INVESTIGATING REPRODUCTIVE PERFORMANCE IN BEEF CATTLE: AN EVALUATION OF THE BOTSWANA EXPERIENCE

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ABSTRACT

The reproductive performance of beef cattle in Botswana is discussed. The factors affecting reproduction have been well defined. The majority of breeding cattle are kept under traditional conditions and have poor reproductive performance. Basic husbandry practices applied in a ranching system result in calving percentages 28% above those achieved under traditional conditions.

The Animal Production Research Unit of the Botswana Ministry of Agriculture maintain a network of ranches for investigating beef and range productivity. Only limited recording has been undertaken in traditional areas. The high quality of data accumulated is due to large scale recording in well defined conditions over a range of environments and a number of years. The data is sufficiently comprehensive for use in extension.

Further research should attempt to define performance at each stage of the female reproductive cycle and if possible relate this to nutritional status. As one APRU ranch has achieved a mean calving percentage of 91%, the particular conditions responsible should be identified. Some possible explanations are discussed. Sophisticated research techniques have only limited application in such an extensive production system.

The two principal features to emerge are the improvement in reproductive performance following the application of basic husbandry practices, and the value of accurate, representative data.

INTRODUCTION

Reproductive performance is a major influence on the efficiency of animal production (Prescott, 1983). Maule (1973) referring to problems of cattle production in the tropics emphasizes "the over-riding importance of obtaining the highest possible production of calves per breeding cow".

Infertility is considered to be a problem in most tropical countries (Vandeplassche, 1982a). Calving percentage varies from 35-60% in the Latin American tropics and from 40-70% in Nigeria (Warnick, 1976). Production data in particular locations is lacking: in tropical Australia standards of acceptable fertility are ill-defined and conflicting reports arise due to differing methods of assessment (Holroyd, 1978).

The term reproductive performance covers all aspects of reproduction including male and female fertility, mating, peri-natal mortality and lifetime production. It may be difficult to determine the point at which poor performance occurs hence the poor definition of criteria.

Since 1970 the Animal Production Research Unit (APRU) of the Botswana Ministry of Agriculture has followed an integrated programme of beef cattle and range research which started by collecting basic data in the country (APRU, 1975a). The aim of this dissertation is to assess the level of knowledge of reproductive performance and methods of investigation in Botswana.

The need for further investigation will be discussed considering the use of modern diagnostic aids. The relevance of the Botswana experience to other countries will be considered.

DESCRIPTION OF BOTSWANA

Botswana is a landlocked country of 600 000 km^2 situated in southern Africa and bisected by the Tropic of Capricorn. The population in 1981 was 832 000 of whom 79% depended on agriculture for their livelihood. Of the agricultural land, 95% (428 000 km^2) is permanent pasture grazed by around three million cattle (FAO Production Yearbook, 1981). The environment is suitable for cattle raising with a low incidence of major diseases. The country is free from contagious bovine pleuropneumonia, rinderpest (FAO/WHO/OIE, 1981) and East Coast fever; trypanosomiasis occurs in a limited area in the north (APRU, 1980). Occasional outbreaks of foot and mouth disease result in restrictions on beef exports and constant vigilance is required to contain the disease (APRU, 1980).

Most of the country lies on a plateau at an altitude of 1 000 m. The more fertile land known as hardveld is in the east and has the highest density of cattle. To the west is the Kalahari Desert, its grazing areas known as sandveld and in the north is the Okavango delta and saltpans. Rainfall is very variable averaging 600 mm in the north to less than 250 mm in the south-west. Rain falls in the summer from October to March when the day temperature can rise above 40°C. The winter is cool and night frosts may occur. Growth of vegetation therefore shows a pronounced seasonality. Except in the Okavango delta, water is scarce and boreholes are the main source for both humans and livestock. The vegetation varies from mixed acacia-combretum savanna in the south-east to mopane shrub and woodland in the north-east and grass-bush savanna in the Kalahari (APRU, 1980).

State land occupies 23% of the country and consists mainly of national parks and reserves. Freehold farming blocks occupy 6% of the area and tribal land the remaining 71%. In 1970 92% of the cattle were kept under traditional "cattle post" conditions and provided 85% of export slaughter cattle. The remaining 8% were kept on freehold ranches providing 15% of export slaughter cattle (International Livestock Centre for Africa (ILCA), 1978). Commercial offtake is about 8% producing 220 000 slaughter cattle annually of which 200 000 are processed by the Botswana Meat Commission at their Lobatse abattoir. The European Economic Community (EEC) and South Africa are the main export markets (APRU, 1980).

REVIEW OF LITERATURE ON REPRODUCTIVE PERFORMANCE IN BOTSWANA

3.1 Definitions

Numerous criteria have been used to measure reproductive performance (e.g. Holroyd, 1978; Vandeplassche, 1982a). In some cases these are poorly defined making comparisons between different sources difficult. The three main criteria used by the APRU are:

(a) Calving percentage: number of calves born dead or alive as a percentage of all females exposed to breeding. A three month breeding season is used.

(b) Calf mortality: calf deaths up to one year old as a percentage of all births.

(c) Productivity: weight of seven month weaner calf produced/cow/year. The term cow year is used to describe the number of cows bred each year.

3.2 APRU aims

The APRU was formed by the Botswana Ministry of Agriculture in 1970. Although much research had been undertaken in Botswana and other tropical countries, there was little conclusive information that could be used by producers and extension workers. Basic data was lacking as research was often conducted on a small scale under poorly defined, atypical conditions and without comparisons. The objective of the APRU was to provide reliable data for planning and extension purposes (APRU, 1975b).

An integrated approach was adopted to measure animal and pasture productivity and their interrelationships. Care was taken

to ensure that the findings were representative of environmental conditions in Botswana (APRU, 1975b). A fundamental knowledge of production levels under traditional "cattle post" conditions was considered essential and field projects were initiated to gather this information. Prior to investigating advanced production methods it was decided to measure production levels under defined "reasonably acceptable" management conditions over a range of environments (APRU, 1975a).

3.3 Cattle posts

3.3.1 Eastern Botswana Between 1971 and 1973 four field projects were established by the APRU in eastern Botswana which contains approximately 80% of the national cattle population. The investigations are described in APRU reports (1975a, 1977) and the four areas are shown in Figure 1. Mobile teams visited twice a year recording weights, calving performance and mortality. Management practices and pasture condition were noted. By 1976 it was considered that continuous monitoring was not revealing any further information and the monitoring units were transferred to the west. Data on reproduction had been collected over 1 618 cow years by 1975.

Estimated calving percentage under traditional management was 47.3%. As calves are born throughout the year the figure is derived by accumulating births in months from the previous calving. The figure suggests that most cows calve in alternate years.

By comparison with improved management units under similar geographical conditions with the same type of cattle, this low figure has been attributed to a number of factors. Overnight kraaling,

Figure 1 Map of Botswana indicating surveys of traditional cattle rearing areas.

Survey by Reed *et al.* (1974):

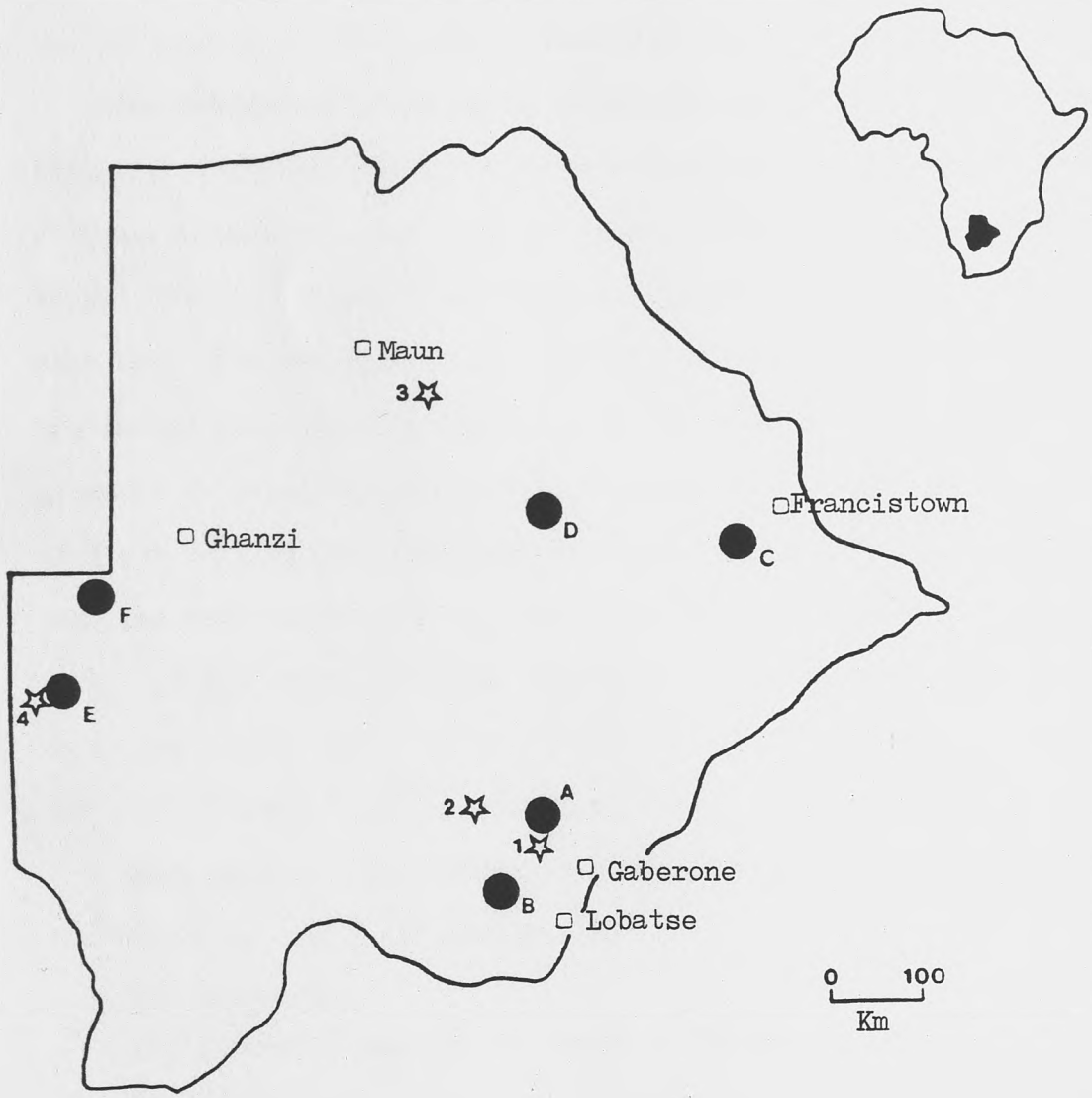
East 1. Moshupa
2. Lethlakeng
3. Makalamabedi

