
Karare	D	257.50 ± 119.68	835.42 ± 107.39	200.00 ± 24.98
	R	236.84 ± 81.27	419.74 ± 49.06	88.89 ± 50.72
Ngurunit	D	-	-	-
	R	15.79 ± 11.20	86.11 ± 19.31	47.20 ± 7.97
Mt. Kulal, Gatab	D	-	-	-
	R	108.33 ± 33.19	136.00 ± 40.67	40.00 ± 9.77
Kargi	D	13.59 ± 7.65	133.33 ± 35.14	53.61 ± 9.46
Olturot	D	0.00	155.00 ± 43.29	72.73 ± 16.19
Kalacha	D	18.18 ± 17.34	60.47 ± 16.81	28.00 ± 10.61

TICKS

Virtually all cattle on Mt. Marsabit and Mt. Kulal were infested with ticks. Differences were present in terms of tick loads, predominant species and preferential attachment sites.

Tick Loads

The mean tick loads ($\pm$ SE) per sampling location are shown in Table 10. Very heavy tick loads were observed in all four sampling locations on Mt Marsabit. On Mt. Kulal the tick loads were lower than on Mt. Marsabit.

Species Of Ticks And Relative Abundance

On Mt. Marsabit and Mt. Kulal the most common ticks were *Rhipicephalus pulchellus* followed, at low levels, by *Amblyomma gemma*, *Boophilus decoloratus* and *Rhipicephalus pravus*. All these tick species were using cattle as a food source since gravid females were present. *Rhipicephalus pulchellus* is the dominant tick species throughout the year both on Mt. Marsabit and on Mt. Kulal.

Tick Attachment Sites

Tick preferential attachment sites were as follows: *Rhipicephalus pulchellus* and *R pravus* attaches mainly under the tail, around the anus (and vulva in female), on the ears and on the dewlap. *Amblyomma gemma* attaches mainly in the inguinal area, especially on udders in females and the scrotum in males. *Boophilus decoloratus* attaches all over the body.

TICK-BORNE DISEASES

No tick-borne disease has been detected within the IPAL study area. Note should be made however, that *Boophilus decoloratus*, a known vector of anaplasmosis and babesiosis, and *Amblyomma gemma*, a known vector of heartwater have been observed on both Mt. Marsabit and Mt. Kulal. *Rhipicephalus appendiculatus*, which is a vector for East Coast Fever, was not identified among the ticks collected.

Table 10. Mean tick body loads (± SE) at locations on Mt. Marsabit and Mt. Kulal.

Assessment location	Age groups	Total sample	Mean total body tick loads (± SE)
Ulaula	Immatures	38	444.39 ± 24.47
	Adults	52	948.73 ± 83.60
Badasa	Immatures	30	278.77 ± 26.90
	Adults	42	513.62 ± 45.83
Marsabit N.	Immatures	33	576.76 ± 41.70
	Adults	61	684.44 ± 38.37
Karare	Immatures	30	510.37 ± 26.98
	Adults	60	1000.55 ± 86.76
Mt. Kulal, Gatab	Adults	50	164.08 ± 12.35

MISCELLANEOUS DISEASES

A number of other diseases were observed during the visits to cattle reported sick. No quantitative studies were undertaken and these diseases will only be reported in brief.

Haemorrhagic Septicaemia

The disease (called *silisa* in Boran and *nolgosso* in Rendille) was diagnosed only on clinical grounds because isolation of the causative bacteria from heart blood, liver, spleen and long bone, recommended by Wandera (1979b), was hampered by both the distance from a competent laboratory and the habit of the pastoralists of using such dead animals for food. The following clinical signs described by Wandera (1979b) were observed: temperature 40-42.5^{o}C, profuse salivation and hot painfull swellings about the throat, dewlap and brisket along with pronounced difficulty in breathing. Signs of pneumonia were prominent and animals in an advanced stage passed blood-stained faeces. Treatment with either Combiotic or sulphamethazine was effective when instituted early, otherwise death resulted.

Blackquarter

This disease (*harka* in Boran and *khanid* in Rendille) was reported frequently in May 1982 on Mt. Marsabit but it was not possible to visit all cases as most reports reached the author when the animals were already dead and destroyed. One case on the farm of Mr. Wario Guracha was visited by the author and was found recumbent with the crepitating swellings of the heavy muscles described by Mugera (1979). The disease was so advanced that it was felt that no form of treatment would be of help. However, after death the animal was destroyed before the author could make smears from the affected muscles to confirm or refute the clinical diagnosis. On the same farm, several cases detected with initial signs of the disease and treated with Terramycin/long acting recovered.

