# THE DOMESTICATION AND NUTRITION OF

# SAMBAR DEER (Cervus unicolor);

# A COMPARATIVE STUDY WITH RED DEER (Cervus elaphus)

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Presented in Partial Fulfilment of the
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Gono Semiadi

1993

"NICK": Sambar s ag (2.5 years of age, 210 kg liveweight).

# THE DOMESTICATION AND NUTRITION OF SAMBAR DEER (Cervus unicolor); A COMPARATIVE STUDY WITH RED DEER (Cervus elaphus)

**(Gono Semiadi, Massey University, Palmerston North, NEW ZEALAND)**

## ABSTRACT

A comparison between sambar and red deer in grazing behaviour, dietary preference, digestive efficiency and changes with time in voluntary feed intake (VFI) and plasma hormone concentrations was conducted at the Flock House Agricultural Centre, New Zealand Pastoral Agricultural Institute, Bulls, New Zealand. The general biology of sambar under field conditions was also studied, and systems developed for the artificial rearing of sambar calves.

1. Two groups of semi-domesticated sambar comprising eight stags and 23 hinds were documented in terms of behaviour, calving pattern, birth weight, hard antler and health status for a 3-year period (1989-1992).

Sambar had a wide spread of calving, from January to November, with mean calving date being 8 May (SD 71.3 days). The hinds calved annually with the calving interval being 329 days (SD 29.7 days). Birth weight of stag and hind sambar calves were similar, being 8.1 kg (SD 1.37 kg) and 7.8 kg (SD 1.72 kg), respectively. The male:female ratio was 1.6:1.0, with mortality of stag calves being 41% and hind calves 6%.

Sambar stags were reasonably well synchronized in hard antler and were in hard antler from May to November. Hard antler in adult stags was carried for 231 days (SD 40 days) and cast annually, while younger stags carried their hard antler for 205 days (SD 107.8 days). Mean antler casting date in adult stags was 7 December (SD 35.4 days) and in young stags was 21 January (SD 45.2 days). During the rut, the dominant sambar stag demonstrated a high degree of tolerance toward the presence of rival stags near the harem. Although sambar are very cautious and nervous animals, they can be quietened under farming conditions by regular daily visits and hand feeding with maize or hay. Malignant catarrhal fever (MCF) was the main health problem in sambar and they appeared resistant to internal parasite problems if set stocked and kept out of contact with red deer.

2. Grazing behaviour was recorded in sambar and red deer for continuous 24 h periods, at 2-monthly intervals, over 12 months. Scan sampling was used with observations made every 12 min. Both groups of deer were grazed separately on adjoining areas of the same pasture for the duration of the study.

Sambar grazed mostly during the night (0100-0500 h), late afternoon and evening (1700-2100 h), whereas red deer grazed mostly during early morning (0500-0700 h), afternoon and early evening (1500-2000 h). Total grazing time was not altered by season and month and was similar for both sambar and red deer (9.1 v 9.4 h/24h). However, sambar spent more time grazing during the night (6.2 v 4.9 h)/24h; $p<0.01$) and less time grazing during the day (2.9 v 4.5 h/24h; $p<0.01$) than red deer. Rate of prehending biting was greater for sambar than for red deer (64.5 v 47.7 bites/min; $p<0.001$). It is suggested that longer night grazing by sambar may have evolved to reduce thermoregulatory stress in tropical environments and as a defensive strategy against attack by predators.

3. Dietary preferences of sambar and red deer were determined by field observations on three occasions, at 2-monthly intervals, by offering the animals access to two legumes, three grasses and two browse species. The animals were allowed to graze freely until 300 observations had been recorded. Nutritive quality of plants on offer and of the diet selected, plant height, plant species purity, plant preference and stem diameter selected were also recorded.

Willow was the first preference of sambar followed by high endophyte perennial ryegrass. Red clover was the first preference by red deer followed by lotus. Sambar selected both willow leaves and stems below 36 mm diameter, whilst red deer selected leaves only. Sambar selected plant components higher in lignin and condensed tannin, but lower in OMD and total N than red deer.

4. Ten sambar and nine red deer calves were taken from their dams within 24 h of birth and artificially reared with ewe milk replacer until weaning at 70 days of age. Body dimensions at birth (weight, height, girth circumference and length), liveweight gain, milk consumption and behavioural aspects during artificial rearing were recorded.

Sambar calves had lower overall milk consumption than red deer calves (312 v 359 gDM/day: $p<0.05$), and showed an earlier peak in milk consumption, a faster rate of decline in milk consumption and earlier self-weaning. Birth weight as a proportion of dam liveweight was lower for sambar than for red deer, but liveweight gains to weaning (347 v 330 g/day) and weaning weights (30.0 v 30.4 kg) were similar. The age at which calves commenced a range of activities, including eating forage and ruminating, were similar for both species. However, "jumping" activities commenced five days later in sambar than in red deer ($p<0.01$). Following milk feeding, sambar calves were less active than red deer calves. This study demonstrated that sambar calves can be successfully artificially reared using ewe milk replacer, but extra precautions are needed to avoid scouring and abomasal bloat, which were more prevalent in sambar than in red deer.

5. Artificially reared sambar and red deer were confined in metabolism cages and fed chaffed lucerne hay ad libitum for the period of four weeks during summer and winter. Measurements were

made of VFI, water intake, apparent digestibility, faeces particle size distribution, eating and ruminating time and the rate of chewing during eating and ruminating. Red deer reduced VFI (kg DM/d) markedly from summer to winter (1898 v 1345 gDM, respectively), while that of sambar increased slightly over this time (1244 v 1404 gDM, respectively). Digestive efficiency was similar in sambar and red deer during both summer and winter (58.1% DMD) and the critical particle size for leaving the rumen was less than one mm sieve size for both deer species. Time spent eating/gDMI was greater for sambar than for red deer during summer (0.28 v 0.16 min/gDMI; $p<0.01$), but there was no difference during winter (0.14 v 0.16 min/gDMI). Relative to red deer, sambar consistently spent more time ruminating/gDMI and spent a greater proportion of total ruminating time as daytime ruminating, and had more daytime ruminating bouts. Sambar had less number of chews/bolus ruminated but more rumination boli/h than red deer. Differences between sambar and red deer were more pronounced in ruminating than in eating behaviour, which may be a mechanism to improve the breakdown of low quality tropical forages.

6. Eight artificially reared deer (5 stags, 3 hinds) from each deer species were randomly allocated to individual indoor pens for a 16-month period. Three sambar later died as a result of a neck injury (n=1) and MCF (n=2). All animals were fed a pelleted diet ad libitum (12 MJME/kgDM; 2.9% N), and the two deer species were compared for rate of body growth, VFI and blood plasma levels of prolactin (PRL), progesterone (P), testosterone (T) and luteinizing hormone (LH). During the rut, scrotal circumference of stags in both species was also measured.

Compared to red deer, both sexes of sambar showed a weak seasonal pattern of VFI and body growth. Peak VFI in sambar occurred in autumn and lowest in spring, whereas red deer had peak VFI in summer and lowest VFI in winter. Growth rate followed the same pattern. Sambar appeared to be more efficient in converting feed to liveweight gain than red deer. Estimated requirements of ME for both maintenance and gain (above maintenance) in sambar tended to be lower than for red deer, with this being true for both sexes. While sambar did not develop secondary fibres during winter, the primary fibres were coarser and sparser than those of red deer.

Plasma PRL concentrations were seasonal in both species, with highest values in summer and lowest values in winter. Relative to red deer, sambar tended to have higher plasma PRL concentrations in autumn, and sambar stags tended to have lower plasma PRL concentrations in summer.

Sambar stags showed elevated levels of plasma T concentrations over a longer period (autumn-spring), but the magnitude was not as high as for red deer. Red stags showed peak plasma LH concentrations during summer and peak plasma T concentrations in autumn, with low values in winter and spring. Spike release of plasma P was detected in red hinds in autumn and sambar hinds in spring, when they were aged respectively 17 and 14 months, and weighed 95.5 and 90.0 kg. It was concluded that sambar have endogenous cycles of VFI, growth and hormone secretion but they were

of reduced amplitude and with different seasonality to those of red deer.

7. Nine artificially reared sambar (5 stags, 4 hinds) were blood sampled without being sedated, on two occasions, May and September 1992, and four adult sambar stags were sedated and blood sampled in September 1992. Blood samples were submitted for haematological analysis, to define normal haematology parameters for sambar.