West 4. Kule-Nojane

Survey by APRU (1975, 1979):

East A. Kweneng
B. Ngwaketse
C. Serule
D. Makoba

West E. Nojane (Kgalagadi District)
F. Kalfontein (Ghanzi District)


Maun
3
Francistown
D
Ghanzi
C
F
4
E
2
A
1
Gaberone
B
Lobatse
0
100
Km

lack of dry season grazing and excessive distance to water can result in undernutrition. Hand milking and failure to wean increase the demands on a stressed cow. Infectious disease and mineral imbalance may cause infertility directly or indirectly. Although cows conceive throughout the year, a peak of conceptions during the rainy season suggests a nutritional cause. The peak coincides with the breeding season for APRU ranches (1st January-31st March).

The University of Edinburgh Veterinary Expedition to Botswana, 1971-1972 surveyed four areas where cattle were managed under traditional conditions (Reed, Doxey, Forbes, Finlay, Geering, Smith and Wright, 1974). Of the three areas in eastern Botswana (Figure 1) mean herd size was 39 head and mean estimated calving percentage 41% (estimated proportion of females over two years old which were pregnant on palpation or had calved within five months). Mean age at first calving over the three areas was estimated at 3.9 years and cows over eight years old had produced an estimated 3.6 calves each. It was considered that some cows were permanently stunted as a result of bearing calves whilst physically immature. Seven per cent of adult females had not calved by the age of six years.

Reed et al. (1974) recognized the following factors which might contribute to such poor performance:

(a) No weaning
(b) Excessive distance to water (1-2 hours walk)
(c) Overgrazing
(d) Overnight kraaling
(e) Lack of supplementation
(f) Lack of disease control
(g) Uncontrolled mating

They recognized phosphorous deficiency as a contributory factor to the major problem of undernutrition and suggested the optimal solution would be improved grazing and bonemeal supplementation. A subjective assessment of body condition found 73-90% of cattle to be in "moderate" condition at the end of the dry season depending on the level of management.

Both authors (Reed et al., 1974; APRU, 1975a) mentioned that management practices vary widely. It is therefore difficult to determine the contribution of different factors to performance levels.

3.3.2 Western Botswana In 1976 the APRU started recording in the drier, sparsely populated Ghanzi and Kgalagadi districts in the west (Figure 1). Investigations were similar to those in the east but recordings were taken every three months and the reports (APRU, 1977; 1979) included information on herd structure. Data on reproductive performance was collected from 3 172 cow years over 44 months on nine cattle posts. For a ranch comparison, performance on the Livestock Project Management Unit at Nojane was also monitored. This project allows tenants to use improved management facilities. A proposed breeding ranch was abandoned due to problems of water supply but it was intended that data from another APRU ranch in the area would eventually be available.

Calving percentage is estimated by accumulating calving intervals in periods of one year and relating this to subsequent births (Table 1A).

The figure of 22.3% for Kalfontein cattle posts is extremely low and is taken to reflect the very harsh environmental conditions (APRU, 1979). It is suggested that this rate is too low to supply

female herd replacements and maintain herd size. Figure 2 shows how the number of replacements required depends on calving rate, calf and heifer mortality and length of reproductive life. From the graph it can be seen that at a calving rate of 22%, 91% of female calves born must survive to breeding age to satisfy a replacement rate of 10%. At a 10% replacement rate cows must live an average of 13 years, or more if age at first calving is greater than three years. Such longevity and survival rates are unlikely in an area where the calving percentage is so low.

At Kalfontein data was collected over 44 months. The total number of calves recorded as a proportion of the total cow years is 38.9% (APRU, 1979) (not all cows and calves participate in the calving percentage calculation). Corresponding figures for the Nojane areas are shown in Table 1B. For the Kalfontein area this figure appears to give a closer approximation of the calving percentage. Reed et al. (1974) included an area in the Kule-Nojane district in their survey (Figure 1) and estimated that 36.2% of all females over two years were pregnant or had calved within five months.

3.3.3 Bull:cow ratio A lack of mature bulls may affect conception rates in some areas. In the west the APRU (1977) found a ratio of mature bulls (> 3 years old) to mature cows of 1:36 perhaps indicating the effectiveness of a previous castration policy. In the four "traditional" areas surveyed by Reed et al. (1974) mature bull:cow ratios were 1:7, 1:14, 1:49 and 1:80. The areas were said to place different emphasis on commercial breeding and the keeping of work oxen.

Table 1A Estimated calving percentage for three areas in western Botswana

Area	Duration of survey (cow years)	Number of calves	Equivalent calving %
Nojane cattle posts	743	343	46.2
Nojane ranches	1 194	487	40.8
Kalfontein cattle posts	1 235	275	22.3

After APRU (1979)

Table 1B Herd structure in three areas in western Botswana

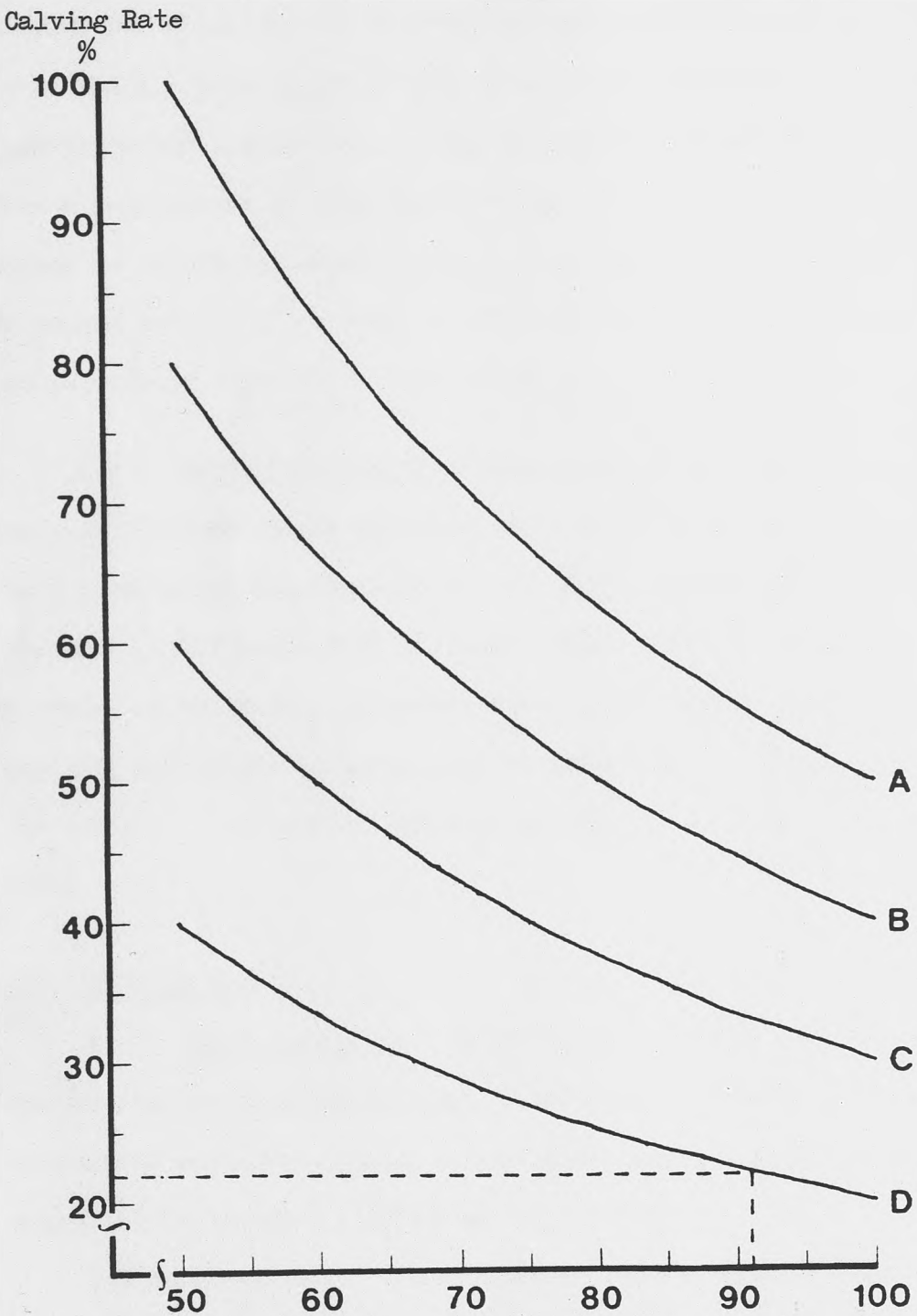
Area	A Total cow years	B Total calves	B/A %
Nojane cattle posts	1 064	529	49.7
Nojane ranches	2 868	1 363	47.5
Kalfontein cattle posts	1 888	735	38.9

After APRU (1979)

Figure 2 Graph showing calf and heifer survival rates necessary to provide a given female herd replacement rate.

