STUDIES ON THE SOCIAL AND
SEXUAL BEHAVIOUR
OF BULLS

by

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PREFACE

This thesis embodies the results of original research wholly performed by the author at the University of Melbourne, School of Veterinary Science. Supervisory and technical assistance has been acknowledged. Where the author has availed himself of the work and methods of others, it has been acknowledged by reference to the appropriate publications.

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GENERAL INTRODUCTION

A very high proportion of beef cows in Australia are mated to bulls at pasture. A multiplicity of systems for pasture mating are presently in use. Bulls are mated singly or in groups, they are set-stocked during the mating period or rotated about the different groups of cows, they are mated at the rate of 2, 3, 4, 5 or 6 bulls per 100 cows, young bulls are mated to cows in company with old bulls or other young bulls (Dickson 1966). There is little scientific basis for any of these mating systems since basic information on the sexual and social behaviour of beef bulls at pasture is lacking. Such data are needed so that optimum use can be made of beef bulls in pasture mating.

The objectives of the present study of bulls mated in groups were:

1. To describe the social behaviour of bulls in mating groups, to devise methods of measuring their social ranking within such groups, to determine the influence of social dominance on their sexual activity and to establish the factors which maintain social ranking in mating groups of beef bulls.

2. To establish a useful measure of the bull's sexual behaviour during pasture mating and to determine the influence of sexual behaviour of bulls on herd fertility.
3. To develop a practical yard test that will accurately predict the sexual behaviour of bulls during pasture mating.

4. To assess the importance of tests of sexual behaviour in the veterinary examination of beef bulls.

5. To determine the influence of locomotor abnormalities, age and breed on the sexual behaviour of bulls.

6. To study the hormonal control of sexual behaviour in the bull.
CHAPTER 1

SOCIAL BEHAVIOUR OF CATTLE WITH PARTICULAR REFERENCE TO THE BULL

A Review

There is little information on the social behaviour of bulls in groups and its influence on their growth and reproductive performance. Young bulls are being increasingly grazed together for bull beef production or for sire selection by comparing their weight gains. Breeding bulls are mated in groups. A knowledge of their social behaviour may improve the productivity of bulls in such groups. The literature on social behaviour of all classes of cattle is reviewed with the aim of highlighting the most important areas of investigation in bulls.

Types of Social Behaviour

Social behaviour of cattle can be classified into amicable or agonistic behaviour (Schloeth 1961; Kilgour and Campin 1973). Amicable behaviour including play is an activity engaged in solely for the sake of itself and not for the expected result of the activity (Schein 1954). Agonistic behaviour encompasses all activity associated with conflict including escape and submissive behaviour (Scott 1956). It has the dual function of establishing and maintaining both social distance and the dominance hierarchy.
Amicable behaviour is displayed by cattle without a stable social dominance order e.g. dairy heifers up to 6 months of age (Schein and Fohrman 1955). Three year old dairy bulls engaged in various forms of sham fighting such as gentle head-to-head pushing and butting (Kilgour and Campin 1973). Other forms of amicable behaviour included licking of the head, neck and preputial region of other bulls. There is no other data on the social behaviour of either dairy or beef bulls younger than 3 years.

Agonistic behaviour is displayed during the formation of the social order. In dairy heifers this occurs before 2 years of age (Schein and Fohrman 1955; Bielhartz and Mylrea 1963; Bouissou 1965, 1972). In the only published study on young bulls, dairy bulls exhibited greatly increased agonistic behaviour between 3.5 to 4.5 years of age (Kilgour and Campin 1973).

Agonistic behaviour in dairy cows follows a definite sequence of movements (Schein and Fohrman 1955). The approach of one cow to another whether by chance or by intention is followed by a threat. The threat and immediate submission by the other cow often occurs so rapidly and so subtly that it may pass unnoticed (Hafez et al 1969). Only the more obvious threatening attitudes have been reported in bulls. These include pawing the ground, rubbing the head and neck in the ground and horning the ground (Schloeth 1961; Kilgour and Campin 1973). At other times bulls may direct the lowered head toward the opponent with the forehead
perpendicular to the ground (Fraser 1957a). Threats may be followed by submission and avoidance or a threat in return. In the latter case, the third movement in the sequence, physical contact, occurs.

Dairy bulls 3.5 to 4.5 years old establishing their social order rarely threatened one another before engaging in such physical contact as bunting, head-to-head pushing and mounting (Kilgour and Campin 1973). The bunting or blows with the forehead to an opponent's body, was often sufficiently violent to toss a bull. Pairs of bulls persisted in violent head-to-head pushing or sparring until one avoided contact. The loser did not leave the group of sparring bulls. It was chosen more and more as the animal to be mounted. In two other groups of dairy bulls, 2.5 to 5 years old bunting and sparring began with or without threatening preliminaries (Dalton et al 1967). No stable social dominance order could be determined in these groups. Mounting was frequent with bulls directing their attention to certain individuals. In another group of dairy bulls, some bulls always stood to be mounted (Hunter and Edwards 1964). The exact role of mounting as an act of social behaviour in bulls is uncertain. It may emphasise the expression of social dominance or simply represent a passive response to an attractive sexual stimulus. Mounting is related to sexual behaviour for in both the head and tail mount, the penis is usually erect, protruding and secreting fluid (Dalton et al 1967; Kilgour and Campin 1973).
With the establishment of their social order, dairy bulls 5.5 to 6.5 years showed a ritualization of agonistic behaviour (Kilgour and Campin 1973). Sparring was preceded by such threatening behaviour as pawing the ground. All threatening and head-to-head pushing occurred at well-defined sparring holes. These were dug in elevated positions or near fencelines. In contrast to the violent head-to-head pushing of bulls establishing their social order, sparring between the older bulls was more threatening than violent. It was by such ritualized encounters that the social dominance hierarchy was maintained (Kilgour and Campin 1973).

In meat producing bulls nothing is published on the transition from amicable to agonistic behaviour. Work is needed on the age at which the transition occurs and the factors which influence the age of transition.

Spatial Requirements of Cattle

Agonistic behaviour serves to space animals out which in turn has the function of eliminating further strife. Bulls need to defend more space than they occupy physically; they need a second type of space, personal space, around them (McBride 1971). Cattle have three systems of space sharing - territories, personal spheres on overlapping ranges and personal space about them as they move in a group.

The method of feeding, sex and age of cattle determines the system of space sharing used. During grazing,
old dairy bulls with an established social order, kept to well-defined territories (Kilgour and Campin 1973). Younger bulls 2.5 to 5.0 years old with no social order showed no individual preference for specific areas of the paddock (Dalton et al 1967; Kilgour and Campin 1973). Until they began to form a social order they grazed the paddock as a widely dispersed group (Kilgour and Campin 1973). In a group of grazing cows, with an established social order, space is divided on the basis of dominance (McBride 1971). High ranking cows are free to move within the group without interference whilst the lower ranking animals such as newly introduced heifers have less freedom to move among the group and thus graze at the periphery of the herd (Sambraus 1971a). Within the herd, subordinate cows keep more than 0.5 m away from the dominant cow (Sambraus 1971a). Should the subordinate enter this personal space, it is threatened and responds by retreating. Cows can show an appeasement type of behaviour which will allow them to enter the personal space of dominant neighbours without eliciting an attack (McBride 1971). Appeasement is signalled by the subordinate cow lowering its head and extending its neck whilst standing in front of its dominant neighbour (Fraser 1957b). By submission and appeasement behaviour cows acknowledge the control of a personal space by dominant neighbours.

When hay was provided by scattering it on the ground in a restricted area of a paddock, old bulls with a stable social order left their territories to share the area
(Kilgour and Campin 1973). Whilst eating hay or drinking at a trough they kept a strict personal space of a few metres between them.

When confined to a yard, cattle may become crowded. Crowding occurs not when animals jostle one another but when they are forced into the personal space of their neighbours (McBride 1971). Dairy bulls become crowded in yards if they are spaced less than 5.5 metres apart (Kilgour 1971). In a crowded yard, the highest ranking heifers mutually repelled one another tending to spread themselves around the yard (Bielhartz and Mylrea 1963). Subordinates avoid dominant animals' personal space and by so doing violate one another's space (McBride 1971). Head-to-head fighting is rarely seen in a crowded yard of cattle (McBride 1971; Bielhartz and Mylrea 1963). Instead subordinates take avoidance action at the approach of a dominant animal while dominant animals stand their ground when approached or bunt the subordinates that fail to avoid them (Bielhartz and Mylrea 1963).

The spatial requirements of meat producing bulls during grazing, supplementary feeding and yarding needs investigation.

Formation and Maintenance of Social Order

Early agonistic interactions between animals appear to determine the dominance-submission relationship between them. This may result from a single encounter e.g. threatening or sparring, or a series of encounters. When
every pair of animals in the herd has determined the relationship between them, the social dominance hierarchy has been established (Hafez et al 1969). Once formed, the social hierarchy in bulls (Schloeth 1961), heifers (Bielhartz and Mylrea 1963; Bouissou 1965) and cows (Wagnon et al 1966; Dickson et al 1967; Brantas 1968) remains stable for as long as the animals are in the same herd.

Several factors may determine the social ranking of an animal during the establishment of the social dominance hierarchy. In a newly constituted group of dairy heifers, the presence of horns and, to a lesser extent bodyweight, significantly influenced the outcome of their first encounters (Bouissou 1972). Young cows entering the milking herd with an already established social order, always lost their first encounters with older cows (Guhl and Atkeson 1959; Bremner 1975). Social experience as well as bodyweight are influential factors. In this herd as in others (Schein and Fohrman 1955; Brantas 1968), age and bodyweight were highly correlated and both significantly influenced a cow’s social ranking. It seems likely that the older cows dominate young newly introduced cows because they are heavier and of greater social experience. However seniority, defined as the length of time in the herd, may be a major factor. Two, 6-year old cows when introduced into an established herd of 2 to 5 year old cows, were dominated by 70% of the younger animals (Schein and Fohrman 1955).
Further experimentation is needed to determine the role of age, seniority and bodyweight in forming and maintaining the social dominance hierarchy. This is of particular importance in bulls, for in mating management, bulls of different age, seniority, bodyweight and breed may be run together with one herd of cows.

**Measurement of Social Order**

The social dominance hierarchy is determined by observing the group of cattle and recording agonistic interactions between each pair of animals. A win for one of the pair clearly indicates a dominance-submission relationship between them (Hafez et al 1969). On the basis of these relationships, 8 of 15 small groups of 4 to 8 heifers were ranked in a linear social order (Bouissou 1965). In larger groups of 4 to 41 animals, a complex hierarchy was exhibited in which there were cases of animals dominating others higher in the social order (Schein and Fohrman 1955; Bielhartz and Mylrea 1963; Bouissou 1965; Wagnon 1965; Wagnon et al 1966). For the measurement of social order in a complex hierarchy, an index termed the dominance value can be calculated for each animal in the group. The dominance value is the number of animals dominated as a fraction of the total animals encountered (Bielhartz and Mylrea 1963). There is no published data on the types of social hierarchy existing in small or large groups of bulls.
Hafez et al. (1969) considered that the social hierarchy of a herd could only be determined if the relationship between every pair of animals is known. However, it is difficult to stage a contest between every pair of animals in herds larger than 15 (Schein and Fohrman 1955; Bielhartz and Mylrea 1963). To estimate the dominance value correctly, only a sample of the pairs of bulls may be necessary. An objective study needs to be undertaken to determine the minimum sample size needed to assess social order in various sized groups of cattle.

Optimal conditions for assessing social ranking are encountered when the incidence of agonistic interaction is high. This situation in heifers and cows exists when animals are competing for feed at a trough, self-feeder or hayrack (Guhl and Atkeson 1959; Wagnon 1965; Dickson et al. 1970) or when they are competing for personal space in the yard (Bielhartz and Mylrea 1963). It can only be presumed that the optimal conditions for assessing social ranking in bulls are similar.

Effect of Agonistic Behaviour on Production

During the establishment of social order in bulls, agonistic behaviour reduces their grazing time and may result in injury.

Grazing - Two groups of bulls displaying amicable behaviour grazed most of the day with only a midday rest period. In contrast, a fighting-mounting group establishing
their social order did virtually no grazing (Kilgour and Campin 1973). In another group in which the social order could not be ascertained (Dalton et al 1967), bulls ceased grazing at any outbreak of fighting or any activity in neighbouring paddocks. They appeared more sensitive to disturbance than other classes of cattle (Dalton et al 1967). This greater reactivity resulted in an increase in idling time at the expense of grazing and ruminating.

Injuries - The level of mild to serious injury in dairy bulls at artificial insemination (A.I.) centres rises from a low level at 2.5 years to a peak at 4 years and then declines (Kilgour and Campin 1973). In the fighting-mounting group of 3.5 to 4.5 year old bulls, sparring occurred with sufficient impact for bulls to sustain injury and bunting was violent enough to toss the bull on its back (Kilgour and Campin 1973). Whether these bulls actually suffered injury was not stated. At another A.I. centre with 1.5 to 6 year old bulls, the problem of injuries to young bulls due to bunting was controlled by reducing the horns to stumps of 7 cm (Hunter and Edwards 1964). Injuries suffered by bulls being mounted include bruising of the back (Hunter and Edwards 1964; Dalton et al 1969) and rupture of the rectal wall due to pénile intromission (L. Larsen personal communication, 1974). Some 0.5% of a large group of bulls had severe lacerations of the rectal wall; of the 13 affected, 4 died. Mounting bulls can suffer penile abrasions and haematomas.
Two approaches have been taken to reduce injuries to young dairy bulls at pasture. Dalton et al (1967) attempted to reduce the idling time of bulls by allowing them access to bare pasture. Grazing time was similar whether bulls grazed sparse or abundant pasture. Whatever the amount of herbage available, the reactivity of bulls ensured that they would cease grazing to investigate any disturbance. The alternative approach recognises this reactivity and aims at minimising agonistic behaviour during idling times. Quiet and frequent handling of bulls, providing bulls with panoramic views and views of agricultural activities and roads, are all claimed to minimise agonistic behaviour (Hunter and Edwards 1964; Hunter and Couttie 1969; A.S. Gubbins personal communication 1972).

Whether bulls being reared for slaughter suffer a depression in growth rate due to fighting and mounting has yet to be determined. If growth rate is reduced, management research should be aimed at methods of directing the sensitivity of young, growing bulls into productive outlets.

Once established, the social order minimises severe agonistic interactions between herd members (Hafez et al 1969). The 5.5 to 6.5 year old dairy bulls observed by Kilgour and Campin (1973) kept to well defined territories and the few interactions they had were more threatening than violent. The records of the wild white cattle of Chillingham show that over the last 50 years only 1 bull has been seriously injured despite frequent male encounters (Earl of Tankerville, cited by Kilgour and Campin 1973).
Effect of Social Order on Production

(i) Growth During Period of Hand Feeding

In groups of steers, heifers and cows, subordinate animals are prevented from eating or are disturbed during trough feeding by dominant herd mates (McPhee et al 1964; Wagnon 1965; Wagnon et al 1966; Bouissou 1970, 1972). Animals of lower social status consistently had slower growth rates than higher ranking animals (McPhee et al 1964; Wagnon 1965). The data of Wagnon (1965) has led to the recommendation that during supplementary feeding at pasture young cows be separated from old cows and if possible, within age groups, thin cows be separated from fat cows.

In most northern hemisphere post-weaning rate of gain tests, bulls are fully fed on concentrates in troughs. In Australian tests, bulls at pasture are fed supplements during periods of pasture shortage. There is a need to determine the relationship between social ranking and growth rate of bulls in both of these situations.

(ii) Reproductive Performance of Bulls

Between 1 and 2.5 years of age young bulls establish their dominance over cows (Schloeth 1961; Sambraus 1971a). Cows over which a yearling bull had not yet established dominance were checked for oestrus (by vulval sniffing) less frequently than cows the bull dominated (Sambraus 1971a). Ayalon (personal communication) attributes the lack of
libido in 10% of yearling teaser bulls to their introduction into herds of mature cows.

Social ranking amongst bulls does influence their sexual activity. The amount of time a bull spent herding (standing behind an oestrous cow guarding it) was influenced to only a small degree by its social ranking (Schloeth 1961; Sambraus 1971a). However mounting occurred most frequently in higher ranking bulls (Schloeth 1961; Sambraus 1971a) and only the two bulls highest in the rank order were seen to serve cows in the herd observed by Schloeth (1961). In another 5 herds each with 2 bulls, the dominant bulls had a total of 48 services compared to 14 services by the subordinates (Sambraus 1971a). Many cows were served only by the higher ranking bull. In a further 4 herds each with 2 bulls, cows were served a mean 1.29 times/oestrus with the dominant bull in each pair achieving 65% of the services (Warnick et al 1971). These data indicate that many cows in the multiple joining situation would only be served by the dominant bull. Thus social ranking must influence the reproductive performance of bulls i.e. the proportion of the calves born that each bull sires.

There is no published data directly relating the social ranking of bulls to their reproductive performance. There are however strong suggestions of a positive relationship. When equal numbers of Hereford and Brahman cross bulls were mated with Hereford cows, less than 10% of the calves branded were by Brahman cross bulls
(Donaldson 1962). Mated separately from the Hereford bulls the following year, the Brahman cross bulls produced an average herd branding. The suggestion of Donaldson (1962) that the Hereford bulls inhibited the sexual activity of the Bos indicus bulls may explain the results of Ittner et al (1954). When equal numbers of similar aged Hereford, Brahman and Shorthorn bulls were joined to a herd of Hereford cows, significantly more calves were sired by the Hereford bulls than by bulls of either of the other breeds (Table 1). This disproportion in the reproductive performance of bulls in a group is also seen in the unpublished data of D.R. Osterhoff. For 5 consecutive years, the calves born to cows mated as a herd to 3 or 4 bulls, were allocated to the correct sire using blood typing. In each year, the oldest or second oldest bull sired more than 60% of the calves while the youngest bull sired 15% or fewer (Table 2). Since age influences social ranking in cows (Schein and Fohrman 1955; Guhl and Atkeson 1959; Brantas 1968), this disproportionate pattern of reproductive performance could be related to the social dominance relationships amongst the bulls. These data of Osterhoff do highlight the possibility of depressing production by using, in the multiple joining situation, a dominant bull of inferior genotype e.g. of slow growth rate. Not only would it affect the average merit of the calf crop but it could also slow down genetic progress in the herd. A dominant bull having poor serving ability or poor semen quality would decrease the first service pregnancy rate, extend the
calving season and, in some circumstances, reduce the overall pregnancy rate.

There is a paucity of information on the social behaviour of bulls used in meat production. Data on the social interactions of 1 to 2 year old bulls grazed together, and of older bulls mated in groups is urgently needed.
**TABLE 1**

Reproductive Performance of Hereford, Brahman and Shorthorn Bulls Joined to Hereford Cows

*(Ittner et al 1954)*

<table>
<thead>
<tr>
<th>Year</th>
<th>1948</th>
<th>1949</th>
<th>1950</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cows</td>
<td>101</td>
<td>101</td>
<td>99</td>
</tr>
<tr>
<td>No. and breed of bulls</td>
<td>2 Hereford</td>
<td>2 Hereford</td>
<td>2 Hereford</td>
</tr>
<tr>
<td></td>
<td>2 Brahman</td>
<td>2 Brahman</td>
<td>2 Brahman</td>
</tr>
<tr>
<td></td>
<td>2 Shorthorn</td>
<td>2 Shorthorn</td>
<td></td>
</tr>
</tbody>
</table>

Calves born

<table>
<thead>
<tr>
<th>Breed</th>
<th>1948</th>
<th>1949</th>
<th>1950</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hereford</td>
<td>57</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Brahman-Hereford</td>
<td>36</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>Shorthorn-Hereford</td>
<td>-</td>
<td>26</td>
<td>16</td>
</tr>
</tbody>
</table>
TABLE 2

Pattern of Calf Production in the Multiple Joining Situation in a Drakensberger Herd

(D.R. Osterhoff - unpublished data)

<table>
<thead>
<tr>
<th>Bulls used</th>
<th>Percentage of calves sired by each bull</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oubaas</td>
<td>70.4(10)*</td>
</tr>
<tr>
<td>Matie</td>
<td>16.7(4)</td>
</tr>
<tr>
<td>Morena</td>
<td>7.4(3)</td>
</tr>
<tr>
<td>Slinger</td>
<td>5.5(2)</td>
</tr>
</tbody>
</table>

* Bulls absent from the herd
+ Age of bull in years
CHAPTER 2

MEASUREMENT OF SOCIAL ORDER IN BEEF BULLS

SECTION 1. Agonistic Behaviour in Groups of Bulls Competing for Cows

INTRODUCTION

The social order in a group of cattle is measured by determining the outcome of contests between every pair of animals in the group (Hafez et al 1969). To determine whether cattle are contesting and to assess the outcome of a contest, a detailed description of the agonistic behaviour of cattle is needed. There is no such data on the agonistic behaviour of beef bulls competing for oestrous cows. Another difficulty in measuring the social order of bulls mated to oestrous cows at pasture is that every pair of bulls in the group may not contest while competing for oestrous cows.

This section has two aims:

(i) to describe the agonistic behaviour of bulls competing for oestrous cows, and

(ii) to determine the proportion of pairs of bulls contesting while competing for oestrous cows over an 8-hour period.

MATERIALS AND METHODS

Two groups of bulls were observed. Group 1 consisted of 16 sexually experienced beef bulls, 3 to 6 years of age, which had been grazing together for at least one year. On May 4, 1973, 25 ovariectomised cows were given 400 µg
oestradiol benzoate intramuscularly (IM) to induce oestrus. The next day the 16 bulls and 25 cows were observed for 8 hours in a 0.7 ha paddock.

Group 2 comprised 17 sexually inexperienced beef bulls, 20 to 33 months of age, which had been grazing together for 6 weeks before the observations were made. On 11 July 1973, 52 ovariectomised cows were given 750 μg oestradiol benzoate IM to induce oestrus. For 8 hours the next day observations were made on the 17 bulls and 52 heifers in a 0.7 ha paddock. Bulls in both groups were individually identified with large numbers sprayed on both sides.

In each group the sequence of agonistic movements of bulls competing for oestrous cows was described in terms of the nomenclature introduced by Schein and Fohrman (1955), i.e. the approach, the threat and physical contact. The outcome of each clearly resolved contest between a pair of bulls was recorded.

RESULTS

In groups 1 and 2, 67 and 77 different pairs of bulls respectively had clearly resolved contests while competing for oestrous cows. This is equivalent to 64% and 57% of the pairs of bulls in groups 1 and 2 respectively. Two of the 17 bulls in group 2 did not engage in sexual activity.

In both groups bulls showed the same sequence of agonistic movements, the approach, the threat and physical contact...
contact while competing for oestrous cows. It was in their response to each of these agonistic movements that the group 1 and group 2 bulls differed.

Approach

A bull mounting a cow attracted the attention of other bulls. In the mixed age group the active approach of a bull was usually followed by the bull subordinate to it abandoning the cow. This sometimes occurred while the dominant bull was still up to 50 metres away. In the 2 year old group the active approach of a dominant animal rarely caused its subordinate to leave a cow.

Threat

Threatening postures varied in intensity. While two bulls were following an oestrous cow one might merely turn its head toward the other. This was termed a threat posture because the threatened bull often abandoned its pursuit of the cow. This head turning was sometimes accompanied by lowering of the head with the forehead perpendicular to the ground, a head posture described by Fraser (1957a). Pawing the ground or taking a few charging steps toward another bull reinforced threatening head postures. In the mixed age group a threat by a dominant bull generally elicited a submissive response from its subordinate. Only when it failed to notice the threat or was highly sexually excited while mounting did a subordinate not readily submit. In most instances a two year old bull after being threatened would threaten in return or ignore
the threat and continue its sexual activity.

*Physical Contact*

A threatened bull that was slow to submit or notice the threat was bunted on the side or rump. A sexually excited bull sometimes continued its mounting attempt despite the bunt(s) and often achieved a service before being pushed off the cow. A subordinate bull in the mixed age group was usually quick to retreat when bunted. No instances of head-to-head fighting were seen in this group. A subordinate bull in the 2 year old group was either repeatedly bunted before it submitted or it abandoned its courting or mounting activity to engage its attacker in head-to-head fighting of a short-lived nature.

**DISCUSSION**

The striking difference between the two groups of bulls was that bulls in the mixed age group ended the sexual encounters of bulls subordinate to them more decisively and quickly than did dominant bulls in the group of 2 year old bulls. In the mixed age group an active approach or a threat was usually sufficient to elicit an obviously submissive response from a subordinate. In the group of 2 year old bulls physical contact was generally necessary for one bull to clearly assert its dominance over another. Bulls in the latter group displayed agonistic behaviour similar to that of dairy bulls in the process of forming a social dominance hierarchy.
(Kilgour and Campin 1973). Such bulls rarely threatened one another before engaging in butting and head-to-head fighting. In an older group of bulls observed by the same authors the social order was maintained by threatening behaviour. These data of Kilgour and Campin (1973) suggest that in group 1 a social hierarchy was established and in group 2 a social dominance hierarchy was in the process of formation.

Even after 8 hours' exposure to oestrous cows, only 64% and 57% of the different pairs of bulls in groups 1 and 2 respectively had had clearly resolved contests while competing for oestrous cows. It would be extremely time consuming to observe a group of bulls until every pair of animals in the group had contested. It is concluded that an alternative method of measuring the social order of a group of bulls in the heterosexual situation must be devised.
CHAPTER 2
MEASUREMENT OF SOCIAL ORDER IN BEEF BULLS

SECTION 2. Social Order of Bulls Competing for Personal Space

INTRODUCTION

In the previous section, two groups of bulls competing for oestrous cows were observed for 8 hours in an attempt to record clearly resolved contests between every pair of bulls in the group. Only about 60% of the different pairs of bulls in each group contested in this period. There may be other situations in which bulls compete with one another more often but maintain the social ranking they had while competing in the heterosexual situation. Crowding bulls together appears to increase the incidence of social activity. Young bulls competing for space in the study of Blockey and Lade (1974) were four times more socially active when confined to a yard than when restricted to a larger area in a paddock. Whether dairy heifers were competing for personal space in a yard or competing for feed in a trough their social ranking within the group was the same (Bouissou 1972). It is possible that the social order of a group of bulls in the heterosexual situation could be determined rapidly and accurately by confining them to yards without heifers and forcing them to compete for personal space.

In this section two groups of bulls were observed in the paddock competing for oestrous heifers and in the yards competing for personal space. The behaviour of bulls in the
latter situation is described and their social ranking in both situations compared.

MATERIALS AND METHODS

The group 1 and group 2 bulls described in the previous section were used in this study. As described in that section these bulls were allowed to compete for oestrous cows for 8 hours and the outcome of contests of 67 and 77 different pairs of bulls in groups 1 and 2 respectively, recorded. These contests were used to determine the social ranking of bulls in the heterosexual situation. Each bull was ascribed a dominance value (DV) the proportion of bulls it dominated to bulls with which it had clearly resolved contests while engaging in sexual activity (Bielhartz and Mylrea 1963). The two bulls in group 2 which failed to engage in sexual activity were excluded.

To determine the social ranking of bulls competing for personal space, each group of bulls was held in a yard 20 m x 20 m without cows. Three observers stimulated contests between bulls by forcing them close to one another. Actions such as an avoidance or a bunt which clearly indicated the outcome of a contest between a pair of bulls, were recorded. For group 1 bulls the distance between each pair of bulls when the subordinate made a movement of avoidance was estimated and recorded. On the basis of the outcome of its contests each bull was ascribed a dominance value (DV), the proportion of bulls it dominated to bulls with which it contested (Bielhartz and Mylrea 1963).
For each group of bulls, the relationship between the DV of bulls in the heterosexual situation and DV of bulls competing for personal space was determined by simple correlation analysis (Steel and Torrie 1960).