Haemoglobin (Hb), packed cell volume (PCV) and plasma protein concentrations of unsedated sambar were slightly higher in stags than in hinds, with no variation between age groups. White blood cell fraction from unsedated sambar varied with age and sex. Differences between unsedated and sedated animals were in Hb, neutrophil, eosinophil and lymphocyte fractions.

8. Areas requiring further research in sambar are the onset of puberty in sambar hinds, duration of breeding season, response to photoperiod change, and the basis of an apparently improved feed conversion efficiency. The production of sambar and red hybrids may also be of potential significance to the NZ deer industry for advanced calving and more efficient venison production.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| BW | body weight |
| C | Celsius |
| cm | centimetre |
| CT | condensed tannin |
| diam. | diameter |
| DM | dry matter |
| DW | drinking water through |
| E | East |
| Exp. | Experiment |
| FCE | feed conversion efficiency |
| Fig. | Figure |
| g | gram |
| g/dl | gram/decilitre |
| gDM | gram dry matter |
| g/head/day | gram/head/day |
| h | hour(s) |
| ha | hectare |
| Hb | haemoglobin |
| kg | kilogram |
| kgDM | kilogram dry matter |
| kg/h/day | kilogram/head/day |
| KJ | kilojoule |
| l/l | litre/litre |
| lat | latitude |
| long | longitude |
| LH | luteinizing hormone |
| LHRH | luteinizing hormone releasing hormone |
| m | metre |
| MCF | Malignant catarrhal fever |
| min | minute(s) |

| | |
|---|---|
| mm | millimetre |
| ml | millilitre |
| ME | metabolisable energy |
| MEMJ | metabolisable energy megajoule |
| N | North, total nitrogen |
| n | number of sample |
| NZ | New Zealand |
| NDF | neutral detergent fibre |
| OM | organic matter |
| OMD | organic matter digestibility |
| OR | observation room |
| p | page, probability |
| PCV | packed cell volume |
| PD | Pere David's deer |
| pg | picogram |
| PRL | prolactin hormone |
| PT | pine trees |
| P | progesterone hormone |
| R | red deer |
| RBC | red blood cell |
| ROB | rate of prehending biting |
| S | South, sambar |
| SD | standard deviation |
| SE | standard error |
| sec | second(s) |
| SEM | standard error of mean |
| sp | species |
| T | testosterone hormone |
| ug | microgram |
| USA | United States of America |
| VFI | voluntary feed intake |
| v | versus |
| WBC | white blood cell |

## PREFACE

During the period of writing this thesis, four chapters have been send for publication in several journals. There are :

1. Chapter 1.
   Semiadi G, P.D Muir and T.N Barry. 1993. General biology of sambar deer in captivity. **New Zealand Journal of Agricultural Research (submitted).**

2. Chapter 2.
   Semiadi G, P.D Muir, T.N Barry, C.J Veltman and J Hodgson. 1993. Grazing pattern of sambar deer and red deer in captivity. **New Zealand Journal of Agricultural Research** 36:253-260.

3. Chapter 4.
   Semiadi G, T.N Barry and P.D Muir. 1993. Growth, milk intake and behaviour of artificially reared sambar deer and red deer fawns. **Journal of Agricultural Science, Cambridge** 121: 273-281.

4. Chapter 5.
   Semiadi G, T.N Barry, J Hodgson and P.D Muir. 1993. A comparison of digestive and chewing efficiency and time spent eating and ruminating in sambar deer and red deer. **Journal of Agricultural Science, Cambridge (submitted).**

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# INTRODUCTION

Deer belong to the order artiodactyla, suborder ruminantia and family cervidae, with 17 genera, 40 species and 190 subspecies (Whitehead 1972). A recent study suggested the addition of the superfamily "Cervoids", indicated by the characteristics of lacrimal orifice and metatarsal gully (Scott & Jones 1987).

Deer are distributed widely throughout the world, with the exception of central and southern Africa (Grzimeck 1990). In the tropical regions, there are 24 recorded native deer species (Loudon 1992), mostly concentrated in southern Asia (Grzimeck 1990), with sambar being the largest and most widespread in its distribution (Whitehead 1972). Red deer have a medium body size and are native to Europe (Grzimeck 1990). The modern farming of red deer is an industry pioneered and developed by New Zealand (NZ) farmers. Many countries have noted this success and are developing deer industries modelled on NZ principles. The farmed deer industry in NZ has increased substantially since its inception in 1969. In 1992 there were 1.3 million farmed deer, which is expected to increase to 3 million by 1996 (Game Industry Board, personal communication).

During the past century several deer species from both temperate and tropical climates have been introduced into NZ. Species found are red (Cervus elaphus, 1851), fallow (Dama dama, 1860), sambar (Cervus unicolor, 1875), sika (Cervus nippon, 1885), white-tailed (Odocoileus virginianus, 1905), wapiti (Cervus canadensis, 1905) and rusa deer (Cervus timorensis, 1907) (King 1990).

In several Asian countries, rusa and sambar are already kept in fenced areas, but their utilization is still limited (Putman 1988). Australia and New Caledonia are two countries which are currently taking seriously the development of tropical deer farming, specifically with rusa, and to a lesser degree with axis/chital (Axis axis) in Australia (van Mourik 1985; Chardonnet 1988; Chapple 1989; Mylrea 1992). In NZ, tropical deer, such as rusa and sambar are used for game hunting. An attempt to domesticate rusa in 1987, by a private company in Northland, failed due to mortality from Malignant Catarrhal Fever (MCF) (P.D Muir, personal communication). Several authors have mentioned the possibility of and the potential for domesticating sambar (Semiadi 1986; John & MacGibbon 1986), but to date this has not occurred on a large scale. Taiwan is currently the only country which commercially farms sambar (Hsia et al. 1987).

Sambar, in NZ, originated from Sri Lanka (Harris 1971), and are now concentrated around the Manawatu coastal region (Douglas 1983, John & MacGibbon 1986), Rotorua and Whakatane areas (P.D Muir, personal communication). Sambar are known to prefer a forest or swampy habitat. In NZ, sambar are the second largest deer after elk/wapiti (John & MacGibbon 1986) and appear to possess a "meaty" type conformation. Most research with sambar has been concentrated in their wild habitat,

with emphasis on their general biology. The latest study on the biology of wild sambar in NZ was conducted by Kelton (1981) and to date no intensive research has been conducted on captive sambar in NZ.

The general objectives of this study were to describe the feeding behaviour, voluntary feed intake, digestion, growth and hormonal profiles of sambar, and to compare these to those of red deer. The specific parameters examined were foraging behaviour, diet preference, voluntary feed intake and growth patterns, calf birth weight, plasma hormonal profiles, and digestive efficiency. The study also evaluated the success of artificially rearing sambar calves from birth, as a first step to domesticating the species. This is necessary in view of the nervous and aggressive nature of sambar, which means that wild sambar cannot be readily acclimatized to deer husbandry practises in the same way as red deer.

# LITERATURE REVIEW

In this section, information from published work relating to nutrition, feeding behaviour, growth and reproduction of sambar and red deer will be discussed and summarized. A comparison with other tropical and temperate deer, and a limited comparison with sheep and other domesticated livestock, will also be made. Two major reasons why sheep are taken into account are that deer and sheep, in NZ particularly, are users of similar types of land resource, and sheep have been intensively used as a model for studying the digestive and metabolic functions of ruminants (Milne 1980).

## 1. FEEDING BEHAVIOUR

Most domesticated ruminants graze during daylight, starting after dawn and finishing before dusk (Dulphy et al. 1980; van Mourik 1985). For several wild tropical ruminants, such as deer, grazing activity mostly occurs during night (Couchman 1978). The factors that influence the grazing activity are temperature, humidity and time of day (van Mourik 1985). Bad weather may also influence the feeding behaviour (Dulphy et al. 1980). In general, the time spent grazing will depend on the feed requirement of each animal, the amount and distribution of vegetation, and rate of eating (Arnold 1981).