The lines represent various replacement rates as shown below and show minimum survival rates to maintain herd numbers at various calving rates. Mean reproductive life corresponding to these rates is shown below.

Line	Female replacement rate. (%)	Mean cow reproductive life (years)
A	25	4
B	20	5
C	15	6.7
D	10	10


Calving Rate
%
100
90
80
70
60
50
40
30
20
A
B
C
D
50
60
70
80
90
100
Minimum proportion of heifers born surviving to breeding age - %.

3.3.4 Calf mortality The APRU (1975) consider the most authoritative estimate of calf mortality under extensive conditions to be 10.2%. Reed et al. (1974) found owners reluctant to divulge true mortality figures and as they may also be forgetful, they were a poor source of this information. Mortality to one year was judged to be 20% for small herds ($\simeq$ 21 head) in one area and 12% in larger herds ($\simeq$ 35 head) in a second area. Mortality over 20% was considered possible in some cases.

3.3.5 Infectious disease Reed et al. (1974) noted the presence of trichomoniasis and vibriosis but did not assess the incidence remarking that local veterinary officers observed it to be low. The APRU (1980) state that the importance of trichomoniasis in Botswana is not known. Botswana Ministry of Agriculture (1980) reported difficulty in assessing the incidence of brucellosis in the country. Vaccinating against brucellosis is recommended (APRU, 1980).

3.4 APRU ranches

3.4.1 Ranch recording From 1970 a network of APRU beef cattle stations was established, 16 of which supported 5 500 cattle maintained under "reasonably acceptable" conditions of management described by the APRU (1975a) as:

(a) Herd separation and dry season reserves using a degree of fencing.

(b) Disease control and mineral supplementation

(c) Adequate water supplies within reasonable distance.

The location of 13 breeding ranches is shown in Figure 3. APRU ranches vary from 500 ha to 6 000 ha in size and total 40 000 ha. The ranches are managed by specially trained managers who can refer to a comprehensive handbook to ensure standard practices are followed (APRU, 1977). A computerized herd recording system is used (Trail and Rennie, 1975) with three senior staff members assigned to data analysis in 1977 (APRU, 1977).

3.4.2 Productivity The APRU breeding season is 1st January to 31st March and with one exception to control a possible disease problem (Sunnyside, 1973), natural mating has been used (APRU, 1975a). Table 2 presents a comparison of productivity under cattle post and standard ranch conditions in eastern Botswana.

Table 2 Comparison of productivity under two management systems (eastern Botswana)

	Cattle Post	Ranch
Calving percentage	47.3	79.8
Calf mortality %	10.2	8.5
7 month weaning percentage	42.5	68.4
Weaning weight Kg	123.5	180.4
Weight of weaner calf/cow/year Kg	52.5	123.4

After APRU (1975a)

Ranch calving percentage is calculated from 8 734 breeding cow years on 14 stations over a period of six years. The major causes of ranch calf mortality are stillbirths-21%, predators-18%, early death-5% and unknown-40% (APRU, 1977). The APRU (1975a) have quantified the major factors affecting fertility on their ranches by least squares analysis and these are examined in the remainder of Section 3.4.

Figure 3 Map of Botswana indicating 13 APRU ranches

1. Masiatilodi
2. Morale
3. Matlolakgang
4. Seleka
5. Dikgatlhong
6. Musi
7. Tsetseku
8. Leupane
9. Impala
10. Good hope
11. Masama
12. Lesego
13. Sunnyside


Maun
7
Francistown
9
12
8
4
Mahalapye
2
3
11
Gaberone
13
1
Lobatse
5
6
10
0
100
Km

3.4.3 Cow age Calving percentage rises from 69% at two and a half years to 82% at six to seven years and thereafter declines. The decline is attributed to an inability to forage properly due to teeth wear. Days from the onset of the breeding season to conception fall correspondingly from 65 days at two and a half years to 54 days at six to seven years old.

Thorpe, Cruikshank and Thompson (1980) in Zambia found that fertility did not decline until 13 years of age. In Zimbabwe, Ward and Tiffin (1975) compared first mating at 15 months with the more usual 27 months. Conception rate (undefined) for heifers in each group was 100%, however only 45% of the younger group reconceived compared with 85% of those first calving at three years old. There was no permanent stunting in the younger group and lifetime production was calculated to be greater.

In a detailed study of factors influencing reconception on APRU ranches, Buck and Light (1982) attempted to distinguish between the confounding effects of age and parity i.e. most primiparous cows are three or four years old. Three year old primiparous cows had a reconception rate (determined by the birth of a calf, alive or dead) of 65% compared with 69% for four year old primiparous cows although the difference was not significant. These results show the problems of getting immature cows back in calf.

3.4.4 Parous state In Botswana heifers and non-parous cows conceive more readily than lactating cows. The breeding season on APRU ranches runs from 1st January to 31st March so that calves are born at the most favourable time of year. Cows calving in the early

part of the calving season have the highest reconception rate as they have a longer period post partum to resume oestrus before the end of the breeding season (Table 3).

Table 3 Effect of parity on conception of beef cows in Botswana

	Calving percentage	Days from start of breeding season to conception*
Heifer	84	49
Non-parous cows	85	48
Early season calving	77	61
Mid season calving	67	75
Late season calving	55	80

*Determined retrospectively by subtracting 284 days from the time to calving

After APRU (1975a)

Other works have confirmed that time to reconception increases with a late calving date (Thorpe et al., 1980). Pleasants and Ginindza (1981) however suggested the opposite. They reported that time to first oestrus was less in later calving cows but did not mention time to conception or subsequent calving dates. As Holness, Hale and Hopley (1980) have suggested that plane of nutrition has a greater effect on conception than on the occurrence of first oestrus, the use of observed oestrus as a criterion of productivity must be questioned.

Research workers in the U.K. have postulated the possible existence of a synchronization mechanism between cows which may be pheromonal or stimulated by specific events such as change of diet (Peters and Riley, 1982). It seems unlikely that this would be of much importance under extensive conditions when other factors are so dominant.

3.4.5 Cow liveweight APRU results support the concept of an optimum or target body weight for conception as discussed by Lamond (1970). Using liveweight at the start of the breeding season as a parameter, the APRU found that calving percentage increased progressively with increasing liveweight from 50% at 300 kg to 85% at 420 kg. Above this weight calving percentage fell. Cow weight change over the post partum period has also been related to subsequent calving percentage. Cows losing weight had a calving rate of 67% but this improved to 76% in cows gaining 20 kg.

Richardson, Oliver and Clarke (1975) support the target body weight concept and have quantified the effect of weight loss from the peak which in Zimbabwe occurs in the autumn before the dry season decline in pasture quality. Post partum liveweight change was not related to subsequent calving rate (number of calves born as a proportion of cows mated); the interpretation being that calving rate depends on liveweight per se and not liveweight change. Also in Zimbabwe, Steenkamp, van der Horst and Andrew (1975) found a negative relationship between the effect of liveweight and liveweight gain post partum and reached the same conclusion. In the light of this information Buck and Light (1982) chose the parameter of liveweight at 90 days post partum. Reconception rate improved from 57% at below 340 kg to 82% at 475 kg. Above 475 kg there was little improvement.

Hale (1975) demonstrated that cows losing weight maintained ovarian activity (manifested by oestrus) at liveweights below that at which they would recommence ovarian activity. Cows losing weight

ceased ovarian activity at 320 kg yet did not recommence until they reached 390 kg.

In summary, liveweight at the time of breeding appears to be of overriding importance although there is some effect of liveweight change.

3.4.6 Breed One of the initial objectives of the APRU was the evaluation of beef breeds and crosses under Botswana conditions (ILCA, 1978). The research revealed that the Tuli has a superior calving performance to the Tswana and Africander (Table 4).

Table 4 Breed comparison in Botswana

Breed	Calving percentage	Number of cows
Africander	65	1 389
Tswana	71	305
Tuli	85	357

After APRU (1975a)

Buck and Light (1982) confirmed the apparent unsuitability of the Africander to Botswanan conditions and showed that breed is the most important factor influencing the reconception of lactating cows under improved ranch conditions. Breed has been shown to be important in Zambia. Thorpe et al. (1980) analysed five years' data on the Angoni, Barotse and Boran breeds and found calving percentages of 82.5, 78.1 and 75.4% respectively. Under-nutrition was not a major factor in this trial as the animals had access to flood plain grazing during the dry season.