RESULTS

In the mixed age group of bulls (Group 1), crowding occurred before bulls came into physical contact. The subordinate took avoidance action when a pair of bulls came within $1.5 \pm 1.3$ (SD) metres of one another. A subordinate bull that was slow to move out of the personal space of its dominant neighbour or failed to notice its approach was bunted. Subtle threats such as lowering of the head were sometimes observed but no head-to-head fighting occurred. Over the 1.5 hour period of observation, 89 different pairs or 75% of the pairs of bulls in group 1 had clearly resolved contests. The ratio of contests resolved by an avoidance to contests decided by a bunt was 2 to 1.

It was more difficult to stimulate the group 2 bulls to compete for personal space than the group 1 bulls. Over a 3 hour period of observation, 94 pairs or 70% of the pairs of bulls in the group had clearly resolved contests. Only when forced vigorously around the yard did these 2 year old bulls avoid or bunt one another. When left undisturbed they would stand in contact with one another without displaying agonistic behaviour.
Of the 89 pairs of bulls having clearly resolved contests in group 1, only 3 pairs (3.4%) had a reversed outcome in a repeat encounter. By contrast, 18 (19.1%) of the 94 pairs of 2 year old bulls having decisive contests had a reversed outcome in a repeat encounter. The difference between the two groups was highly significant ($\chi^2 = 11.2, p < 0.001$).

In both groups the DV that each bull displayed while competing for oestrous cows was highly correlated with its DV while competing for personal space in the confines of a yard ($r = 0.94$ and 0.96 for groups 1 and 2 respectively).

DISCUSSION

The term, stability of social order, has been frequently used in the literature on bovine behaviour but has never been defined. It is proposed that the stability of social order in a group of cattle be defined as the proportion of pairs of animals in the group having a reversed outcome in a repeat encounter. The greater stability of social order in group 1 than in group 2 may explain the greater ease with which competition between the group 1 bulls in the yard was stimulated.

Bulls in both groups showed greater social activity competing for personal space in yards than they did competing for oestrous cows at pasture. Despite this not every pair of bulls contested in the yard situation. However it is possible that the social order can be determined accurately without
every pair of bulls in the group contesting. Just how many pairs of bulls need to contest in various sized groups of bulls requires definition.

What can be concluded from this study is that bulls competing for personal space in yards have the same social ranking in their group as they have while competing for oestrous cows at pasture. This greatly simplifies the measurement of social order of groups of bulls in the heterosexual situation. Cows do not have to be ovariectomised or be induced to show oestrus. The observation period can be reduced by at least four fold. Furthermore contests between certain bulls can be more easily staged in the yard situation than in the heterosexual situation.
CHAPTER 2
MEASUREMENT OF SOCIAL RANKING

SECTION 3. Social Order of Bulls in Small Groups

INTRODUCTION

When beef bulls are mated in groups to herds of cows in southern Australia the size of the bull group is generally 8 or fewer. Bouissou (1965) determined the types of social dominance hierarchies existing in groups of 4 to 8 heifers. Of the 15 groups she studied, 7 had a linear hierarchy while the remainder had either a linear-tending or a complex social hierarchy. The occurrence of complex and linear-tending hierarchies in small groups of heifers means that each animal must encounter every other animal in the group to determine the social order of the group. Whether these types of hierarchies occur in small groups of beef bulls is unknown.

Using 14 groups of 5 to 8 bulls and forcing bulls within groups to compete for personal space, information on this point was gathered and is presented in this section.

MATERIALS AND METHODS

Three herds of beef bulls were used. Herd 2 consisted of 19 Hereford bulls 3 to 9 years of age which had been grazing together for at least one year. They were allotted at random to 3 groups, each of 6 or 7 animals. In herd 2 were 16 Hereford bulls, 3 to 6 years old and 16 Aberdeen Angus bulls, 2 to 5 years of age. All 32 bulls had been grazed together for at least 1 year. Within breeds bulls
were allotted to 2 mixed aged groups of 8. Then combining breeds the 32 bulls were allotted to 4 mixed age groups of 8 with 4 Hereford and 4 Angus bulls per group. Herd 3 comprised 17 Angus bulls, aged 20 to 33 months, which had been associated for 6 weeks. They were allotted at random to 3 groups of 5 or 6 bulls.

Each group of 5 to 8 bulls was confined to a circular yard, 10 m in diameter, and bulls forced to compete for personal space. The dominance-submission relationship between every pair of bulls in a group was determined by forcing bulls to avoid or bunt one another and recording the outcome of these encounters. On the basis of these relationships, bulls within groups were ranked in social order with all instances of bulls dominating others higher in the social order included.

RESULTS AND DISCUSSION

Of the 14 groups of 5 to 8 bulls, 6 had linear hierarchies, 6 linear-tending hierarchies and 2 had complex social hierarchies (Figure 1). This is in close agreement with the data of Bouissou (1965) for dairy heifers. She found that 7, 4 and 4 of the 15 groups of 4 to 8 heifers had linear, lineartending and complex social hierarchies, respectively.

Had all groups of bulls had linear hierarchies, the dominance-submission relationship between every pair in the group could have been determined by forcing specific pairs of
bulls to contest rather than all pairs of bulls. The occurrence of linear-tending and complex hierarchies in these small groups of bulls indicates that all pairs of bulls need to have encounters to determine the social order of the group. In a small yard this can be done rapidly and with minimal danger to a cautious observer.
FIG 1  Dominance order in groups of 5 to 8 bulls. Each circle or square represents a bull and the value within the bull number. Direction of the arrow indicates the dominance of one bull over another.
CHAPTER 2

MEASUREMENT OF SOCIAL RANKING

SECTION 4. Social Order of Bulls in Large Groups

INTRODUCTION

In their review of social behaviour of cattle Hafez et al (1969) stated that the social order of a group could only be determined if the dominance-submission relationship between every pair of animals in the group was known. In groups of 5 to 8 bulls this can be done rapidly by stimulating contests between bulls in a small yard (Chapter 2.3). The problem in staging contests between every pair of bulls in larger groups is that it is extremely time consuming. In 1.5 hours, 3 observers were able to stimulate clearly resolved contests between only 75% of the pairs of bulls in a group of 16 bulls with a stable social order (Chapter 2.2). An alternative approach to staging a contest between every pair of animals is to stimulate a certain proportion of pairs to contest and to determine the social order of the group from this sample.

This section describes a simulation study undertaken to assess the minimum proportion of pairs of bulls that need to contest in order to determine the social order in various sized groups.
MATERIALS AND METHODS

Experiment 1

Three hypothetical groups of 16, 32 and 48 bulls were formed. In each group bulls were ranked in a linear social order i.e. bull 1 dominates all bulls, bull 2 dominates all but 1, bull 3 dominates all but 1 and 2 and so on. Thus each bull had a stable dominance-submission relationship with every other bull in its group. These relationships were stored in the computer memory. On the basis of these relationships the dominance value of each bull in each group, the proportion of bulls dominated to bulls encountered, was computed. Since each bull encountered every other bull in its group this dominance value was termed DV 100%.

The next step was to use a sampling method to assess the minimum proportion of pairs of bulls needed to accurately determine the DV 100% of the bulls in each group. Using the computer, pairs of bulls in a group were selected at random until a certain proportion of all the pairs of bulls in the group had been selected. These selected pairs were termed a sample of the total number of pairs in the group. The proportion of total pairs in the sample expressed as a percentage was termed the sample size. In the group of 16 bulls, the sample sizes were 25%, 33.3%, 50% and 66.6%. In the groups of 32 and 48 bulls the sample sizes were 16.6%, 25%, 33.3%, 50% and 66.6%. Ten samples of each size were drawn from each group. The dominance value
of each bull in each sample was computed on the basis of the dominance-submission relationship of each pair of bulls in the sample. From a sample which comprised 50% of the pairs of bulls in the group the dominance value of each bull was termed DV 50%. For each sample from each group of bulls the correlation between the DV of each bull in the sample and DV 100% of each bull was determined using simple correlation analysis (Steel and Torrie 1960). From the 10 samples of each sample size in each group the mean correlation coefficient was determined. This was the parameter used to determine the accuracy of the sample size in measuring the social order of the group.

Experiment 2

Groups of cattle of 8 or more have a complex rather than a linear social order (Schein and Fohrman 1955; Bielhartz and Mylrea 1963; Bouissou 1965; Wagnon 1965; Wagnon et al 1966). In a complex social order some animals dominate others higher in the social order. The minimum sample size needed to determine the social order in a group may be higher in a complex hierarchy than in a linear social hierarchy. Thus the minimum sample size derived from the linear model in experiment 1 may be too small to accurately measure the social order of a group with a complex hierarchy. The aim of this
experiment was to determine the minimum sample size at which the social order in a linear or a complex hierarchy could be measured with a similarly high degree of accuracy.

The linear social hierarchy was represented by the hypothetical group of 16 bulls in experiment 1. The complex hierarchy was represented by a group of 16 bulls which were confined to a yard and forced to compete for personal space by 3 observers. Over a 3-hour period, 107 of the 120 pairs of bulls in the group had clearly resolved contests. The remaining 13 contests were simulated and decided on the basis of linearity. The dominance-submission relationships of all of the 120 pairs of bulls in the group were stored in the computer memory. The dominance value of each bull was computed on the basis of all these relationships and was termed DV 100%.

Using the computer, pairs of bulls in the group with the complex hierarchy were selected at random to make up sample sizes of 25%, 33.3%, 50% and 66.6%. Ten samples of each size were drawn. The dominance value of each bull in each sample was computed on the basis of the dominance-submission relationship of each pair of bulls in the sample. For each sample the correlation between the DV of each bull in the sample and the DV 100% of the bull was calculated using sample correlation analysis. From the 10 samples of each sample size the mean correlation coefficient between DV of bulls in each sample size and DV 100% was determined. The mean correlation coefficients of the 25% samples drawn
from the complex or linear hierarchical groups were compared as were the mean correlation coefficients of the 33.3%, 50% and 66.6% samples. The mean coefficients from the group of 16 bulls with the linear hierarchy were those determined in experiment 1. The statistical analysis used to compare means was the Student "t" test (Steel and Torrie 1960).

RESULTS AND DISCUSSION

In the two groups of 16 bulls, mean correlation coefficients were significantly higher in the linear hierarchical group than in the complex hierarchical group when the sample size was 25%, 33.3% or 50% (Table 3). Only when the sample size reached 66.6% was there no significant difference between the mean correlation coefficients of the two groups (Table 3). The mean correlation coefficient for the 66.6% samples of the linear group of 16 bulls was 0.96. The interpretation of these data was that when the mean correlation coefficient of samples drawn from a linear hierarchical group reached 0.96, samples of the same size drawn from a complex hierarchical group would not have a mean correlation coefficient significantly different from 0.96. On this basis the mean correlation coefficient indicating an accurate estimate of DV 100% was considered to be $0.96 \pm 0.01$ (SD). This degree of sampling accuracy was attained with the 50% and 33.3% samples of the 32 and 48 bull groups respectively (Table 3).
The 50% sample of a 32-bull group and the 33.3% sample of a 48-bull group are both equivalent to each bull in the group contesting with a mean 16 other bulls. Thus for bull groups between 32 and 48 in size, the social order can be determined accurately by stimulating each bull in the group to contest with an average of 16 other bulls.

Although each bull in a group had contests in every sample each bull did not have the same number of contests. The 48 bulls in the 33.3% samples had between 9 and 25 contests while the 32 and 16 bulls in the 50% and 66.6% samples respectively, had between 10 and 22, and between 7 and 14 contests, respectively. This variation in number of contests per bull reflects the real-life situation in which it is impractical to stimulate each bull in a group to contest with an equal number of different bulls.

CONCLUSION

It is concluded that the social order in large groups of beef bulls can be determined without the need to have every pair of bulls in the group contesting. The social order in groups of 16, 32 and 48 bulls can be determined accurately by stimulating encounters between 66.6%, 50% and 33.3% respectively of all the pairs of bulls in the group.
\[
\begin{array}{|c|c|c|c|c|c|}
\hline
\text{No. of bulls in group and type of social hierarchy} & \text{Proportion of pairs of bulls contesting as a \% of the total number of pairs in each group} \\
& 16.6 \% & 25 \% & 33.3 \% & 50 \% & 66.6 \% \\
\hline
16 & 0.80 & 0.88 & 0.94 & 0.96 \\
\pm 0.09 & \pm 0.05 & \pm 0.03 & \pm 0.01 \\
\text{in a linear hierarchy Experiment 1} & \\
16 & 0.73 & 0.82 & 0.90 & 0.95 \\
\pm 0.07 & \pm 0.05 & \pm 0.03 & \pm 0.02 \\
\text{in a complex hierarchy Experiment 2} & \\
32 & 0.86 & 0.90 & 0.94 & 0.97 & 0.99 \\
\pm 0.05 & \pm 0.05 & \pm 0.05 & \pm 0.01 & \pm 0.01 \\
\text{in a linear hierarchy Experiment 1} & \\
48 & 0.92 & 0.94 & 0.96 & 0.98 & 0.99 \\
\pm 0.03 & \pm 0.01 & \pm 0.01 & \pm 0 & \pm 0 \\
\text{in a linear hierarchy Experiment 1} & \\
\hline
\end{array}
\]
CHAPTER 3
INFLUENCE OF SOCIAL RANKING OF BULLS IN
A GROUP ON THEIR SEXUAL ACTIVITY

INTRODUCTION

When two bulls are mated at pasture to a group of cows the dominant bull achieves significantly more services than its subordinate (Sambraus 1971a; Warnick et al 1971). However these authors gave no data on the age of the bulls observed. Whether the social ranking of bulls in a group influences their sexual activity could depend on the age composition of the mating group. Bulls in a mixed age group ended the sexual encounters of animals subordinate to them more decisively and quickly than did dominant bulls in a 2 year-old group of bulls (Chapter 2.1).

In this chapter a study was made of the influence of social ranking in groups of different age composition on the sexual activity of beef bulls.

MATERIALS AND METHODS

Bulls

Group 1 consisted of 17 Angus bulls, 20 to 33 months of age, purchased from 9 different stud properties and grazed together for 6 weeks before observations were made.

Group 2 comprised 11 Angus bulls, aged 20 to 30 months, from 6 different studs and grazed together for 3 to 4 months prior to the experiment.
In group 3 were 8 bulls, 7 Angus and 1 Hereford, ranging from 3.5 to 5 years of age. These bulls had been grazed together as part of a large herd for at least a year. Only the bulls in group 3 had previously been mated to cows.

Group 4 comprised 12 bulls, 10 Hereford and 2 Angus, aged between 2.5 and 3.5 years. Each had been purchased 8 to 11 months prior to the observations and had had a 10 week mating period with cows. For the 4 month period between the end of mating and the experiment they were grazed together.

_Determination of social ranking_

In 3 separate herds, the bulls in group 1, groups 2 and 3 and group 4 were confined to a yard $20 \times 20$ m in area. Contests were stimulated by forcing bulls close to one another. Although groups 2 and 3 were placed together for convenience, only those contests between bulls within groups were noted. Actions such as an avoidance or a bunt which clearly indicated a dominance-submission relationship between a pair of bulls were recorded as were repeat encounters showing two outcomes between a pair of bulls. In the latter instance the value of unity was assigned to each pair and if each of the pair won a contest each would be credited with 0.5 wins. Seventy-eight per cent, 70% and 75% of the possible combinations of bulls in groups 1, 2 and 4 respectively and all the possible pairs of bulls in group 3, were observed contesting. The dominance value (DV) of
each bull in each group was determined as the proportion of bulls dominated to bulls with which contests were held (Bielhart and Mylrea 1963).

Observations on sexual activity

Each group of bulls was mated to oestrous cows in a small paddock and observations made of their sexual activity over a 1 or 2-day period. Details of the observation periods, size of observation paddocks and number of oestrous cows joined to each group of bulls are shown in Table 4. The method of oestrous induction was to administer 1 mg oestradiol benzoate to ovariectomised cows the day before observations were made. Only those cows which showed "standing" oestrus are included in Table 4. All cows and bulls were identified with large numbers sprayed on each side.

All mounts with or without service which brought the bull's chin in contact with a cow's back were recorded as was the identity of the bull and cow. It was assumed that had the bulls been wearing chin ball harnesses (Lang et al 1969) such mounts would have resulted in cows being marked i.e. detected in oestrus. A bull was considered to have served a cow when the mount culminated in a pelvic thrust and the observed withdrawal of a fully extended penis from the vagina.
Statistical analysis

For each group of bulls the relationships between DV of bull and
(i) number of mounts achieved by each bull,
(ii) number of cows mounted,
(iii) number of services achieved, and
(iv) number of cows served by each bull,
was determined by simple correlation analysis (Steel and Torrie 1960).

RESULTS

Of the pairs of bulls contesting in groups 1, 2, 3 and 4, 19.1%, 21.0%, 0% and 6.0% respectively had a reversed outcome in a repeat encounter. The difference between groups 1 and 2, the 2 year old bulls, and groups 3 and 4, the mixed age groups, in stability of social order, was highly significant ($\chi^2 = 12.4, p < 0.001$).

The social ranking that a 2 year old bull held in its group had no significant influence on the number of cows it mounted or served or on the number of mounts or services it achieved (Groups 1 and 2 - Table 5). In marked contrast the social ranking of bulls in the mixed age groups (Groups 3 and 4) was significantly correlated with all four measures of sexual activity (Table 5). The inhibitory effect of social dominance was so marked in group 3 that only the two bulls highest in rank order served cows.
DISCUSSION

In the two mixed age groups of bulls studied here, social ranking significantly influenced the sexual activity of bulls. In the other groups of mixed age bulls observed, only the bulls ranked first or second in the social order served cows (Schloeth 1961; Charlton 1969). From these data one would expect a higher proportion of calves to be sired by the high ranking bulls in a mixed age group than by the bulls of lower social ranking. Such a disproportion was strikingly evident in the proportion of calves sired by each bull in two South African herds (Osterhoff 1966). Five mixed age bulls were used in herd 1 and 4 mixed age bulls in herd 2. The sire of each calf born was determined by blood typing. In each of the herds 1 and 2, two of the bulls sired 69.8% and 87.1% respectively of the calves born. Whether these two bulls in each herd were ranked high in the social order is unknown for no observations of bulls during mating were made.

CONCLUSION

It is concluded that social ranking significantly influences the sexual activity of bulls in mixed age groups but not the sexual activity of 2 year old bulls in groups with an unstable social order.
<table>
<thead>
<tr>
<th>Group of bulls</th>
<th>Period of observation (hours)</th>
<th>No. of bulls</th>
<th>No. of oestrous heifers</th>
<th>Size of observation paddock (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>17</td>
<td>31</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>11</td>
<td>20</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>8</td>
<td>14</td>
<td>0.7</td>
</tr>
<tr>
<td>4</td>
<td>Period 1 - Two consecutive 13-hr days</td>
<td>12</td>
<td>30 on day 1, 17 on day 2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Period 2 - Two consecutive 13-hr days</td>
<td>12</td>
<td>28 on day 1, 17 on day 2</td>
<td>2</td>
</tr>
</tbody>
</table>
TABLE 5
Relationship between Dominance Value (DV) of Bulls in their Mating Group and their Sexual Activity

<table>
<thead>
<tr>
<th>Group of Bulls</th>
<th>Correlation coefficient between DV and</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of mounts</td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>0.80*</td>
</tr>
<tr>
<td>4 Period 1</td>
<td>0.60*</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.64*</td>
</tr>
</tbody>
</table>

* p <0.05
CHAPTER 4
EFFECT OF AGE, SENIORITY, BODYWEIGHT AND BREED OF BULL ON SOCIAL RANKING

INTRODUCTION

Osterhoff (1966) found that in each of two herds a disproportionately high number of calves were sired by 2 of the 4 or 5 bulls in each mating group. Data presented in the previous chapter suggested that this disproportionate reproductive performance of bulls could be due to the effect of social ranking on the serving activity of bulls. Further data (D.R. Osterhoff, personal communication 1972) lends some support to this suggestion. For another 4 years the calves born from the herd 2 cows which were joined to 3 or 4 bulls each year, were allocated to the correct sire by blood typing. The percentages of calves sired by each bull in all 5 years and the ages of the bulls are given in Table 6. In each of the five years, the oldest or second oldest bull sired more than 60% of the calves, while the youngest bull sired 15% or fewer. Although it is known in dairy cows that age of cow has a significant influence on social ranking (Schein and Fohrman 1955; Guhl and Atkeson 1959; Brantas 1968), there is no published data on this relationship in bulls. Such data are needed to elucidate the role of social ranking on the reproductive performance of Osterhoff's bulls.

Confounded with age are two other factors, body-weight and seniority, defined as the length of time in the herd. As a bull becomes older both its bodyweight and its
seniority increase. With young bulls entering the bull herd at 1 to 3 years of age and at different bodyweights, any one of these three could be the major factor establishing and maintaining the social order.

When Hereford bulls were mated with other breeds of bulls to groups of Hereford cows, the Hereford-sired significantly more calves than the bulls of the other breeds (Ittner et al. 1954; Donaldson 1962). The latter author believed that this was due to the influence of social ranking on sexual activity.

This chapter describes a study of the effects of age, bodyweight, seniority and breed in maintaining the social ranking of bulls.

MATERIALS AND METHODS

Experiment 1

Herd 1 comprised 50 Hereford bulls which varied in age from 2.5 to 9 years (mean 4 ± 1 (SD) year). Their length of time in the herd (seniority) varied from 8 to 49 months (mean 2 ± 1 (SD) years). On the day before the observations each bull was weighed (mean 768 ± 85 (SD) kg). All 50 bulls were confined to a yard 20 m x 40 m in area and forced to compete for personal space until 35% of the possible combinations of bulls had been observed contesting.
Herd 2 consisted of 26 Aberdeen Angus bulls varying in age from 2 to 5.5 years (mean 3 ± 1 (SD) years). Their length of time in the herd (seniority) varied from 2.5 to 50 months (mean 1.5 ± 1 (SD) years). The 26 bulls were confined to a yard 20 m x 20 m in area and forced to contest with one another until 53% of the possible pairs of bulls had had decisive contests.

In each herd contests which clearly showed a dominance-submission relationship between a pair of bulls were recorded. The dominance value of each bull in each herd was determined as the proportion of bulls dominated to bulls encountered (Bielhartz and Mylrea 1963).

For the 50 bulls in herd 1, the simple correlation coefficients between the four variables, dominance value, age, seniority and bodyweight were computed. Then the partial correlation coefficients between dominance value and age, dominance value and seniority, and dominance value and bodyweight after eliminating the effects of the other two variables, were computed using the statistical technique described by Snedecor and Cochrane (1967). For the 26 bulls of herd 2, the simple correlation coefficients between the 3 variables, dominance value, age and seniority were determined. The partial correlation coefficients between
dominance value and age, and dominance value and seniority after eliminating the effect of the other variable, were then computed.

Experiment 2

The effect of breed on social ranking of bulls was studied by confining 16 Hereford bulls with a mean age of $47.0 \pm 12$ (SD) months and mean seniority of $27.0 \pm 12$ (SD) months, and 16 Angus bulls, mean age of $41.0 \pm 12$ (SD) months and mean seniority $24.0 \pm 14$ (SD) months, to a yard $20 \text{ m} \times 20 \text{ m}$ in area and forcing them to contest with one another until 33% of the possible pairs of bulls had had clearly resolved contests. The dominance value of each bull was determined. All 32 bulls had been grazing together for at least 11 months. They were weighed the day before observations were made.

RESULTS

Experiment 1

In herds 1 and 2, both age and seniority of bulls were significantly correlated with their social ranking as was bodyweight in herd 1 (Table 7). However in herd 1, age, seniority and bodyweight were highly correlated with one another as were age and seniority in herd 2 (Table 7). After the confounding effects of these variables on social ranking were eliminated by partial correlation analysis, only seniority had a significant influence on the social ranking
of bulls in each herd (Table 8). The importance of seniority is emphasised by the fact that those bulls newly introduced to herds 1 and 2 lost 92% and 98% respectively of their encounters with bulls introduced to the herd a year before them.

Experiment 2

The groups of Hereford and Angus bulls were not significantly different in seniority (27.0 ± 12 (SD) months and 24.0 ± 14 months respectively, t₃₀ = 0.63). The Hereford bulls were significantly heavier than the Angus bulls (800 ± 79 (SD) kg compared to 612 ± 79 (SD) kg, t₃₀ = 6.5, p <0.001). In general the Hereford bulls dominated the Angus bulls. Specifically, Hereford bulls that had been in the herd for 1, 2, 3 or 4 years won 84.6, 88.9, 96.3 and 95.2% respectively of the contests with Angus bulls of any seniority. Angus bulls of high seniority fared no better against the Herefords than their breed mates of low seniority.

DISCUSSION

Both Schein and Fohrman (1955) and Guhl and Atkeson (1959) found in dairy cows that age, seniority and bodyweight were highly correlated with social ranking. However neither of them separated the effects of these factors on social ranking. The present study clearly demonstrates that, within a breed, it is the seniority of a bull that maintains its social ranking.
The finding in experiment 1 that age and seniority were highly correlated and that both significantly influence the social ranking of bulls strongly supports the suggestion that the disproportionate reproductive performance of mixed age bulls of Osterhoff (Table 6) was due to the influence of social ranking on their serving activity.

There are two possible explanations for the social superiority of Hereford over Angus bulls. They were heavier than the Angus bulls and they had horns while the Angus bulls did not. Both bodyweight and the presence of horns are of major importance in establishing social ranking in cattle (Bouissou 1972). Since Herefords are significantly heavier than Brahmans of the same age (Ittner et al 1954) it is considered that the disproportionately higher reproductive performance of Hereford bulls mated to cows with Brahman bulls (Ittner et al 1954; Donaldson 1962) is due in part to their social superiority over Brahman bulls.
TABLE 6
Reproductive Performance of 3 or 4 Bulls Joined to a Group of Cows over a 5-year Period

<table>
<thead>
<tr>
<th>Bulls used</th>
<th>Percentage of calves sired by each bull</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oubaas</td>
<td>70.4+ (10)</td>
</tr>
<tr>
<td>Matie</td>
<td>16.7 (4)</td>
</tr>
<tr>
<td>Morena</td>
<td>7.4 (3)</td>
</tr>
<tr>
<td>Slinger</td>
<td>5.5 (2)</td>
</tr>
</tbody>
</table>

* Bulls absent from the herd
+ Age of bull in years
TABLE 7  
Correlation Coefficients between Age, Seniority,  
Bodyweight and Dominance Value of Bulls  
in Herds 1 and 2

<table>
<thead>
<tr>
<th>Herd</th>
<th>Variables</th>
<th>Dominance value</th>
<th>Age</th>
<th>Seniority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age</td>
<td>0.63***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seniority</td>
<td>0.74***</td>
<td>0.77***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bodyweight</td>
<td>0.55***</td>
<td>0.55***</td>
<td>0.66***</td>
</tr>
<tr>
<td>2</td>
<td>Age</td>
<td>0.85***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seniority</td>
<td>0.87***</td>
<td>0.92***</td>
<td></td>
</tr>
</tbody>
</table>

*** p < 0.001
TABLE 8
Some Partial Correlation Coefficients between Dominance Value (DV), Age (A), Seniority (S) and Bodyweight (BW) in Herd 1 and between DV, A and S in Herd 2

<table>
<thead>
<tr>
<th>Herd</th>
<th>DV with A</th>
<th>DV with S</th>
<th>DV with BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.14</td>
<td>0.47***</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>0.23</td>
<td>0.46*</td>
<td>-</td>
</tr>
</tbody>
</table>

* p < 0.05
*** p < 0.001
CHAPTER 5
SEXUAL BEHAVIOUR OF BULLS AT PASTURE
- A REVIEW

The role of a bull when joined to a group of cows at pasture is to identify each cow when it becomes sexually receptive and to serve it as many times as is necessary to impregnate it. The following review describes the behaviour of bulls in fulfilling this role. It considers how efficiently bulls accomplish their task and reviews the methods of predicting this efficiency prior to mating.

Behaviour in detecting oestrous cows

Bulls use both olfaction and vision to detect cows which are sexually receptive. The bull sniffs the vulva of any cow it meets in passing. Non-oestrous cows are abandoned (Sambraus 1971b). Oestrous cows attract the attention of bulls by displaying such visual cues as mounting, being mounted or a posture involving arching of the back and elevation of the tail (Sambraus 1971b). This posture occurs during urination and also after service (Hammond 1927; Heinemann 1958; Wohanka 1962). Once attracted to a cow, the bull sniffs the vulva to determine whether the cow is in oestrus.