### 1.1 Feeding classification & diet selection

Hoffman (1985) classified wild ruminants as grazers (grass and roughage eaters), intermediate feeders (adaptable mixed feeders) and concentrate selectors (browsers). Observations of wild red deer indicate that these animals can be classified as intermediate feeders (Kay et al. 1980), but there is still contradiction among authors in classifying wild sambar. Burke (1982) and Santiapillai et al. (1981) tend to classify sambar as browsers, while Bentley (1978) and Dinnerstein (1983) classify them as grazers. Observations by Ngampongsai (1987) suggest that sambar are more intermediate feeders. Wide variation in sambar feeding habits could reflect the ability of the animals to occupy new habitat quite easily (Santiapillai et al. 1981).

A brief review of diet selection by ungulates is presented by Hanley (1982). In general, the ungulates select diets depending on body size, type of digestive system, ratio of reticulo-rumen to body weight, and mouth size. Stomach and faecal cuticle analysis revealed that wild sambar eat a broad variety of vegetation (Kelton 1981; John & MacGibbon 1986), even though Riney (1957) reports that sambar prefer coarse grasses. In Victoria, Australia, browse material is the major diet for sambar, particularly during severe winters. They sometimes eat one species of plant exclusively (Burke 1982). Kelton's (1981) study in the Manawatu region, NZ, showed that flax (Cordyline australis) comprised the greatest proportion of the diet for wild sambar, because of the abundance of the plant. This is

supported by Ngampongsai (1978) in Thailand, where Imperata cylindrica grass is the major species consumed because of its abundance.

In summer, wild red deer select grass, the shoots and leaves of deciduous trees and shrubs, while in winter small branches are consumed. In early spring and autumn the animal selects more deciduous woodland than other diets, with red stags less selective than red hinds during grazing (Kay & Staines 1981; Putman 1988). Domesticated red deer show a high preference of legumes over grasses (Hunt & Hay 1990). Nutritionally, red deer prefer plants which are highly digestible and rich in protein, but low in crude fibre and lignin. Red hinds are noted to prefer food rich in crude protein, compared to stags (Staines & Crisp 1978 as quoted by Kay & Staines 1981). In winter the stags usually consume a diet which is higher in fibre content than hinds (Clutton-Brock et al. 1982).

**1.2 Time budgeting**

The activities of foraging ruminants can be categorized into three groups, grazing, ruminating and resting (Hodgson 1982), with each animal species having its own pattern. Generally, the grazing time of domesticated ruminant species is about 5 h/12 h daylight (van Mourik 1985), in two major periods, before dusk and after dawn. Rumination time ranges from 5-9 h/24 h, depending on the degree of fibre in the diet (Holmes 1989).

No reliable information has been recorded on the time budget of tropical deer. Bentley (1978) suggested that photoperiod is the main factor influencing tropical deer feeding habits. In Victoria, Australia, wild sambar generally move and graze before dusk and before dawn; during winter, night grazing increases. In a tropical habitat such as Nepal, wild sambar are seen actively grazing between 0600-0900 and 1600-1900, local time (Mishra 1982). Observations in Thailand from one adult captive sambar hind, reveal that the animal had three feeding cycles; early morning, late evening and night (Ngampongsai 1978). He also noted that in captivity the animal tended to spend more time resting, ruminating and walking than feeding and drinking.

With red deer, the time spent grazing is influenced by season, being shorter in summer compared to winter. On average, wild red deer grazed for 6-10 h with the peak time between 1600-2000 h in both summer and winter. Wild red deer graze less actively at night (Clutton-Brock et al. 1982). Feeding cycles from wild red deer have been recorded as 6-9 cycles/24 h (Kay & Staines 1981). Red deer calves will not start eating grass until aged 31 days (Loudon et al. 1984). The physiological state of animals will also affect their feeding behaviour. According to Clutton-Brock et al. (1982), lactating wild red deer will use 49-56% of their daylight time for grazing. This will decline with increasing lactation. Fallow deer spend 3-4 h grazing at a time and then rest and ruminate for 2-3 h, with the pattern maintained throughout the day (Jackson 1974 in Putman 1988).

### 1.3 Rate of prehending biting

On unimproved pasture, the rate of prehending biting (ROB) of red hinds is lower compared to improved pasture (33 bites/min to 56 bites/min, respectively). This results in increasing grazing time: 11.7 v 7.8 h, on unimproved v improved pasture, respectively (Loudon et al. 1984). Clutton-Brock et al. (1982) noted no difference in ROB of both sexes of wild red deer (50-60 bites/min) or rumination time (84.6 and 85.3 chews/min) in stags and hinds, respectively, grazing different plant communities. No data are available for ROB of tropical deer.

## 2. SEASONALITY

Comprehensive studies of the biology and physiology of captive tropical deer is in its infancy, with most work being conducted in non-tropical environments (Kelton 1981; van Mourik 1985; Chapple 1989; Mylrea 1992). At equatorial latitudes, ungulates are believed to have day-length-dependent rhythms which are controlled by environmental factors such as rainfall and nutrition (Skinner 1978). Loudon & Brinklow (1992) argue that some deer species living at lower tropical latitudes also show an inherent rhythmicity, which could be associated with the seasonality of feed intake and reproduction cycles. A transition latitude between seasonal and aseasonal reproductive cycle deer lies between latitudes $14^0$ N and $18^0$ S (Goss 1983). Rusa stags in Victoria, Australia, are reported to have acclimatized to the local environment (van Mourik et al. 1985), as have tropical Burmese brow-antlered hinds (Cervus eldi thamin) in North America (Monfort et al. 1990). Sadleir (1987) argues that environmental factors are more important than photoperiod in regulating the tropical deer reproductive cycle. A comparative study between rusa and red stags under Australian sub-tropical environments indicates that rusa show no seasonal trend in their growth until at least 15 months of age (Suttie et al. 1992a). Similar results were also found with chital (Chapple 1989).

To adapt to a changing temperate climate, temperate deer have a pronounced yearly physiological seasonality. Seasonal cycles present are voluntary feed intake (VFI) and body growth, velvet antler stripping and casting, replacement of coat and colour changes, fasting metabolic rate, and reproduction (Kay & Ryder 1978; Lincoln 1985; Barry et al. 1991; Domingue et al. 1991a&b). With red deer, elevated feed intake and growth rate occur in spring and summer, decreasing to low values in winter (Suttie et al. 1989; Domingue et al. 1991a), with antler casting occurring in spring (Fennessy & Suttie 1985). The reproductive activity in both sexes is high during autumn/early winter (Kelly et al. 1985, Fennessy & Suttie 1985). All these seasonal cycles are regulated by hormonal changes, whilst daylength entrains the cycles (Barrell et al. 1985; Lincoln 1985; Suttie & Simpson 1985). Thus, the seasonal rhythms in red deer are endogenous (Loudon & Brinklow 1992).

## 3. NUTRITION & PRODUCTION

### 3.1 Voluntary feed intake pattern

There are no published data on the VFI pattern of tropical deer. The closest comparative study conducted was between red deer and non-tropical Asiatic Pere David's (PD, Elaphurus davidianus). A similar pattern of feed intake in both species occurred during the first autumn. Later, PD showed an earlier peak in VFI than red deer, related closely to significant changes in hormonal levels (Loudon et al. 1989). In their native habitat, Ngampongsai (1978) assumed no clear seasonality of VFI could be expected in sambar due to the good availability of feed throughout the year. The VFI of one captive adult sambar hind, fed roughage was 1084 gDM/day (Ngampongsai 1978).

The pattern of VFI in temperate deer is pronounced in two years of age stags (Fennessy & Milligan, 1987), but less marked in younger deer (Suttie et al. 1989). Peak VFI occurred during period of long daylength with low VFI being associated with decreasing daylength (Suttie et al. 1984). Both pelleted diets or natural grazing gave similar trends of feed intake, indicating that the seasonality in temperate deer is regulated by physiological aspects (Barry et al. 1991). Red stags aged 3-15 months had an increasing feed intake soon after weaning in summer, 11 kgDM/week, dropping during winter to 9 kgDM/week, and rising again in spring to 15 kgDM/week (Suttie et al. 1989). This is shown in Figure 1A. Milne (1980) states that the seasonal change in VFI and energy metabolism in red deer is prominent, with the changes in VFI relating to the change in the amount of digesta in rumen and rumen capacity. This was later confirmed by Domingue et al. (1991a), where the rumen pool size of red stags was 50% greater and the VFI was 34% higher in summer than during winter.