3.4.7 Hybrid vigour Light, Buck and Lethola (1982) found a higher proportion of crossbred cows calved than pure Tswana although differences were not significant. They suggested that hybrid vigour contributed to improved fertility. Thorpe et al. (1980) found that Angoni and Barotse dams bred pure achieved a higher calving rate (live calves born/breeding cow) than if they were crossed although the results were not conclusive. Thus the effect of hybrid vigour appears small compared to other factors.

3.4.8 Infectious disease Diseases of reproduction are not considered to be a major cause of poor reproductive performance on APRU ranches. Female calves are vaccinated with S.19 against brucellosis (Buck and Light, 1982).

In Zimbabwe it is considered that brucellosis causes serious losses in less than 20% of herds (Swanepoel, Blackburn, Lander, Vickers and Lewis, 1975). In Nigeria 6.25% of a sample of 48 cattle on research institutes were considered infected with brucellosis. There were no records of the cattle having been vaccinated (Falade, Nwufoh and Nmezi, 1981). Esuruoso and Ayanwale (1980) also in Nigeria found 1.5 to 14.3% of cattle tested in private herds to be infected with brucellosis. Blood, Henderson and Radostits (1979) consider the incidence of brucellosis to be very variable. In extensive herds where females are likely to be continually exposed to infection, it appears that brucellosis although important is unlikely to be the reason for 50% of cows failing to calve.

Swanepoel et al. (1975) isolated Vibrio fetus from only 1% of specimens submitted for laboratory diagnosis but, from the results

of vaginal mucus agglutination tests, postulated that nearly one half of the herds in Zimbabwe are infected. Bovine vibriosis is usually manifested by delayed return to service. Most infected females eventually conceive but 5-10% may abort after approximately five months. Most females are free of the infection by three months post partum and subsequently have well-developed immunity (Clark, 1971). Thus in an endemic area 5-10% of heifers are likely to abort, older cows being largely immune.

Brucellosis and vibriosis are the most important infectious causes of infertility in Zimbabwe that have been identified (Swanepoel et al., 1975).

3.5 Production coefficients

From the knowledge accumulated in Botswana the APRU (1979) suggested production coefficients (Table 5) which should be attainable under a reasonably acceptable level of management.

Table 5 Production coefficients attainable under improved management in Botswana

Trait		Coefficient
Pregnancy rate[1] %	Excellent	>80
	Good	70-80
	Poor	<70
Effective calving rate[2] %		65
Mortality 1-2 years %		2
Adult mortality %		3
Cow culling rate %		18
Bull culling rate %		33
Steer sale age years		2.5
Heifer target weight kg		320
Weaning age months		7
Breeding season		1 Jan.-31 Mar.
Bull:cow ratio		1:25-30

[1]By palpation 6-8 weeks after end of breeding season.

[2]Calves surviving to one year as a proportion of breeding cow number.

After APRU (1979)

ASSESSMENT OF APRU METHODS AND FINDINGS

4.1 Aims of assessment

This chapter aims to critically examine the methods used by the APRU and to identify any gaps in the accumulated knowledge of reproductive performance. It is appreciated that the integrated approach adopted by the APRU involved all aspects of animal and range production but this review concentrates on reproductive performance.

4.2 Cattle post recording

Collecting data on reproductive performance in traditionally managed areas is problematical. Data on reproductive performance was collected from 149 cattle posts in eastern Botswana (APRU, 1975a) and initially from 13 cattle posts in the west (APRU, 1977). Mention has been made of the variation in husbandry practices that occurs (Section 3.3.1). It would be difficult and of limited value to determine reproductive performance in every situation. The figures produced that encompass such variation are generalizations only. The APRU (1975a) state that data collected from cattle posts is background information to be used as a baseline for detailed research under defined conditions.

The estimated calving percentage at the Kalfontein cattle posts has been questioned (Section 3.3.2). It is possible that cattle movements in the area made it difficult to monitor individual cow performance for sufficient length of time. The drop in mature cow numbers from 721 in December 1976 to 478 in December 1978

together with a 23% drop in total numbers (APRU, 1979) indicate the volatile herd structure.

The problem of collecting mortality data under extensive conditions is such that the APRU (1975a) use other sources of data. It is noted that young calf mortality undetected in three-monthly visits does not lead to error in overall productivity figures as it is reflected by a low calving percentage (APRU, 1977).

4.3 Ranch recording

APRU ranch investigations are carried out on a large scale in a range of environments in order to be representative of conditions pertaining to Botswana. At least two breeds are maintained on each station (APRU, 1977). Ranch and year effects are calculated by least squares analysis to overcome any bias from these sources.

It is interesting to note that Buck and Light (1982) found ranch effects to be the third largest source of variation affecting reconception of lactating cows (Table 6). A breed x ranch interaction is also found and the authors agree that this effect cannot be readily explained with the information available. In an attempt to explain ranch effects, pertinent APRU data was further analysed and the results are presented in Table 7.

Mean calving percentage over seven years varies from 68-91%. Other figures have been compared with calving percentage. Breed types on each ranch varied and could not be quantified from the data available. Africanders predominated on the ranches with low calving percentage and Tswana on those with high rates. There is a slight negative relationship between calving rate and rainfall.

Table 6 Mean squares from analysis of variance for reconception of lactating beef cows in Botswana

Source of variation	d.f.	m.s.
Breed	2	5.900**
Ranch	5	1.155**
Year	7	0.419**
Calving period (early, mid, late season)	2	4.854**
Age/parity	7	0.650**
Live weight 90 days post partum	7	0.984**
Breed x weight	14	0.444**
Breed x age/parity	14	0.404**
Breed x year	14	0.406**
Breed x ranch	6	0.321*
Breed x calving period	4	0.538**
Error	2 627	0.149

*P < 0.05

**P < 0.01

After Buck and Light (1982)

Table 7 Analysis of APRU ranch differences

Ranch	Calving % 1971-1978	Veld Type	Location	Total cow years 1971-1978	Area ha	Stocking rate ha/head	Rainfall 1970-1978 mm	Rainfall Standard Deviation mm	Weaning weight kg	Mortality to 1 year %	Mortality to 2 years %	Weight of weaner/cow/year kg
Masiatilodi	91	Sandveld	South	507	2 186	13.2	535	156	193	5	6	167
Morale	87	Hardveld	Central	403	1 829	10.4	500	152	200	5	6	164
Matlolakgang	86	S	Central	501	2 130	11.3	479	117	195	6	7	158
Seleka	82	H	N. East	342	2 338	12.2	390	138	188	6	7	146
Dikgatlhong	80	S	South	788	2 561	13.6	681	234	189	10	13	136
Musi	79	S	South	3 163	6 638	8.7	611	161	186	9	11	132
Tsetseku	78	S	N. West	538	1 902	13.2	470	245	195	16	(23)	128
Leupane	76	H	N. East	1 092	2 991	15.3	489	168	188	8	11	131
Impala	75	H	N. East	775	1 612	9.1	525	184	179	13	14	117
Goodhope	74	H/S	South	1 103	2 295	10.3	602	195	175	8	11	120
Masama	71	S	Central	1 294	4 065	12.4	620	196	183	12	15	114
Lesego	70	H	N. East	774	3 720	18.2	428	184	178	8	11	114
Sunnyside	68	H	South	831	1 597	7.1	684	185	183	17	20	103
Mean	78			932	2 759	11.7	540	178	187	9.5	11.9	133
Correlation with calving %				-0.246	-0.168	0.008	-0.305	-0.467	0.780**	-0.673*	-0.656*	0.982***

*P < 0.05
**P < 0.01
***P < 0.001

After APRU (1979)

As annual variation in rainfall is perhaps more important than the level itself, calving rate was compared with standard deviation of rainfall and also showed a slight negative correlation. Annual rainfall figures are of limited value only and may not reflect "effective" rainfall. The figure does not account for spatial variation, intensity and within year distribution all of which might affect the moisture available to the plant.

The four ranches with the highest calving rate each have less cows presented for breeding than other ranches. Although the effect was not significant, it is perhaps surprising that the number of cows presented for breeding on each ranch was not standardized. The number of bulls in a breeding herd might have varied from 2 to 21 which may have influenced conception rates. Social hierarchy has been shown to influence mating activity of bulls (Farin, Chenoweth, Mateos and Pexton, 1982). Intensity of management may also vary when breeding herd size ranges from 26 to 521 although the calving rate at these two extremes was 88% and 86% respectively (APRU, 1979).

An analysis of year differences may be misleading because of carry-over effects. There is no obvious effect of location, veld type or stocking rate. There is, however, a negative correlation between calving rate and mortality and a strong positive correlation with weaning weight. The close relationship between these three traits suggests that those factors influencing calving rate also determine overall productivity. It is suggested that nutrition is one of the major factors involved. Grosskopf (1973) observed a similar relationship between reconception of cows and pre-weaning

growth rate of their calves and suggested this could be used as a screening test when investigating fertility problems in beef herds.