The relative importance of the bull's olfaction and vision in initially detecting cows in oestrus appears to depend on the incidence of visual cues. In two herds of less than 15 cows no mounting by cows occurred (Schloeth 1961; Rollinson 1963). On days when herds of 13 to 49 cows
had no cows in oestrus, no mounting by cows was observed (Wohanka 1962; Sambraus 1971b). On these days bulls sniffed the vulvae of 95% of cows in the herds (Sambraus 1968). On days when 1 or 2 cows were in oestrus a significantly fewer proportion of cows, 73%, were inspected for oestrus in this way. When several cows are in oestrus they form, along with pro-oestrous cows, an easily identifiable group (Wohanka 1962; Williamson et al 1972). This group, the sexually active group, continually moves about the paddock with its members active in smelling vulvae, chin resting and in mounting. In four herds of 62 to 124 cows, bulls appeared to detect oestrous cows by seeing mounting cows within the sexually active group rather than by olfaction (Mattner et al 1974). The relevance of the sexually active group to oestrous detection by bulls needs definition.

**Courtship behaviour**

Once the bull has detected an oestrous cow it induces it to stand quietly for service. The bull stands close behind an attractive cow licking and sniffing it around the vulva or other parts of the hindquarters (Sambraus 1971b). During this courtship behaviour the bull tests the tolerance of the cow to mounting by a) resting its chin on the cow's back and/or b) signalling its intention to mount (Sambraus 1971b). The latter varies in intensity from a sudden lifting of the head without body movement to the bull pressing its head and neck against the cow's hindquarters whilst shifting its
weight to its own hindquarters. Non-receptive cows respond to chin resting or the intention to mount by moving away quickly whilst a receptive animal stands quietly. In the latter case mounting attempts follow (Sambraus 1971b).

**Serving behaviour**

Sambraus (1971b) has classified this behaviour into the mount without service and the mount with service. Any attempted mount in which the bull lifts the forequarters high enough off the ground to clasp the cow's back between the legs is termed a mount. Mounting from the back and clasping brings the tip of the erect and protruding penis near the vaginal orifice. The bull makes a series of pelvic oscillations called seeking movements which, in a mount with service, culminate in the tip of the penis reaching and penetrating the vaginal orifice (Hultnas 1959). Two events then occur simultaneously. There is a sudden lengthening of the penis with the straightening of the sigmoid flexure (Bonnadonna 1956). The latter brings the bull's pelvic region into direct apposition with the cow's perineum and maximum intromission leading to ejaculation is achieved (Hafez et al 1969). Spinal deviation of the penis after intromission occurs in 50% of normal bulls (Seidel and Foote 1967).

**Cow's influence on male sexual behaviour**

The sexual activity of cows strongly influences the type of sexual behaviour displayed by bulls. When no cows
are in pro-oestrus or oestrus, bulls engage in only vulval sniffing (Sambraus 1971b). This is heavily concentrated in the few hours after dawn (Rollinson 1963; Sambraus 1968). When there is a pro-oestrous cow in the herd, the bull follows it closely, courting it and attempting to mount (Rollinson 1963; Sambraus 1971b). The bull mounts the cow in late pro-oestrous many times but never serves it for the cow will not stand quietly (Rollinson 1963). Even during oestrus the cow varies markedly in its willingness to stand to be mounted. This desire is low early in oestrus and rises to a peak in mid-oestrus (Sambraus 1971b). Bulls mounted cows in early oestrus a mean of 6.0 times prior to the first service compared to 2.8, 1.9 and 1.0 times before the second, third and fourth services respectively (Sambraus 1971b). For a period after each service the cow will not stand to be mounted (Wohanka 1962; Sambraus 1968). During this period the sexually active bull restores the cow's willingness to permit service by vulval sniffing, courtship activity and mounting in that strict order (Sambraus 1971b).

Oestrous cows have both a passive and active role in determining the serving activity of bulls. Some cows will permit a bull to serve them only once; others will willingly stand for more than 10 services (Rollinson 1963; Sambraus 1971b). As the number of cows in oestrus in a day increases from 1 to 4, the daily serving activity of the bull increases correspondingly (James 1952; Sumner et al 1968).
In their active role, oestrous cows seek the company of the bull (Wohanka 1962; de Alba and Asdell 1946) and at the height of oestrus, mount the bull as well as oestrous and non-oestrous cows (Sambraus 1969; 1971b). About 60% of their mounting activity is directed at bulls. The latter would explain why serving activity during the day closely follows the mounting activity of oestrous cows (Sambraus 1969; 1971b).

Efficiency of bulls in detecting oestrous cows

One factor that is known to influence the efficiency of bulls in oestrous detection is the cow : bull ratio. At the ratio of 24 to 30 cows per bull, groups of bulls mounted 95% to 100% of oestrous cows (Donaldson 1968; Beerwinkle 1974; Mattner et al 1974). In the study of Beerwinkle (1974), the bulls were not observed continuously. Each was fitted with a chin ball harness (Lang et al 1968). This device operates on the principle that during mounting the bull invariably rubs its chin along the back, sides and rump of an oestrous cow. A bull with a marking device on its chin leaves clear streaks on the cow (Lang et al 1968). Two other groups of Beerwinkle’s bulls were joined at the rates of 60 or 100 cows per bull. These bulls marked 64% and 51% respectively of the oestrous cows. In the study of Mattner et al (1974) those bulls each joined with 62 cows mounted only 66% of cows displaying oestrus. The close agreement between the data of Beerwinkle (1974) and Mattner et al (1974) confirms the view of Lang et al (1968)
that a cow mounted by a bull fitted with a chin ball harness is invariably marked.

At the cow : bull ratios of up to 30 : 1 there was little variation in the efficiency of bulls in detecting oestrous cows (Donaldson 1968; Beerwinkle 1974; Mattner et al 1974). At higher cow : bull ratios there may be greater variation between groups of bulls in the efficiency of oestrous detection.

**Efficiency of bulls in serving oestrous cows**

Although each of the oestrous cows joined at the ratio of 30 cows per bull was mounted by a bull, not all cows were served (Mattner et al 1974). This is because bulls during pasture mating mount oestrous cows many more times than they serve them (Rollinson 1963; Sambraus 1971b; Mattner et al 1974).

The efficiency of a bull in serving oestrous cows may be measured as the proportion of the oestrous cows in its herd it serves at least once. Furthermore it is probable that the higher the proportion of oestrous cows a bull can serve twice or more, the higher the conception rate of the cows with which it is joined. Increasing the number of inseminations to cows in the 28-hour period after onset of oestrus does increase their conception rate. The pregnancy rates of cows inseminated once or twice were 58.5% and 75.6%, respectively (Jondet 1955). In another experiment 1621 cows were inseminated 1, 2 or 3 times in the
period 6 to 28 hours after the onset of oestrus (Ivankov 1959). Conception rates increased significantly with each additional insemination from 60% to 72% to 80%. It seems logical that the more services a group of bulls can achieve during pasture mating, the more oestrous cows they can serve at least once and the higher the proportion of these cows they serve twice or more. For this to be true bulls would need to distribute their services equally to all oestrous cows. Information on this point is confined to single bulls with only 1 cow in oestrus. One bull studied by James (1952) served each of 10 cows 5.0 ± 2 (SD) / times; a bull observed by Sambraus (1971b) served 7 cows, in oestrus on different days, 4, 5 or 6 times each. The other bull in James' (1952) study varied markedly in the number of times it served 7 cows, 7.0 ± 6 (SD).

When two, three or four cows are in oestrus on the same day the number of services a bull achieves in a day increases correspondingly (James 1952; Sumner et al 1968). Whether these services were equally distributed to all oestrous cows was not stated. Bulls do give undivided attention to one oestrous cow while ignoring other oestrous cows in the immediate vicinity (Wohanka 1962; Bartlett 1967; Mattner et al 1974). However Wohanka (1962) and Sumner et al (1968) found that after serving a cow several times the bull turns its whole attention to another oestrous cow particularly one more recently in oestrus. Quantitative data on whether bulls with one or more oestrous cows
distribute their services equally are needed.

Tests to predict the efficiency of bulls in pasture mating

No method with the expressed aim of predicting the efficiency of bulls in pasture mating has yet been devised. To date only tests to determine whether a bull is capable of normal service have been used. The method used by Hultnas (1959) was to allow a bull to serve an artificial vagina three times and after a five minute rest, allow it access to a non-oestrous restrained cow. The period of exposure was not stated. Some 95% of 1,987 bulls served the cow. Whether the 5% of bulls not serving failed to serve during pasture mating was not stated. Osborne et al (1971) and then Chenoweth (1974) modified this method to make it suitable for testing unhandled beef bulls. They allowed a bull access to a yard with oestrous standing cow for 5 minutes. For bulls with no previous mating experience this period of exposure was too short. Only 54% of 39 virgin bulls exposed to an oestrous cow achieved a service. The behaviour of bulls mounting but not serving suggested that these bulls would have completed service given more time (Osborne et al 1971). Even for bulls with mating experience this 5 minute test was too short to determine whether a bull is able to serve normally. Chenoweth (unpublished data) joined 13 bulls, which had failed to serve in the 5 minute test, to 25 to 30 cows each in a
pasture mating. Only two bulls failed to impregnate any of their cows. The remainder impregnated 56.8 ± 12 (SD) % of cows joined to them.

Bulls achieving a service in the 5 minute test of Chenoweth (1974) vary markedly in their efficiency during pasture mating. Chenoweth (unpublished data) joined 15 bulls which had served a cow during the test to 25 to 30 cows each. These bulls impregnated 42 to 97% of their cows (73 ± 18 (SD) %). All bulls voided good quality semen at both pre- and post-mating examinations. The wide variation in pregnancy rate may have been due to variation between bulls in the number of services achieved during the 3-month mating period. The 5 minute test was too short to reflect these differences between bulls.

Bulls able to serve vary markedly in the number of services they are able to achieve per unit time. Forty-seven bulls allowed to serve an artificial vagina at will completed between 3 and 36 services in an hour (Almquist and Hale 1956). Tested under similar conditions the 10 bulls of Wierzbowski (1966) completed between 6 and 41 services in 105 minutes. Further work is needed on the relationships between a bull's performance in such test situations and its efficiency during pasture mating.
CHAPTER 6
MEASUREMENT OF THE SEXUAL EFFICIENCY OF BULLS DURING PASTURE MATING

INTRODUCTION

It was considered in the review (Chapter 5) that the sexual efficiency of a bull during pasture mating should be measured as the proportion of the oestrous cows in its herd it serves at least once. This is a valid parameter of sexual efficiency but it does present practical difficulties in its measurement. An alternative method of assessing the sexual efficiency of a bull during pasture mating is to determine the number of services it achieves during the mating period. This is termed its serving capacity. For serving capacity to be highly correlated to the proportion of oestrous cows served, bulls must distribute their services equally to oestrous cows. Whether they do or do not is unknown.

The aim of this study was to determine the relationship between the serving capacity of bulls and the proportion of oestrous cows they serve.

MATERIALS AND METHODS

Cows

During March-April 1973, 53 Hereford heifers aged 19 to 22 months were ovariectomised via a flank incision. During July, the spayed heifers were induced to show oestrus by an intramuscular injection of 0.75 mg oestradiol benzoate in 2 ml peanut oil. The injection was given 16.5 to 18.5 hours
before the start of observations the following morning. Heifers were individually identified with large numbers sprayed on each side.

Bulls

Four herds of bulls were used in the experiment. Herds 1 and 2 comprised 18, two to 3 year old Aberdeen Angus bulls and 30, two to 3 year old Hereford bulls respectively with no previous mating experience. On 5th July 1973, these bulls were run as one group of 48 with 52 oestrous ovarietomised heifers for 8 hours to give them mating experience.

Herd 3 consisted of 18, two to 3 year old bulls, 9 of which came from Herd 1. Two three year old bulls had been used the previous year for pasture mating whilst the remaining 7 had no mating experience prior to their use in the experiment.

Herd 4 comprised 9, four to 5 year old Angus bulls with mating experience over at least two mating seasons. Bulls were individually identified with large numbers sprayed on each side.

Conduct of Experiment

On the days of observation each herd of bulls was placed with oestrous heifers at the ratio of 6 bulls to about 10 heifers in a 2 ha paddock. The number of oestrous
heifers joined to each herd of bulls, the dates of observation and the length of observation periods are shown in Table 9.

Observations recorded

Two or three observers kept the herds under constant surveillance for 7.5 hours. The recording sheet maintained by a non-observing recorder consisted of the heifers' numbers listed vertically and the time divided into ¼ hour periods listed horizontally. Each time a heifer stood while being mounted by another heifer it was recorded St in the appropriate time slot of that heifer's column. Each time a bull mounted a heifer without service or with service it was recorded St (number of bull) or S (number of bull) respectively, in the particular heifer's column. The definitions mounts without or with service as described by Sambraus (1971b) were used in this study.

Analysis of data

The length of oestrus for each heifer was defined as the interval between the first and last time a heifer was observed standing while being mounted by another heifer. The mean oestrus length (and standard deviation) was determined for each group of heifers.

Serving capacity was defined as the number of mounts with service a bull completed during the 7.5-hour observation period. Within herds and with all herds pooled the
relationship between the individual serving capacity of bulls and the number of heifers each bull served was determined by simple correlation analysis.

Within herds bulls were ranked in descending order of serving capacity. The upper, middle and lower one thirds of each herd were termed the high, medium or low serving capacity groups respectively. For each group within each herd the following information was obtained:

(i) the numbers of oestrous heifers mounted or not mounted by the group of bulls,
(ii) the numbers of oestrous heifers served 0, 1 or 2 + times by the group of bulls (for herd 4, numbers of heifers served 0 or 1 + times by group of bulls).

Within each herd the influence of serving capacity group on (i) and (ii) was determined by chi-square analysis of 3 x 2 or 3 x 3 contingency tables (Cochran 1954).

For another analysis, the mean serving capacity of bulls in each of the 12 groups was calculated. Groups of bulls were ranked in descending order of mean serving capacity. For each group of bulls the following was determined:

(a) percentage of oestrous heifers mounted by the group of bulls
(b) percentage of oestrous heifers served by the group of bulls
(c) percentage of oestrous heifers served two or more times by the group of bulls.

The relationship between the mean serving capacity of a group
of bulls and (a), (b) or (c) was determined by simple correlation analysis.

RESULTS

Oestrous heifers joined to bull herds 1, 2, 3 and 4 for 7.5 hours showed standing oestrus for 6.1 ± 1.6, 6.0 ± 1.4, 6.7 ± 1.3 and 6.9 ± 1.2 hours respectively.

The serving capacity of bulls in herds 1, 2, 3 and 4 is shown in Table 10. In each herd there was a large variation between bulls in the number of services they achieved.

In all 4 herds bulls distributed their services equally to those oestrous heifers they served. In herds 1, 2, 3 and 4, the correlation coefficients between the number of heifers that each bull served and the number of services that each bull achieved were 0.97, 0.99, 0.94 and 0.99 respectively. Figure 2 with the data from all herds pooled shows that whatever its serving capacity a bull rarely served the same heifer twice.

In each of the four herds, groups of bulls of high, medium or low serving capacity differed significantly in the proportion of oestrous heifers in the herd that they mounted and the proportion of oestrous heifers that they served 0, 1 or 2 more times (Table 11).

Table 12 shows the mean serving capacity of each of the 12 serving capacity groups and the percentages of oestrous heifers mounted, served and served 2 + times by the
bulls of each group. As the serving capacity of bull groups declined, the proportion of oestrous heifers mounted decreased significantly \((r = 0.80, p < 0.001)\), the proportion of oestrous heifers served decreased significantly \((r = 0.94, p < 0.001)\) and the proportion of oestrous heifers served 2 or more times decreased significantly \((r = 0.98, p < 0.001)\).

**DISCUSSION**

Whatever its serving capacity each bull distributed its services equally to those oestrous heifers it served. Furthermore after a bull had served a heifer it rarely served the same heifer again. This efficient distribution of services by bulls ensured that as the serving capacity of a group of bulls increased, the proportion of the oestrous heifers served at least once increased \((r = 0.94)\). An oestrous heifer after being served by one bull might receive further services from other bulls in the group. Again the higher the serving capacity of the bulls in the group the higher the proportion of oestrous heifers served twice or more \((r = 0.98)\). These data clearly demonstrate that the serving capacity of a group of bulls is an accurate measure of their sexual efficiency during pasture mating.

Furthermore these data strongly suggest that the serving capacity of bulls influences the conception rate of cows to which they are joined. An oestrous cow that is not served will not conceive and cows inseminated two or more
times during oestrus have a higher conception rate than cows inseminated only once (75.6% cf 58.5%, Jondet 1955; 75.9% cf 59.8%, Ivankov 1959). The wide variation between bulls in their serving capacity further emphasises the importance of determining whether serving capacity influences the conception rate of cows during pasture mating.

Even though heifers were in oestrus for a mean of only 6 to 7 hours, groups of low to moderate serving capacity bulls were able to detect 40 to 80% of them in oestrus. Had these bulls been with heifers for the length of oestrus experienced by entire heifers (14.3 ± 5.1 (SD) hours, Donaldson et al 1968) few oestrous heifers would have remained undetected. However heifers inseminated during oestrus have a significantly higher conception rate than heifers inseminated after the end of oestrus (64% cf 42%, Laster et al 1972). In artificial insemination programmes in beef cattle, sterilised bulls fitted with chinball harnesses (Lang et al 1968) are often used and heifers inspected for marks two or three times daily (Beerwinkle 1974). The present study indicates that the higher the serving capacity of the teasers the higher the proportion of cows that are mounted in their first 7 hours of oestrus. These data suggest that the use of high serving capacity bulls as heat detectors may increase the conception rate of inseminated heifers.
<table>
<thead>
<tr>
<th>Herd</th>
<th>No. of Bulls</th>
<th>No. of oestrous heifers</th>
<th>Period of observation</th>
<th>Date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18</td>
<td>31</td>
<td>0845-1615 hr (7.5 hr)</td>
<td>12 July</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>52</td>
<td>0900-1630 hr (7.5 hr)</td>
<td>20 July</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>30</td>
<td>0900-1630 hr (7.5 hr)</td>
<td>27 July</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>15</td>
<td>0900-1630 hr (7.5 hr)</td>
<td>27 July</td>
</tr>
</tbody>
</table>
TABLE 10
Serving Capacity of Bulls in Four Herds

<table>
<thead>
<tr>
<th>No. of bulls completing</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>2</td>
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<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

(     )* No. of services achieved by each bull with a serving capacity of 8 or more
<table>
<thead>
<tr>
<th>Herd 1</th>
<th>Herd 2</th>
<th>Herd 3</th>
<th>Herd 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Med</td>
<td>Low</td>
</tr>
<tr>
<td>Mean SC</td>
<td>10.5</td>
<td>4.3</td>
<td>0.7</td>
</tr>
<tr>
<td>±SD</td>
<td>±5.3</td>
<td>±0.8</td>
<td>±0.8</td>
</tr>
<tr>
<td>No. of bulls</td>
<td>(6)</td>
<td>(6)</td>
<td>(6)</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(3)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

**No. of oestrous heifers**

- mounted
  - (23)† | 30 | 24 | 16
  - (7)†  | 1  | 7  | 15
  - joined to herd | 31 | 31 | 31
  - \( \chi^2 = 17.0, P < 0.001 \)

- not mounted
  - (23)† | 47 | 42 | 37
  - (10)  | 5  | 10 | 15
  - joined to herd | 52 | 52 | 52
  - \( \chi^2 = 6.0, P < 0.05 \)

- served 0 times
  - (15)† | 6  | 12 | 27
  - (9)†  | 11 | 13 | 4
  - (7)†  | 14 | 6  | 0
  - joined to herd | 31 | 31 | 31
  - \( \chi^2 = 35.2, P < 0.001 \)

- served 1 time
  - (31)  | 17 | 30 | 46
  - (13)  | 16 | 17 | 6
  - (8)   | 19 | 5  | 0
  - joined to herd | 52 | 52 | 52
  - \( \chi^2 = 43.5, P < 0.001 \)

- served 2+ times
  - (31)  | 11 | 20 | 29
  - (13)  | 12 | 7  | 1
  - (8)   | 7  | 3  | 0
  - joined to herd | 30 | 30 | 30
  - \( \chi^2 = 24.6, P < 0.001 \)

- served 4+ times
  - (31)  | 5  | 11 | 15
  - (13)  | 10 | 4  | 0
  - (8)   | 7  | 3  | 0
  - joined to herd | 15 | 15 | 15
  - \( \chi^2 = 15.7, P < 0.001 \)

(†) Figures in brackets are expected numbers of oestrous heifers mounted or served 0, 1 or 2+ times.
<table>
<thead>
<tr>
<th>Herd</th>
<th>Serving capacity group</th>
<th>Mean serving capacity</th>
<th>% of oestrous heifers mounted by bulls in group</th>
<th>% of oestrous heifers served by bulls in group</th>
<th>% of oestrous heifers served 2+ times by bulls in group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>10.5</td>
<td>97</td>
<td>81</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>6.9</td>
<td>90</td>
<td>68</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>5.2</td>
<td>97</td>
<td>63</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>5.0</td>
<td>93</td>
<td>67</td>
<td>27</td>
</tr>
<tr>
<td>1</td>
<td>Moderate</td>
<td>4.3</td>
<td>78</td>
<td>61</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>2.8</td>
<td>81</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>2.3</td>
<td>80</td>
<td>33</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Moderate</td>
<td>1.3</td>
<td>53</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Low</td>
<td>0.7</td>
<td>52</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>0.6</td>
<td>71</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>0.2</td>
<td>70</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Low</td>
<td>0</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
FIG 2 Relationship between total number of services & number of heifers served by each bull

\[ y = 0.8x + 0.33 \]

\[ r = 0.96 \]
CHAPTER 7
INFLUENCE OF SERVING CAPACITY OF BULLS AND AGE COMPOSITION OF MATING GROUP ON HERD FERTILITY.

INTRODUCTION

Serving capacity of a group of bulls was highly correlated with the proportion of oestrous heifers that bulls served at least once and the proportion of oestrous heifers that they served twice or more (Chapter 6). These data strongly suggest that the serving capacity of bulls influences the conception rate of cows during pasture mating.

In small herds of cows mated to a mixed-age group of bulls only the bulls ranked first or second in social order served oestrous cows (Schloeth 1961; Charlton 1969; Chapter 3). In such groups, age of bull strongly determines its social ranking (Chapter 4). In groups of 2 year old bulls no established social order exists (Chapter 3). Within these groups the lower ranking bulls served as many oestrous heifers as the higher ranking bulls (Chapter 3). In pasture mating, young bulls may be mated to cows either in a group of older bulls or in a group of bulls of their own age (Dickson 1966). In the latter situation social dominance is not likely to reduce the serving capacity of any bull in the group. Mated in a mixed-age group however young bulls could have their serving capacity depressed. This may depress herd fertility by reducing the serving capacity of the mating group.
The hypotheses that serving capacity and age composition of the mating group of bulls significantly influence herd fertility were tested in this chapter.

MATERIALS AND METHODS

Selection of bulls

The aim was to form four mating groups of bulls, two of which consisted of high serving capacity animals and two of which comprised bulls of medium serving capacity. One high and one medium serving capacity group was to consist of three young bulls, 2 to 3 years of age whilst each of the remaining groups was to be of a mixed-age composition, a 5 year old and two, 2 to 3 year old bulls. These mating groups were termed the high-young (HY), high-mixed (HM), medium-young (MY) and medium-mixed (MM) groups.

The 2 to 3 year old and 5 year old bulls were selected from two of the Aberdeen Angus herds described in Chapter 6, herds 1 & 4 respectively. In the observations described in Chapter 6, the serving capacity of bulls in herds 1 & 4 was determined. This estimate of serving capacity was used in the selection of bulls for the present study.

In August 1973, the bulls in herds 1 & 4 were subjected to a breeding soundness examination. This consisted of a visual examination of the locomotor system, a manual examination of scrotal contents and internal
genitalia, and an examination of semen. Scrotal circumference was measured and taken as an index of testicle size (Hahn et al 1969). Semen was collected by massage of ampullae and seminal vesicles and submitted for the laboratory examination described by Galloway (1966).

Four bulls in herd 1 were not considered for selection. One had unilateral epididymitis, another had poor quality semen and two others had lost their eartags and could not be positively identified. Only bulls found free from abnormalities that could interfere with reproductive efficiency were considered for selection. The remaining 14 bulls in herd 1 and the 9 bulls in herd 4 were ranked within herds in descending order of serving capacity. In herd 1 the bulls ranked 1 to 5 were termed the high serving capacity animals and those ranked 5 to 10 the medium serving capacity bulls. In herd 4 the bulls ranked 1 and 5 were termed the high and medium serving capacity bulls respectively.

Using these 12 bulls the four mating groups HY, HM, MY and MM were formed. On the day of mating each bull was fitted with a chin ball harness (Lang et al 1968).

Heifers

The day before mating 800 Hereford heifers, 12 to 15 months of age, were weighed individually. The 456 heifers weighing more than 270 kg were allocated in
order of weighing to 4 equal groups of 114 animals. Mean body weight and standard deviation for groups 1, 2, 3 & 4 was 313.2 ± 18 kg, 311.0 ± 22 kg, 310.0 ± 21 kg and 312.1 ± 22 kg respectively.

Each heifer was identified with a large numbered eartag and fitted with a KaMaR heat mount detector (HMD).

Conduct of Experiment

On 11/9/73, each mating group of 3 bulls was placed with a herd of 114 heifers for 6 weeks. The mating paddocks were 60 to 80 ha. in area. For the first month the herds were rotated around the four mating paddocks at weekly intervals.

At the end of the 1st, 2nd, 3rd, 4th and 6th weeks of mating, each herd was yarded. Bulls were separated from the heifers immediately after yarding and the tanks of their chin ball harnesses refilled with marking fluid. At the final yarding, the 12 bulls were subjected to a breeding soundness examination consisting of an examination of genitalia and the laboratory examination of semen.

At each yarding heifers were carefully examined in a narrow race to determine whether they had been in oestrus during the previous week and whether they had been mounted by bulls. A heifer was considered to have been in oestrus and not mounted when its heat mount detector (HMD) was fully red or missing and it was not marked with coloured dye on either rump, back or withers. A heifer
was considered to have been in oestrus and mounted by bulls when its HMD was fully red, partially red or missing and when it was marked or when its HMD was not triggered and it was well marked. Triggered or missing HMD's were not replaced.

Four weeks after the end of mating, heifers were examined for pregnancy by rectal palpation. The relative degree of filling of the gravid and non-gravid uterine horns was used to give an estimate of stage of pregnancy (Barr & Armstrong 1973). The mating data (week in which heifer showed oestrus and was mounted by bulls) was then consulted and another rectal examination made to determine the week in which the heifer conceived. Heifers less than 7 to 10 weeks pregnant were examined again 5 weeks later.

**Observations**

During the first 3 weeks of mating, each herd was observed in the mating paddocks on 4 different days for a total of 30 hours.

**Statistical analysis**

For each mating group, the following reproductive indices were determined:

1) efficiency with which bulls detected the first oestrus displayed by heifers. This was expressed as the proportion of heifers mounted by bulls during their first oestrus, to heifers exhibiting their first oestrus.
2) first oestrous conception rate, defined as the proportion of heifers conceiving at their first oestrous, to heifers displaying their first oestrous.

3) second oestrous conception rate, expressed as the proportion of heifers conceiving at their second oestrous, to heifers exhibiting their second oestrous.

4) pregnancy rate, defined as the proportion of heifers pregnant after 6 weeks of mating, to heifers joined.

5) number of heifers conceiving in each week of mating.

The influence of serving capacity on these reproductive indices was determined by comparing group HY to group MY and group HM to group MM using chi-square analysis (Cochran 1954). To determine the effect of age composition of mating groups on the 5 reproductive indices, groups HY and MY were combined and compared to the combined HM and MM groups using chi-square analysis (Cochran 1954).