### 3.2 Growth pattern & growth rate

A study with Javan rusa hinds in Queensland, Australia, showed the highest growth rate occurred between 2-14 months of age, usually during winter, and thereafter consistently declined until 26 months of age. The lowest daily growth rate occurred between 300-360 days. The reverse trend was found with rusa stags, aged between 14-26 months, with the highest growth rate occurring in autumn (212 g/day), lowest in winter (45 g/day) (Woodford & Dunning 1992). During the rut, rusa stags could lose 15% of their liveweight (Woodford & Dunning 1992), whereas chital stags lost only 5-7% (English 1992). In chital stags, liveweight continued to increase up to five years of age, with no significant seasonal liveweight changes. Variation in liveweight between chital stags of the same age is believed to be due to the time of birth (Chapple 1989). No information is available on the growth pattern of sambar.

Following the VFI pattern, growth in young red deer is high during spring and summer, low in winter and moderate in their first autumn (Figure 1B, Suttie et al. 1989). Typical of adult red stags, growth ceases between 14-20 months of age, and during the rut, adult stags may lost up to 30% of their body weight (Adam 1988). Photoperiodic effects are believed to be the major cause in slowing

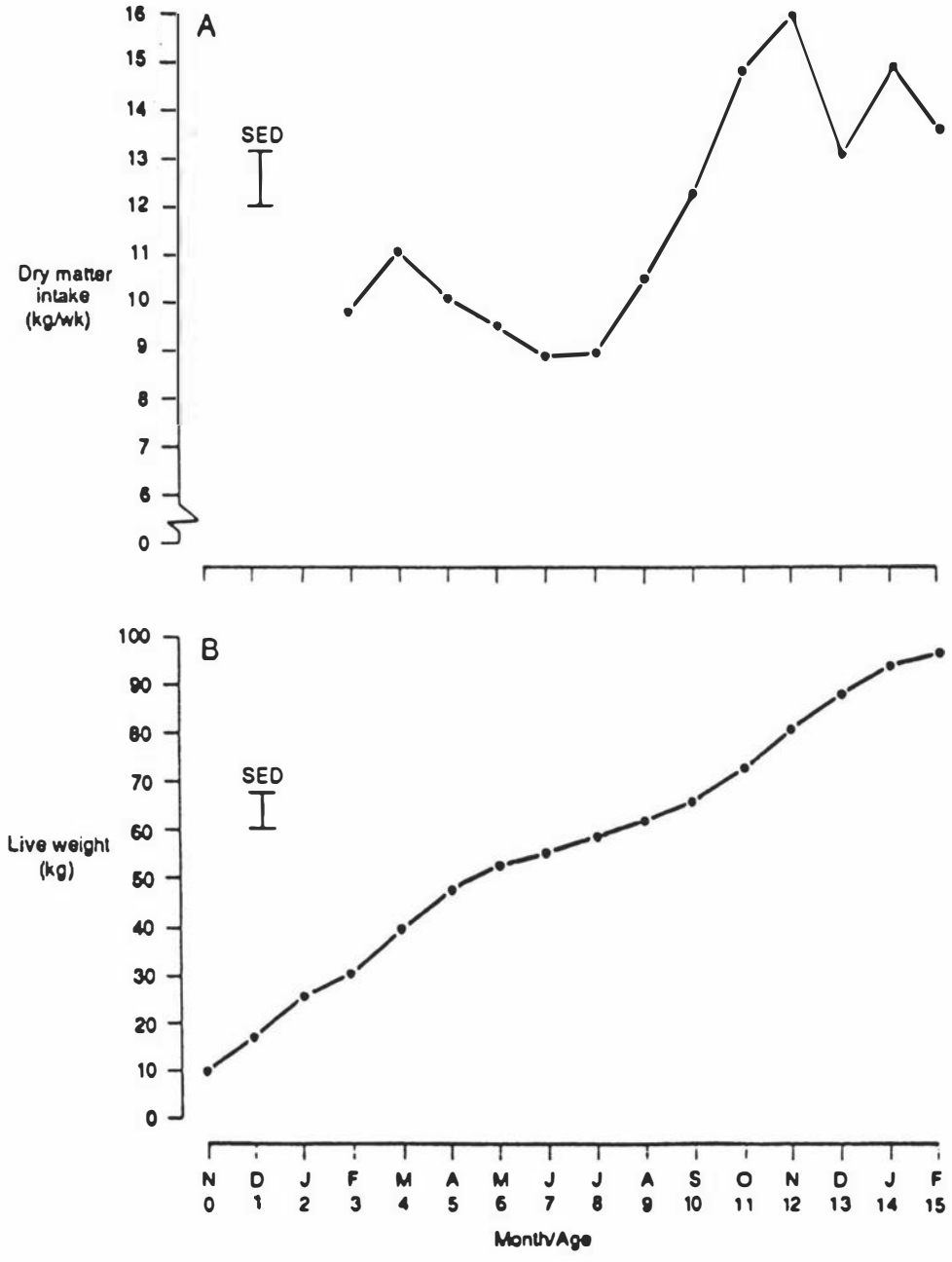


Figure 1.(A) Voluntary feed intake and (B) growth patterns of young red stags fed indoors on a pelleted diet ad libitum, under southern hemisphere conditions (Suttie et al. 1989).

growth during winter and increasing growth in spring (Suttie & Kay 1985). A comparative study of growth between rusa and red deer under a sub-tropical environment indicates that photoperiodic effects did not influence the growth of both rusa stags and hinds (Suttie et al. 1992a, Figure 2). This needs further study.

At birth, healthy red deer calves can reach nine kg in liveweight (Couchman 1978), and at both birth and weaning, stag calves are usually 13% heavier than hind calves (Moore et al. 1988a). Asher & Adam (1985) confirmed that high liveweight gain in red deer calves from birth to weaning is closely related to dam weight and birth weight. A Scottish study of lactating red hinds and deer calves grazing either hill pasture or improved pasture indicated no difference in liveweight gain between the two pasture types until 30 days of age (Loudon et al. 1984), indicating that early growth is most influenced by maternal milk production. The highest reported growth rate of farmed red deer calves is 461 g/day, when both dam and calf were grazing on red clover pasture (Niezen et al. 1993). Weaned calves grazing red clover during autumn and spring have consistently higher growth rates than those animals grazing conventional perennial ryegrass based pasture (Semiadi et al. 1993).

### 3.3 Carcass weight

The range of liveweight in wild sambar stags is between 136-350 kg, with hinds between 113-225 kg (Bentley 1978; Mishra 1982; Douglas 1983; English 1988). Under Victorian (Australia) farm conditions, the heaviest sambar hind ever recorded was 228 kg (Anderson 1984). On the other hand, the range of liveweight in wild red stags is between 135-227 kg, and in hinds between 114-152 kg (Couchman 1978; Kay et al. 1984). Mature liveweight of farmed red stags and hinds aged three years can reach up to 180 kg and 110 kg, respectively (Couchman 1978).

Premium are usually paid for carcasses in excess of 50 kg (92 kg liveweight), which, generally can be achieved at 15 months of age. Through better pasture improvement, the time to achieve optimum carcass weight can be shortened to 12 months of age for red stags. Carcass dressing percentages in red deer are 53-55% (Ataja et al. 1992; Semiadi et al. 1993). With Javan rusa, the carcass dressing percentages were recorded as 62% (Woodford & Dunning 1992), and 60% for chital (Chapple 1989). Carcass weights for mixed age wild sambar killed by local people in east Kalimantan (Indonesia) have been up to 115 kg in stags and 105 kg in hinds (Sukmaraga 1982).