The APRU have paid little attention to the role of the bull; instead multiple sire herds are used (Buck and Light, 1982) to compensate for poor individual performance. A bull:cow ratio of 1:25-30 is recommended for Botswana (APRU, 1980). Rupp, Ball, Shoop and Chenoweth (1977) note that a bull:cow ratio of 1:25 is common for a limited breeding season under range conditions but consider that fertility, libido and mating ability are more important factors. In one trial, groups of bulls selected for high or low fertility had fertilization rates of 100 and 72% respectively (Kidder, Black, Wiltbank, Ulberg and Casida, 1954).

4.4 Linking of results

An important aspect of APRU investigations was the linking of results from the two management systems. Calves were purchased from cattle posts at 6-7 months of age and reared under ranch conditions for comparison with calves born on the station from AI and Tswana bulls. At least three contemporaries were recorded on the cattle post. Ranch-born calves had 210-day weaning weights 55 kg higher than cattle post calves. Ranch-born, purchased and cattle post calves had 18 month weights of 293, 245 and 210 kg respectively (APRU, 1975a).

4.5 Summary

The APRU field assessment provided a reasonable description of production levels under traditional management systems but was

lacking in some respects. Some inaccuracy is inevitable when monitoring at three or six monthly intervals and the information collected covered a range of management practices. The problems were appreciated by the APRU whose aim was to collect baseline data only.

APRU ranch investigations have provided criteria for improved productivity under Botswana conditions. The differences in reproductive performance between APRU ranches cannot be fully explained from the information available. There may be a small effect of breeding herd size. Bull performance is important but such a random effect is unlikely to bias the results from a large body of data. The relationship between calving percentage and weaning weight is important and suggests a nutritional effect. It is possible that the quality of management may partly account for the negative correlation between calving percentage and mortality but this aspect requires further investigation.

Ranch and year effects suggest that some variation is inevitable even under well defined conditions. In the light of this, production targets may be best defined as a range above a minimum level. This also highlights the importance of conducting investigations in a range of locations over a number of years.

The APRU (1975a) emphasize the importance of continuous investigations within a productive system. Adequate data handling facilities, representative conditions and continuity of trained staff are stressed.

FURTHER RESEARCH IN BOTSWANA

5.1 Possible areas for research

The Botswana experience has shown that many factors influence reproductive performance. Buck and Light (1982) highlighted the complexity of those factors influencing reconception. Ranch differences indicate that nutrition is an important factor that may not be fully explained by the criterion of liveweight at mating. Lamond (1970) stressed the need for investigations into the exact nature of nutritional infertility in cattle in the tropics and mentioned the need for a more sophisticated assessment of nutritional status. A precise definition of the role of nutrition would permit further investigation of other causes of infertility. Sreenan (1982) suggests the main factor delaying resumption of normal cyclicity in the beef cow is underfeeding and questions whether nutrition can be partitioned from other related effects.

Investigation of the stages of the reproductive cycle may be revealing to determine whether cows are in anoestrus, suboestrus or cycling normally. Further investigation may determine whether mating and fertilization occur and the incidence of embryo and foetal mortality. Calf mortality rates are high on some ranches (Table 7) and the negative correlation with calving percentage justifies further investigation.

As hand milking is a common practice in Botswana (APRU, 1975a) and the possibility of using indigenous cattle for milk production has been expressed (ILCA, 1978), it may be worthwhile investigating the effect of interrupted suckling on fertility. It has been shown

that the act of suckling has a depressing effect on fertility (Smith, Payne, Tervit, McGowan, Fairclough, Kilgour and Goold, 1981). Temporary weaning can stimulate the onset of oestrus (Holness, Hopley and Hale, 1978) and there is some evidence that once-daily suckling results in a shorter time to reconception (Randel, 1979).

5.2 Techniques for investigating reproductive status

5.2.1 Monitoring post partum ovarian activity Pre-service cows can be identified as cyclical by observing oestrus or by detecting luteal tissue in the ovaries. Luteal activity can be determined by rectal palpation or by estimating the concentration of progesterone in body fluids (Munro, Boyd, Watson, McBride, Martin, Booth and Holdsworth, 1982).

The inaccuracies involved in detecting oestrus by observation are well documented. Munro et al. (1982) found that in a well regulated dairy system, 67% of cycling cows were identified by observation. Ball, Cowpe and Harker (1983) found the unaided stockman identified 70% of "possible oestrous events". Applying paste to the female's tail-head increased detection rate to 81.5% without decreasing accuracy (i.e. the same proportion of "false" heats were identified). Pleasants and Ginindza (1981) used tail-paint as an aid to oestrus detection in Brahman and Nguni cattle but did not assess the accuracy of their results. The short oestrous period of Bos indicus (Anderson, 1944) is likely to make oestrus detection particularly difficult.

Holdsworth and Markillie (1982) evaluated the use of pedometers in dairy herds to record increased activity during oestrus. The

devices gave a high proportion of false positives, were difficult to read and liable to mechanical damage. They were considered unsatisfactory in their present form and are unsuitable for beef cattle as the cows must be gathered to take readings.

Donkin (1980) considers that ovarian palpation *per rectum* can provide much useful information providing assessment is based on a series of examinations which are related to observations and records. Dawson (1975) classified ovarian structures correctly by palpation in only 67% of cows but considered that a number of the wrong assessments would not have led to a misleading estimate of the cow's reproductive status e.g. detecting a cyst in only one instead of both ovaries. He argued that a misleading assessment was made in 17% of cows. Huhold (1982) used 38 operators to carry out rectal explorations in 200 cows. Ovarian function was misdiagnosed in 65% of explorations.

Terqui, Chupin, Gauthier, Perez, Pelot and Mauleon (1982) consider the most accurate criterion of *post partum* ovarian activity to be variation in progesterone levels in blood or milk. In a field trial blood samples were taken at 10-day intervals and the first *post partum* ovulation was detected in 80-100% of cases. Inaccuracies were attributed to short luteal phases of less than ten days duration.

Abdel Rahim, Lowman and Deas (1980) measured milk progesterone levels in lactating beef cows twice weekly. Progesterone profiles of cows conceiving to first service showed a typical smooth curve whilst those of cows failing to conceive were irregular. Holness *et al.* (1980) found an association between plasma progesterone levels

measured weekly prior to service and conception. Only 12% of estimated first ovulations were fertile and over 50% were apparently unaccompanied by oestrus ("silent"). Heap and Holdsworth (1981) consider weekly sampling adequate to assess the restoration of ovarian cycling post partum.

Milk progesterone levels are influenced by the level of milk fat and so a standard assay procedure is required (Heap, Holdsworth, Gadsby, Laing and Walters, 1976). In beef cows blood samples may be as convenient and can include dry cows and heifers. Radioimmunoassay of progesterone requires sophisticated laboratory facilities for handling radioactive material and expensive reagents (Heap and Holdsworth, 1981). Cheaper and simpler enzyme immunoassay techniques are being developed (Nakao, Sugihashi, Saga, Tsunoda and Kawata, 1983).

5.2.2 Pregnancy diagnosis In an APRU trial (Buck, Light and Makobo, 1980) pregnancy diagnosis by rectal palpation at 42-49 days resulted in 21% false positives attributed to error or subsequent foetal mortality. Of cows diagnosed non-pregnant, 7% subsequently produced calves.

Assay of progesterone in blood or milk at about 24 days after mating is almost 100% accurate in detecting non-pregnancy. A positive result is thought to indicate pregnancy in a high proportion of females but only approximately 80% of these survive to term (Heap and Holdsworth, 1981).

Pregnancy diagnosis by rectal palpation provides useful information but is unreliable for interpretation of research results

(Buck et al., 1980). Pregnancy diagnosis of beef cows in the tropics by progesterone assay is unlikely to justify the cost of the equipment alone. Observation or recording of mating is a necessary requirement. Oestrone sulphate assay has been found to be 100% accurate in diagnosing pregnancy after 15 weeks (Heap and Holdsworth, 1981).

5.3 Monitoring nutritional status

Levels of blood metabolites have been used to equate nutritional status and fertility in high yielding dairy cows (Bostedt, 1982; Lotthammer, 1982). Problems have been encountered with the technique. Parker and Blowey (1976) found that selected blood components did not show a consistent relationship to nutrient balance or potential fertility (proportion of cows holding to first service). A multiple analysis of blood components was considered to be of limited value. Kronfield, Donoghue, Copp, Stearns and Engle (1982) recognized that problems had been experienced in interpretation and questioned the statistical methods used.

Richardson and Kegel (1980) in Zimbabwe found plasma urea nitrogen was correlated to the protein content of the diet of healthy, growing cattle. Accuracy was affected by time of sampling after feeding, protein source and tissue catabolism. It was noted that acute parasitism of the digestive tract might raise blood urea levels and thus invalidate their use as indicators of protein status.

In Botswana the APRU (1979) investigated seasonal variations in blood components as an indicator of nutritional status. Only blood urea reflected seasonal variation in protein intake. Despite

the low crude protein content of the grazing in the dry season, in only one instance did blood urea levels fall below the lower limit of the Compton Metabolic Profile Test (9.5 mg urea N/100 ml). The interpretation was that the heifers studied were able to select a diet of higher nutritive value than clipped herbage samples. Other explanations may be conjectured. Bos indicus may have higher blood urea levels than Bos taurus. Lack of water may concentrate the blood. Lack of energy in the rumen may result in surplus N which is converted to urea. Tissue deamination may give high blood urea levels. The lack of response from other indicators of protein status was contrary to results from temperate countries. The presence of tick-borne parasites was noted and it was thought that immunological responses to ticks and blood parasites may affect blood protein levels more than nutrition.