RESULTS

Bulls

The mean serving capacity of bulls in the HY and HM mating groups was markedly different from the mean serving capacity of the bulls in the MY and MM mating groups (Table 13).

The results of the pre- and post-mating examinations of bulls are shown in Tables B-14. The bulls in mating groups HY, MY and MM were normal in locomotor function, had normal accessory organs and were voiding good quality semen at the start and end of mating. During mating these bulls maintained normal locomotor function.
The HM bulls at the start of mating were sound for breeding. At the end of the 2nd week of mating, bull A10 was injured by another bull and was replaced by bull A1. The latter at the pre-mating examination showed mild degenerative changes in the semen. These were no longer evident at the end of mating (Table 14). For several days in the 3rd week of mating bull 32 was lame and when observed for 8 hours on one of these days, showed no interest in oestrous heifers. Of the 24 heifers displaying their first oestrus during week 3, only 11 (45.8%) conceived. This is significantly lower ($P < 0.01$) than the conception rate of 81.7% for the 82 heifers showing their first oestrus in the other 5 weeks of mating.

**Heifers**

During mating two heifers were culled, one for severe lameness, the other for photosensitisation. At the rectal examination, 30 heifers (7 or 8/group) were 5 to 8 months pregnant and another two were free martins. These 34 heifers were excluded from the analysis. All heifers showed oestrus in the 6 weeks of mating and 95.1% exhibited their first oestrus in the first 3 weeks.

**Sexual behaviour**

Observations showed that oestrous heifers spent all their time in an easily identifiable group which
Williamson et al (1972) termed the sexually active group (SAG). Within the SAG heifers engaged in chin resting, mounting and standing to be mounted. The group of sexually active heifers roamed the paddock extensively passing through larger groups of grazing heifers and walking up to 2 km to other groups of grazing animals. Oestrous heifers rarely left the SAG while other heifers drifted in and out of the group.

The concentration of oestrous heifers in the SAG appeared to help bulls in detecting heifers in oestrus. There were 22 instances observed in which a bull had not been within 50 metres of any oestrous cow for more than 30 minutes. In 17 of these instances the bull walked over to the SAG immediately after one heifer mounted another in the group. In another 4 instances the SAG migrated to a bull to initiate sexual activity and only in one instance did a bull detect an oestrous heifer by vulval sniffing.

Within each group of 3 bulls there was a stable social order. In the two mixed-age groups the 5 year old bull dominated the 2 year old bulls. On days when there were heifers in oestrus the dominant bull in each mating group spent $91 \pm 6 \text{(SD)} \%$ of its time in the SAG. The subordinate bulls spent significantly less time in the SAG, $53 \pm 22 \text{(SD)} \%$, ($t_{10} = 3.1 \ p < 0.02$). When the SAG contained more than 3 oestrous heifers the dominant
bull in any mating group could not prevent its subordinates from serving heifers. When 3 or fewer oestrous heifers were in the SAG the old bull in the mixed age mating groups successfully prevented the younger bulls from entering the SAG. In the same situation in the young bull groups the dominant male tried to keep the subordinates away from the oestrous heifers but it was generally unsuccessful.

Influence of serving capacity on reproductive indices

The reproductive indices of the four mating groups of bulls are presented in Table 15. Each group of bulls mounted 96 to 100% of the oestrous heifers. Serving capacity of the mating group significantly influenced the first oestrus conception rate of heifers but not their conception rate at their second oestrus (Table 15). The mating load for each group of bulls during the first three weeks when 95.1% of heifers had their first oestrus was high, 34.1 ± 10 (SD) heifers in oestrus/week. During weeks 4 to 6 when 83.3% of the heifers having their second oestrus experienced that oestrus, the mating load was significantly (P < 0.001) lower, 11.1 ± 3 (SD) heifers in oestrus/week.

Serving capacity of the mating group of bulls did not significantly influence the proportion of heifers impregnated over the 6-week mating period (Table 15).
However serving capacity did significantly influence the proportion of heifers conceiving in each week of mating (Table 15). Heifers joined to high serving capacity bulls conceived significantly earlier in the mating period than heifers joined to medium serving capacity bulls.

*Influence of age composition of the mating groups on reproductive indices*

The reproductive indices of the combined young bull mating groups, HY and MY, and the combined mixed age mating groups, HM and MM, are presented in Table 16. Bulls in the mixed age groups detected a lower proportion of heifers in oestrus and impregnated a lower proportion of oestrous heifers at their first and second oestrus than the young bulls in the HY and MY mating groups (Table 16). These differences were not statistically significant. However over the 6-week mating period, the HY and MY bulls impregnated significantly more heifers than the HM and MM bulls (93.8% cf 84.8% P < 0.005). Age composition of the mating group did not influence the proportion of heifers conceiving in each week of the mating period.
DISCUSSION

In this study groups of bulls joined at the rate of 1 bull per 38 heifers detected 96 to 100% of heifers experiencing oestrus. This is in close agreement with the data of Donaldson (1968), Beerwinkle (1974) and Mattner et al (1974) who found that groups of bulls joined at the rate of 1 bull per 24 to 30 cows mounted 95 to 100% of the oestrous cows. It is considered that the high efficiency of bulls in oestrous detection is related to the concentration of oestrous females in a sexually active group. The SAG through its extreme mobility and its mounting activity appears to play the role of the "oestrus detector" by attracting other sexually active females to it. This view is supported by the data of Wohanka (1962) and Williamson et al (1972) who found that pro-oestrous cows spend long periods in the SAG for several days before they exhibit oestrus. The observations in the present study showed that when bulls were separated from oestrous heifers for more than 30 minutes they re-established contact after seeing mounting activity within the SAG or by the SAG migrating to them. Mattner et al (1974) also found that bulls detected oestrous cows by group mounting activity rather than by vulval sniffing. Once in the SAG the dominant bull spent a large proportion of its time within the SAG while subordinate bulls spent as much time in the
SAG as the dominant bull would allow. With oestrous heifers adopting such a positive role in oestrous detection it is not surprising that the serving capacity of bulls joined at the rate of 1 bull per 38 heifers did not influence their efficiency in oestrous detection.

Heifers joined to the HY, HM, MY and MM mating groups of bulls had first oestrus conception rates of 81.0%, 73.5%, 60.7% and 56.7% respectively (Table 15). The close similarity between these conception rates and those in the studies of Jondet (1955) and Ivankov (1959) is quite striking. Cows inseminated once or twice in one oestrus by Jondet (1955) had conception rates of 58.5% and 75.6% respectively. Those cows that Ivankov (1959) inseminated 1, 2 or 3 times in one oestrus had conception rates of 60%, 72% and 80% respectively. These data suggest that the MY and MM bull groups served heifers on their first oestrus an average of once while the HM and HY bull groups served heifers on their first oestrus a mean of 2 and 3 times respectively. In the first three weeks of joining when 95.1% of these heifers were experiencing their first oestrus, the number of oestrous heifers that each group of bulls had to contend with was 34.1 ± 10 per week. It is suggested that the high serving capacity bulls were more efficient at this high mating load than the medium serving capacity bulls.
In the last three weeks of joining when the mating load was 11.3 ± 3 oestrous heifers per week, 83.3% of the heifers having a second oestrus were experiencing that oestrus. The failure of serving capacity to significantly influence the second oestrus conception rate suggests that, at this low mating load, medium serving capacity bulls were able to serve heifers as many times as the high serving capacity animals.

Serving capacity did not significantly influence the pregnancy rate of heifers (Table 15). This is not unexpected. With 95.1% of heifers showing their first oestrus in the first 3 weeks, almost all heifers had the opportunity to experience a second oestrus and conceive late in the 6-week mating period. Few herds have 95% of animals in oestrus in the first 21 days. In 11 beef herds the proportion of cows showing oestrus in the first 21 days of mating varied from 49% to 95% (mean 63%) (Wiltbank 1970). In another herd of beef heifers, 69% of animals exhibited oestrus in the first 21 days (Laster et al 1972). Had only 60 to 70% of heifers shown oestrus in the first 3 weeks, only that proportion would have displayed a second oestrus in a 6-week mating period. In this situation differences in serving capacity of bulls may have caused differences in pregnancy rate. Alternatively with fewer heifers in oestrus per week, medium serving capacity bulls may have served oestrous heifers a mean 2 or 3 times and impregnated as many heifers on their first oestrus as high serving capacity bulls.
Further studies are needed to determine the influence of serving capacity of bulls on conception rate and pregnancy rate in herds differing in the proportion of animals exhibiting oestrus in the first 3 weeks.

Heifers joined to high serving capacity bulls conceived significantly earlier in the mating period than heifers joined to medium serving capacity bulls. This effect was mediated through the significant influence of serving capacity on the first oestrus conception rate of heifers. Week of conception has important effects on calf production and subsequent fertility. At weaning, calves from later calving heifers and cows are younger and consequently lighter than calves from animals that calve earlier in the season (Lesmeister et al 1973; Burns 1967). Late calving cows show their first oestrus later in the next mating period than early calving cows (Wiltbank 1970). The latter is of particular relevance to first calf cows for they exhibit their first oestrus after calving significantly later than older cows (95.8 cf 72.0 days, Laster et al 1973). The end result is two-fold. Heifers calving late have a significantly lower pregnancy rate as first calf cows than heifers calving early (Reynolds 1967). Of the heifers that are impregnated as first calf cows the late-calvers calve significantly later in subsequent seasons than the early-calving heifers (Lesmeister et al 1973).
The practice of joining bulls in mixed age groups to cows is common in Victoria (Dickson 1966). In the present study the association of a 5 year old bull with younger bulls compared to mating only young bulls with heifers significantly depressed pregnancy rate. The inhibitory effects of an old bull in restricting the sexual activity of its younger subordinates not only depresses pregnancy rate but can also influence the proportion of calves sired by each bull. The unpublished data of D.R. Osterhoff (personal communication 1972) showed that in each of 5 years of mating a mixed age group of 3 or 4 bulls to cows, the oldest or second oldest bull in the group sired 60 to 76% of the calves born while the youngest bull in the group sired 5 to 15%. Had the older bulls had a slower growth rate than their younger subordinates the average weaning weight of the calf crop would have been reduced and genetic progress in the herd slowed down. These data indicate that mating groups of bulls should comprise bulls of the same or similar age.

CONCLUSION

It is concluded that both serving capacity of bulls and the age composition of the mating group can significantly influence herd fertility.
### TABLE 13

Age, Serving Capacity and Results of Pre- and Post-mating Physical Examination of Bulls in the Four Mating Groups

<table>
<thead>
<tr>
<th>Mating group</th>
<th>No. of bull</th>
<th>Age of bull (yrs)</th>
<th>Serving Capacity of bull (Mean ± SD)</th>
<th>Physical examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Young (HY)</td>
<td>50</td>
<td>2.0</td>
<td>16</td>
<td>N *</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>2.1</td>
<td>10</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>52</td>
<td>2.1</td>
<td>6</td>
<td>N</td>
</tr>
<tr>
<td>High-mixed (HM)</td>
<td>32</td>
<td>2.3</td>
<td>15</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>2.0</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>A10</td>
<td>5.0</td>
<td>8</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>5.0</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Medium-Young (MY)</td>
<td>53</td>
<td>2.5</td>
<td>4</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>2.5</td>
<td>3</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>59</td>
<td>2.5</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>Medium-mixed (MM)</td>
<td>56</td>
<td>2.5</td>
<td>4</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>2.5</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>A5</td>
<td>5.0</td>
<td>2</td>
<td>42</td>
</tr>
</tbody>
</table>

* N = Normal
TABLE 14
Results of the Pre- and Post-mating
Semen Examinations of Bulls in the Four Mating Groups

<table>
<thead>
<tr>
<th>Mating Group</th>
<th>No. of Bull</th>
<th>Alive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>with abnormal heads</td>
</tr>
<tr>
<td>High-Young (HY)</td>
<td>50</td>
<td># 83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* 71</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>52</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>High-Mixed (HM)</td>
<td>32</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td></td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>A10</td>
<td>77</td>
<td># 4.5</td>
</tr>
<tr>
<td>A1</td>
<td>81</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65</td>
</tr>
<tr>
<td>Medium-Young (MY)</td>
<td>53</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>59</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>Medium-Mixed (MM)</td>
<td>56</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>A5</td>
<td>77</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66</td>
</tr>
</tbody>
</table>

# Premating examination
* Postmating examination
<table>
<thead>
<tr>
<th>Reproductive Index</th>
<th>Mating Group</th>
<th>Mating Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HY</td>
<td>MY</td>
</tr>
<tr>
<td>Efficiency of oestrous detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of heifers mounted</td>
<td>105 (100%)</td>
<td>107 (100%)</td>
</tr>
<tr>
<td>No. of oestrous heifers</td>
<td>105</td>
<td>107</td>
</tr>
<tr>
<td>First oestrous conception rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of heifers conceiving at 1st oestrus</td>
<td>85 (81.0%)</td>
<td>65 (60.7%)</td>
</tr>
<tr>
<td>No. of heifers showing 1st oestrus</td>
<td>105</td>
<td>107</td>
</tr>
<tr>
<td>P &lt; 0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second oestrous conception rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of heifers conceiving at 2nd oestrus</td>
<td>15 (88.2%)</td>
<td>34 (72.3%)</td>
</tr>
<tr>
<td>No. of heifers showing 2nd oestrus</td>
<td>17</td>
<td>47</td>
</tr>
<tr>
<td>Pregnancy rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of heifers pregnant</td>
<td>100 (95.2%)</td>
<td>99 (92.5%)</td>
</tr>
<tr>
<td>No. of heifers joined</td>
<td>105</td>
<td>107</td>
</tr>
<tr>
<td>No. of heifers conceiving in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 1</td>
<td>45 (84.7)*</td>
<td>24 (34.3)*</td>
</tr>
<tr>
<td>2</td>
<td>22 (23.1)</td>
<td>24 (22.9)</td>
</tr>
<tr>
<td>3</td>
<td>14 (18.6)</td>
<td>23 (18.4)</td>
</tr>
<tr>
<td>4</td>
<td>10 (9.0)</td>
<td>8 (9.0)</td>
</tr>
<tr>
<td>5 &amp; 6</td>
<td>9 (14.6)</td>
<td>20 (14.4)</td>
</tr>
<tr>
<td>P &lt; 0.025</td>
<td>P &lt; 0.025</td>
<td></td>
</tr>
</tbody>
</table>

* Expected No. of heifers conceiving each week
TABLE 16
Effect of Age Composition of Mating Group of Bulls on Efficiency of Oestrous Detection, Conception Rate, Pregnancy Rate and Number of Heifers Conceiving in Each Week of Mating

<table>
<thead>
<tr>
<th>Reproductive index</th>
<th>Mating Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HY and MY</td>
</tr>
<tr>
<td>Efficiency of oestrous detection</td>
<td></td>
</tr>
<tr>
<td>No. of heifers mounted</td>
<td>212 (100%)</td>
</tr>
<tr>
<td>No. of oestrous heifers</td>
<td>212</td>
</tr>
<tr>
<td>First oestrus conception rate</td>
<td></td>
</tr>
<tr>
<td>No. of heifers conceiving at 1st oestrus</td>
<td>150 (70.7%)</td>
</tr>
<tr>
<td>No. of heifers showing 1st oestrus</td>
<td>212</td>
</tr>
<tr>
<td>Second oestrus conception rate</td>
<td></td>
</tr>
<tr>
<td>No. of heifers conceiving at 2nd oestrus</td>
<td>49 (76.6%)</td>
</tr>
<tr>
<td>No. of heifers showing 2nd oestrus</td>
<td>64</td>
</tr>
<tr>
<td>Pregnancy rate</td>
<td></td>
</tr>
<tr>
<td>No. of heifers pregnant</td>
<td>199 (93.8%)</td>
</tr>
<tr>
<td>No. of heifers joined</td>
<td>212</td>
</tr>
<tr>
<td></td>
<td>P &lt; 0.005</td>
</tr>
<tr>
<td>No. of heifers conceiving in</td>
<td></td>
</tr>
<tr>
<td>Week 1</td>
<td>69 (67.6)*</td>
</tr>
<tr>
<td>2</td>
<td>46 (41.7)</td>
</tr>
<tr>
<td>3</td>
<td>37 (37.5)</td>
</tr>
<tr>
<td>4</td>
<td>18 (19.0)</td>
</tr>
<tr>
<td>5 &amp; 6</td>
<td>29 (33.2)</td>
</tr>
</tbody>
</table>

(  )* Expected no. of heifers conceiving each week
CHAPTER 8

DEVELOPMENT OF A SERVING CAPACITY TEST

SECTION 1. Serving Capacity of Bulls in a Simulated Pasture Mating

INTRODUCTION

No method of predicting the sexual efficiency of bulls during pasture mating has yet been devised. Now that it is known that serving capacity is an accurate measure of their sexual efficiency (Chapter 6) the next step was to develop a practical test that will accurately predict the serving capacity of bulls during pasture mating.

The logical approach to the development of such a test is to determine the serving capacity of a number of bulls during a 2 to 3 month pasture mating and then to devise a test in which the bulls' performance correlates highly with their serving capacity during the pasture mating period. Observing bulls for 2 to 3 months in a large paddock to determine their serving capacity is an extremely difficult task. The alternative is to join the bulls in a small observation paddock with ovariectomised cows and to induce a different number of cows to exhibit oestrus each day for 3 weeks. This length of simulated mating is chosen because in most herds the mating load is heaviest in the first 3 weeks of the mating period (Wiltbank 1970).

This simulated mating also provides the opportunity to determine whether the number of services a bull achieves in a day is an accurate predictor of its serving capacity over the 3-week pasture mating period.
In this section the serving capacity of 12 bulls over a 19-day mating period was determined and the daily variation in the number of services that each bull achieved was assessed.

MATERIALS AND METHODS

Selection of Bulls

Thirty, 2.5 to 3.5 year old Hereford and Aberdeen Angus bulls were associated with 90 oestrous, ovariectomised cows in a 3 ha paddock for two, 10-hour observation periods. The number of services achieved by each bull in the 20-hour period was determined. The range was from 0 to 23 services. Twelve bulls representing the range in number of services achieved were selected.

Conduct of Experiment

The aim of the experiment was to simulate a 19-day pasture mating by varying the number of oestrous cows exposed to the 12 bulls each day. From 90 ovariectomised cows the following 5 groups were formed: group 1 of 30 cows, groups 2 and 3 each of 20 animals and groups 4 and 5 each comprising 10 cows. On days 1, 2, 3, 4 and 5, cow groups 1, 2, 3, 4 and 5 respectively were brought into oestrus. On days 6 and 7, no cows were induced to exhibit oestrus. On days 8, 9, 10, 11 and 12, cow groups 1, 2, 3, 4 and 5 respectively were again induced to show oestrus. On days 13 and 14, no cows were brought into oestrus and on days 15, 16, 17 and
18 and 19, cow groups 1, 2, 3, 4 and 5 respectively were induced to exhibit oestrus. Ovariectomised cows were induced to show oestrus during a 13 to 14 hour observation period by the intramuscular injection of 0.75 mg oestradiol benzoate, 16 to 17 hours before observations began. At 0630 hr on each observation day, the group of cows injected the previous day was allowed into the 3 ha mating paddock with the 12 bulls. Bulls and cows were then kept under constant observation until between 1930 and 2030 hr when the cows were removed from the mating paddock. No observations were made on days 6, 7, 13 or 14 when bulls were not associated with cows.

The 19-day simulated mating was conducted during February, 1974 at the Rural Finance and Settlement Commission's property at Simpson, Victoria.

Data Collected and its Analysis

Bulls and cows were identified with large numbers sprayed on both sides. Every instance of a cow standing to be mounted by a bull or cow and the time of its occurrence was recorded. Cows which were mounted only once or not mounted at all during the observation period were not considered to have shown oestrus. The length of induced oestrus was taken as the interval between the first and last time a cow was mounted. For each day of observation the number of cows in oestrus and their mean oestrus length was calculated.
Every mount by a bull with or without service and the identity of the mounted cow was recorded. The serving capacity of each bull, number of services achieved in the 19-day mating period, was calculated.

RESULTS

Of the 270 cows induced to exhibit oestrus over the 19-day mating period, 239 showed oestrus. The mean length of oestrus was 9.2 ± 3.0 (SD) hours. The number of cows in oestrus each day of mating and their mean oestrus length on these days is shown in Table 17.

Table 18 shows the number of services achieved by each of the 12 bulls on each day of mating and the serving capacity and number of cows served by each bull during the 19-day mating period. There was great variation between bulls in their serving capacity over the 19-day mating period. The range in the serving capacity of bulls was from 2 to 105 and the mean was 45.5 ± 35.0 (SD).

Each of the 9 bulls with serving capacity between 2 and 47 rarely served the same cow twice e.g. bull 4 which served 43 cows had a serving capacity of only 47 (Table 18). Each of the high serving capacity bulls 9, 7 and 3 frequently served the same cow more than once (Table 18).

Most bulls showed a marked daily variation in number of services they achieved (Table 18). The daily variation in number of oestrous heifers (indicated at the foot of Table 18) accounts for some of this daily variation in serving
capacity. However even on days when the mating load was similar most bulls still showed a marked daily variation in serving capacity (Table 18).

DISCUSSION

The most common bull:cow ratio used in pasture mating in Victoria is 3 bulls to 100 cows (Dickson 1966). Had the 12 experimental bulls been in a normal pasture mating they would have been joined to 400 cows. The question that arises is how closely the simulated mating mimicked a normal pasture mating. Of the 1270 cows exhibiting oestrus in the first 19 days of a mating period, between 3% and 7% were in oestrus per day (Beerwinkle 1974). On each day of observation in the simulated mating the number of oestrous cows varied from 7 to 30. This represents a range of 1.8% to 7.5% of 400 cows (Table 17). No cows were in oestrus for 4–(21%) of the 19 days of simulated mating. For 24 (20%) of the 120 hours that the 4 herds described in Chapter 7 were observed, no heifers were in oestrus. Over the 19-day mating period, 239 heifers exhibited oestrus. This is equivalent to 60.0% of a herd of 400 heifers (Table 17) and closely agrees with the data of Wiltbank (1970). He found that in 11 beef herds the proportion of cows showing oestrus in the first 21 days of mating averaged 63%. The 239 heifers remained in standing oestrus for a mean 9.2 ± 3.0 (SD) hours. The only comparable data are those of Rollinson (1963) and Baker (1967). The cows continuously observed by the
former remained in oestrus for a mean 2.2 hours. Sixty-eight percent of the crossbred cows studied by Baker (1967) had oestrus lengths between 4 and 12 hours. An unstated proportion of Baker's cows were in oestrus for less than 3 hours.

To facilitate observations bulls and heifers were confined to a 3 ha mating paddock and no observations were made at night. In these respects a normal pasture mating is not unlike the simulated mating. Bulls don't often serve cows at night (Goerttler 1945; Sambraus 1971b). The 7 bulls observed by the latter for 550 hours achieved a total of 140 services between 0500 and 2000 hr but did not serve any cows during the hours of darkness. These data indicate that sexual rest at night as practiced in the simulated mating may be normal behaviour for bulls. Observations on 6 herds of more than 100 cows have shown that oestrous cows and heifers congregate into a sexually active group (Williamson et al 1972; Mattner et al 1974; Chapter 7). Whether oestrous cows are confined to a small area by a fence or by their urge to associate with other oestrous cows, is not likely to effect the serving capacity of bulls.

It is considered that 239 cows in oestrus for 9.2 ± 3.0 hours closely approximates the mating load likely to be experienced by 12 bulls joined to 400 cows for a 19-day period.

Although the bull:cow ratio during pasture mating varies from farm to farm, from 2 to 6 bulls per 100 cows
(Dickson 1966), each farmer invariably joins each of his bulls with a similar number of cows. The marked variation in the serving capacity of the 12 bulls in this study (from 2 to 105) shows that this practice is erroneous. Data from the 4 herds described in Chapter 6 also supports the view that there are marked between-bull differences in serving capacity. However, before bulls can be joined to as many cows as they are capable of serving, a test to predict their serving capacity during pasture mating must be developed.

Observing bulls over a day-long period (8 to 14 hours) and counting the number of services that each bull achieves may be a useful way of predicting their serving capacity over the whole pasture mating period. This experiment shows that this would give a poor estimate of a bull's serving capacity. Most of the 12 bulls showed a marked daily variation in the number of services they achieved (Table 18). In general the more cows in oestrus in a day the more services each bull achieved. James (1952) and Sumner et al (1968) also found that the daily serving activity of bulls increased as the number of cows in oestrus increased. Furthermore, during pasture mating the number of cows in oestrus does vary greatly from day to day (Beerwinkle 1974). Even on days when a similar number of cows were in oestrus most bulls showed a marked daily variation in the number of services they achieved (Table 18). This marked within-bull variation in daily number of services completed makes the day-long estimate of services achieved a poor predictor of the serving
capacity of bulls during the entire mating period.

CONCLUSIONS

The following conclusions can be made from this study:

(1) there was a marked between-bull variation in their serving capacity over the 19-day simulated pasture mating, and

(2) the number of services that the bulls achieved varied so much from day to day that the number of services a bull achieved in a day was a poor predictor of its serving capacity over the 19-day pasture mating.
### TABLE 17

Daily Mating Load During the 19-Day Simulated Mating of
12 Bulls with Cows Induced to Show Oestrus

<table>
<thead>
<tr>
<th>Day of mating</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6 &amp; 7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13 &amp; 14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>1-19</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cows induced to show oestrus</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>270</td>
</tr>
<tr>
<td>No. of cows showing oestrus</td>
<td>30</td>
<td>17</td>
<td>17</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>28</td>
<td>17</td>
<td>17</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>25</td>
<td>18</td>
<td>19</td>
<td>7</td>
<td>7</td>
<td>239</td>
</tr>
<tr>
<td>No. of cows showing oestrus as a % of 400</td>
<td>7.5</td>
<td>4.3</td>
<td>4.3</td>
<td>2.0</td>
<td>1.8</td>
<td>0</td>
<td>7.0</td>
<td>4.3</td>
<td>4.3</td>
<td>2.5</td>
<td>2.5</td>
<td>0</td>
<td>6.25</td>
<td>4.5</td>
<td>4.8</td>
<td>1.8</td>
<td>1.8</td>
<td>60.0</td>
</tr>
<tr>
<td>Length of oestrus (hours)</td>
<td>10.5</td>
<td>10.1</td>
<td>9.2</td>
<td>9.7</td>
<td>6.7</td>
<td>-</td>
<td>8.1</td>
<td>11.4</td>
<td>9.9</td>
<td>9.4</td>
<td>9.5</td>
<td>-</td>
<td>8.7</td>
<td>8.9</td>
<td>8.8</td>
<td>8.9</td>
<td>8.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Mean ± SD (hours)</td>
<td>+</td>
<td>+</td>
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TABLE 18
Number of Services Achieved by Bulls on Each Day of Mating and Their Serving Capacity over the 19-Day Mating Period

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<th>Bull</th>
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<th>3</th>
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<th>6 &amp; 7</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12 &amp; 14</th>
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| +    |    |    |    |    |    |        |    |    |    |    |        |    |    |    |    |    |
|      |    |    |    |    |    |        |    |    |    |    |        |    |    |    |    |    |

( ) Number of heifers served
+ Days when no. of heifers in oestrus was 25 - 30
17 - 19
7 - 10
CHAPTER 8
DEVELOPMENT OF A SERVING CAPACITY TEST

SECTION 2. Serving Capacity of Bulls in a Yard with Unrestrained or Restrained Cows

INTRODUCTION

It was concluded in Chapter 8.1 that there was a marked between-bull variation in the serving capacity of bulls over a 19-day pasture mating and that the number of services a bull achieved in a day of pasture mating was a poor indicator of its serving capacity over the 19-day period.

A better prediction of a bull's serving capacity during pasture mating may be gained by confining bulls to a yard with oestrous cows and measuring the number of services achieved over a period of several hours. This situation provides more control than at pasture. For example, the number of oestrous cows exposed to a bull or group of bulls can be maintained at a constant number. Also cows can be restrained in an immobile state. The latter may be important in shortening the test. Prior to each service bulls at pasture engage in lengthy periods of courtship in order to induce oestrous cows to stand quietly for service (Sambraus 1971b). Having the oestrous cows immobilised could stimulate bulls into greater serving activity at the expense of courtship activity.