## 4. REPRODUCTION

### 4.1 Hind maturity & oestrous

In most deer species, hinds become sexually mature between 15-18 months (Bentley 1978; Couchman 1978; Anderson 1984; van Mourik 1986). This may be influenced by liveweight and food availability (Putman 1988). Chital hinds are reported mature at 9-10 months (Chapple 1989), while others suggest 14-17 months of age (Acharjyo & Mishra 1980). Farmed rusa hinds show their first

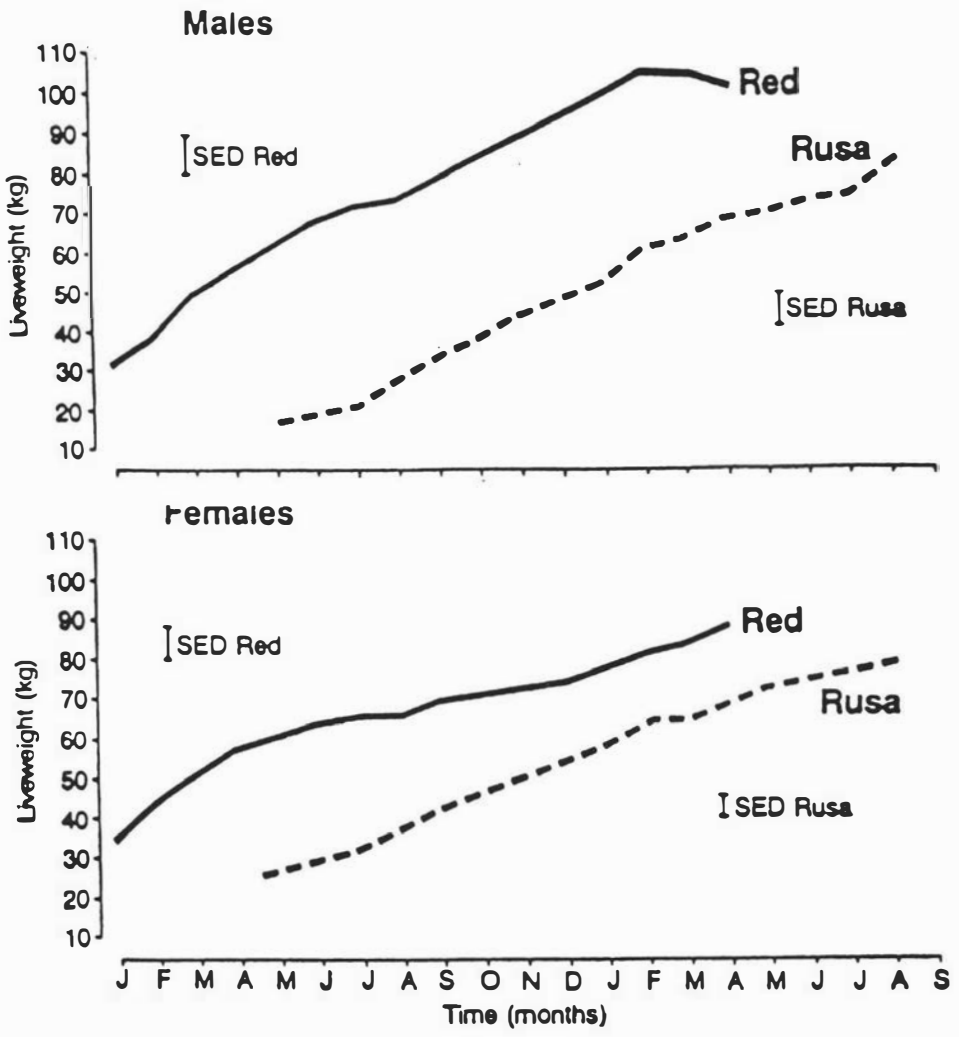


Figure 2. Growth pattern of rusa and red deer grazing pasture, under sub-tropical environments (Southern hemisphere). Rusa were about two months of age in May and red deer were about three months of age in January, resulting an age differences of four months between both species (Suttie et al 1992).

sign of puberty at eight months of age (Woodford & Dunning 1992), providing the body weight is greater than 40 kg (Woodford 1991).

Table 1 shows that, in general, both temperate and tropical deer species have a similar duration of oestrus (26.3 v 26.6 h), but the length of the oestrous cycle in tropical deer tends to be shorter than in temperate deer (20.3 v 24.4 days).

Table 1. Duration of oestrus (h) and length of oestrous cycle (days) in several temperate and tropical deer.

| Species | Length of oestrus (h) | Length of oestrous cycle (days) |
|---|---|---|
| **Temperate deer** | | |
| Alces alces | - | 25-30 |
| Cervus elaphus | 16-24 | 17.5-18.3 |
| Odocoileus hemionus | - | 22-29 |
| Odocoileus virginianus | 37.5-42.3 | 28 |
| Rangiferus tarandus | 50 | 24 |
| Dama dama | - | 24-26 |
| **Tropical deer** | | |
| Cervus eldi thamin | 12-24 | 19 |
| Axis axis | - | 12-23 |
| Cervus timorensis | 6-25, 48 | 10-18, 20-22 |
| Cervus unicolor | - | 17 |

Data compiled from Bemmer (1950, in Syarief 1974), Bentley (1978), Couchman (1978), Sadleir (1987), English (1988), Clutton-Brock & Albon (1989), Chapple (1989), Monfort et al. (1990), Woodford (1991) and Mylrea (1992).

**4.2 Calving time, calving interval & calving rate**

Although tropical deer living within or outside their natural habitat show year round calving (Table 2), little is known about their reproductive seasonality. Peak calving of sambar in tropical regions is reported to be close to the monsoon season (Santiapillai et al. 1981; Mishra 1982), although there are reports of regional differences (Syarief 1974; Putman 1988).

The gestation period between tropical and temperate deer is somewhat closer, but the calving interval varies in tropical deer as the calving is not influenced by the season as occurred in temperate deer (Table 3). Because of the irregularity of the breeding season and its independence from photoperiod effects, Bentley (1978) assumed that wild sambar hinds might produce two calves within

Table 2. Calving time in sambar and rusa living in tropical and non-tropical regions.

| | J | F | M | A | M | J | J | A | S | O | N | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sambar deer** | | | | | | | | | | | | | |
| Nepal | x | x | x | x | x | p | p | x | x | | x | x | Mishra 1982 |
| India | x | x | x | x | x | x | x | x | x | p | p | x | Ali 1985 |
| Sri Lanka | | x | | x | x | | | | | | x | p | Santiapillai et al. 1981 |
| Myanmar | x | x | x | x | x | p | p | | | | | | Thom 1937 |
| Indonesia | | | x | x | x | x | | | | x | x | | Amir 1978 |
| Australia | | | | | p | p | | | | | x | x | Couchman 1978 |
| Australia | x | x | x | p | p | p | p | p | x | x | x | x | Anonymous 1979 |
| New Zealand | | | x | x | | | x | | x | | | | Riney 1957 |
| Britain | x | x | x | x | p | p | x | x | x | x | x | x | Zuckerman 1953 |
| U.S.A | x | x | | | x | x | x | x | x | x | x | x | Shea et al. 1990 |
| **Rusa deer** | | | | | | | | | | | | | |
| Indonesia | | | | | x | x | | | | | | | Amir 1978 |
| Mauritius | | | x | x | x | | | | | | | | Douglas 1983 |
| Australia | | | x | x | x | x | x | x | x | x | x | | Woodford & Dunning 1992 |
| Australia | x | x | p | p | x | x | x | x | x | x | x | x | Anonymous 1979 |
| Britain | | x | | x | x | x | | | x | x | x | x | Zuckerman 1953 |

x= occurrence of birth, p= peak time

510-545 days. Calving rate for farmed red deer averages 70-90% to weaning at three months of age (Couchman 1978). Calving rate of rusa in Mauritius is reported between 80-100% (Lalouette 1985), and in Australia 97% (Woodford 1991), while Mylrea (1991) reports 90-94%. In their native habitat, rusa wean their offspring at 4-7 months of age (Mackenzie 1985). No data are available on calving rate and weaning time for sambar.

Table 3. The gestation period (days) and calving interval (days) in tropical and temperate deer.

| Species | Gestation period (days) | Calving interval (days) | Author |
|---|---|---|---|
| **Tropical deer** | | | |
| Axis axis | 238-242 | 281-285 | Mylrea 1991 |
| Cervus timorensis | 215-225 | | Bentley 1978 |
| Cervus timorensis | 217-277 | 359-372 | van Mourik 1986 |
| Cervus timorensis | 248-258 | 280-400 | Woodford & Dunning 1992 |
| Cervus timorensis | 253 | 271-281 | Woodford 1991 |
| Cervus timorensis | 236-262 | | Mylrea 1991 |
| Cervus unicolor | 240 | | Bentley 1978 |
| **Temperate deer** | | | |
| Cervus elaphus | 231 | | Clutton-Brock et al. 1982 |

In contrast to tropical hinds, red hinds are regarded as short day breeders, because of a breeding season during autumn, when daylength is short (Asher et al. 1989; Duckworth & Barrell 1991). The breeding season can be delayed if long daily photoperiod in autumn are also delayed (Duckworth & Barrell 1991), but there is no evidence under natural breeding conditions that the calving season comes earlier as latitude increases (Fletcher 1974). Under farmed conditions in NZ, red deer calved from early November to late December, with mating taking place between mid-March and late May. Red stags become fertile in summer when testes secrete testosterone and produce spermatozoa (Asher et al. 1989). The rut in red deer can last for six weeks (English 1988).