Interpreting the results of blood profile tests for protein and energy status is problematical. The problems are exacerbated in the grazing animal where diet quality and time of feeding are not usually known. Some internal and external parasites appear to be a major interference in the prediction of protein status.

Lowman, Scott and Somerville (1976) describe a method of assessing body condition in Bos taurus cattle by scoring physical features. The effect of body condition at calving and mating on fertility is emphasized. Van Niekerk (1982) in South Africa fed beef cows to achieve a certain condition score at parturition which was maintained until mating. Non-pregnant cows were maintained at the desired condition score once it had been achieved. Pregnant cows were heavier than non-pregnant cows at the same condition score and the difference

was judged to be the weight of the calf. Calving percentages (all calves born) at scores of 1.5, 2.0 and 3.0 were 8%, 43% and 78% respectively.

Frood and Croxton (1978) condition scored dairy cattle in the U.K. from calving throughout lactation. Condition score was positively related to liveweight in the first seven months of lactation and thereafter liveweight increased whilst condition score remained constant. It was considered that condition scoring could be used to predict body reserves and in later lactation may be a better indicator than liveweight.

Few facilities are required for condition scoring which may justify investigations into its commercial use in Botswana. Buck and Light (1982) consider condition scoring may be useful for selecting cows that require feeding.

As a research tool, condition scoring may aid the determination of target weights for particular classes of animal. Target weight can be expected to vary with breed, age, mature size and lactational status. Condition scoring may be useful in assessing body reserves in late pregnancy. Frood and Croxton (1978) found the change in liveweight per unit score to be less in heifers than cows. The correlation between score and liveweight was also less for heifers; some heifers gaining weight whilst their condition score fell. Further investigations using condition scoring may help to predict which beef heifers fail to reconceive after calving.

5.4 Research proposals

Production coefficients for use in extension have been well defined by the APRU. Under improved management a calving percentage between 70 and 90% should be attainable. A mean calving rate over 90% is a realistic maximum under Botswana conditions. This compares with 90.1% (calves born alive) achieved by 45 upland beef herds recorded in U.K. (Meat and Livestock Commission, 1983).

A possible area for research is a further definition of APRU ranch differences. There may be an optimum or maximum herd size for natural mating in a particular environment. Further effort to determine the causes of mortality may be justified although it is appreciated that under range conditions many deaths are undiagnosed. Management may be an important factor in this respect.

A combined method of observation, tail-painting and rectal palpation can provide a reasonable assessment of ovarian activity. Progesterone assay is the most accurate technique but would only be possible on a limited scale. A substantial, single-purpose laboratory is required for the handling of radioactive material and safety procedures (including waste disposal) must be observed. The necessary laboratory equipment including deep-freeze, centrifuge and radioactivity counter can be purchased for £12 000. A reliable electricity supply is required. Annual expenditure on articles such as glassware and assay materials would be of the order of £6 000 (C.A. Llewelyn, personal communication). With such equipment a trained operator (probably expatriate as a suitably experienced person is unlikely to be available locally) might be able to obtain progesterone profiles of 200-300 cows in a year.

In total, approximately 200 cows calve annually on Sunnyside, Masama and Goodhope ranches. Sampling of these cows would be suitable as these ranches all have poor reproductive performance and are reasonably close to Gaberone where it is envisaged the laboratory would be situated. Blood samples would be taken weekly from two weeks prior to the start of the breeding season until the bulls were withdrawn. Sampling of individuals may cease after mating, as detected by chin-ball markers on the bulls. Ideally the cows would be weighed and/or condition scored concurrently in an attempt to determine whether anoestrous and suboestrous cows were suffering from undernutrition. Progesterone profiles can be considered as useful but not essential in this instance. It may be more realistic to wait until simpler assay techniques become available.

Alternatively, much could be achieved by the use of chin-ball markers on bulls and regular observation. Each bull could be assessed for mating ability and this could be combined with fertility tests on semen. Only females not served would require examination and ovarian activity could be assessed by several palpations.

The use of biochemical parameters of protein and energy status is not recommended as a research tool in Botswana. Condition scoring may be a useful aid to assessing nutritional status. On a herd basis, weaning weights may be of use as a guide to cow nutritional status.

The collection of basic production data is well advanced in Botswana and it is pertinent to consider that national productivity may be increased further by applying present knowledge rather than pursuing further research. To this end the use of mathematical

models to define production alternatives, using data already accumulated, has been studied (ILCA, 1978; Konandreas and Anderson, 1982).

RELEVANCE OF BOTSWANA EXPERIENCE TO OTHER COUNTRIES

6.1 Importance of records

It is emphasized that without the aid of accurate records, levels of reproductive performance cannot be determined precisely. Without records the reasons for poor performance can only be speculated. This is inevitable as all aspects of reproductive performance cannot be assessed at one instance. The APRU reports show how much can be achieved with records alone.

Trail (1980) emphasized the need to assess productivity traits together to provide meaningful information. Important productivity traits were considered to be reproductive performance, cow and calf viability, milk yield, growth and cow weight. Referring to the lack of information on indigenous breeds, the author points out that very little published research provides information on three or four traits which can be used to compile an index of productivity. Studies in Botswana and Kenya are cited as examples of well conducted research providing useful information.

The APRU approach of standardization is important. Such is the complexity of the factors affecting reproductive performance that meaningful comparisons necessitate a quantification or standardization of as many variables as possible.

In other countries knowledge of reproductive performance is incomplete or non-existant and investigations may be haphazard and inconclusive. Kumi-Diaka, Ogwu and Osori (1981) report on the significance of atrophic ovaries in livestock production in Northern Nigeria. The seasonal incidence of anoestrus was studied from 1976-1979 yet no figures for calving performance are quoted and anoestrus

is not related to calving date. It is stated that nutrition is a possible cause of anoestrus as the animals were thin and emaciated but other unknown factors may have been involved.

Accurate records are an essential prerequisite for defining and solving problems of reproduction.

6.2 The value of surveys

In the absence of adequate continuous records, an estimate of reproductive performance can be provided from surveys. Accuracy improves with several visits. On a single visit, errors arise in determining calf age, stage of pregnancy, incidence of abortion and calf losses (Stonaker, Villar, Osorio and Salazar, 1976). Calf mortality is particularly difficult to record by survey (Reed et al., 1974). Monitoring over several years is likely to provide a better estimation of production levels.

In many countries where the majority of cattle owners are illiterate, a survey may be the only practical method of gathering information. The APRU only use surveys to collect basic data; the vast majority of information on reproduction coming from continuous recording on APRU ranches.

6.3 Significance of management

In Botswana a mean difference in calving percentage of 28% was estimated between traditional cattle posts (47%), and APRU ranches (75%) which applied basic husbandry and management techniques.

In the Americas the application of management practices such as seasonal breeding and culling of non-pregnant cows resulted in

20-29% increases in pregnancy rate (Warnick, 1976). The author also advocates pregnancy diagnosis and bull evaluation. Maule (1973) referring to southern Africa considers that, without doubt, low (< 50%) calving percentages and high calf mortality are the results of poor nutrition, husbandry and management. Season, breed and year effects are mentioned which broadly agree with those defined by the APRU (1975a). Vandeplassche (1982b) observes that high fertility rates have been realized in a minority of herds spread over a wide range of climatic conditions. Thus poor reproductive performance cannot be wholly attributed to the environment. The author attributes infertility in tropical countries to faulty management and the lack of use of breeding records.

Stonaker et al. (1976) surveyed what were considered the best and worst cattle raising areas in the Llanos of Columbia. Despite environmental differences, estimated annual calving percentages differed by only 3% (52% and 55%). Some herds had high calving rates although no figures were quoted and the factors responsible were difficult to identify.

The inference from APRU results, supported by evidence and opinions from other countries, is that the overwhelming reason for poor reproductive performance in the tropics is poor nutrition to which a low level of husbandry contributes.

6.4 Approach to investigations: the CIAT example

6.4.1 CIAT objectives The Llanos of Columbia occupies 671 625 km^2 and contains approximately seven million cattle (Anon., 1973). One of the activities of the Centro Internacional de Agricultura Tropical (CIAT) is to evaluate beef production systems in Columbia, Venezuela and Brazil (CIAT, 1978). The CIAT Beef Program, later renamed the Tropical Pastures Program started operating in 1978. The Program objective was: "to remove the main constraints to increased beef (and milk) production in the acid, infertile soils of the tropics by developing low-cost pasture technology for the various ecosystems and associated animal management practices feasible for those regions" (CIAT, 1979). Despite environmental differences, the reasons for the poor reproductive performance identified by Stonaker et al. (1976) may be similar to those in Botswana. A comparison between the CIAT and APRU approaches to research is therefore valid.

6.4.2 Farm surveys Between 1977 and 1979, 16 Columbian Llanos farms were surveyed three or four times a year. Mean conception rate (from rectal palpation) on 15 farms over two years was 49.8% (CIAT, 1979). The farms were scored for ten management practices. Analysis of reported figures shows a weak correlation between the score and conception rate or estimated calving percentage (Table 8). Estimated calving percentage and conception rate were also poorly correlated as noted by CIAT (1979).