The aims of this experiment were to determine whether restraining cows in immobility increased the serving activity of bulls and whether the number of services a bull achieves in
a yard test is a useful indicator of its serving capacity during pasture mating.

MATERIALS AND METHODS

The 12 bulls whose serving capacity over a 19-day simulated pasture mating was determined in Chapter 8.1 were used in these experiments. The experiments were conducted in mid-April 6 weeks after the end of the simulated pasture mating.

In experiments 1 and 2, eight and 7 ovariectomised cows respectively were injected with 1 mg oestradiol benzoate 18.5 hours before the start of the yard test. For 2 hours before each test the cows were placed in a yard adjacent to the 12 bulls used in the pasture mating. The aim of this exercise was to sexually stimulate bulls prior to the test by the mounting activity of the cows.

The tests in both experiments were conducted in a 40 m x 20 m yard surfaced with mud and gravel.

In experiment 1, the 8 cows and 12 bulls were run into the yard at 1200 hr and observed for 3 hours. All instances of cows standing to be mounted by cows or bulls were recorded as were all services by bulls.

For experiment 2, conducted the following day, the 7 cows were restrained in one of two ways. Three cows were tied by a rope around the base of their horns to the side of the yard. Each of the remaining cows were placed in a service crate fixed to the side of the yard. A service crate consisted
of a yoke-head bail bolted to lateral shafts on either side of the cow. Along the lengths of the yard 2 or 3 cows were placed and along each breadth one cow was positioned. At 0900 hr the 12 bulls were run into the yard and over the next 3 hours all mounts and services by bulls were recorded. The number of services achieved by each bull in the first hour, in the first two hours and in the 3 hours of the test was correlated to the serving capacity of each bull in the 19-day simulated pasture mating by simple correlation analysis.

RESULTS

Of the 8 unrestrained cows induced to exhibit oestrus in experiment 1, 6 were in standing oestrus for each hour of the 3-hour test. The 7 cows restrained by either a rope to the side of the yard or in a service crate (experiment 2) remained relatively immobile throughout the 3-hour test period.

Over a 3-hour period the 12 bulls with unrestrained cows (experiment 1) completed 1.08 ± 2.2 (SD) services each. This was significantly lower than the 3.67 ± 2.4 (SD) services achieved by each of the 12 bulls when associated with restrained cows for 3 hours (experiment 2).

In experiment 1, bulls 9, 7 and 3 completed 6, 5 and 2 services respectively while the remaining 9 bulls failed to serve in the 3-hour period. Bulls 9, 7 and 3 were ranked 1, 2 and 3 respectively in order of serving capacity over the 19-day pasture mating.
The number of services achieved by each bull during experiment 2 are shown in Table 19.

In the latter part of experiment 1 and during experiment 2, bull 3 showed lameness of all 4 feet and mounted cows with difficulty. The lameness disappeared when the bull was moved from the mud-gravel surface of the experimental yard to a concrete yard. Two weeks later when the 12 bulls were walked across the experimental yard only bull 3 became lame. Again the lameness abated when the bull walked on the concrete yard. In the simulated pasture mating (Chapter 8.1) bull 5 protruded its penis only 3 cm during seeking and had difficulty making penis-vulva contact with cows that would not stand still during mounting. It had low serving capacity during pasture mating (Table 19). When mounting immobile cows in the yard test bull 5 again displayed short penile protrusion but easily made penis-vulva contact and achieved 6 services in the first hour compared to the 0 and 1 service achieved by bulls 1 and 6 respectively. These bulls were of similar serving capacity to bull 5 during pasture mating (Table 19) and had normal penile protrusion and no difficulty in making penis-vulva contact during pasture mating. Bull 5 because of its short penile protrusion and bull 3 because of its lameness in the experimental yard have been excluded from the correlation analysis of experiment 2.

Correlation coefficients between the serving capacity of the remaining 10 bulls and the number of services they achieved in the first hour, in the first 2 hours and in
the 3 hours of the yard test were 0.91, 0.92 and 0.92 respectively (P <0.001). The similarity in the correlation coefficients is due to the fact that bulls achieved relatively few services after the first hour (Table 19).

DISCUSSION

The 3-hour yard test in which oestrous cows were unrestrained was efficient in identifying those bulls displaying high serving capacity during pasture mating. However due to their lack of serving activity in the same situation the medium serving capacity bulls 4, 32, 10 and 1 could not be distinguished from the low serving capacity animals 5, 6, 8, 2 and 58 (Table 19).

Although immobilisation of cows did significantly increase the serving activity of bulls in the yard test, it did enable a bull with short penile protrusion to achieve many more services than bulls displaying similar serving capacity to it during pasture mating. This does not mean that the procedure of immobilising cows should be eliminated from the test. It simply means that a test in which cows are restrained is not efficient in predicting the serving capacity of bulls which have a short penile protrusion during seeking. Fortunately only a small proportion of bulls display this abnormality. Of 202 beef bulls observed for serving behaviour on one farm, only 4% had short penile protrusion during seeking (M.A.deB. Blockey, unpublished data).
For bulls with a normal penile protrusion the number of services achieved in 1, 2 or 3 hours with immobilised cows was highly correlated with their serving capacity over the 19-day pasture mating. The fact that these bulls achieved relatively few services after the first hour needs some explanation. The 22 dairy bulls that Almquist and Hale (1956) allowed serve an artificial vagina at will achieved no services after 1 to 2 hours. When the teaser they used was replaced or moved to a different position these bulls began serving again. The authors concluded that the bulls did not suffer physical fatigue but became sexually satiated with the particular stimulus situation. Even though the stimulus situation in the present study consisted of 7 cows positioned around the periphery of the yard, bulls still became sexually satiated with it after 1 to 2 hours.

CONCLUSION

It is concluded that the serving capacity of bulls during pasture mating can be accurately predicted by determining the number of services achieved by bulls associated with immobilised cows for 1 hour.
TABLE 19
Serving Capacity of Bulls in a Pasture Mating and in a Yard Test with Immobilised Oestrus Cows (Experiment 2)

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<th>Bull no.</th>
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<th>Number of services achieved during yard test</th>
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<td></td>
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CHAPTER 8
DEVELOPMENT OF A SERVING CAPACITY TEST

SECTION 3. Does the Predictive Accuracy of the Test Increase if Bulls are Tested Twice?

INTRODUCTION

In the previous section the number of services that bulls achieved when associated with restrained cows for 1 hour was shown to be highly correlated with their serving capacity in a 19-day simulated pasture mating. In this section it is proposed to determine whether two 1-hour yard tests gives a more accurate prediction of the serving capacity of bulls than one yard test.

MATERIALS AND METHODS

Eleven of the 12 bulls observed in the simulated pasture mating 8 weeks previously were used in this experiment. Bull 5 which displayed short penile protrusion during seeking was excluded.

Tests 1 and 2 were conducted a day apart under identical conditions. At 1600 hr, 18 hours before the start of a test, 5 ovariectomised heifers were injected with 1 mg oestradiol benzoate to induce oestrus. Overnight the heifers were placed in a yard adjacent to the paddock in which the 11 bulls were grazing. The next day at 0900-1000 hr, the 5 heifers were restrained to the sides of a 20 m x 20 m concrete yard. The means of restraining heifers was to tie them by a rope around the base of their horns to a yard post. The
bulls were run into the yard and over the next hour all services by bulls were recorded. The number of services achieved by each bull in test 1, in test 2 and in test 1 and 2 combined was correlated to their serving capacity in the 19-day simulated pasture mating (Chapter 8.1) by simple correlation analysis.

RESULTS

The serving activity of the 11 bulls in tests 1 and 2 is shown in Table 20. The group of bulls displayed only half the serving activity in test 2 that they showed in test 1. Correlation coefficients between the serving capacity of bulls during pasture mating and the number of services achieved in test 1, test 2 and in tests 1 and 2 combined were 0.82, 0.90 and 0.88 respectively.

DISCUSSION

At their second test in 24 hours in the same yard, the bulls in this study displayed less than 50% of their serving capacity in the first test. Dairy bulls allowed to serve an artificial vagina at will and exposed to the same stimulus situation twice in 7 days showed 70% of the serving activity in the second test that they displayed in the first test (Almquist and Hale 1956). These authors attributed this marked reduction in serving activity to the bulls becoming sexually satiated with the stimulus situation.
These data of Almquist and Hale (1956) and the present data indicate that tests to determine the repeatability of bulls' performance in the yard test should be done more than one week apart.

CONCLUSION

It is concluded that subjecting bulls to two yard tests instead of one does not increase the accuracy of predicting the serving capacity of bulls during pasture mating.
<table>
<thead>
<tr>
<th>Bull No.</th>
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CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

SECTION 1. Uniformity Tests of Identical Twin Bulls

INTRODUCTION

The yard test described in Chapter 8 was efficient in predicting the serving capacity of bulls during pasture mating. It was considered possible that the test could be simplified without influencing the number of services that bulls achieve in the test i.e. their serving capacity in the test.

The most useful animals for examining modifications to the test procedure were considered to be identical twin bulls. Twin brothers allowed to serve an artificial vagina each week from 18 to 42 months of age showed great similarity in the proportion of services they completed (Bane 1954). Should twin brothers display similar serving capacity in the yard test they could be used to determine the effect that different test procedures such as method of cow restraint, use of oestrous cows, prior sexual stimulation, had on the serving capacity of bulls. One twin brother from each set could undergo the test with a particular procedure included while the other brother from each set was undergoing the test with the procedure excluded. Similarity in their serving capacity would indicate that the exclusion of the test procedure did not influence the serving capacity of bulls.
Identical twin brothers would only be useful if the twin brothers were of similar serving capacity. In some of the sets of identical twin bulls studied, twin brothers have not displayed similar serving activity. Wierzbowski (1966) allowed 5 sets of twin bulls to serve an artificial vagina at will over a 24-hour period. In only one set did twin brothers achieve a similar number of services. Between the ages of 18 and 27 months, twin brothers in two of the six sets studied by Bane (1954) were dissimilar in serving activity. Sets of identical twin bulls were reared for use in the modification stage of the test's development. The aim of this study was to determine whether twin brothers within these sets displayed similar serving capacity.

MATERIALS AND METHODS

Diagnosis of zygosity and rearing of twins

Nine pairs of twin bulls were purchased as 2 to 8 week old calves in the period August-September 1972. The twins were initially considered identical because on morphological inspection they satisfied the criteria established by the Victorian Department of Agriculture from the work of Bonnier (1946) (Table 21). Further verification of monozygosity was made by submitting a blood sample from each calf for blood grouping (Bell and Francis 1970). These examinations were carried out by the Veterinary Blood Grouping Laboratory of the University of Queensland.
The 7 sets of twins purchased at 2 to 4 weeks of age were reared on milk powder and calf meal and weaned at 6 to 8 weeks of age onto calf meal and pasture. The two remaining sets of twins were weaned off their beef mothers onto pasture when 7 to 8 weeks old. The bulls were grazed as a group on pasture and hay supplements until February 1974 when they were 18 to 20 months old.

Pasture mating

For 18 hours on 27-28 February the 18 bulls were associated with 28 oestrous ovarietomised heifers in a 3 ha paddock and observed. All mounts by bulls with or without service were recorded. On the basis of their mounting activity 5 pairs of bulls representing the range in mounting activity of the 9 pairs were selected.

Uniformity tests in yards

Two groups of 5 bulls, A and B, were formed with one brother from each of the 5 sets of identical twins. On 26 May 1974, six ovarietomised cows were injected with 1 mg oestradiol benzoate (ODB).

Test 1. 1) from 1400 to 1640 hr on 27 May, the 10 bulls were sexually stimulated by placing them in a yard beside the group of 6 mounting cows, 11) three cows were restrained, two in service crates and one by a halter, in each of two adjacent yards 1 and 2. The yards were 15 m x 20 m in area,
iii) at 1700 hr group A and group B bulls were run into yard 1 and 2 respectively and the serving capacity of each bull in 60 minutes, SC-60, was determined.

Test 2.
i) from 0800 to 0840 hr on 28 May, the 10 bulls were placed in a yard beside the group of 6 cows injected with ODB on 26 May,
ii) the 6 cows were restrained in yards 1 and 2 as in test 1,
iii) at 0900 hr, group A and group B bulls were run into yards 2 and 1 respectively and the SC-60 of each bull determined.

The SC-60 of twin brothers in both tests was compared.

RESULTS

The twin brothers within each set had identical blood types (without evidence of chimaerism) and identical transferrin, albumin and haemoglobin types. The twin brothers in each also satisfied the morphological criteria outlined in Table 21.

During the pasture mating, the twin bulls, all of small stature, had difficulty in making penis-vulva contact with the large, ovarioctomised heifers. For this reason the 5 pairs of bulls representing the range in sexual activity of the 9 pairs were selected on the basis of their mounting activity (Table 22). This table also shows the number of services achieved by the 10 bulls in tests 1 and 2 in the
yard. In 4 of the 5 sets, twin brothers showed similar serving capacity. In the remaining set bull 1 had a similar number of mounts to bull 2 but it achieved fewer services (Table 22). Both bulls 1 and 2 showed short penile protrusion during seeking.

**DISCUSSION**

Because the twin brothers in each set had identical blood types and satisfied the morphological criteria, each set of twin bulls was considered monozygous. This decision can be made with confidence for Osterhoff (1966) concluded that the accuracy of diagnosing zygosity in twins approached 100% when blood grouping was used in conjunction with morphological inspection.

Fortunately, in four of the 5 sets of twins, twin brothers displayed almost identical serving capacity in both tests. It was concluded that these four sets of twins could be used with confidence in the modification stage of the test's development. It was also considered that bull 1 in the remaining twin set should be persisted with in the hope that in future experiments it improved its serving technique and displayed similar serving capacity to its twin brother.
TABLE 21

Check List for Morphological Inspection of Twin Calves

Twins should be restrained and examined together in a good light.

Twins must be identical in:

i) head shape

ii) shade of hair colour (undercoats as well as surface)

iii) colour of eye lashes, ear fringes, hoofs, whiskers and tailtips

iv) the inner surface of ears.

Twins must be similar but need not be identical in:

i) coat colour pattern (shape and area)

ii) colour markings of muzzle, palates and tongues.
<table>
<thead>
<tr>
<th>Bull no.</th>
<th>Pasture mating Mounts</th>
<th>Services</th>
<th>Uniformity tests in yards SC-60 Test 1</th>
<th>SC-60 Test 2</th>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>24</td>
<td>11</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>7</td>
<td>0</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>32</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

* No. of mounts with and without service.
CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

SECTION 2. Effect of Method of Restraining Cows on Serving Capacity of Bulls

INTRODUCTION

In previous experiments cows were induced to display "standing" oestrus and immobilised either by placing them in service crates or restraining them to the side of the yard by a rope around the horn base or by a halter. However some cows induced to show oestrus will not stand to be mounted during the whole of the 1-hour test period. If not restrained effectively such cows could swivel their hindquarters about and by disrupting mounting attempts, could lower the serving capacity of bulls. Restraint by a halter is likely to be less effective in immobilising such cows than restraint by a service crate which is designed to prevent excessive lateral movement of the hindquarters. The aim of this study was to determine:

i) the effectiveness of the two methods of restraining cows,

and ii) the influence of the method of restraint on the serving capacity of bulls.
MATERIALS AND METHODS

Animals

Two groups of 5 bulls, A and B, were formed with one brother from each of 5 sets of identical twins. Six ovariectomised cows were administered 1 mg oestradiol benzoate on 29 May 1974.

Service crates

Plans of the service crate used to restrain cows are shown in Figures 3 and 4. The head bail and guide frames were made of galvanised iron tube 3.5 cm internal diameter. The service crate was fixed to a yard post by either a screwed rod through the post or by a chain around the post and fixed to a mounting bracket bolted to the front of the guide frame. Lateral movement in a concrete yard was prevented by telescopic braces and in an earthen yard, by metal stakes driven into the ground through holes in the base of the guide frame. To get a cow into a service crate it was halterled, a rope attached to the end of the halter and the cow released into the yard containing the service crate. The rope was passed through the open bail head, around the yard post and back through the head bail again. By physical coercion the cow was forced into the crate and the yoke-head bail closed.
Test 1

This was conducted on 30 May 1974 as follows:

i) from 0730 to 0820 hr the 10 bulls were sexually stimulated by placing them in a yard beside the group of 6 mounting cows,

ii) three cows were placed in service crates in yard 1 and in the adjacent yard 2, three cows were restrained by halters,

iii) at 0830 hr the group A and group B bulls were run into yards 1 and 2 respectively and the serving capacity of each bull in 60 minutes, SC-60, was determined,

iv) all mounts by bulls were recorded as was the response of the cows to each mount i.e. whether the cow swivelled its hindquarters about or stood quietly.

Test 2

This was conducted on 30 May 1974 and was the reverse of test 1:

i) from 1530 to 1620 hr the 10 bulls were placed in a yard adjacent to the 6 cows,

ii) the 6 cows were restrained in yards 1 and 2 as in test 1,

iii) at 1630 hr the group A and group B bulls were run into yards 2 and 1 respectively and the SC-60 of each bull determined,

iv) all mounts by bulls were recorded as was the response of cows to each mount.
Statistical analysis

The comparison between the mean serving capacity of bulls tested with cows in service crates or tested with cows restrained by halters was made using the Student "t" test (Steel and Torrie 1960).

RESULTS

Prior to test 1, the 6 cows were very active in mounting one another but they showed no mounting activity in the hour before test 2. During tests 1 and 2, the bulls associated with cows restrained in service crates achieved 58 and 59 mounts respectively. Cows remained immobile during all 117 mounts. Their twin brothers mated to cows restrained by halters achieved only 34 and 31 mounts in tests 1 and 2 respectively. Forty eight percent and 32% respectively of these mounting attempts were disrupted by the cows swivelling their hindquarters. The bulls mated to the halter-restrained cows had significantly lower serving capacity than their twin brothers associated with cows restrained in service crates (0.8 ± 1.0 (SD) vs 4.2 ± 2.9 (SD), t_{18} = 3.3, p < 0.01 and Table 23).
DISCUSSION

Prior to test 1 the cows treated with oestradiol benzoate were in standing oestrus. Seven hours later no cows were still in oestrus. Whether they were in oestrus prior to the test or not the halter-restrained cows frequently swivelled their hindquarters about while those cows restrained in service crates remained relatively immobile. Periodic sexual unresponsiveness is not only a characteristic of ovariectomised cows induced to exhibit oestrus. During natural oestrus cows have periods in which they will not stand to be mounted (Wohanka 1962; Rollinson 1963; Sambraus 1968; 1971b). Therefore the method of restraint must be capable of immobilising the oestrous cow during these un receptive periods. If the restrained cow is not immobilised the lateral movement of its hindquarters will decrease the number of mounts that bulls attempt and disrupt those mounts they do attempt. The result is that bulls display low serving capacity. The present data shows that service crates do keep cows immobile while restraint by a halter is ineffective.
### TABLE 23

**Effect of Method of Cow Restraint on Serving Capacity of Bulls**

<table>
<thead>
<tr>
<th>Method of restraining cows</th>
<th>Serving capacity of twin bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Twins 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>Test 1</td>
</tr>
<tr>
<td>Service crate</td>
<td>6</td>
</tr>
<tr>
<td>Halter</td>
<td>0</td>
</tr>
</tbody>
</table>


FIGURE 3. Plan of service crate used to immobilise cows

DETAIL A
METHOD OF FIXING
GUIDE FRAME TO TIMBER POST
(MOUNTING BRACKET NOT USED)

DETAIL B
(PART PLAN VIEW)
METHOD OF FIXING GUIDE FRAME TO ANY SIZE METAL POST

DETAIL C
METHOD OF FIXING
BRACE TO TIMBER RAILS

TELESCOPIC BRACE
GUIDE FRAME

SIDE ELEVATION OF SERVICE CRATE
FIGURE 4. Plan of service crate used to immobilise cows

YOKE-HEAD BAIL (ADJUSTABLE)

YOKE-HEAD BAIL (CLOSED POSITION)

GRAVITY LOCK

YOKE HEAD BAIL (OPEN POSITION)

TELESCOPIC BRACE

FORK END

METAL STAKE

1500 (ADJUSTABLE)

760

1660

TYPICAL ARRANGEMENT, MOUNTED ON SOIL (SYMmetrical about \( \xi \))

TYPICAL ARRANGEMENT, MOUNTED ON CONCRETE (SYMmetrical about \( \xi \))

FRONT ELEVATION OF SERVICE CRATE
CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

SECTION 3. Do Cows Restrained in Service Crates Need to Be in Oestrus?

INTRODUCTION

The previous experiment showed that cows which had displayed no mounting activity prior to the test remained immobile in service crates while being mounted by bulls. These data suggest that non-oestrous cows will remain immobile when restrained in service crates. However bulls may require the olfactory and gustatory stimuli provided by oestrous cows to display their true serving capacity.

In this experiment the serving capacity of twin brothers tested with either oestrous or non-oestrous cows in service crates was compared.

MATERIALS AND METHODS

Animals

Two groups of bulls, A and B, were formed with one brother from each of 5 sets of identical twins. On 3 June, 3 of 6 ovariectomised cows were administered 1 mg oestradiol benzoate.
Test

This was conducted on 4 June 1974 in the following manner:

i) from 0730 to 0820 hr the 10 bulls were sexually stimulated by placing them in a yard beside the group of 6 cows,

ii) the 3 oestrous cows and the 3 non-oestrous cows were restrained in service crates in two adjacent yards, 1 and 2 respectively,

iii) at 0830 hr, bull groups A and B were run into yards 1 and 2 respectively and the serving capacity of each bull in 60 minutes, SC-60, was determined,

iv) the response of cows to each mount was recorded.

RESULTS

The 3 cows induced to show oestrus stood to be mounted by one another in the hour before the test. The bulls mated to these cows displayed similar serving capacity to their twin brothers mated to non-oestrous cows restrained in service crates (Table 24). One of the non-oestrous cows swivelled its hindquarters on 2 of the 8 occasions it was mounted. This cow was not served. The other 2 non-oestrous cows remained immobile during 43 mounting attempts as did the 3 oestrous cows during 66 mounting attempts.
DISCUSSION

The finding that service crates can immobilise non-oestrous cows during most mounting attempts and that bulls display their true serving capacity when tested with these cows, simplifies the conduct of the test immeasurably. The induction of "standing" oestrus in cows presents practical difficulties. Ovariectomised cows are rarely available on farms and a reliable method of inducing oestrus in entire cows has not been developed. Even if cows were induced to show oestrus, there would be periods during oestrus in which they would not stand to be mounted (Wohanka 1962; Rollinson 1963; Sambraus 1968, 1971).

The present data demonstrate that bulls do not need the olfactory and gustatory stimuli provided by oestrous cows to display their true serving capacity. Instead it appears that immobility is the characteristic of oestrous behaviour which stimulates the bull to mount and serve a cow. Support for this view comes from the observations of Sambraus (1971b). He found that a bull at pasture tests the tolerance of the oestrous cow to mounting by resting its chin on the cow's back and/or signalling its intention to mount. The cow that responded by standing quietly was nearly always mounted soon after.

It is concluded that cows restrained in service crates for the serving capacity test need not be in oestrus.
TABLE 24

Effect of the Physiological State of the Cow on Serving Capacity of Bulls

<table>
<thead>
<tr>
<th>Physiological state of cow</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>11</th>
<th>12</th>
<th>27</th>
<th>28</th>
<th>31</th>
<th>32</th>
</tr>
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<tbody>
<tr>
<td>Oestrous</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-oestrous</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

SECTION 4. Effect on Serving Capacity of Sexually Stimulating Bulls Before the Test

INTRODUCTION
In previous experiments bulls have been sexually stimulated before the yard test to avoid having them waste valuable time sexually stimulating themselves during the test. This may not be necessary. They may become sexually stimulated within a short time of being exposed to restrained cows and achieve as many services in the 1 hour test period as bulls sexually stimulated before the test. Five sets of identical twin bulls were used to test this hypothesis.

MATERIALS AND METHODS

Animals
Two groups of 5 bulls, A and B, were formed with one brother from each of 5 sets of identical twins. Six entire, non-oestrous cows were available.

Tests
The serving capacity tests were conducted in early June 1974 as follows:
1) the 6 cows were restrained in service crates, 3 in yard 1 and 3 in the adjacent yard 2,
ii) in test 1, the group A bulls without prior sexual stimulation were given a 1-hour test in yard 1 while the group B bulls watched from an adjacent yard; the group B bulls then underwent a 1-hour serving capacity test in yard 2.

iii) in test 2 conducted the following day, the group B and group A bulls were tested for serving capacity in yards 1 and 2 respectively; this time the group B bulls had no prior sexual stimulation while the group A bulls had a 1-hour of sexual stimulation before their test.

Statistical analysis

A comparison between the mean serving capacity of bulls receiving 1-hour of or no sexual stimulation before the test was made using the Student "t" test (Steel and Torrie 1960).

RESULTS

During the hour of sexual stimulation, 8 of the 10 bulls mounted bulls in their group one or more times. Bulls 11 and 12 failed to mount bulls. Almquist (1973) considers that mounting is the criterion for establishing that bulls are sexually stimulated. The 8 bulls that were sexually stimulated in the hour before testing achieved significantly more services than their twin brothers which received no sexual stimulation (6.5 ± 2.7 (SD) vs 3.6 ± 1.7 (SD), t_{14} = 2.4, p < 0.05 and Table 25).
An inspection of Table 25 from left to right shows that although sexual stimulation before the test increased the serving capacity of twin bull pairs it did not alter their ranking in terms of serving capacity.

DISCUSSION

If the aim was to rank a group of 5 bulls in order of serving capacity it would not be necessary to sexually stimulate them before the test. Whether bulls are sexually stimulated or not does not alter their ranking in order of serving capacity within a group. However sexual stimulation is necessary if several groups of bulls are to be tested and ranked in order of serving capacity. As the present data show, bulls in the first group to be tested would display lower serving capacity if not sexually stimulated than those bulls tested after them.

CONCLUSION

It is concluded that bulls undergoing a serving capacity test should be sexually stimulated before the test. The most practical way of doing this is to allow them to watch other bulls mounting cows.
TABLE 25

The Influence of One-hour of Sexual Stimulation before Testing on the Serving Capacity of Bulls

<table>
<thead>
<tr>
<th>Period of sexual stimulation</th>
<th>Twins 3 &amp; 4</th>
<th>Twins 1 &amp; 2</th>
<th>Twins 27 &amp; 28</th>
<th>Twins 31 &amp; 32</th>
<th>Twins 11 &amp; 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Test</td>
<td>Test</td>
<td>Test</td>
<td>Test</td>
<td>Test</td>
</tr>
<tr>
<td>60 minutes</td>
<td>10</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>(21)</td>
<td>(12)</td>
<td>(11)</td>
<td>(11)</td>
<td>(8)</td>
</tr>
<tr>
<td>0 minutes</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(12)</td>
<td>(7)</td>
<td>(5)</td>
<td>(5)</td>
<td>(0)</td>
</tr>
</tbody>
</table>

( ) Total number of services achieved by each twin pair.
CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

SECTION 5. Effect of Period of Sexual Stimulation on Serving Capacity

INTRODUCTION

Data presented in the Chapter 9:4 indicated that bulls should be given sexual stimulation before undergoing the serving capacity test. The period of sexual stimulation given bulls in previous experiments, one hour, may be unnecessarily long.

In this experiment, 4 sets of identical twin bulls were used to compare the serving capacity of bulls sexually stimulated for either 10 or 60 minutes prior to testing.

MATERIALS AND METHODS

Animals

Two groups of 4 bulls, A and B, were formed with one brother from each of 4 sets of identical twins. A further set of twin bulls 1 and 2 was used to sexually stimulate the other bulls. Three entire, non-oestrous cows were available.