Anthrax

As the author came to the study area for the first time in October 1981 he was greeted with a report of an outbreak of this disease between

Laisamis and Ngurunit. The disease (*chita* in Boran and *sugerihara* in Rendille) was later reported at North Horr in March 1982 and Korr in September 1982. In all these outbreaks the reports reached the author too late to make any attempt to confirm them. There was another outbreak of the disease in the Ngurunit area in February 1983. On visiting the area, the author saw a woman with her two children having localized lesions (malignant pustule or malignant carbuncle) on their skins. They soon admitted that they used the hide of one of the dead cows for bedding. The hide was identified and destroyed by fire. The woman and children were treated with penicillin at a missionary dispensary at Ngurunit and the malignant carbuncles were cured. This was the only evidence of anthrax confirmed by the author.

Cysticercosis

The most important such parasite of cattle in Marsabit is *Cysticercus bovis* which is the larval stage of *Taenia saginata*, a tapeworm of man. The importance of *C. bovis* lies in the fact that if beef is found heavily infested with it it may be condemned leading to economic loss.

Hydatidosis

Another parasite of cattle in Marsabit is the hydatid cyst which is the larval stage of *Echinococcus granulosus*, a tapeworm of dogs. The parasite is not of great importance within the IPAL study area because few people keep dogs.

Bovine Mastitis

Bovine mastitis is not uncommon in Marsabit. Numerous kinds of bacteria, fungi and yeasts can produce the disease. The organisms that cause mastitis are commonly carried from diseased cows to healthy cows on the hands of milkers. No attempt was made to isolate the organisms that cause mastitis in Marsabit due to distance from a competent laboratory.

DISCUSSION AND CONCLUSIONS

This study has identified a number of important diseases of cattle in Marsabit District. The economic effects of these diseases are difficult to quantify because of their interactions with each other and the effects of other factors such as climate, nutrition and management.

TRYPANOSOMIASIS

The Veterinary Department in Marsabit District has repeatedly stated that trypanosomiasis is endemic in Marsabit District. While this study supports the existence of bovine trypanosomiasis within the IPAL study area, it does not confirm that the disease in its known blood form is endemic throughout the study area. Instead the study has surfaced some strange parasites which Mugera (1982) described as different stages of binary fission of trypanosomes. Mugera's report, when viewed in the light of the available information on the reproduction of both the salivarian and stercorian trypanosomes, can relate the parasites to the developmental stages of *Trypanosoma lewisi* which is a stercorian trypanosome of rats (Hoare, 1970, 1972). The observation made later does not, however, confirm the above view. Instead it was suggested that the parasites seen in the blood of cattle are developmental stages of *Trichomonas*. *Trypanosoma lewisi* has not been reported in cattle in the veterinary literature but it is possible that it exists. Trichomonads have not been reported in the blood of cattle either and the parasite seen was very puzzling indeed. It is of interest to note that the parasites are prevalent on Mt. Marsabit where ticks, especially *Rhipicephalus pulchellus*, are rampant. It is possible that *T. lewisi* was once transmitted from wild rodents to cattle by some unknown vectors and is now being transmitted from cattle to cattle by ticks through faecal contamination. Congenital transmission is also possible as the parasites were seen in calves of three months of age. More detailed studies are needed to clarify the situation before definite conclusions can be drawn.

Blood-sucking insects, especially those of the family Tabanidae, have been caught in several places within the IPAL study area. The potential for mechanical transmission therefore exists within the study area. The failure to find *Glossina longipennis* during this study is surprising as there are areas suitable for this arid-area tsetse fly. One possible explanation is that they are very difficult to detect when present in low densities.

BRUCELLOSIS AND FOOT AND MOUTH DISEASE

A considerable number of reactors in most sampling locations to *B. abortus* suggests that this zoonosis is widespread and endemic within the IPAL study area. The point prevalence percentage was particularly high at Ulaula, one of the main sources of milk for Marsabit town. The role of this disease in the abortion of cows is known. Unless high abortion rates can be controlled, cattle productivity will be severely limited.

The results from the studies on foot and mouth disease suggest that it is endemic within the IPAL study area and that the recent outbreaks were of types O, A, C and SAT_2. Later outbreaks which followed the above survey were confirmed as type O.

INTERNAL PARASITES

The results from the studies on internal parasites confirm the clinical impression that animals of post-weaning age are the most severely affected. The results of the faecal samples from highland areas cultured for strongyle identification show that the voracious blood sucker *Haemonchus* is by far the most important species. Seasonal effects on egg levels were clearly demonstrated being higher during the dry season than during the rainy season (Tables 8 and 9). This finding means that most animals were being infected during the rainy season.

TICKS

The figures obtained by counting ticks in the highland areas (Table 10) represent a high level of parasitism and would suggest a considerable loss of blood and skin damage. On Mt. Marsabit ticks are among the suspects in the epidemiology of the strange haemoparasites seen. The control of ticks is simple but laborious requiring constant application of acaricides. The strategy for control is the provision of adequate dips in the highland areas of Marsabit District.

OTHER DISEASES

Diseases such as anthrax and blackquarter can be controlled easily by annual vaccination. Others, such as haemorrhagic septicaemia and bovine mastitis, can be controlled using appropriate antibiotics. Cycticercosis and hydatidosis are best controlled through public education

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