Table 8 Analysis of CIAT survey results to show the correlation between management, estimated calving percentage and conception rate

Farm	A Relative Management Level[1] %	B Estimated Calving Rate[2]. 1978 %	C Conception Rate[3] 1978, 1979 %
2	24	45	56
4	81	34	NA
5	72	57	41
6	40	77	57
7	43	42	51
8	70	67	65
9	36	54	50
11	63	51	56
12	33	38	44
13	16	59	42
14	47	48	43
15	40	56	54
17	75	52	48
18	41	44	39
19	10	30	43
20	44	45	58
Mean	46	49	49.8

After CIAT (1978, 1979)

Correlation A x B $r = 0.170$ (14 df. $P > 0.05$)
A x C $r = 0.267$ (13 df. $P > 0.05$)
B x C $r = 0.440$ (13 df. $P > 0.05$)

[1] Degree of adoption of 10 practices

[2] $\frac{\text{No. of lactating cows 1-6 months + No. pregnant 3-9 months}}{\text{Total No. of cows}}$

[3] Conceptions over 2 years determined by palpations over 18 months.

Low body weights particularly for lactating cows indicated that inadequate nutrition was the main cause of poor reproductive performance. It was considered that the application of known techniques such as culling and seasonal mating would increase productivity (CIAT, 1978). The limitation of surveys is illustrated by the use of conception rates to predict calving rates and by low calf mortality rates which are questioned by CIAT (1979).

6.4.3 Station research CIAT, in conjunction with other organizations operate a research station at Carimagna in the Columbian Llanos. In 1977 a large experiment was initiated to evaluate the strategic use of improved pastures. A restricted mating season was considered essential for rational use of the pastures and a natural concentration of calving during late dry season had been observed. It was intimated from early results that a May to July mating period (early wet season) in combination with the use of improved pastures would assure high conception rates (CIAT, 1978).

Interim results from 1979-1981 showed best performance under continuous mating and "relatively small" improvements from improved pastures (CIAT, 1981) (Table 9). The poor results from the pastures are partly explained by a failure of the legumes in 1979 when animals were moved from the experimental area. The experiment terminated in 1981 and although the final analysis had not been completed, it was concluded that legumes play a major role in improving calving rates (CIAT, 1982). Calving percentage in all the experimental herds was higher than the average of 50% (Table 8) in the Columbian Llanos. The good performance was attributed to a combination of factors such

as consistent mineral supplementation, culling, pasture burning and close supervision; yet there was no control to quantify the combined effect of such factors (CIAT, 1981).

Table 9 Calving percentages* in CIAT breeding herd experiment at Carimagna. 1979-1981.

Breeding season	Savanna	Savanna + pasture	Mean
Continuous	73	78	76
June-September (120 days)	61	61	61
May-July (90 days)	59	69	64
Mean	64	69	67

*Calves born/100 cows bred

After CIAT (1981)

6.6.4 Comparison with Botswana From the information available in annual reports, the CIAT Tropical Pastures Program compares unfavourably with Botswana's Integrated Programme of Beef Cattle and Range Research in two respects:

(a) Objectives: CIAT aimed to improve beef production by the strategic use of improved pastures before potential productivity on natural pasture had been well defined.

(b) Experimental design: CIAT have just one beef experimental station in the Columbian Llanos and experiments are apparently conducted without adequate replication or controls. Inferences drawn in early stages of experiments are sometimes inconsistent with final results leaving conclusions tenuous. There is apparently heavy

reliance on inaccurate techniques such as rectal palpation e.g. in a study on the impact of improved technology on seven commercial farms (CIAT, 1981).

The factors determining the reproductive performance of cattle in the Columbian Llanos appear to have been less well defined than the corresponding factors in Botswana. This can be attributed to poorly defined experimental conditions with a lack of replicates and controls.

CONCLUSION

The factors affecting reproductive performance in Botswana have been well defined and quantified. The success of the APRU approach is due to extensive recording in well defined conditions over a range of environments and a number of years. The significance of applying basic husbandry practices is demonstrated by the 28% difference in calving rate between traditional cattle posts and APRU ranches. A mean calving percentage of 91% achieved on one APRU ranch is a realistic maximum under Botswana conditions.

It is suggested that the application of accumulated knowledge should take priority over further research into reproductive performance. A possible area for further research is an investigation of APRU ranch differences in calving rate and calf mortality. The importance of nutrition is stressed and it would be useful to relate this to an assessment of performance at each stage of the female reproductive cycle.

Progesterone assay is an accurate research technique for monitoring ovarian activity although its use may not be justified economically; a combined technique of rectal palpation and oestrus detection may suffice. The use of biochemical parameters to monitor protein and energy status is not recommended; rather condition scoring appears to be a useful technique requiring investigation.

The value of the Botswana experience to other countries lies in demonstrating the benefits of collecting accurate representative data, and of applying basic husbandry practices.

REFERENCES

Abdel Rahim, S.E.A., Lowman, B.G. and Deas, D.W. (1980). Clinical application of milk progesterone in the diagnosis of sub-fertility in suckled cows. Vet. Rec., 106: 28-30.

Anderson, J. (1944). The periodicity and duration of oestrus in zebu and grade cattle. J. agric. Sci., 34: 57-68.

Animal Production Research Unit (APRU) (1975a). A five year programme of integrated beef cattle and range research in Botswana: 1970-1975. Part 1. Technical Results. Ministry of Agriculture, Gaberone.

Animal Production Research Unit (APRU) (1975b). A five year programme of integrated beef cattle and range research in Botswana: 1970-1975. Part 2. Presentation and implementation of research results for extension services. Ministry of Agriculture, Gaberone.

Animal Production Research Unit (APRU) (1977). An integrated programme of beef cattle and range research in Botswana: 1970-1977. Ministry of Agriculture, Gaberone.

Animal Production Research Unit (APRU) (1979). Livestock and range research in Botswana: Annual report. Ministry of Agriculture, Gaberone.

Animal Production Research Unit (APRU) (1980). Beef Production and Range Management in Botswana. Ministry of Agriculture, Gaberone.

Anon. (1973). University of Edinburgh veterinary expedition to Colombia 1973. University of Edinburgh.

Ball, P.J.H., Cowpe, J.E.D. and Harker, D.B. (1983). Evaluation of tail paste as an oestrus detection aid using serial progesterone analysis. Vet. Rec., 112: 147-149.

Blood, D.C., Henderson, J.A. and Radostits, O.M. (1979). Veterinary Medicine. Bailliere Tindall, London. pp 500-509.

Bostedt, H. (1982). Measures for raising the fertility status in dairy herds. Vet. Med. Rev., 1/82: 3-17.

Botswana Ministry of Agriculture (1980). Department of Animal Health and Tsetse Fly Control. Activity Report: 1975-1980. Ministry of Agriculture, Gaberone.

Buck, N.G. and Light, D. (1982). Breed and environmental factors affecting the reconception of indigenous beef cows in Botswana. Anim. Prod., 35: 413-420.

Buck, N.G., Light, D. and Makobo, A.D. (1980). Conception rates of beef cattle in Botswana following synchronization of oestrus with cloprostenol. Anim. Prod., 30: 61-67.

Centro Internacional de Agricultura Tropical (CIAT) (1978). Annual Report. CIAT, Cali, Colombia, pp B.124-B.142.

Centro Internacional de Agricultura Tropical (CIAT) (1979). Tropical Pastures Program, Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical (CIAT) (1981). Tropical Pastures Program, Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical (CIAT) (1982). Report. CIAT, Cali, Colombia. pp 90-93.

Clark, B.L. (1971). Venereal diseases of cattle. The Post-Graduate Foundation in Veterinary Science, Publication No. 11. University of Sydney, Australia.

Dawson, F.L.M. (1975). Accuracy of rectal palpation in the diagnosis of ovarian function in the cow. Vet. Rec., 96: 218-220.

Donkin, E.F. (1980). Reproductive activity in dairy cows post partum. 1. The technique of palpation per rectum. Zimbabwe J. agric. Res., 18: 65-70.

Esuruoso, G.O. and Ayanwale, F.O. (1980). Bovine brucellosis in Lagos State of Nigeria. Bull. Anim. Hlth. Prod. Afr., 28: 11-15.

Falade, S., Nwufoh, J.K. and Nmezi, L.Y. (1981). Brucellosis: an investigation in selected herds in Oyo State, Nigeria. Bull. Anim. Hlth. Prod. Afr., 29: 197-201.

FAO (1981). FAO Production Yearbook, Vol. 35, FAO, Rome.

FAO/WHO/OIE (1981). Animal Health Yearbook. FAO Animal Production and Health Series, No. 18. FAO, Rome.

Farin, P.W., Chenoweth, P.J., Mateos, E.R. and Pexton, J.E. (1982). Beef bulls mated to oestrus synchronized heifers: single vs multi-sire breeding groups. Theriogenology, 17: 365-371.

Frood, Moira J. and Croxton, D. (1978). The use of condition-scoring in dairy cows and its relationship with milk yield and live weight. Anim. Prod., 27: 285-291.

Grosskopf, J.F.W. (1973). The correlation between the average daily gain of calves and the reconception of their dams as a screening test when investigating problems with fertility in beef herds. S. Afr. J. Anim. Sci., 3: 87-90. (Article in Afrikaans, English summary).

Hale, D.H. (1975). Nutrition, hormones and fertility. Rhodesia agric. J., 72: 69-73.