Test

This was conducted in mid-June 1974 as follows:
1) the 3 cows were restrained in service crates in one yard and the 8 bulls of groups A and B were placed in an adjacent yard,
ii) twin bulls 1 and 2 were allowed into the yard with the restrained cows for 10 minutes,

iii) twins 1 and 2 were removed and replaced by the group A bulls which underwent a 40 minute serving capacity test,

iv) group A bulls were replaced by twin bulls 1 and 2 and remained with the restrained cows for a further 10 minutes,

v) after the total of 60 minutes sexual stimulation the group B bulls underwent a 40 minute serving capacity test,

vi) the serving capacity of twin brothers in groups A and B was compared.

RESULTS AND DISCUSSION

In each of their two, 10 minute periods with restrained cows, twin bulls 1 and 2 mounted the cows up to 10 times. The bulls sexually stimulated for 10 minutes displayed similar serving capacity to their twin brothers sexually stimulated for 60 minutes (Table 26). These data indicate that the period of sexual stimulation provided by bulls mounting cows can be shortened to 10 minutes.
TABLE 26

Effect of Period of Sexual Stimulation on the Serving Capacity of Bulls

<table>
<thead>
<tr>
<th>Period of sexual stimulation</th>
<th>Serving capacity of twin bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Twins 3</td>
</tr>
<tr>
<td>10 minutes</td>
<td>8</td>
</tr>
<tr>
<td>60 minutes</td>
<td>9</td>
</tr>
</tbody>
</table>
CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

Section 6. Influence of Bull:Cow Ratio on Serving Capacity

INTRODUCTION

During pasture mating, the bulls in a group compete with one another for oestrous cows and under some circumstances the socially dominant bulls can restrict the serving capacity of their subordinates (Sambraus 1971a; Warnick et al 1971; Chapter 3). To accurately predict the serving capacity of bulls pasture mated in groups, the yard test has been designed so as to stimulate bulls to compete for restrained cows. To create this necessary competition, the ratio of bulls to cows in the yard test has been maintained at 5:3. The fact that some non-oestrous cows will not remain immobile in service crates (Chapter 9:3) poses a problem. Should one of the 3 cows exposed to a group of 5 bulls refuse to stand to be mounted, the bull:cow ratio is increased from 5:3 to 5:2. Such an increase might be followed by an increase in competition between bulls and a concomitant decrease in the serving capacity of bulls of lower social ranking.

In this experiment 5 sets of identical twins were used to determine the influence of increasing the bull:cow ratio from 5:4 to 5:2 on the serving capacity of every bull in the testing group.
MATERIALS AND METHODS

Animals

Two groups of 5 bulls, A and B, were formed with one brother from each of 5 sets of identical twins. Six non-oestrous cows were available.

Test 1

This was conducted on 10 June 1974 as follows:

i) the 6 cows were restrained in service crates, 4 in yard 1 and 2 in an adjacent yard 2,

ii) twin bulls 11 and 12 were run into yard 1 for 10 minutes to sexually stimulate themselves and the other 8 bulls,

iii) the group A and group B bulls were exposed to the restrained cows in yards 1 and 2 respectively and the serving capacity of each bull over a 60 minute period determined.

Test 2

This was conducted 7 hours after the completion of test 1 and was the reverse of test 1. After being sexually stimulated for 10 minutes, the group A and group B bulls underwent a 60-minute serving capacity test with 2 and 4 restrained cows respectively.

Statistical analysis

A comparison between the mean serving capacity of bulls tested at the ratio of 5 to 4 or at the ratio of 5 to 2 was made using the Student "t" test (Steel and Torrie 1960).
RESULTS

At either bull:cow ratio, bulls in groups of 2 to 4, crowded around one cow at a time. They competed by jostling one another for the position directly behind the cow or occasionally (6 of 169 mounts) by bunting a bull mounting a cow. While competing for restrained cows these 22 to 24 month old bulls were rarely able to assert their dominance over one another. Consequently no social order could be recognized.

Bulls tested at the ratio of 5 bulls to 2 cows had a similar serving capacity to their twin brothers tested at the ratio of 5:4 (mean 4.1 ± 3.3 (SD) cf 3.6 ± 2.8 (SD), t_{18} = 0.35, N.S. and Table 27). An inspection of Table 27 from left to right shows that whether 5 bulls were tested with 4 or 2 cows, the rank order of twin pairs in terms of serving capacity remained the same.

DISCUSSION

The 2 year old bulls in this study had not established a stable social order. This is characteristic of other groups of 2 year old bulls studied (Chapters 2:2 and 3). Whilst it can be concluded that a reduction in the number of restrained cows from 4 to 2 will not influence the serving capacity of any bull in a group of 5, two-year-old animals, the conclusion may not be valid for a group of mixed
age bulls. In such groups the high social ranking animals, invariably the older bulls, severely inhibit the serving activity of low ranking animals during pasture mating (Chapter 3). However, because the association of an old bull with younger bulls can depress herd fertility (Chapter 7) it is recommended that each mating group of bulls consist of bulls of the same age. Under these circumstances bulls undergoing the yard test prior to pasture mating would be tested in groups of bulls of the same age.

Within their own age group, 3, 4 or 5 year old bulls have a strict social order and when tested for serving capacity in groups of 5 clearly display dominance-submission relationships (Chapter 10). At a bull:cow ratio of 5:3, their social ranking in the testing group did not significantly influence their serving capacity (Chapter 10). Whether an increase in the bull:cow ratio decreases the serving capacity of lower ranking bulls in testing groups of 3, 4 or 5 year old animals remains to be demonstrated. When testing such bulls, restrained cows that will not remain immobile should be replaced or tranquillised into immobility should an effective method of doing so be developed.
TABLE 27
Influence of the Bull:cow Ratio on Serving Capacity of Bulls

<table>
<thead>
<tr>
<th>Ratio of bulls to cows</th>
<th>Serving capacity of twin bulls</th>
<th>Twins 3 &amp; 4</th>
<th>Twins 1 &amp; 2</th>
<th>Twins 27 &amp; 28</th>
<th>Twins 31 &amp; 32</th>
<th>Twins 11 &amp; 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test</td>
<td>Test</td>
<td>Test</td>
<td>Test</td>
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<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

5:4

<table>
<thead>
<tr>
<th></th>
<th>Twins 3 &amp; 4</th>
<th>Twins 1 &amp; 2</th>
<th>Twins 27 &amp; 28</th>
<th>Twins 31 &amp; 32</th>
<th>Twins 11 &amp; 12</th>
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<tbody>
<tr>
<td>10</td>
<td>(16)</td>
<td>(7)</td>
<td>(7)</td>
<td>(4)</td>
<td>(2)</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

5:2

<table>
<thead>
<tr>
<th></th>
<th>Twins 3 &amp; 4</th>
<th>Twins 1 &amp; 2</th>
<th>Twins 27 &amp; 28</th>
<th>Twins 31 &amp; 32</th>
<th>Twins 11 &amp; 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>(18)</td>
<td>(11)</td>
<td>(7)</td>
<td>(4)</td>
<td>(1)</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

( ) Serving capacity of twin pair.
CHAPTER 9
MODIFICATION OF THE SERVING CAPACITY TEST

SECTION 7. Shortening the Test

INTRODUCTION

The serving capacity test described in previous chapters has been of one hour's duration. This may be unnecessarily long. Bulls allowed to serve an artificial vagina at will over a one-hour period achieved about half their total number of ejaculates in the first 20 minutes (Almquist and Hale 1956). Over 68 tests the correlation between ejaculates completed in the first 20 minutes and in the hour of testing was 0.87.

In this experiment, bulls varying widely in serving capacity were used to determine the effect of shortening the serving capacity test to 40 minutes.

MATERIALS AND METHODS

The experimental bulls were 20-19-to 20-month-old Hereford bulls with no previous sexual experience. Three service crates were set up in each of two adjacent yards and a non-oestrous cow placed in each crate. To provide sexual stimulation, 4 bulls were allowed to mount the cows for 10 minutes before the first two groups of 5 bulls, 1 group per yard, were tested. After a one hour testing period, the remaining two groups of bulls were tested for serving capacity.
For each of the 20 bulls the number of services achieved in the first 40 minutes was related to the total number of services achieved in 1-hour by simple correlation analysis (Steel and Torrie 1960).

RESULTS AND DISCUSSION

There was a large variation within the group in the serving capacity of bulls. The range of services completed in 1-hour was 0 to 38 and the mean (± SD), 6.2 ± 5. The 20 bulls completed 85.4% of their 1-hour tally of services in the first 40 minutes. The 6 bulls achieving 1 or 2 services in 40 minutes did not serve again in the remaining 20 minutes. The extremely high correlation coefficient of 0.99 between the 40 minute and 60 minute tally of services for each bull clearly shows that the serving capacity test can be shortened to 40 minutes without reducing its efficiency.
CHAPTER 10
INFLUENCE OF SOCIAL RANK IN THE TESTING GROUP
ON THE SERVING CAPACITY OF BULLS

INTRODUCTION

Because the association of an old bull with younger bulls can depress herd fertility (Chapter 7), it is recommended that each mating group of bulls consist of animals of the same age. Under these circumstances bulls undergoing a serving capacity test prior to pasture mating would be tested in groups of bulls of the same age.

It is known that bulls 20 to 30 months old have an unstable social order and that their social ranking within the group does not influence their serving capacity during pasture mating (Chapter 3). It is unlikely that the social ranking of such bulls in testing groups of 5 would significantly influence their serving capacity in the yard test. Social ranking in mixed age groups of bulls 3 years and older does significantly influence their serving capacity during pasture mating (Chapter 3). When tested with bulls of the same age, these animals would be expected to have their serving capacity strongly influenced by their social ranking in the testing group.

It is not known whether beef bulls 3 years and older display a social order within their own age groups. Should they do so then the extent to which social ranking influences their serving capacity in the test will determine the efficiency of the test in identifying high serving capacity animals.
Should the influence be great a high serving capacity bull as a subordinate in a testing group may achieve few if any services. As a dominant bull in another testing group it may complete 10 or more services.

In this experiment the influence of social ranking of 3, 4 or 5 year old bulls on their serving capacity was assessed by altering the rank order of bulls in testing groups and measuring the change in their serving capacity.

MATERIALS AND METHODS

**Bulls**

The 74 Hereford bulls used were 36 three-year-old animals, 23 four-year-old bulls and 15 bulls, aged 5 to 6 years. These bulls had been grazed together since their introduction to the herd at 2 years of age.

**Measurement of Social Ranking**

The social ranking of each bull within its own age group was determined by confining each age group of bulls to a yard 20 m x 20 m and forcing bulls to invade one another's "personal space". All instances of a bull clearly avoiding another or retreating when bunted, were recorded. Recording ceased when, in the groups of 15, 23 and 36 bulls, more than 75%, 50% and 25% respectively of the different pairs of bulls in these groups had had clearly resolved contests. The dominance value (DV) of each bull within its age group was calculated using the method of Bielhartz and Mylrea (1963).
Determination of Serving Capacity

Within each age group bulls were ranked in descending order of DV and allotted to testing groups of 5 or 6 animals. For test 1, each testing group consisted of 2 high DV animals, 2 medium DV bulls and 1 or 2 low DV animals. For test 2, the testing groups comprised bulls of similar DV e.g. all bulls of high DV or all of low DV. This method of forming groups was used so that the majority of bulls changed their social ranking in the testing group from test 1 to test 2.

Three service crates were set up in each of two, adjacent yards 20 m x 20 m and a non-oestrous cow forced into each service crate. To provide sexual stimulation for the first two groups to be tested, 2 or 3 bulls selected at random were allowed 10 minutes in one of the yards with restrained cows. Bulls being tested over the remainder of the day gained stimulation from the sexual activity of bulls tested before them. A group of 5 or 6 bulls was allowed into each of the two yards and over the next 40 minutes, the following information was recorded for each bull:

(a) its serving capacity (number of services),
(b) uninterrupted mounts and mounts disrupted by another bull,
(c) the results of contests between any pair of bulls competing for a cow.

The social ranking of bulls in each testing group was initially determined by ranking bulls in the group in order of their previously determined DV. When a bull in a test clearly
dominated another with a higher DV, the appropriate change was made to the rank order of the testing group.

On 3 September 1974, the 36, three year old bulls underwent test 1 between 0950 and 1250 hr and test 2 between 1540 and 1810 hr. The 23, four year old bulls had test 1 between 1210 and 1340 hr on 4 September and test 2 between 1500 and 1630 hr on 5 September. The 15, five-to 6-year-old bulls had tests 1 and 2 on 5 September, test 1 between 1115 and 1300 hr and test 2 between 1630 and 1800 hr.

Statistical Analysis

(i) Change in serving capacity from test 1 to test 2

When bulls are retested in the same stimulus situation within 24 hours, their response in the second test varies from 0 to >100% of their serving capacity in the first test (Chapter 8.3). For the analysis of this experiment, change in serving capacity from test 1 to test 2 was expressed as the proportion of services achieved in test 2 to services achieved in test 1. On this basis each bull was classed as having achieved in test 2, <50%, 50 to 99% or 100% or more of its response in test 1.

(ii) Analysis 1

This analysis was conducted to determine whether a change in social ranking from test 1 to test 2 resulted in a significant change in serving capacity. The 38 four and 5 to 6 year old bulls were treated as one group and the
three-year-old bulls as another group. Within these two age groups bulls were classed as having improved their social ranking from test 1 to test 2, having maintained the same rank position or having dropped in social ranking from test 1 to test 2. For each age group (3-year-old and 4-to 6-year-old), 3 x 3 contingency tables were set up with change in serving capacity and change in social ranking as the two variables. The effect of one variable on another was determined by chi-square analysis (Cochran 1954).

(iii) Analysis 2

Data from the 3-, 4- and 5-to 6-year-old bulls were pooled to determine whether the magnitude of the change in social ranking significantly influenced the change in serving capacity. For this analysis bulls were classed as

(a) having improved their social ranking from test 1 to test 2 by 3 or more positions,
(b) having improved rank order by 1 or 2 positions,
(c) having maintained the same rank order,
(d) having dropped in rank order by 1 or 2 positions,
or (e) having dropped rank order by 3 or more positions.

A 3 x 4 contingency table was set up with change in serving capacity and change in social ranking as the two variables. The effect of one variable on another was determined by chi-square analysis (Cochran 1954).
(iv) Effect of social ranking on the proportion of disrupted mounts

The 36, three year old bulls were treated as one group and the 38, four to 6 year old bulls as another. The proportion of disrupted mounts to total mounts by bulls with a social ranking of 1, 2, 3, 4 or 5-6 was determined. Within each of the two age groups data from tests 1 and 2 were pooled. The effect of a bull's social ranking in its testing group on the proportion of its mounts that were disrupted was determined by chi-square analysis (Cochran 1954).

RESULTS

Stability of Social Order

Bulls within each age group were quick to avoid a bull dominant to them or retreated rapidly when bunted by a dominant animal. They displayed a stable social order. Of the 163, 128 and 82 different pairs of bulls contesting in the 3, 4 and 5 to 6 year old groups respectively, only 11 (6.7%), 3 (2.3%) and 5 (6.1%) pairs respectively, had a reversed outcome in a repeat contest between them.

Effect of Social Ranking on Proportion of Mounts Disrupted

During the serving capacity tests, bulls in each age group competed for restrained cows. The 3 year old bulls disrupted a significantly higher proportion of each other's mounts than did the 4 to 6 year old bulls (13.4% cf 8.4%, $\chi^2 = 5.1, P < 0.05$). In both groups, the lower the social ranking...
of the bull, the higher the proportion of its mounts that were disrupted. In the 3 year old group, bulls ranked 1, 2, 3, 4, 5 or 6 in their testing groups had 5.2, 9.3, 14.0, 13.5, 20.8 and 19.3% respectively, of their mounts disrupted \( \chi^2 = 14.3, P < 0.025 \). In the 4 year old and 5 to 6 year old groups, bulls ranked 1, 2, 3, 4 or 5-6 had 1.4, 2.1, 25.0, 3.3 and 7.0% respectively of their mounts disrupted \( \chi^2 = 35.6, P < 0.001 \).

**Serving Capacity of Bulls**

During test 1, the range in serving capacity over the 3 age groups was 0 to 17, mean 3.94 ± 3.5 (SD). In test 2, bulls averaged 64.4% of their response in test 1. The range in serving capacity in test 2 was 0 to 8, mean 2.54 ± 2.2 (SD).

**Effect of Change in Social Ranking on Change in Serving Capacity**

Whether bulls in the 3 year old or 4 to 6 year old groups increased, maintained or decreased their social ranking from test 1 to test 2, did not significantly influence their change in serving capacity (Analysis 1 - Table 28). Nor did the magnitude of the increase or decrease significantly influence their change in serving capacity (Analysis 2 - Table 29).
DISCUSSION

Despite the fact that bulls had a stable social order within age groups and that their social ranking in the testing group significantly influenced the level of disruption to their mounting activity, their social ranking in the testing group did not influence their serving capacity. The explanation for this was that the overall level of disruption to their mounting activity was low (13.4% in 3 year old bulls and 8.4% in the 4 to 6 year old animals). This occurred because of three factors. The cows were restrained sufficiently far apart (5 metres) for most bulls to complete a mount with or without service before dominant bulls standing behind other cows could chase them away. In general, bulls, after serving a cow moved to another cow, giving other bulls access to the females they left. As bulls of high social ranking became sexually satiated with the test situation they relinquished the cows to lower ranking animals.

Although it can be concluded that social ranking in the testing group does not influence the serving capacity of bulls of the same age it would be unwise to extrapolate this finding to the pasture mating situation. During pasture mating the dominant bull spends almost all of its time with the oestrous cows. Because the latter remain within a metre of one another in the sexually active group, the dominant bull in a mixed age mating group can prevent up to 3 cows at a time from being served by subordinate bulls (Chapter 7). Social ranking in mating groups of 2 year old bulls does not influence their
serving capacity during pasture mating (Chapter 3). This may not be true of 3-, 4- or 5-to 6-year-old bulls. Within their age group these older bulls have a more stable social order than 2-year-old bulls with only 2.3 to 6.7% of their repeat encounters resulting in a reversed outcome compared to 19.1 to 21.0% of repeat encounters between pairs of 2-year-old bulls (Chapter 3).
### TABLE 28
Effect of Increasing, Maintaining or Decreasing Social Ranking in the Testing Group on Change in Serving Capacity in 3 year old or 4 to 6 year old Bulls

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Change in social ranking from test 1 to test 2</th>
<th>Number of bulls changing their serving capacity in test 2 by &lt; 50%</th>
<th>50-90%</th>
<th>100% or &gt; of their serving capacity in test 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Increased</td>
<td>4 (5)*</td>
<td>3 (4.2)</td>
<td>8 (5.8)</td>
</tr>
<tr>
<td></td>
<td>Maintained</td>
<td>1 (2)</td>
<td>2 (1.7)</td>
<td>3 (2.3)</td>
</tr>
<tr>
<td></td>
<td>Decreased</td>
<td>7 (5)</td>
<td>5 (4.2)</td>
<td>3 (5.8)</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 4.4, \text{ not significant} \]

| 4 to 6            | Increased                                     | 5 (5.5)                                                | 4 (4.4)| 5 (4.1)                                         |
|                   | Maintained                                     | 5 (3.6)                                                | 3 (2.8)| 1 (2.6)                                         |
|                   | Decreased                                      | 5 (5.9)                                                | 5 (4.7)| 5 (4.3)                                         |

\[ \chi^2 = 2.2, \text{ not significant} \]

( )* Expected number of bulls
TABLE 29
Effect of Magnitude of Increase or Decrease in Social Ranking in the Testing Group on Change in Serving Capacity in 3 to 6 year old Bulls

<table>
<thead>
<tr>
<th>Change in social order position from test 1 to test 2</th>
<th>Number of bulls changing their serving capacity in test 2 by &lt; 50% 50-90% 100% or &gt; of their serving capacity in test 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased rank order by 3 or more positions</td>
<td>1 (3.8)* 3 (2.8) 6 (3.4)</td>
</tr>
<tr>
<td>Increased rank order by 1 or 2 more positions</td>
<td>9 (7.6) 4 (5.7) 7 (6.7)</td>
</tr>
<tr>
<td>Maintained rank order position</td>
<td>6 (5.7) 5 (4.3) 4 (5.1)</td>
</tr>
<tr>
<td>Decreased rank order by 1 or 2 positions</td>
<td>8 (6.8) 6 (5.1) 4 (6.1)</td>
</tr>
<tr>
<td>Decreased rank order by 3 or more positions</td>
<td>4 (4.2) 3 (3.1) 4 (3.7)</td>
</tr>
</tbody>
</table>

\( \chi^2 = 6.4 \), not significant

( )* Expected number of bulls
CHAPTER 11
THE WITHIN BULL VARIATION IN SERVING CAPACITY FROM TEST TO TEST

INTRODUCTION

In the 19-day simulated pasture mating (Chapter 8.1), most of the 12 bulls showed a large within-bull variation in the number of services they achieved from day to day. This raises the possibility that individual bulls might vary in their serving capacity from one yard test to another. Information on this point is presented in this chapter.

MATERIALS AND METHODS

From 27 May to 11 June 1974, 5 sets of 2 year old identical twin bulls underwent serving capacity tests in 5 experiments described in Chapter 9. The serving capacity data in those tests that were performed more than 2 days apart and in which bulls did not have a reduced serving capacity as a result of a treatment, were used in this chapter. There were 5 such serving capacity tests performed on 27 May (Chapter 9.1), 30 May (Chapter 9.2), 4 June (Chapter 9.3), 6 June (Chapter 9.4) and 11 June (Chapter 9.6).

Some 6 months later in the period 14 to 23 December, four pairs of the twin bulls each underwent four serving capacity tests with three days between each test. Prior to each test two groups of bulls were formed with one brother from each set. Each group of 4 bulls was exposed to 3 non-oestrous cows restrained in service crates and the
serving capacity of bulls determined over a 40-minute period.

The within-bull variation in serving capacity in both the June and December periods was graphically expressed. The mean (±SD) serving capacity of each bull during each period was determined and for the 8 bulls tested in both periods, their mean serving capacity in June and December periods compared using the Student "t" test (Steel and Torrie 1960).

On 10 February 1975, 41, 20 month old Hereford bulls with no previous mating experience were tested for serving capacity. They were divided into 4 groups of 9 to 12 bulls. After 10 minutes sexual stimulation provided by 6 of these bulls mounting restrained cows the first group underwent a 40-minute serving capacity test with 6 non-oestrous cows restrained in service crates. The other 3 groups of bulls were then successively tested with a change of cows after completing the test on the group 2 bulls. Any cow not standing to be mounted was administered 0.6 to 0.9 cc xylazine by intramuscular injection.

On 24 February, the 41 bulls were given a second serving capacity test in the same testing groups with each group tested in the same order as previously.

The repeatability of serving capacity from one test to another was determined by correlating the serving capacity

+ Rompun - Bayer
of bulls in test 1 and test 2 (Steel and Torrie 1960).

RESULTS

In general, the sexual experienced twin bulls displayed little within-bull variation in serving capacity from test to test in both the May-June and December series of tests (Figure 5). The pooled estimates of the within-bull standard deviation were 1.1 for the 10 bulls during May-June and 1.3 for the 8 bulls during December. In the May-June tests, 7 of the 8 low to medium serving capacity animals varied in serving capacity from test to test by no more than 2 services while the high serving capacity bulls (3 and 4) varied in serving capacity by no more than 3 services (Figure 5). In their first test after 6 months each bull achieved its maximum number of services ever. In the 3 subsequent tests in December the serving capacity for all 8 bulls remained relatively stable at a high, medium or low level with a variation of no more than 2 services (Figure 5).

For each of the 8 bulls the mean serving capacity displayed during May-June was not significantly different from the mean serving capacity shown during December (Table 30).

The young bulls used to sexually stimulate the group 1 Hereford bulls before the first test were sexually inactive until one of them mounted a cow. Then the others rapidly followed its example. In test 1 the sexually inexperienced bulls had a mean (±SD) serving capacity of 6.71 ± 5.4 (range 0 to 28). Sexual experience did not improve their
serving capacity for in test 2, their mean (±SD) serving
capacity was 6.78 ± 4.6 (range 0 to 23).

The correlation coefficient between the serving
capacity of bulls in test 1 and test 2 was +0.86 (Figure 6). Thirty two (78%) of the 41 bulls changed their serving
capacity by no more than 3 services from test 1 to test 2. Six of the 9 bulls that changed their serving capacity by 4 to 6 services achieved at one of the tests a minimum of 7 to 23 services (mean 11). The remaining 3 bulls had a serving capacity of 0, 0 or 4 in test 1, yet achieved 5, 6 or 9 services respectively in test 2 (Figure 6).

Xylazine was effective in immobilising 3 of the 4 cows that swivelled their hindquarters about when the young Hereford bulls attempted to mount.

DISCUSSION

Once sexually stimulated, the young Hereford bulls with no previous association with cows mounted the restrained cows and achieved as many services in their first exposure to cows as they achieved in a second test. When reared in homosexual groups young bulls mount one another displaying penile erection, protrusion and seeking movements (Kilgour and Campin 1973; Blockey and Lade 1974). The present data suggest that this homosexual mounting activity enables most bulls to display their inherent serving capacity on their first exposure to cows.
On their second test, only 9 (22%) of the 41 Hereford bulls changed their serving capacity in test 1 by more than 3 services. Six of these bulls achieved 7 or more services at both tests. Whether a bull achieved 7 or 11 services it would still be classed as a high serving capacity animal. Of greater concern are the two bulls which failed to serve in test 1 yet achieved 5 or 6 services in test 2. Had they had previous sexual experience prior to test 1 they may have shown similar serving capacity in tests 1 and 2.

The sexually experienced twin bulls maintained their serving capacity at a high, medium or low level over periods as short as 10 or 15 days or as long as 6 months. Whether bulls maintain their serving capacity as they age in years remains to be demonstrated.

CONCLUSION

It is concluded that a high proportion of sexually experienced or inexperienced bulls show little variation in their serving capacity from one test to another.
### TABLE 30
Serving Capacity of Bulls Tested
Six Months Apart

<table>
<thead>
<tr>
<th>Bull No.</th>
<th>Mean ± SD for 5 tests in June</th>
<th>Mean ± SD for 4 tests in December</th>
<th>t* value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>10.0 ± 1.2</td>
<td>10.3 ± 2.5</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>8.4 ± 1.5</td>
<td>9.5 ± 1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>27</td>
<td>4.2 ± 1.6</td>
<td>4.3 ± 1.3</td>
<td>0.1</td>
</tr>
<tr>
<td>28</td>
<td>3.4 ± 0.5</td>
<td>4.2 ± 1.0</td>
<td>1.4</td>
</tr>
<tr>
<td>31</td>
<td>3.2 ± 0.8</td>
<td>4.0 ± 0.8</td>
<td>1.3</td>
</tr>
<tr>
<td>32</td>
<td>3.0 ± 1.0</td>
<td>4.2 ± 1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>11</td>
<td>1.4 ± 0.9</td>
<td>1.8 ± 0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>12</td>
<td>0.6 ± 0.9</td>
<td>2.0 ± 1.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

* p < 0.05 for t* = 2.4
FIG 5 Serving capacity of individual bulls in five tests in May-June and in four tests, six months later
FIG 6 Relationship between serving capacity of Hereford bulls in Test 1 & Test 2
CHAPTER 12
THE SERVING CAPACITY TEST. ITS USE IN THE EXAMINATION OF BULLS FOR BREEDING SOUNDNESS

INTRODUCTION

The term, breeding soundness examination, refers to the veterinary examination of bulls to assess their usefulness as breeding animals in a pasture mating situation. Ideally it should consist of a) a physical examination of the genital system, b) a field and laboratory examination of semen and c) an examination of serving behaviour (Galloway 1966; Anon 1967). In practice, when veterinarians are asked to examine bulls prior to sale or breeding, they always conduct a physical examination, they often include an examination of semen but they rarely observe bulls serving or attempting to serve. If a serving test is not done, bulls of low serving capacity would not be culled and nor would those with physical abnormalities detectable only during an attempted service. The latter would include bulls with such penile abnormalities as deviations or adhesions of the penis and prepuce. It could also include bulls with certain abnormalities of the locomotor system. Bulls with spondyloarthrosis or spondylosis deformans sometimes exhibit no lameness but always show abnormal serving behaviour (Bane and Hansen 1962). The development of degenerative joint disease (DJD) to the stage of joint crepitus may take from 2 to 5 years (Shupe 1959). Abnormalities in serving behaviour may be useful in diagnosing DJD of the hip before crepitus can be detected.
However few bulls that are unsound for breeding may have abnormalities that can be diagnosed only during a serving test. To gain information on this point, 548 beef bulls were examined for breeding soundness over a 3 year period.