### 4.3 Stag maturity

No comprehensive study of reproduction has ever been conducted on sambar. In India, wild sambar stags are reported to come to their first rut at 19 months of age (Bentley 1978). Rusa stags are fertile at 12 months, with an average body weight of 45-50 kg (Anderson 1984). Red stags are fertile

at about 18 months (Couchman 1978), while Wilson (1984a) gives 14-15 months as the age at puberty. Spermatocytes were seen at nine months of age, indicating reproductive tract function, and at 12 months of age elongated spermatids were present. At 12-15 months of age, the seminiferous tubules were mature and fully developed (Webster et al. 1992).

**4.4 Antler**

Observations of tropical deer either in their natural habitat or after relocation to non-tropical regions, indicate that stags in hard antler can be found at any time of the year (Table 4), suggesting a less pronounced reproductive cycle. Anecdotal reports of wild sambar carrying their hard antlers for more than one year have been questioned by Mishra & Wemmer (1983). Woodford & Dunning (1992) report that on rare occasions farmed rusa in Queensland, Australia, as well as chital (English 1992) can retain hard antlers for more than a year.

With studies of antler development in tropical deer being conducted outside of the tropical native habitat, results are often contradictory. A study with chital in Texas, USA (lat. 27:3 N), concluded that the stag population had a relatively well synchronized antler cycle within herds (Bubenik et al. 1991), but this did not occur in Great Britain (Loudon & Curlewis 1988). Rudd (1978) concludes that wild sambar in NZ have adapted to a seasonal antler growth pattern. Pedicle growth in Indonesian sambar is reported as early as 4-6 months of age (Schroder 1976), close to pedicle growth of rusa at 5-9 months of age (Woodford & Dunning 1992). Since the reproductive cycles of tropical stags appear to be independent of photoperiod (Lincoln 1985), a different approach in trying to understand the role of the antler cycles in tropical deer was conducted by Woodford (1991) through an examination of the interaction between male-male and male-female deer. The hypothesis of Woodford (1991) is that pheromone could play a major role in initiating antler growth and casting. Several studies show that tropical stags are fertile at any stage of antler development (chital, Mylrea 1992; rusa, G.W Asher, personal communication).

Antler cycles (velvet antler growth, velvet stripping, hard antler and casting) of temperate deer are closely related to their reproductive cycle and are therefore under the influence of reproductive hormones (Wilson 1984b; Fennessy et al. 1988, Lincoln 1992). Stags commence antler growth in spring, harden during summer and cast early in the following spring (Wilson 1984b). These activities are closely related to photoperiod (Goss 1983; Suttie et al. 1992b).

Full antler growth in red deer takes about 164 days, of which 52-73 days is the process of ossification (Muir et al. 1987). Early pedicle growth is initiated by increasing levels of plasma testosterone, which is stimulated by increasing luteinizing hormone pulse frequency. Pedicle growth in red deer may also be liveweight dependent, requiring a minimum of 56.3 kg (Suttie et al. 1991).

Table 4. Antler conditions of sambar and rusa living in tropical and non-tropical regions.

| | J | F | M | A | M | J | J | A | S | O | N | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sambar deer** | | | | | | | | | | | | | |
| Indonesia | | | cv | v | | | | | v | | | v | Amir 1978 |
| India | | | h | h | v | v | v | v | v | | | | Thom 1934 |
| Myanmar | | | c | c | c | c | c | | | | | h | Thom 1934 |
| Nepal | h | h | h | h | h | h | h | h | h | h | h | h | Mishra 1982 |
| New Zealand | v | v | v | h | h | h | h | h | h | h | h | h | Riney 1957 |
| New Zealand | v | v | v | v | v | h | h | h | h | h | h | | Rud 1978 |
| USA | v | v | v | h | h | h | h | h | h | h | h | h | Shea et al. 1990 |
| **Rusa deer** | | | | | | | | | | | | | |
| Indonesia | c | | | | | h | h | h | | | | c | Amir 1978 |
| Australia | c | c | v | v | v | v | h | h | h | h | h | h | Anonymous 1979 |
| Australia | | | | | | v | cv | | | | | | Couchman 1978 |

c= antler casting, v= velvet antler h= hard antler

## 5. HORMONAL PROFILE

Studies of the hormonal profile of tropical deer are limited, and non-existent for sambar. In temperate deer, seasonal hormonal secretions have been associated with seasonal cycles in liveweight, VFI, metabolic rate, reproductive activity and the breeding season.

### 5.1 Luteinizing hormone (LH)

Luteinizing hormone is secreted in episodic rhythm from the anterior pituitary gland, and is regulated by luteinizing hormone releasing hormone (LHRH), secreted from the hypothalamus (Lincoln 1985). A limited study of chital stags indicates that they exhibit little seasonal variation of plasma LH concentrations when relocated to northern latitudes (27:30N) (Bubenik et al. 1991). A study of rusa in Victoria, Australia, showed that the animals responded to the decreasing daylength by increasing concentrations of plasma LH (van Mourik et al. 1986). This was the first report to indicate that after spending time away from the tropics, the animals became entrained to a new photoperiod.

In red deer, LH secretion is associated with antler development in the stags and the reproductive cycle in both sexes (Lincoln 1985). The seasonal pattern of both plasma LH concentrations and LH responses during antler development is marked, being low whilst stags are in hard antler and high during velvet antler growth (Fennessy et al. 1988). In both sexes, daylength regulates the frequency of LH secretion, being low during short day and high during long day (Suttie et al. 1989). The pattern of LH pulse frequency in red deer changes according to age. At six months, LH pulse frequency increases; between 6-8 months pulse frequency intensifies before decreasing between 8-12 month of age (Suttie et al. 1991). In red hinds, during early and mid-pregnancy, plasma LH concentrations are frequently undetectable (Kelly et al. 1982).

### 5.2 Testosterone (T)

The pattern of plasma T release in red stags reflects the interrelationship between antler condition and sexual cycles. Very low plasma levels of T occur at antler casting and during velvet growth, while high plasma levels of T are associated with a high degree of fertility and antler in hard condition (Fennessy & Suttie 1985; Bubenik et al. 1991), and coincides with the mating season. Testosterone is also known as a stimulator for pedicle growth in temperate deer (Suttie et al. 1991). In white-tailed deer, maximal concentrations of plasma T is not required for the process of spermatogenesis and stripping of velvet (Bubenik 1982 as quoted by van Mourik & Stelmasiak 1990). Under NZ conditions, red stags exhibit low levels of plasma T throughout winter (May) and spring (November), followed by an increase during late December, which eventually reaches peak levels in the April breeding season (Fennessy & Suttie 1985). There is also a relationship between the seasonal T cycles and VFI in red stags, with low levels of feed intake occurring during decreasing photoperiod, when plasma T concentrations is increasing towards peak levels (Suttie & Kay 1985).

A study of chital stags in the USA indicates a similar pattern of T release. As in temperate deer stags, a low levels of plasma T is associated with antler casting and a high levels of plasma T with hard antler (Bubenik et al. 1991). Rusa stags in Australia have elevated T concentrations in autumn (May), but the main rutting period does not start until the end of July (winter), and extends to October (spring) (van Mourik & Stelmasiak 1990).

### 5.3 Prolactin (PRL)

Studies show that in temperate deer, plasma PRL concentrations are correlated with feed intake patterns (Curlewis et al. 1988), and are responsive to change in photoperiod (Adam et al. 1992) via the pineal hormone melatonin (Curlewis 1992). Recent studies show that photoperiodic information can also be detected in utero by the foetus, judging from the levels of plasma PRL in new born deer calves (Adam et al. 1992). Low winter plasma levels of PRL rise in spring prior to hard antler cast, and peak in midsummer (Barrell et al. 1985; Curlewis 1992). As plasma PRL concentrations decline in late summer, plasma T concentration increase and reach peak levels during the breeding season in April (Barrell et al. 1985).