Heap, R.B. and Holdsworth, R.J. (1981). Modern diagnostic methods in practice: hormone assays in reproduction and fertility. Br. vet. J., 137: 561-571.

Heap, R.B., Holdsworth, R.J., Gadsby, J.E., Laing, J.A. and Walters, D.E. (1976). Pregnancy diagnosis in the cow from milk progesterone concentration. Br. vet. J., 132: 445-464.

Holdsworth, R.J. and Markillie, N.A.R. (1982). Evaluation of pedometers for oestrus detection in dairy cows. Vet. Rec., 111: 16.

Holness, D.H., Hale, D.H. and Hopley, J.D.H. (1980). Ovarian activity and conception during the post partum period in Afrikaner and Mashona cows. Zimbabwe J. agric. Res., 18: 3-11.

Holness, D.H., Hopley, J.D.H. and Hale, D.H. (1978). The effects of plane of nutrition, liveweight, temporary weaning and breed on the occurrence of oestrus in beef cows during the post partum period. Anim. Prod., 26: 47-54.

Holroyd, R.G. (1978). Methods of investigating beef cattle fertility. In Beef Cattle Production in the Tropics. (ed. R.M. Murray and K.W. Entwhistle) James Cook University, Townsville, Australia, pp 233-246.

Huhold, K. (1982). Möglichkeiten und Grenzen der rektalen Befunderhebung bei der Diagnostik der Ovarfunktion des Rindes. Monatshefte für Veterinärmedizin, 37: 723-725. (English abstract in Anim. Breed. Abstr., 51: 197).

International Livestock Centre for Africa (ILCA) (1978). Mathematical modelling of livestock production systems: Application of the Texas A & M University beef cattle production model to Botswana. ILCA Systems Study No. 1. Addis Ababa.

Kidder, H.E., Black, W.G., Wiltbank, J.N., Ulberg, L.C. and Casida, L.E. (1954). Fertilization rates and embryonic death rates in cows bred to bulls of different levels of fertility. J. Dairy Sci., 37: 691-697.

Konandreas, P.A. and Anderson, F.M. (1982). Cattle herd dynamics: an integer and stochastic model for evaluating production alternatives. ILCA Research Report No. 2. Addis Ababa.

Kronfield, D.S., Donoghue, S., Copp, R.L., Stearns, F.M. and Engle, R.H. (1982). Nutritional status of dairy cows indicated by analysis of blood. J. Dairy Sci., 65: 1925-1933.

Kumi-Diaka, J., Ogwu, D. and Osori, D.I.K. (1981). Significance of atrophic ovaries in livestock production in Northern Nigeria. Vet. Rec., 108: 277-278.

Lamond, D.R. (1970). The influence of undernutrition on reproduction in the cow. Anim. Breed. Abstr., 38: 359-372.

Light, D., Buck, N.G. and Lethola, L.L. (1982). The reproductive performance, mothering ability and productivity of crossbred and Tswana beef cows in Botswana. Anim. Prod., 35: 421-426.

Lotthammer, K.H. (1982). Effect of improving energy intake during early lactation by corn-silage on metabolism and fertility of dairy cows. In Factors Influencing Fertility in the Postpartum Cow. (Ed. H. Karg and E. Schallenberger). Martinus Nijhoff Publishers, The Hague, pp 409-412.

Lowman, B.G., Scott, N. and Somerville, S. (1976). Condition scoring of cattle. Bull. E. Scott. Coll. Agric. No. 6. Revised Edn.

Maule, J.P. (1973). The role of indigenous breeds for beef production in southern Africa. S. Afr. J. Anim. Sci., 3: 111-130.

Meat and Livestock Commission (1983). Beef Yearbook. Meat and Livestock Commission, Bletchley, England.

Munro, C.D., Boyd, H., Watson, E.D., McBride, B., Martin, B., Booth, J.M. and Holdsworth, R.J. (1982). Monitoring pre-service reproductive status in dairy cows. Vet. Rec., 110: 77-81.

Nakao, T., Sugihashi, A., Saga, N., Tsunoda, N. and Kawata, K. (1983). An improved enzymeimmunoassay of progesterone applied to bovine milk. Br. vet. J., 139: 109-118.

Parker, B.N.J. and Blowey, R.W. (1976). Investigations into the relationship of selected blood components to nutrition and fertility of the dairy cow under commercial farm conditions. Vet. Rec., 98: 394-404.

Peters, A.R. and Riley, G.M. (1982). Milk progesterone profiles and factors affecting post partum ovarian activity in beef cows. Anim. Prod., 34: 145-153.

Pleasants, A.B. and Ginindza, M.M. (1981). The effect of pre-calving nutrition on the productivity of beef breeding cows in Swaziland. Zimbabwe J. agric. Res., 19: 7-12.

Prescott, J.H.D. (1983). Lecture notes. School of Agriculture, University of Edinburgh.

Randel, R.D. (1979). Once daily suckling - A practical management tool for rebreeding first calf heifers. J. Anim. Sci., 49 (Suppl. 1): 44.

Reed, J.B.H., Doxey, D.L., Forbes, A.B., Finlay, R.S., Geering, I.W., Smith, S.D. and Wright, J.D. (1974). Productive performance of cattle in Botswana. Trop. Anim. Hlth. Prod., 6: 1-21.

Richardson, F.D. and Kegel, Lynne (1980). The use of biochemical parameters to monitor the nutritional status of ruminants. 1. The relation between concentration of urea nitrogen in the plasma of growing cattle and crude protein content of the diet. Zimbabwe J. agric. Res., 18: 53-64.

Richardson, F.D., Oliver, J. and Clarke, G.P.Y. (1975). Analyses of some factors which affect the productivity of beef cows and of their calves in a marginal rainfall area of Rhodesia. 1. Factors affecting calving rate. Anim. Prod., 21: 41-49.

Rupp, G.P., Ball, L., Shoop, M.C. and Chenoweth, P.J. (1977). Reproductive efficiency of bulls in natural service: effects of male to female ratio and single- vs multiple-sire breeding groups. J. Am. Vet. Med. Ass., 171: 639-642.

Smith, J.F., Payne, E., Tervit, H.R., McGowan, L.T., Fairclough, R., Kilgour, R. and Goold, P.G. (1981). The effect of suckling upon the endocrine changes associated with anoestrus in identical twin cows. J. Reprod. Fert., Suppl. 30: 241-249.

Sreenan, J.M. (1982). Concluding remarks of the Chairman. In Factors Influencing Fertility in the Postpartum Cow (Ed. H. Karg and E. Schallenberger). Session IV: Environmental influences and the impact of nutrition and lactation. Martinus Nijhoff Publishers, The Hague, pp 323-421.

Steenkamp, J.D.G., van der Horst, Conny and Andrew, M.J.A. (1975). Reconception in grade and pedigree Africander cows of different sizes: postpartum factors influencing reconception. S. Afr. J. Anim. Sci., 5: 103-110.

Stonaker, H.H., Jaime Villar, Gustavo Osorio and Jairo Salazar (1976). Differences among cattle and farms as related to beef cow reproduction in the eastern plains of Colombia. Trop. Anim. Hlth. Prod., 8: 147-154.

Swanepoel, R., Blackburn, N.K., Lander, K.P., Vickers, D.B. and Lewis, A.R. (1975). An investigation of infectious infertility and abortion of cattle. Rhod. vet. J., 6: 42-55.

Terqui, M., Chupin, D., Gauthier, D., Perez, N., Pelot, J. and Mauleon, P. (1982). Influence of management and nutrition on postpartum endocrine function and ovarian activity in cows. In Factors Influencing Fertility in the Postpartum Cow. (Ed. H. Karg and E. Schallenberger). Martinus Nijhoff Publishers, The Hague, pp 384-408.

Thorpe, W., Cruikshank, D.K.R. and Thompson, R. (1980). Genetic and environmental influences on beef cattle production in Zambia. 1. Factors affecting weaner production from Angoni, Barotse and Boran dams. Anim. Prod., 30: 217-234.

Trail, J.C.M. (1980). Performance recording in Africa: Past, present and future. Government of Botswana subregional seminar on performance recording systems for livestock development. FAO/SIDA. Gaberone, Botswana.

Trail, J.C.M. and Rennie, T.W. (1975). Botswana: performance testing of beef cattle. Wld. Anim. Rev. (FAO) 14: 37-41.

Vandeplassche, M. (1982a). Reproductive efficiency in cattle: a guideline for projects in developing countries. FAO Animal Production and Health Paper No. 25. FAO, Rome.

Vandeplassche, M. (1982b). Infertility as a limiting factor in the productive cattle breeding in tropical countries. In Tropical Animal Production for the Benefit of Man. Proceedings of an International Colloquium. Prins Leopold Instituut voor Tropische Geneeskunde, Antwerpen, Belgium, pp 182-187.

Van Niekerk, A. (1982). The effect of body condition as influenced by winter nutrition, on the reproductive performance of the beef cow. S. Afr. J. Anim. Sci., 12: 383-387.

Ward, H.K. and Tiffin, J. de W. (1975). Progress in beef cow productivity. Rhodesia agric. J., 72: 1-7.

Warnick, A.C. (1976). Management factors affecting reproductive efficiency of beef cattle in developing countries. In Beef Cattle Production in Developing Countries (ed. A.J. Smith) Centre for Tropical Veterinary Medicine, University of Edinburgh, pp 132-137.