This chapter presents data on the incidence of abnormalities for which bulls are culled and discusses the relative importance of the physical and serving behaviour examinations in detecting these abnormalities. The composition of the herd provided the opportunity to determine the influence of age and breed on the incidence of abnormalities for which bulls were culled.

MATERIALS AND METHODS

Management of bulls

The bulls were purchased from stud herds at 1.5 to 2.5 years of age and mated for the first time within 6 months of purchase. The majority of these bulls were fed concentrates as a supplement to grazing in the three months prior to sale.

There were two mating seasons per year, one of 10 weeks starting in early September and the other of 8 weeks beginning in mid-May. In each mating season bulls were joined in groups of 3 to 13 at the rate of 3 bulls per 100 cows. The mating paddocks were open and undulating and varied from 60 to 400 hectares in size. Between mating seasons all bulls were grazed together. Each year prior to the September joining bull's hoofs were inspected and those overgrown were trimmed.
Bulls

The number of Hereford and Angus bulls examined in each of the 3 years and the age structure of these herds is shown in Table 31.

Techniques of examination

The physical examination consisted of the following:

i) a manual inspection of joints of the mid and lower limb and a visual inspection of hoofs and eyes,

ii) observations on gait abnormalities during the walk and trot,

iii) manual examination of hip and stifle joints in an attempt to detect crepitus in bulls with a hind limb lameness,

iv) manual palpation of scrotal contents, penis and internal genitalia. Scrotal circumference was measured and taken as an index of testicle size when both testes were of similar size (Foote 1969). Testicular consistency was scored in terms of firmness (1 very firm to 5 very soft) and resilience (1 very high to 5 very low).

Semen was collected by either massage of ampullae and seminal vesicles or by electroejaculation. A field microscopic examination for wave motion and motility was made. Semen was prepared for laboratory examination as described by Galloway (1966).

In 1973 and 1974 bulls were tested for serving ability. In 1973 bulls were allowed access to oestrous, ovariotomised heifers in a yard. Bulls failing to serve in the yards were observed with oestrous heifers for a
further 8 hours in a 1 hectare paddock. In 1974, oestrous cows were tied with a halter to the side of the yard and bulls allowed access to them for up to 40 minutes. Animals failing to serve were retested under the same conditions a week later.

In 1975 bulls were given a serving capacity test. Sexually stimulated bulls in groups of 10 to 12 were placed in a yard with 6 non-oestrous cows restrained in service crates. Within these groups bulls were of similar age and of the same breed. Serving capacity was defined as the number of services a bull achieved in the 40 minute test period.

During the serving ability or capacity tests bulls were carefully observed for abnormalities in mounting, clamping with forelegs, penile protrusion during seeking and hindquarter movement during the ejaculatory thrust. The proportion of mounts in which the penis spiralled before intromission was recorded in bulls showing corkscrew deviation of the penis.

Diagnostic use of techniques and bases for culling

In 1973 semen was collected from all 202 bulls and submitted for laboratory examination. In 1974 and 1975 bulls scoring 2 or 1 for testicular consistency were not subjected to semen collection. These testicles were considered normal and characteristic of good testicular function (D.B. Galloway - personal communication). Nor was semen collected from bulls with a scrotal circumference of less than 30 cm. These bulls were culled as having abnormally small testicles. Animals with testicular consistency scores of 3 or 4 were suspected
of having testicular dysfunction and subjected to semen collection. If the semen collected had good motility and wave motion, the bull was considered to have satisfactory testicular function. Semen samples from bulls which, on two or more occasions, voided semen of poor motility and wave motion, were submitted for laboratory examination. In all three years, bulls consistently voiding semen with less than 50% live sperm were considered to have testicular dysfunction and culled.

Bulls with seminal vesiculitis were culled when one or both glands was enlarged and very firm with lobules sharply demarcated (Galloway 1964). When a cauda epididymis was very firm and 2 to 3 times normal size, the bull was culled for epididymitis.

Abnormalities of the locomotor system were diagnosed after the visual and manual inspections and the observation of bulls walking or mounting. Bulls with severely overgrown claws, foot abscess, large interdigital granuloma or leg injuries, were culled only if very lame. Bulls with firm, enlarged limb joints were culled if the lesion(s) caused moderate to severe lameness and/or pain when mounting, clapping or thrusting. In most instances the diagnosis of degenerative joint disease (DJD) of the hip was based on the dragging of the affected hind limb and the detection of crepitus. In the absence of crepitus the clinical signs used to diagnose DJD of the hip were toe dragging indicative of poor hip flexion, favouring of the affected limb while mounting or thrusting and a characteristically short jump while thrusting. All
bulls with DJD of the hip were culled. A diagnosis of spondylosis deformans was made when an old bull supported itself by its lower jaw on the cow's hind quarters and mounted by levering itself up with the help of its neck muscles (Bane and Hansen 1962).

Bulls that were culled because of penile abnormalities included a) those with a ventro-lateral deviation, b) those with corkscrew penis which spiralled on 10% or more of their service attempts, c) those with adhesions of the penis and prepuce which prevented full protrusion (termed penile haematoma) and d) those with severe penile haematomas causing prolapse of the penis. The latter were disposed of immediately without a veterinary examination.

Bulls failing to serve in either yard or paddock test in 1973 were termed poor serving capacity animals and culled as were bulls which did not serve or served only once in their re-test in 1974. Bulls completing 0 or 1 service in the serving capacity test in 1975 were culled. Bulls showing poor serving capacity as a result of a physical abnormality were culled for the latter.

Statistical analysis

The influence of age and breed on the incidence of abnormalities was assessed by chi-square analysis (Cochran 1954).
RESULTS

Of the 548 bulls examined, 113 (20.7%) were considered unsound for breeding and culled. A further 3 (0.6%) were found dead in the paddock. The incidence of specific abnormalities for which the 113 bulls were culled is shown in Table 32. Of the bulls culled, 31 were detected on clinical signs only apparent during an attempted or successful service. The 31 included bulls with penile deviation (10), penis-prepuce adhesions (5), spondylosis deformans (3), degenerative joint disease of hips (8), and arthropathy of knee (1), fetlock (3), and hock (1). These 31 and the 17 bulls with poor serving capacity accounted for 42.5% of the bulls culled.

Effect of age, breed and year on culling rate

The culling rate for 2 to 4 year old bulls was low (13.8% and 10.2% for Hereford and Angus respectively) and was not significantly affected by either age (2, 3 or 4 years) or breed. However at 5 years of age, culling rate increased significantly to 38.6% for Hereford bulls (P < 0.001) and 35.7% for Angus bulls (P < 0.01). Hereford bulls 6 years and older had a similar culling rate (45.6%) to the 5 year old bulls.

A significantly lower (P < 0.01) proportion of bulls was culled in 1973 (10.9%) than in either 1974 (27.9%) or 1975 (24.6%). Year and age effects are confounded for in 1973 only 15.3% of bulls were 5 years or older compared to 31.8% of bulls in 1974-75 (P < 0.001).
Effect of age and breed on the incidence of specific abnormalities

DJD of hips. Of the Hereford and Angus bulls examined, 4.5% and 3.9% respectively had degenerative joint disease of the hips. The incidence of this condition was 1.5% in 2 to 4 year old bulls compared to 13.5% in bulls 5 years or older ($P < 0.001$). There was a dramatic and highly significant increase from 4 to 5 years of age in the incidence of bulls with DJD of the hips (from 3.5% to 15.3%, $P < 0.001$).

Arthropyathy of other joints. Whilst breed had no significant effect on the incidence of this condition, age did, with 8 of 10 bulls culled for arthropathy of joints other than the hip, being 5 years of age or older ($P < 0.05$).

Foot lameness. Both age and breed significantly ($P < 0.001$) influenced the incidence of foot lameness (foot abscess, overgrown claws, interdigital granuloma) with all 14 affected bulls being Herefords and 13 of these being 5 years or older.

Penile abnormalities. Only 1 of the 17 bulls suffering penile haematoma was older than 4 years. There was also a significant breed effect with 6.1% of the 2 to 4 year old Hereford bulls suffering penile haematoma compared with only 0.8% of the 2 to 4 year old Angus bulls ($P < 0.05$). However significantly more Angus bulls had penile deviations than Hereford bulls (5.2% cf 0.5%, $P < 0.01$). The 8 affected
Angus bulls had a corkscrew deviation whilst the two Hereford bulls had a ventro-lateral deviation of the penis.

Poor serving capacity. There were no significant age or breed differences in the bulls culled for poor serving capacity.

DISCUSSION

Of the 54 bulls culled for locomotor abnormalities, 16 (30%) showed no gait abnormality during the physical examination. Only after repeated mounting, clasping and thrusting did they display serving behaviour suggestive of a joint dysfunction. A closer examination of these bulls after a period of mounting activity often revealed a gait abnormality, an abnormal joint angulation or an abnormal claw conformation considered to result from the locomotor disturbances. Examples of the latter were two bulls which had DJD of the hip associated with a corkscrew configuration of a lateral hind claw.

Of the 26 bulls culled for penile abnormalities, 12 (46.2%) were identified on physical examination alone. These were bulls with a penile haematoma sufficiently severe to prolapse the penis. A further 5 bulls had adhesions between the penis and prepuce which prevented full penile protrusion during seeking. In some bulls the fibrous thickening could be detected on manual examination. However to determine the effect of the fibrous thickening on penile
protrusion these bulls had to be observed seeking. The 10 bulls with a penile deviation could only be detected during the serving test. Although 96% of bulls protrude the penis during electroejaculation (Carroll et al. 1963), this method of examining the penis for a deviation is not efficient. Normal bulls frequently spiral the penis due to an abnormal erection response stimulated by the electroejaculator (Carroll et al. 1963). The Hereford bulls with a ventrolateral deviation and some of the Angus bulls with a corkscrew deviation, spiralled the penis before intromission on every service attempt. Other Angus bulls spiralled the penis on 50% to 75% of service attempts and still others on less than 10% of mounts. These bulls had to be observed over many service attempts before a decision on culling could be made. This is important for bulls spiralling the penis on < 10% of attempted services are not considered to suffer a depression in fertility (Ashdown and Pearson 1973).

The total of 62 bulls with abnormalities recognized during the physical examination represents 11.3% of the 548 bulls examined. Dickson (1966) conducted a questionnaire survey of 107 beef producers in Victoria and found that 10.2% of the 985 bulls in the survey were culled for physical abnormalities which the farmers considered were detrimental to fertility. As in the present study, bulls with abnormalities of the locomotor system (7.1% of 985 bulls) and bulls with penile injuries (2.3%) made up most of these culls. The similarity in these culling rates (11.3% cf 10.2%)
suggests that veterinarians conducting only a physical 
examination of bulls accomplish little more than would an 
observant farmer. It could be argued that the organs that 
only the veterinarian would examine (testicles, epididymis 
and seminal vesicles) had an unusually low incidence of 
abnormalities. This is not the case. The incidence of 
small testicles, epididymitis and seminal vesiculitis in 
the present study was 1.3%, 0.4% and 0.5% respectively. 
In the large American studies conducted, the incidence of 
these conditions was 1.3%, 0.4% and 1.5% respectively (Carroll 
et al 1963; Ball et al 1964).

Of the bulls culled, 42.5% would have been 
considered sound for breeding had not a serving test been 
done. This clearly demonstrates that a serving test is an 
important component of the examination of bulls for breeding 
soundness. However not just any serving test will suffice. 
The 5 minute test described by Osborne et al (1971) is too 
short to diagnose corkscrew penis or early arthropyathy in 
affected animals. Bulls must be tested in a sexually 
stimulating environment that will encourage them to mount 
or serve many times in a short period. The serving capacity 
test provides this environment. The fact that several cows 
are available, that they are restrained in the standing 
position and that bulls are competing for cows and seeing 
sexual activity about them, serves to stimulate most bulls 
to attempt at least 6 services during the 40 minute test.
TABLE 31

Number of Hereford and Angus Bulls of Each Age
Examined in 1973, 1974 and 1975

<table>
<thead>
<tr>
<th>Age of bulls (years)</th>
<th>No. of Hereford bulls examined</th>
<th>No. of Angus bulls examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>142</td>
<td>125</td>
</tr>
</tbody>
</table>

* The 41, 2 year old bulls examined in 1975 had not been mated.
TABLE 32

Incidence of Specific Abnormalities in the 548 Bulls Examined

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>No. &amp; % of Bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degenerative joint disease of hips</td>
<td>25 (4.6%)</td>
</tr>
<tr>
<td>Arthropathy of other limb joints</td>
<td>7 (1.3%)</td>
</tr>
<tr>
<td>Spondylosis deformans</td>
<td>3 (0.5%)</td>
</tr>
<tr>
<td>Foot abscess</td>
<td>6 (1.1%)</td>
</tr>
<tr>
<td>Horn overgrowth</td>
<td>6 (1.1%)</td>
</tr>
<tr>
<td>Interdigital granuloma</td>
<td>2 (0.4%)</td>
</tr>
<tr>
<td>Non-specific lameness</td>
<td>5 (0.9%)</td>
</tr>
<tr>
<td>Penile haematoma</td>
<td>17 (3.1%)</td>
</tr>
<tr>
<td>Deviation of penis</td>
<td>10 (1.9%)</td>
</tr>
<tr>
<td>Poor serving capacity</td>
<td>17 (3.1%)</td>
</tr>
<tr>
<td>Small testicles</td>
<td>7 (1.3%)</td>
</tr>
<tr>
<td>Testicular dysfunction</td>
<td>3 (0.5%)</td>
</tr>
<tr>
<td>Seminal vesiculitis</td>
<td>3 (0.5%)</td>
</tr>
<tr>
<td>Epididymitis</td>
<td>2 (0.4%)</td>
</tr>
<tr>
<td></td>
<td>113 20.7%</td>
</tr>
</tbody>
</table>
CHAPTER 13
EFFECT OF PHYSICAL CHARACTERISTICS OF BULLS ON THEIR SERVING CAPACITY

SECTION 1. Locomotor Abnormalities

INTRODUCTION

Abnormalities of the locomotor system were the biggest single reason for bulls being unsound for breeding (Chapter 12). Some 48.2% of the unsound bulls had degenerative joint disease (DJD), foot abnormalities causing lameness or a non-specific lameness. These bulls were culled because it was considered that they would have lower serving capacity than bulls free of locomotor abnormalities. This hypothesis was tested with 125 beef bulls given a physical examination and a serving capacity test.

MATERIALS AND METHODS

Bulls

The herd of bulls consisted of 85 Hereford and 40 Aberdeen Angus aged between 4 and 8 years.

Physical examination

The physical examination consisted of the following:

i) a visual inspection of hoofs and a manual inspection of joints of the mid and lower limb,

ii) observations of gait abnormalities during the walk and trot,
iii) Manual examination of hip and stifle joints to detect crepitus in bulls with a hind limb lameness,
iv) observations on bulls during service attempts for abnormalities in mounting, clasping with forelegs, penile protrusion during seeking and hindquarter movement during the ejaculatory thrust.

Bulls were classed as normal if they a) were free of penile abnormalities b) showed no lameness and c) showed no locomotor abnormality during attempted services. Animals were considered abnormal in locomotor function if they were lame and/or showed abnormalities in mounting, clasping or thrusting.

Diagnoses of locomotor abnormalities were based on the following clinical signs:

1) Foot lameness - presence of severely overgrown claws or a large interdigital granuloma accompanied by lameness of the affected limbs

11) Arthropathy of lower limb joints - enlargement and/or abnormal angulation of fetlock, knee or hock joints accompanied by lameness of the affected limb or difficulty in mounting or clasping

iii) Degenerative joint disease of hip or stifle. Detection of crepitus provided a positive diagnosis. In the absence of crepitus clinical signs used to diagnose DJD of the hip were toe dragging and favouring of the affected limb while mounting or thrusting.
iv) Spondylosis deformans. This was diagnosed when an old bull placed its lower jaw on the cow's back and mounted by levering itself up with its head and neck. The effect of the abnormality on the bull's locomotion was noted.

**Determination of serving capacity**

Bulls were tested for serving capacity in groups of 10 to 12. Each group comprised bulls of the same or similar age and the same breed. Six non-oestrous cows were restrained in service crates and a group of sexually stimulated bulls allowed access to them. Cows were replaced after 2 or 3 groups of bulls had been tested. Serving capacity was measured as the number of services achieved in the 40 minute test period.

**Statistical analysis**

Each normal or abnormal bull was placed in one of 3 serving capacity classes: 0 to 2, 3 to 5, 6 or more services in the 40 minute test. Once constructed, this 2 x 3 contingency table was analysed by chi-square analysis (Cochran 1954) to determine whether abnormal bulls had lower serving capacity than normal bulls.

**RESULTS**

Of the 125 bulls examined, 100 were considered to have normal locomotor function. Five of the 25 abnormal bulls had penile abnormalities (penis-prepuce adhesion (1), rupture
of corpus cavernosum urethra (1), corkscrew deviation of penis (3)) and were excluded from the analysis. The remaining 20 bulls had either degenerative joint disease of the hips (9), arthropathy of other limb joints (3), spondylosis deformans (3) or a foot lameness (5). Full details of the serving capacity of these bulls and the effect of their physical abnormalities on locomotion are shown in Table 33.

The 2 x 3 contingency table (Table 34) shows the observed and expected numbers of normal and abnormal bulls in the different serving capacity classes. The highly significant difference between observed and expected values ($X^2 = 17.1, P < 0.001$) demonstrated that the serving capacity of bulls with locomotor abnormalities was markedly lower than the serving capacity of normal bulls.

DISCUSSION

It is probable that bulls with locomotor abnormalities show higher serving capacity in the yard test than they would if mated with cows in the paddock. In the yard test cows are restrained in service crates. Consequently bulls do little walking and almost every mount results in a service. In the paddock bulls walk long distances each day either accompanying oestrous females or making investigational treks about the paddock when no cows are in oestrus (Chapter 7). Furthermore cows and heifers are receptive to service for only short periods during oestrus (Sambraus
1971b). Consequently bulls mount cows a mean 8.5 times for every service they achieve in the paddock (Mattner et al 1974). The effect of a physical abnormality on locomotion would be greater under these conditions of intense locomotor activity than in the relatively leisurely conditions of the yard test.

This discussion is particularly relevant to those 5 bulls achieving 6 or more services in the yard test. One is tempted not to cull these bulls. Their high serving capacity makes them valuable for mating and their respective abnormalities had little effect on their locomotion in the yard test (Table 33). However paddock mating would be expected to exacerbate the effect of the abnormality on locomotion and in so doing reduce them to low serving capacity animals.

Some 30% of bulls culled for physical abnormalities of the locomotor system would not have been detected had they not been observed mounting, clasping and thrusting in a serving capacity test (Chapter 12). The present data clearly demonstrates that these bulls would have lower serving capacity than normal bulls. There would be a loss in calf production as a result of mating such bulls (Chapter 7).

Bulls with penile abnormalities interfering with intromission might also be expected to cause low conception rates when joined to cows. More than half the bulls culled for penile abnormalities in Chapter 12 could only be identified in a serving capacity test.
The probable reduction in herd fertility resulting from the mating of bulls with locomotor or penile abnormalities should be sufficient reason for veterinarians to include the serving capacity test in their examinations of bulls for breeding soundness.
TABLE 33
Serving Capacity and Locomotor Disturbance of Bulls with Locomotor Abnormalities

<table>
<thead>
<tr>
<th>Bull no.</th>
<th>Physical abnormality and effect on locomotion</th>
<th>Serving capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A10</td>
<td>Arthropathy of front fetlock joint. Mild lameness, mild difficulty in clasping.</td>
<td>3</td>
</tr>
<tr>
<td>A9</td>
<td>DJD* of hip. Mild lameness.</td>
<td>3</td>
</tr>
<tr>
<td>A16</td>
<td>DJD of hip. Moderate lameness, mild difficulty in thrusting.</td>
<td>4</td>
</tr>
<tr>
<td>A37</td>
<td>Arthropathy of hocks. Moderate lameness, moderate difficulty in mounting.</td>
<td>2</td>
</tr>
<tr>
<td>61</td>
<td>Arthropathy of stifle. Severe lameness.</td>
<td>0</td>
</tr>
<tr>
<td>33</td>
<td>Large interdigital granuloma. Moderate lameness.</td>
<td>2</td>
</tr>
<tr>
<td>39</td>
<td>Spondylosis deformans. Moderate difficulty in mounting.</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>Spondylosis deformans. Mild difficulty in mounting.</td>
<td>2</td>
</tr>
<tr>
<td>34</td>
<td>Spondylosis deformans. Mild difficulty in mounting.</td>
<td>6</td>
</tr>
<tr>
<td>63</td>
<td>Horn overgrowth of forelimbs. Severe lameness.</td>
<td>5</td>
</tr>
<tr>
<td>44</td>
<td>Arthropathy of knee. Moderate lameness, mild difficulty in clasping.</td>
<td>1</td>
</tr>
<tr>
<td>HB3</td>
<td>DJD of hip and horn overgrowth of forelimbs. Moderate lameness.</td>
<td>3</td>
</tr>
<tr>
<td>HB5</td>
<td>Horn overgrowth of forelimbs. Severe lameness.</td>
<td>1</td>
</tr>
</tbody>
</table>

*DJD - Degenerative joint disease.
TABLE 33 (cont)
Serving Capacity and Locomotor Disturbance of Bulls
with Locomotor Abnormalities

<table>
<thead>
<tr>
<th>Bull no.</th>
<th>Physical abnormality and effect on locomotion</th>
<th>Serving capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>Horn overgrowth of forelimbs. Moderate lameness.</td>
<td>2</td>
</tr>
<tr>
<td>83</td>
<td>DJD of hip. Mild lameness, mild difficulty in thrusting.</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>DJD of hip. No lameness, mild difficulty in thrusting.</td>
<td>7</td>
</tr>
<tr>
<td>114</td>
<td>Large interdigital granuloma. Mild lameness, mild difficulty in mounting.</td>
<td>8</td>
</tr>
<tr>
<td>76</td>
<td>DJD of hip. Mild lameness.</td>
<td>8</td>
</tr>
<tr>
<td>113</td>
<td>DJD of both hips. Moderate lameness, difficulty in mounting.</td>
<td>2</td>
</tr>
<tr>
<td>118</td>
<td>DJD of hip. Severe lameness and moderate difficulty in mounting.</td>
<td>2</td>
</tr>
</tbody>
</table>
### Table 34
Serving Capacity of Bulls with Normal or Abnormal Locomotor Function

<table>
<thead>
<tr>
<th>Bulls</th>
<th>No. of bulls achieving in the test services</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 2</td>
<td>3 - 5</td>
</tr>
<tr>
<td>Normal</td>
<td>9 (15)</td>
<td>41 (39)</td>
</tr>
<tr>
<td>Abnormal</td>
<td>9 (3)</td>
<td>6 (8)</td>
</tr>
</tbody>
</table>

( ) Expected number of bulls in each class.
CHAPTER 13
EFFECT OF PHYSICAL CHARACTERISTICS OF BULLS
ON THEIR SERVING CAPACITY

SECTION 2. Age and Breed

INTRODUCTION

There is no published study on the effect of age and breed on the serving capacity of beef bulls. Such a study should exclude bulls with locomotor or penile abnormalities for these abnormalities have a significant age or breed incidence (Chapter 12) and bulls with these abnormalities have a significantly lower serving capacity than bulls with normal locomotor or penile function (Chapter 13:1).

The effect of age and breed on serving capacity was determined in 141 mixed age Hereford and Angus bulls considered to have normal locomotor and penile function.

MATERIALS AND METHODS

Bulls

The herd of bulls comprised a) the 100 normal bulls described in Chapter 8:1 and b) 41, two year old Hereford bulls. The former group consisted of 39 four-year-old and 29 five-to 8-year-old Hereford bulls and 21 four-year-old and 11 five-to 8-year-old Aberdeen Angus bulls. They were considered normal in locomotor and penile function
after the physical examination described in Chapter 13.1. The 41 young bulls underwent the same physical examination and were all classed as free of locomotor or penile abnormalities.

Determination of serving capacity

The 100 bulls 4 years or older had had previous mating experience whilst the 41 young bulls had never been mated to cows either in the yard or the paddock. To give them mating experience the young bulls in groups of 10 to 12 were placed with 6 non-oestrous cows restrained in service crates for 40 minutes. Two weeks later they were given a serving capacity test. The 100 older bulls also underwent a serving capacity test at this time. Bulls were tested in groups of 10 to 12 animals of the same age and breed. Once sexually stimulated, bulls in these groups were allowed access to 6 non-oestrous cows restrained in service crates. Serving capacity was measured as the number of services achieved in the 40 minute test period.

Statistical analysis

On the basis of its serving capacity, each bull was placed in one of four classes: 0 to 2, 3 to 5, 6 to 8, 9 or more. The observed and expected numbers of 2, 4 and 5 to 8 year-old Hereford bulls in these 4 classes were compared using chi-square analysis (Cochran 1954). There were insufficient Angus bulls to make a meaningful age comparison within that breed. To make the breed comparison
the 4 and 5 to 8 year old bulls were combined within breeds. The observed and expected number of Hereford and Angus bulls in the 4 serving capacity classes were compared using chi-square analysis (Cochran 1954).

RESULTS

Table 35 shows the observed and expected numbers of 2, 4 and 5 to 8 year old Hereford bulls in the different serving capacity classes. The lack of a significant difference between them ($X^2_6 = 10.2$) shows that a bull's age does not influence its serving capacity.

The similarity between the observed and expected numbers of Hereford and Angus bulls in the four serving capacity classes (Table 36) shows that Hereford and Angus bulls did not differ significantly in their serving capacity ($X^2_3 = 2.4$).

DISCUSSION

In the present study, age of bull and its mating experience were confounded. However mating experience does not significantly influence the serving capacity of sexually inexperienced bulls (Chapter 11) and in view of this, is considered unlikely to influence the serving capacity of sexually experienced bulls.

To determine a heritability estimate for serving capacity, 5 or more bull progeny of 60 different sires need to have their serving capacity determined for a paternal half-sib correlation analysis (L.P. Jones, personal
communication 1975). The failure of age to influence serving capacity means that bull progeny of any age could be used in this estimate provided they were free of locomotor or penile abnormalities.

Hereford and Angus bulls were used for the breed comparison because these breeds comprise 72% and 20% respectively of breeding bulls in Victoria (Dickson 1966). Had Brahman bulls, which are commonly used in northern Australia, been included in this comparison there might have been a significant breed effect on serving capacity. When each of the bulls studied by Chenoweth and Osborne (1975) was exposed to an oestrous heifer for 5 minutes, 16.6% of Hereford bulls achieved a service compared to only 3.9% of Brahman bulls. Further data on the influence of breed on the serving capacity of bulls are needed.