In red hinds there is a possible relationship between PRL secretion during the breeding season and pelage growth. Red hinds treated with bromocriptine during the breeding season show a delay in the seasonal rise in PRL secretion, which reduces the amplitude of the peak plasma PRL levels causing a delay in the onset of seasonal anestrous (Curlewis et al. 1988). Prolactin is undetectable during early and mid-pregnancy, but the concentrations of plasma PRL in either pregnant or non-pregnant hinds is high in early summer (Kelly et al. 1982).

Plasma PRL concentrations in chital and rusa stags show a similar response to photoperiod, to that shown by temperate deer (Bubenik et al. 1991; van Mourik & Stelmasiak 1985), but the relationship between plasma PRL and T levels are weaker in tropical deer (van Mourik & Stelmasiak 1985). Hormonal profiles of tropical and temperate deer stags are compared in Figure 3.

## 6. ARTIFICIAL REARING

### 6.1 Milk composition & milk substitute

Artificial rearing of deer calves has been undertaken successfully with several deer species: white-tailed (Long et al. 1961), black-tailed, Odocoileus hemionus columbianus (Parker & Wong 1987), red (Fennessy et al. 1981) and rusa deer (van Mourik 1983; Sookhareea & Dryden 1993). Compared to other domesticated animals, deer's milk is high in fat, protein and total solids (Arman et al. 1974; Robbins et al. 1987a) but lower in lactose (P.R Wilson, personal communication). Table 5 shows a comparison of deer milk to that of other domesticated animals. An excess lactose in milk substitute for deer calves tends to cause diarrhoea (P.R Wilson, personal communication). Previous

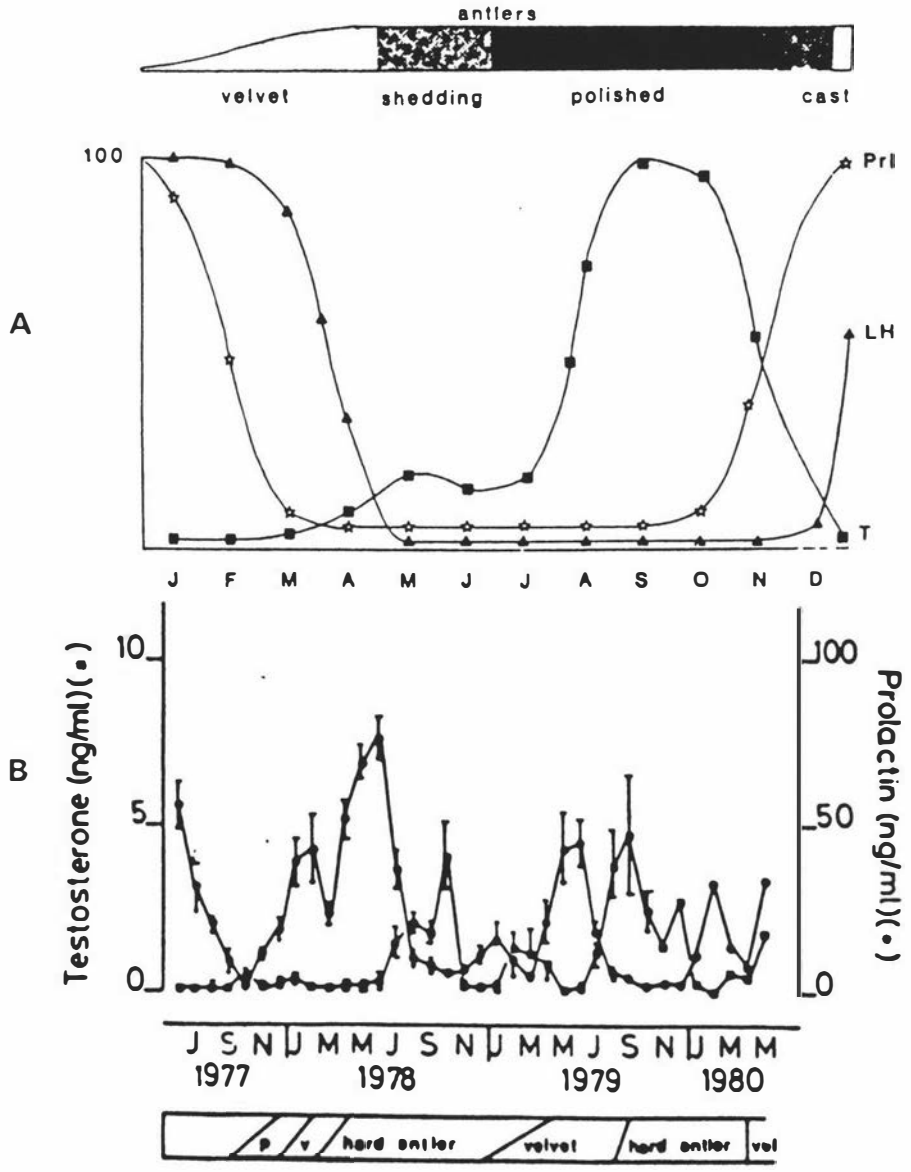


Figure 3. A comparison of the hormonal profiles (testosterone, prolactin) in (A) rusa stags under sub-tropical environments (Southern hemisphere, Winter= Jun-Aug), and (B) red stags under temperate environments (Northern hemisphere, Winter= Oct-Dec) (Suttie & Kay 1985; van Mourik & Stelmasiak 1990).

studies have presented several milk substitutes to deer calves, ranging from goat, ewe, and cow milk, to evaporated, or animal milk replacement with vitamin and mineral enrichment (Long et al. 1961; Silver 1961; McEwan & Whitehead 1971; van Mourik 1983). While all results claimed to be successful, little detail is given of the problems faced.

Table 5. Comparisons of milk composition (%) of several deer species and domesticated animals.

| | DM | Fat | Protein | Sugar | Ash |
|---|---|---|---|---|---|
| **Deer** | | | | | |
| Alces alces | 21.5-24.5 | 5.8-10 | 8.4-10.3 | 3 | 1.5-2.0 |
| Odocoileus hemionus | - | 12.6 | 7.2 | 4.8 | 1.4 |
| Odocoileus virginianus | 22.5 | 7.7 | 8.2 | 4.6 | 1.5 |
| Rangifer tarandus | 26.3 | 10.9 | 9.5 | 3.4 | 1.3 |
| Cervus elaphus | 19-22.1 | 6.7-9.4 | 5.7-7.1 | 4.2-4.9 | 1.1-1.4 |
| Cervus timorensis | 23.8 | 11.5 | 5.9 | - | - |
| Cervus unicolor | - | 11.1 | 9.8 | - | - |
| **Domesticated animals** | | | | | |
| Bos taurus | 12.4 | 3.7 | 3.2 | 4.6 | 0.7 |
| Bubalis bubalis | 16.8 | 6.5 | 4.3 | 4.9 | 0.8 |
| Ovis aries | 18.2 | 7.1 | 5.0 | 4.9 | 0.8 |

Data from Slee & Presidente (1981), Robbins et al. (1987a) and Sookhareea & Dryden (1993)

**6.2 Feeding rate & weaning age**

In the wild, the suckling frequency of red deer calves has been recorded as seven times/day, but of these only four attempts are successful (Loudon et al. 1983). Under farm conditions, red deer calves have been noticed to suckle on an average three times/day (Kelly & Drew 1976). With artificial rearing, the frequency of feeding time ranged from 3-6 times/day in the first two weeks, reducing to 1-4 times/day until weaning (Long et al. 1961; Fennessy et al. 1981). As weaning approaches, dry feed was also offered. Weaning date was determined either by body weight or age (Youngson 1970; Wood et al. 1961; Fennessy et al. 1981). Earliest studies indicate that artificially reared red deer calves were weaned at six months and offered the first dry feed at 14 weeks (Youngson 1960). A later study shows that weaning date could be conducted as early as 9-12 weeks (Fennessy et al. 1981). Current NZ deer farm practice is to wean red deer calves at 3.5-4 months of age.