CONCLUSION

It is concluded that age of Hereford bulls did not influence their serving capacity provided they were free of locomotor or penile abnormalities.
TABLE 35
Serving Capacity of Hereford Bulls of Different Ages

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Number of bulls achieving services</th>
<th>Total number of bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 2</td>
<td>3 - 5</td>
</tr>
<tr>
<td>2</td>
<td>8 (5)</td>
<td>10 (14)</td>
</tr>
<tr>
<td>4</td>
<td>3 (5)</td>
<td>13 (13)</td>
</tr>
<tr>
<td>5 - 8</td>
<td>3 (4)</td>
<td>14 (10)</td>
</tr>
</tbody>
</table>

( ) Expected number of bulls in each class.
TABLE 36

Serving Capacity of 4 to 8 year old Hereford and Angus Bulls

<table>
<thead>
<tr>
<th>Breed</th>
<th>Number of bulls achieving</th>
<th>Total no. of bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 - 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 - 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 or more</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Hereford</td>
<td>6 (6)</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>27 (28)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 (24)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 (10)</td>
<td></td>
</tr>
<tr>
<td>Ab. Angus</td>
<td>3 (3)</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>14 (13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13 (12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 (4)</td>
<td></td>
</tr>
</tbody>
</table>

( ) Expected number of bulls in each class.
CHAPTER 13
EFFECT OF PHYSICAL CHARACTERISTICS OF BULLS
ON THEIR SERVING CAPACITY

SECTION 3. Scrotal Circumference

INTRODUCTION

If a bull of high serving capacity is to impregnate as well as to serve a large number of cows, it must have a high sperm production and produce good quality semen. For example, the 3 highest serving capacity bulls in the simulated pasture mating (Chapter 8:1) achieved between 93 and 105 services over the 19 day mating period. To have high fertility, these 3 year old bulls averaging 5 services per day would have to ejaculate $6 \times 10^9$ sperm/day (Osborne and Singleton 1973). This is well within the realms of possibility. Some 50% of the dairy bulls studied by Almquist et al (1958) and Hafs et al (1959) maintained a daily sperm output of between $5.6$ and $8.4 \times 10^9$ sperm for 32 weeks. In addition 10 3-year-old dairy bulls maintained a daily sperm output of $5.9 \times 10^9$ sperm for 4 weeks (Hahn et al 1969).

Sperm output in young bulls is limited by testicle size as measured by scrotal circumference. In a group of 10 dairy bulls, 17 to 22 months old, the correlation between weekly sperm output and scrotal circumference was +0.81 (Hahn et al 1969). In yearling Hereford bulls, the correlation between total sperm per ejaculate and scrotal circumference was +0.42 (Fagerlin et al 1972).
It seems likely that for young bulls of high serving capacity to achieve their potential for high fertility they must have testicles above a certain minimum size. Determining the minimum scrotal circumference for bulls of different serving capacity is beyond the scope of this project. However should serving capacity and scrotal circumference be positively and significantly correlated, the need to determine these minima would be eliminated. In this section the relationship between serving capacity and scrotal circumference was studied in young Hereford bulls.

MATERIALS AND METHODS

The experimental bulls were from 3 Hereford herds in south eastern Australia. The number of bulls in each herd and the range in age at the time of the experiment are shown in Table 37.

Scrotal circumference of each bull was measured with a flexible plastic tape around the greatest diameter of the testes and scrotum (Foote 1969).

Serving capacity of each bull was measured as the number of services achieved during a 40 minute test. In herds 1 and 2, sexually stimulated bulls were tested in groups of 5 or 6 with 3 non-oestrous heifers restrained in service crates. Two groups were tested at the same time in adjacent yards. In herd 3, groups of 10 to 12 bulls were tested with 6 non-oestrous restrained heifers.
For each herd, the relationship between serving capacity and scrotal circumference was determined by simple correlation analysis (Steel and Torrie 1960).

RESULTS

In each of the 3 herds there was a large variation in the scrotal circumference and the serving capacity of bulls (Table 38).

In no herd was serving capacity significantly correlated with scrotal circumference. The correlation coefficients for herds 1, 2 and 3 were -0.14, +0.09 and -0.04 respectively.

DISCUSSION

The lack of a significant and positive correlation between serving capacity and scrotal circumference means that the potential of high-serving-capacity bulls may be limited by their sperm production. Bulls mated in a group utilise their sperm output efficiently in that each bull serves an oestrous cow only once (Chapters 6 and 8:1). Notwithstanding this, high serving capacity bulls with testicles smaller than a certain size may have a sperm production too low for their successful use with a large number of cows. The sperm output of high serving capacity bulls in a simulated pasture mating needs to be monitored to determine the minimum scrotal circumference of high serving capacity bulls. Practical recommendations on the number of cows to mate to high serving capacity bulls must await this type of detailed experimental study.
TABLE 37
Details of Experimental Bulls and Time of Experiment

<table>
<thead>
<tr>
<th>Herd</th>
<th>No. of bulls</th>
<th>Range in age of bulls (months)</th>
<th>Time of experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>18 - 20</td>
<td>November, 1974</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>18 - 21</td>
<td>November, 1974</td>
</tr>
<tr>
<td>3</td>
<td>41</td>
<td>18 - 20</td>
<td>February, 1975</td>
</tr>
</tbody>
</table>
### TABLE 38

Serving Capacity and Scrotal Circumference of Young Bulls in Three Hereford Herds

<table>
<thead>
<tr>
<th>Herd</th>
<th>Serving capacity Mean ± SD (Range)</th>
<th>Scrotal circumference Mean ± SD (cms) (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.2 ± 4.0 (0-19)</td>
<td>33.5 ± 2.0 (30-41)</td>
</tr>
<tr>
<td>2</td>
<td>4.7 ± 3.0 (0-11)</td>
<td>32.9 ± 3.0 (27-39)</td>
</tr>
<tr>
<td>3</td>
<td>6.6 ± 6.0 (0-28)</td>
<td>34.7 ± 2.0 (29-39)</td>
</tr>
</tbody>
</table>
CHAPTER 14
HORMONAL CONTROL OF SERVING CAPACITY OF BULLS

INTRODUCTION

Studies in guinea pigs (Grunt and Young 1952), rats (Larsson 1966), chickens (McCollom et al 1971), rams (Mattner and Braden 1975), and now bulls (Chapters 8 and 11), have shown that, within species, individuals vary greatly in their serving activity and that these differences between individuals persist. The reason why individual guinea pigs differ in serving activity was established by the scientifically classic experiment of Grunt and Young (1952). Adult males varying in serving activity were divided into high, medium and low groups and the individuals in each group castrated. After castration had eliminated the serving activity of all individuals they were given daily injections of testosterone propionate in doses equalised on the basis of bodyweight. The between-group differences in serving activity which existed before castration were restored. The serving activity of the castrates was only restored to its precastrational level by daily doses of testosterone above a threshold level. Further increases in daily testosterone dose up to 4 times the threshold level did not increase the serving activity of the guinea pigs above their precastrational level. These data led to the hypothesis that 1) the presence of testosterone above a threshold level is necessary to maintain serving activity, 2) the action of testosterone on the tissues mediating serving activity, the soma, is limited by somatic
responsiveness and 3) differences in somatic responsiveness to threshold levels of testosterone account for differences in serving activity between individuals. Researchers who have repeated this classic experiment in other species have found this hypothesis to be valid for rats (Larsson 1966), rams (Clegg et al 1969) and chickens (McCollom et al 1971).

Nothing is known about the hormonal control of serving capacity in bulls. In this chapter the experiment of Grunt and Young (1952) has been conducted to determine whether their hypothesis adequately explains differences in serving capacity between bulls.

MATERIALS AND METHODS

Bulls

The experimental bulls were 4 sets of sexually experienced twin bulls, 28 to 30 months of age. Each set of bulls had had their monozygosity established by blood typing and morphological inspection (Chapter 9:1). Two groups of bulls, A and B, were formed with one brother from each twin set.

Determination of serving capacity

The testing procedure to determine the serving capacity of bulls was as follows:

1) 3 entire cows were restrained in service crates in a 15 m x 20 m yard,
2) one group of bulls was placed in a yard adjacent to the restrained cows and sexually stimulated by allowing 2 other bulls to mount these cows for 10-15 minutes,

3) the 4 bulls were then released into the yard with the restrained cows and over the next 40 minutes the number of services achieved by each bull, i.e. their serving capacity, was determined,

4) the bulls in the other group were prevented from seeing this sexual activity by yarding them behind a wooden barrier more than 20 m from the testing yard,

5) the bulls in the second group were sexually stimulated for 10 minutes and then exposed to the same 3 cows for a 40 minute serving capacity test.

In a preoperative period from 14 to 23 December 1974, each group of bulls was given four, 40 minute serving capacity tests, each test at 3 day intervals.

On 23 December, the bulls in group B were castrated by surgical removal of the testicles. Group A bulls were left entire so that each castrate had a twin brother as a non-castrated control. At weekly intervals for 6 weeks after castration, the bulls within groups A and B were given a 40 minute serving capacity test. This period was termed the postoperative period.

The period of testosterone therapy began on 12 February some 7 weeks after castration. On 12, 16, 20, 25 February and on 1 March, the group B castrates were given an intramuscular injection of testosterone propionate (TP)
at a dose rate of 1 mg/kg of bodyweight. The animals injected during February and their group A controls were given a 40 minute serving capacity test 24 hours after the administration of TP. The March serving capacity tests of group A and B bulls were conducted 48 hours after the TP injection.

All 8 bulls were blood sampled by venipuncture on 2 January, 10 days after castration, on 13 and 21 February, 24 hours after the first and third TP injections respectively and on 3 March, 48 hours after the TP injection. The concentration of testosterone in the plasma samples was determined using the radioimmunoassay method of Wang et al (1974) by Dr. B. Hudson, Howard Florey Institute.

Statistical analysis

Differences in serving capacity and plasma testosterone levels between groups, between twin pairs or between individuals were analysed by comparing means (± standard deviation) in the Student 't' test (Steel and Torrie 1960).

RESULTS

In the preoperative period the mean serving capacity of group A and group B bulls was similar (4.9 ± 3.5 and 5.2 ± 3.5 respectively). Castration of group B bulls resulted in a highly significant decrease in both serving capacity and plasma testosterone level. The castrate
group had a mean serving capacity of 2.0 ± 2.3 in the 6 week postoperative period while their entire twin brothers maintained a serving capacity of 5.3 ± 3.3 (t_{46} = 3.9, P < 0.001). Ten days after castration the castrate and entire bulls had mean plasma testosterone levels of 1.2 ± 0.2 ng/ml and 14.9 ± 3.0 ng/ml respectively (t_{6} = 7.9, P < 0.001). The administration of testosterone to the group B bulls restored their serving capacity to the level displayed by the group A bulls. In the 3 week period of testosterone therapy, the castrate and entire bulls had a mean serving capacity of 3.7 ± 3.3 and 4.1 ± 3.2 respectively. This similarity in serving capacity occurred despite the fact that the entire bulls had significantly higher plasma testosterone levels than the castrates (18.9 ± 4 ng/ml cf 9.8 ± 2 ng/ml, t_{14} = 5.1, P < 0.001).

The serving capacity displayed by each twin pair during the preoperative period and the serving capacity rating of each pair are shown in Table 39. The differences in serving capacity between the high pair and each of the medium pairs, between high and low pairs and between each of the medium pairs and the low pair were all highly significant (P < 0.001). Within each pair, twin brothers showed similar serving capacity in the preoperative period (Figures 7 and 8).

Within 3 weeks of castration, the castrates in each pair had declined to their nadir in serving capacity (Figures 7 and 8). Serving capacity of the castrates in the medium and low pairs was maintained at 0 or 1 for the remainder of the 6 week postoperative period while the
castrate from the high serving capacity pair continued to achieve 4 or 5 services per test (Figures 7 and 8). In the 4th, 5th and 6th weeks after castration the latter served with a weak body thrust (back legs did not leave the ground) and a 35 cm penile protrusion on thrusting. By contrast the entire twin brother continued to display good body thrust on service (back legs left the ground) with a 60 cm protrusion of penis. In the postoperative period, the entire bull in each pair maintained its serving capacity at its preoperative level (Figures 7 and 8).

The 4 castrates were similar in bodyweight (range 461 to 481 kg). The administration of a similar dose of testosterone propionate (TP) to each castrate caused an immediate restoration of its serving capacity to its pre-castrational level and to the contemporary level of its entire twin brother (Figures 7 and 8). In the next 3 tests of the TP therapy period, twin brothers within each pair displayed similar serving capacity (Figures 7 and 8). In the first 4 tests in the period of testosterone therapy, the castrates from the high pair, the medium pairs and the low pair displayed serving capacities of $9.3 \pm 2.1$, $2.8 \pm 0.7$ and $1.0 \pm 0$ respectively. All were significantly different from one another ($P < 0.001$). The depression in serving capacity of the high and medium pairs on 17 and 21 February may have been due to the "heat wave" conditions prevailing at that time. When tested on 3 March, 48 hours after the TP injection, the castrates in each of the high and medium pairs showed
lower serving capacity than their twin brothers (Figures 7 and 8). The mean plasma testosterone level of castrates 48 hours after TP injection, $3.0 \pm 0.7$, was significantly lower than their mean testosterone level 24 hours after injection, $9.8 \pm 2.0$ ($t_{10} = 5.2, P < 0.001$).

In the 11 serving capacity tests after their twin brothers were castrated, the entire bulls from the high pair, the medium pairs and the low pair maintained significantly different serving capacities, $9.8 \pm 1.3$, $3.8 \pm 1.0$ and $1.5 \pm 0.5$ respectively. These bulls sampled four times each over the same period had mean plasma testosterone concentrations of $16.0 \pm 3.0$, $16.0 \pm 3.0$ and $22.4 \pm 3.0$ ng/ml respectively. The mean testosterone levels of the low serving capacity animal were significantly higher than that of either the high or medium serving capacity bulls ($P < 0.05$).

**DISCUSSION**

The findings that castration significantly reduced the serving capacity of bulls and that testosterone therapy restored it to its precastrational level demonstrate that the presence of testosterone is necessary for the maintenance of serving capacity in bulls. Grunt and Young (1952) found that the serving activity of castrate guinea pigs was only restored to its precastrational level by doses of testosterone above a threshold level. In this study the castrates had plasma testosterone levels of $> 7$ ng/ml in the period of testosterone therapy and displayed similar serving capacity to their entire twin brothers. When the castrates had mean
testosterone levels of 1.2 ng/ml (10 days postcastration) or 3.0 ng/ml (48 hours after TP injection) they displayed lower serving capacity than their twin brothers. These data indicate that the threshold level of circulating testosterone necessary to maintain serving capacity in these bulls was between 3 and 7 ng/ml.

Increasing the dose of testosterone above the threshold level does not increase the serving activity of guinea pigs (Grunt and Young 1952), rats (Larsson 1966), mice (Champlin et al 1963), rams (Clegg et al 1969) and rabbits (Agmo and Kihlstrom 1974) above their precastrational levels. The entire bulls in this study had significantly higher plasma testosterone levels than their castrate twin brothers receiving testosterone therapy (mean 18.9 cf 9.8 ng/ml) yet, within pairs, twin brothers displayed similar serving capacity. It is concluded that the neural tissues mediating serving activity (termed the soma by Grunt and Young 1952) require only a threshold level of circulating testosterone to maintain the serving capacity of the bull.

Although each castrate received a similar dose of testosterone (461 to 481 mg), their responses in terms of serving capacity were significantly different. Each animal returned to its high, medium or low precastrational level and to the contemporary level of serving capacity displayed by its twin brother. In the postoperative periods, the entire bulls from the high pair, the medium pairs and the low pair differed significantly in their serving capacity yet had similar levels of circulating testosterone. These
data indicate that differences between bulls in their serving capacity are not due to differences in the circulating level of testosterone but to differences in the responsiveness of the soma to threshold levels of testosterone.

The lowest level of serving capacity maintained by each castrate in the postoperative period was positively related to its precastrational level of serving capacity (Figures 7 and 8). The plasma testosterone level in each animal 10 days after castration was < 1.5 ng/ml. In the period 3 to 6 weeks after castration when each castrate was maintaining its nadir in serving capacity, plasma testosterone levels must have been negligible. Even so, individual differences in serving capacity persisted. These data further emphasise the importance of differences in somatic responsiveness in accounting for differences in serving capacity between bulls.

CONCLUSION

It is concluded that differences between bulls in their serving capacity are due to differences between animals in the responsiveness of their soma to threshold levels of testosterone.
### TABLE 39
Serving Capacity of Twin Pairs in Four Preoperative Tests

<table>
<thead>
<tr>
<th>Twin pair</th>
<th>Serving capacity</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 and 4</td>
<td>9.9 ± 1.8</td>
<td>High</td>
</tr>
<tr>
<td>27 and 28</td>
<td>4.1 ± 1.0</td>
<td>Medium</td>
</tr>
<tr>
<td>31 and 32</td>
<td>4.3 ± 1.0</td>
<td>Medium</td>
</tr>
<tr>
<td>11 and 12</td>
<td>1.9 ± 1.0</td>
<td>Low</td>
</tr>
</tbody>
</table>
FIG 7. Serving capacity of castrates 4 and 28 and their entire twin brothers 3 and 27 respectively in the pre- and postoperative periods & in the period of testosterone therapy.
FIG 8 Serving capacity of castrates 12 and 32 and their entire brothers 11 and 31 respectively in the pre- and postoperative periods & in the period of testosterone therapy.
CHAPTER 15
GENERAL DISCUSSION

The general aim of the present study was to provide a scientific basis for the management of beef bulls during pasture mating. In this chapter, an attempt is made to discuss data derived from this study which are of practical importance to mating management.

In all the groups of cattle observed, bulls competed with one another for oestrous cows. Two year old bulls mated together had an unstable social order (Chapter 2:2 and 3). The social ranking of each of these bulls did not significantly influence its serving activity (Chapter 3). Groups of mixed age bulls had a stable social order (Chapter 2:2 and 3) which was maintained by seniority (Chapter 4). Since, in most breeding herds, replacement bulls are about 2 years old when they enter the herd, age is the relevant factor determining social ranking in mixed age mating groups. The social ranking that bulls held in such groups was highly correlated with their serving activity during pasture mating (Chapter 3).

Associating an old bull with young bulls during a 6-week pasture mating with heifers compared to mating only young bulls with heifers, depressed the pregnancy rate by 9.0% (Chapter 7). Mating bulls in mixed age groups also has a detrimental influence on the pattern of calf production. The unpublished data of D.R. Osterhoff showed that in each of 5 years of mating a mixed age bull group to cows, the oldest or second oldest bull sired 60 to 76% of calves born while
the youngest bull in the group sired 5 to 15%. Had the older bulls had a slower growth rate than their younger subordinates, the average post-weaning growth rate of calves would have been lower than had young bulls only been used. These data indicate that mating groups of bulls should comprise bulls of the same or similar age.

In mixed breed mating groups, breed of bull significantly influenced social ranking within the group (Chapter 4). When Hereford and Brahman bulls are mated to cows together the Hereford bulls consistently sire a higher proportion of the calf crop than the Brahman bulls (Ittner et al 1954; Donaldson 1962). This could be due, in part, to the social dominance of one breed of bull over the other.

It was demonstrated that serving capacity was an accurate measure of a bull's sexual behaviour during pasture mating (Chapter 6). Groups of bulls observed for either 7.5 hours or 19 days showed a wide between-bull variation in serving capacity (Chapters 6 and 8:1).

Differences in serving capacity of bulls did not influence the proportion of oestrous heifers they detected in oestrus during a normal pasture mating (Chapter 7). Oestrous heifers during pasture mating congregated in a group within which they displayed intense mounting activity while roaming restlessly around the mating paddock. By attracting both bulls and other sexually active heifers they, rather than the bulls, played the role of the "oestrus detector" (Chapter 7). Serving capacity of bulls did however
influence the proportion of heifers that they mounted in the first 7 hours of oestrus (Chapter 6). Beef heifers inseminated during oestrus have a significantly higher conception rate than those inseminated after the end of oestrus (Laster et al 1973). These data suggest that the use of high serving capacity bulls as teasers may increase the conception rate of inseminated heifers.

Differences in the serving capacity of bulls did significantly influence the proportion of heifers conceiving at their first oestrus (Chapter 7). The result of this was that heifers mated to high serving capacity bulls conceived significantly earlier in the mating period (and presumably calved significantly earlier) than heifers mated to medium serving capacity bulls (Chapter 7). Week of conception has important effects on the calf production of heifers and their subsequent fertility. At weaning, calves from later calving heifers are significantly lighter than calves from heifers calving early (Lesmeister et al 1973). Of greater importance is the fact that late calving animals display their first oestrus later in the next mating period than early calving animals (Wiltbank 1970). This is of particular relevance to first calf cows which exhibit their first oestrus a mean 91 to 96 days after calving (Wiltbank 1970; Laster et al 1973). Thus, even if heifers conceive in the first week of the heifer mating they will not show their first oestrus as first calf cows until early in the next mating period. The end result is twofold. Heifers calving late have a significantly lower
pregnancy rate as first calf cows than heifers calving early (Reynolds 1967). Of the heifers that are impregnated as first calf cows, the late calvers calve significantly later in subsequent seasons than the early-calving heifers (Lesmeister et al 1973). These data demonstrate the importance of heifers conceiving early. The present study indicates that this aim is more likely to be achieved by mating heifers to high serving than to medium serving capacity bulls.

What should also be stressed is the importance of mating the higher serving capacity bulls in the herd to first calf cows rather than to mature cows. First calf cows exhibit their first oestrus after calving significantly later than older cows (95.8 cf 72.0 days, Laster et al 1973). Since the period from the start of the calving season to the start of mating is 80 to 85 days, first calf cows have their first chance to conceive later in the mating period than older cows. The chance of first calf cows conceiving early in the mating period can be maximised by mating them to high serving capacity bulls. They also have fewer chances of conception during a mating period than older cows. Their chances of being impregnated, particularly during a short mating (6 to 8 weeks), will be maximised by mating them to high serving capacity bulls.

In summary, it is suggested that the highest serving capacity bulls in the herd should be mated to heifers and first calf cows, in that order of priority, and the remainder of the bulls be mated to the mature cows. It should also be stressed that these mating groups should consist of bulls of the same or similar age.
The serving capacity of bulls during a 19-day pasture mating could not be predicted accurately by the number of services bulls achieved in a day. Within bulls, the latter varied greatly from day to day. However the serving capacity of bulls during pasture mating could be accurately predicted by mating a group of bulls to a number of immobilised cows in a yard. The number of services achieved by each bull in 60 minutes was highly correlated \((r = 0.82\) to 0.91) with its serving capacity during a 19-day pasture mating. Each of the procedures in this initial yard test was investigated to determine its influence on the serving capacity of bulls. The test was then modified to make it more suitable for practical use in the field. The modified test consisted of the following:

(i) non-oestrous cows are placed in service crates. These service crates are sufficiently effective in immobilising cows that cows need not be induced to show oestrus. The crates can be folded up and at least 4 crates can be transported in a 2 x 1 m trailer. They can be erected in the yards at the rate of 10 minutes per crate.

(ii) bulls must be sexually stimulated before the test by allowing them to watch other bulls mount the restrained cows for 10 or more minutes. Those cows that swivel their hindquarters about excessively during this 10 minute period can be either tranquillised or replaced.
(iii) up to 12 bulls can be tested at once
(iv) the bull:cow ratio is maintained at 5:2 or 5:3
(v) the duration of the yard test is 40 minutes.

Bulls showed a marked between-bull variation, 0 to 28, in their serving capacity over 40 minutes. The serving capacity bulls displayed from test to test was highly repeatable (Chapter 11). Whether a high serving capacity bull held high or low social ranking in its testing group, it still displayed high serving capacity (Chapter 10).

In summary, an accurate, practical yard test for predicting the serving capacity of bulls pasture mated in groups, has been developed. Whether the same test can be used to predict the serving capacity of singly mated bulls, remains to be demonstrated.

Information on the serving capacity of the bulls in a herd can be used in various ways. As discussed previously, bulls can be ranked in order of descending serving capacity and mated to heifers, first calf cows and older cows in that order of priority. The greatest potential use of this information is in deciding how many cows to join to each bull. Bulls varied greatly in the number of cows they served in 3 weeks, from 2 to 85 (Chapter 8.1). It is logical that the number of cows a bull is joined to, should depend, to a large extent, on its serving capacity displayed in the yard test. It should also depend on its sperm production. The failure of serving capacity and scrotal circumference (a measure of sperm production) to be positively correlated (Chapter 13.3)
means that the potential of some high serving capacity bulls may be limited by their sperm production. It is considered that the optimum way of determining the number of cows to join to bulls of different serving capacity and sperm production, is to construct a simulation model which describes the serving activity and sperm output during pasture mating of bulls of different serving capacity.

Another potential use of information on serving capacity is in the selection of bulls for breeding programmes. Its usefulness here depends on the demonstration that serving capacity is a heritable trait. No estimate on the heritability of serving capacity has been published. To gain this information, the serving capacity of 5 or more bull progeny from 60 different sires must be determined for use in a paternal half-sib correlation analysis (L.P. Jones, personal communication 1975). Should serving capacity prove to be heritable, bull breeders could increase the serving capacity of the young bulls they offer for sale by using sires of high serving capacity. Because of the hierarchical nature of the bull breeding industry, the selection and use of stud sires of high serving capacity should increase the serving capacity of bulls used in commercial herds.

It has been suggested that the sexual activity of bulls during pasture mating can be determined by measuring the plasma testosterone level of bulls in response to sexual stimulation (Post et al 1974). This indirect method would be unsuccessful for differences between bulls in their serving capacity are not due to differences in the circulating level of testosterone but to differences in their somatic responsiveness.
to threshold levels of testosterone (Chapter 14). These data also suggest that low serving capacity bulls cannot have their serving capacity increased by large injections of testosterone as adults. However it is possible that their somatic responsiveness to testosterone can be increased if given testosterone therapy during some critical period of neonatal development. The latter has been extensively studied in laboratory animals (Phoenix et al. 1967) and may be a relevant area of study in cattle.

Apart from determining the serving capacity of bulls, the test is of major importance in the examination of beef bulls for breeding soundness. Of the 113 bulls considered unsound for breeding, 48 (42.5%) would not have been detected had not a serving test been conducted (Chapter 12). The 48 bulls included 15 with penile abnormalities, 16 with locomotor abnormalities and 17 with low serving capacity. The incidence of physical abnormalities, detectable only during repeated mounts or services, was sufficiently high to warrant the inclusion of a serving test in any examination of bulls for breeding soundness. The finding that bulls with physical abnormalities have a significantly lower serving capacity than normal bulls further emphasises the need to include a serving test in such an examination (Chapter 12.1). Not just any test will suffice. The 5-minute test described by Osborne et al. (1971) is too short to diagnose corkscrew deviation of the penis or early arthropathy in most affected
animals. Bulls must be tested in a sexually stimulating environment that will encourage them to mount or serve many times in a short period. It is considered that the serving capacity test provides this environment.
SUMMARY

This thesis embodies studies on the social and sexual behaviour of beef bulls mated in groups. Bulls of all ages competed with one another for oestrous cows. A strict social order existed in mixed age groups and in similar age groups of bulls 3 years or older. In mixed age groups social ranking was maintained by seniority. In these groups the serving activity of a bull was strongly influenced by its social ranking. The old dominant bull restricted the serving activity of its younger subordinates and in so doing reduced pregnancy rate of the cow herd to which the mixed age group of bulls was mated.

An accurate measure of a bull's sexual behaviour during pasture mating was its serving capacity, the number of services it achieved in a mating period. Groups of bulls displayed a wide between-bull variation in serving capacity during pasture mating. High serving capacity bulls impregnated a higher proportion of heifers on their first oestrus than bulls of medium serving capacity. The result was that heifers mated to the former conceived significantly earlier in the mating period than heifers mated to the latter.

The serving capacity of bulls during a 19 day pasture mating was highly correlated \( r = 0.82 \) to 0.91 with the number of services they achieved in 60 minutes in a yard with a number of immobilised cows. Modification of the yard
test showed that cows must be restrained in service crates, they need not be in oestrus, bulls should be sexually stimulated for 10 or more minutes before the test and the bull:cow ratio can vary from 5:4 to 5:2. Other experiments showed that the test could be shortened to 40 minutes, that within age groups the social ranking of a bull in its testing group did not influence its serving capacity, and that bulls maintained their serving capacity at a high, medium or low level in successive tests.

The test proved an essential part of the examination of bulls for breeding soundness. Some 42.5\% of bulls unsound for breeding would not have been detected had the serving capacity test been excluded. These included bulls with penile abnormalities, degenerative joint disease and bulls of low serving capacity. Bulls with locomotor abnormalities had significantly lower serving capacity than normal bulls.

Serving capacity and scrotal circumference were not significantly correlated. Nor did age of bull significantly influence its serving capacity.

Differences between bulls in their serving capacity were not due to differences in the circulating level of testosterone but to differences in their somatic responsiveness to threshold levels of testosterone.
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