### 6.3 Growth rate

The average weaning weight of artificially reared deer is close to the estimated liveweight of calves in the wild (Silver 1961), although some authors claim a better result. For example, Silver (1961) and Wood et al. (1962) claimed that feeding white-tailed deer calves with evaporated milk gave a slightly heavier liveweight than naturally fed deer calves. Bottle-fed red deer calves are reported to have a growth rate of 239 g/day (hinds) and 329 g/day (stags) (Fennessy et al. 1981).

## 7. CONCLUSIONS

The present review indicates there is limited data available on the physiology and nutrition of tropical deer, particularly pertaining to sambar. As most studies of tropical deer are concentrated in non-tropical environments, the data available are more concerned with those deer which are acclimatized to non-tropical environments.

There is little data on tropical deer feeding habits. It appears likely that they are intermediate selectors, changing their feeding habits between grazing and browsing, depending on feed abundance. There are limited studies which indicate that the physiological activity of tropical deer is independent from photoperiod. For example, growth in rusa is not affected by the season of the year. Similarly, chital and rusa hinds can calve at any time of the year, and stags can be found in hard antler all year round. The pattern of release in plasma PRL, LH and T in rusa is not as pronounced as in temperate deer. Some reports claim that the hormonal patterns of tropical stags transported to non-tropical environment have adapted to local conditions, but this is also disputed. There is no data on digestion in tropical deer.

Red deer are categorized as grazers, with most of their grazing activity occurring during morning and late afternoon/early evening. The seasonality of red deer is significantly linked to photoperiod, with peak VFI and growth occurring during spring and summer, and the nadir in winter. Rumen pool size in red deer changes between summer and winter, although the digestibility remains the same. Fasting metabolic rate and antler cycles, are regulated by photoperiod. Peak levels of plasma T coincides with peak season of breeding activity, and peak levels of plasma PRL responds to an increasing daylength. There is a close relationship between the release of PRL, LH and T hormones. Calving in red deer is concentrated during spring, and mating takes place in late autumn/early winter. Several studies indicate success in artificial rearing deer calves using a wide range of milk products/replacers.

As the knowledge of the physiology and nutrition of tropical deer is limited, areas requiring study at this stage are grazing behaviour, growth and VFI patterns, digestive efficiency and hormone profiles.

# CHAPTER 1

# GENERAL BIOLOGY OF SAMBAR IN CAPTIVITY

## INTRODUCTION

Interest in deer farming has increased worldwide, since the success of the NZ deer industry. Even though most of the deer species now being farmed are of temperate origin (wapiti/elk, red and fallow deer), tropical deer may also have potential for deer farming. Indeed, Australia and New Caledonia are currently developing systems for the farming of tropical deer (Chapple 1989; Chardonnet 1988).

An understanding of the biology of tropical deer is essential for the development of efficient management systems. The two most extensive studies conducted with tropical deer species are with rusa in Australia and New Caledonia (van Mourik 1985; Chardonnet 1988) and chital in Australia (Chapple 1989; Mylrea 1992).

During the establishment of a small sambar herd in NZ, it was possible to note some biological and behavioural aspects of these deer living in captivity, particularly those aspects relevant to deer farming.

## MATERIALS AND METHODS

### Location

The study was carried out at Flock House Agricultural Centre, New Zealand Agricultural Institute, Bulls, located on the west coast of the North Island, NZ (lat. 40° 14' S and long. 175° 16' E). Average annual rainfall is 875 mm with a dry period from January to March (summer), and strong westerly winds during October and November (spring). The mean monthly temperature ranges from 9°C to 20°C.

### Animals

The biology and behaviour of two semi-domesticated sambar (groups A & B) were observed from November 1989-November 1992. The initial number of animals comprised 10 hinds and five stags transferred from enclosures in adjacent Turakina and Rongotea areas, and transported to Flock House deer farm over 1989 and 1990, and 13 hinds and three stags imported from Victoria, Australia, in July 1990.

Group A comprised two stags and six hinds from the Rongotea area and were set stocked initially in a 1.7 ha paddock, with access to 0.1 ha of open pampas (Cortaderia sp.). In 1990 the paddock was divided equally (0.85 ha each) for research purposes (Chapter 2 & 3). The remaining

animals (6 stags and 17 hinds), from Turakina and Australia, were in group B and were set stocked in a 2.4 ha paddock, with access to 0.1 ha area of pine trees (Pinus radiata). The pampas and the pine trees functioned as natural shelter areas, particularly during the season of strong westerly winds.

Because of the aggressiveness and temperamental nature of both groups A and B animals, no yarding, handling or health management (drenching, vaccination) was applied. All mating occurred naturally and hard antlers were never cut. In May 1992, adult and yearling stags from groups A and B were removed because of fighting, leaving only one adult stag in each group.

**Observations**

Records of calving in group A commenced in November 1989 through irregular inspection. In January 1991 the observations were intensified by inspecting the paddocks at least once every three days. As the number of calving increasing, the frequency of inspection was increased to a daily basis. Four adult hinds from both groups could be identified individually. Each calf was ear tagged, weighed, taken from the mother within 24 h, and artificially reared for research purposes (Chapters 5&6).

During the period of inspection for newborn calves, the status of hard antler and velvet growth from identified stags were noted. Cast hard antlers were collected. Any specific behaviour was also noted. Fresh faecal samples were obtained from both groups on a monthly basis, by collecting 8-12 pellets/animal from at least 70% of the total animals, and examined for lungworm larvae (Dictyocaulus viviparus) and gastrointestinal helminth eggs (Strongylade spp.) by the Department of Veterinary Pathology, Massey University. Any undamaged dead animals were examined by veterinarian.

Between February 1991 and May 1991, when, for the first time, group B was intensively inspected for newborn calves, the behaviour of the animals towards the presence of humans was observed. Flight distance (the distance when the animals started to run away from being approached by humans) was measured as an approximate, the number of groups formed and the number of animals per group were recorded.

**Calculation of data**

Calving dates and birth weights were tabulated on a monthly basis, over a 3-year period. The data for the 1991 calving season of animals from group B, imported from Australia, were not included, based on the assumption that the period of quarantine/transport would have altered the normal NZ breeding pattern. However, birth weight was recorded and included. Date of antler casting, period of velvet antler growth and the period of time stags were in hard antler were calculated from the antler data. Date of velvet stripping was recorded when one of the antlers showed a pronounced velvet stripping. Date of antler casting was calculated as the mean of two sides. Cast antlers were measured for their length and antler beam circumference, and weighed. Antler length was measured from the

base of the coronet to the farthest tip of the beam, and antler beam circumference was measured approximately five cm above the brow tine, using flexible polypropylene tape.

## RESULTS

### Calving pattern & calving interval

Figure 1.1 shows the calving distribution of sambar in captivity calculated from data collected over three years and which shows calving occurred from January-November, with a peak during April and May (autumn). Table 1.1 shows overall mean calving date from both groups as 8 May (SD 71.3 days, n= 31), where little variation between years, within group A and between groups A & B, was found. The mean calving interval from the identified hinds was recorded as 329 days (SD 29.7 days, n=6). Assuming the gestation period of sambar to be eight months (Thom 1937; Schaller 1967; Bentley 1978), the approximate length of time before the next conception took place after parturition, for those identified hinds, was 89 days. Conception rate for hinds over 12-month periods (January-December) in both groups, for the 3-year period was 100% (n=43).

Table 1.1 Mean calving date patterns in two groups of captive sambar under New Zealand conditions.

| Group | Year | n | Mean date (SD) |
|---|---|---|---|
| A | 1989 | 3 | 24 March (19.5) |
| | 1990 | 3 | 9 April (49.0) |
| | 1991 | 6 | 30 May (104.0) |
| | 1992 | 6 | 29 May (93.0) |
| B | 1992 | 13 | 28 May (76.5) |
| | Mean | 31 | 8 May (71.3) |

### Birth weight, sex ratio & mortality

Birth weights for all live stag and hind calves were similar, 8.1 kg (SD 1.37, n=17) and 7.8 kg (SD 1.72 kg, n=15), respectively. Pooled data from live and dead calves over a 3-year period showed that the sex ratio of male to female was 1.6:1.0 (n=43). Mortality of calves within 24 h after birth was 28% (n=12/43), with a high proportion of deaths due to inclement weather (33.3%, n=4) and victimized by adult sambar (33.3%, n=4), followed by unknown causes (25%, n=3) and stillbirth (8.3%, n=1). Mortality of stag calves was 41% (n=11) and 6% (n=1) for hind calves.

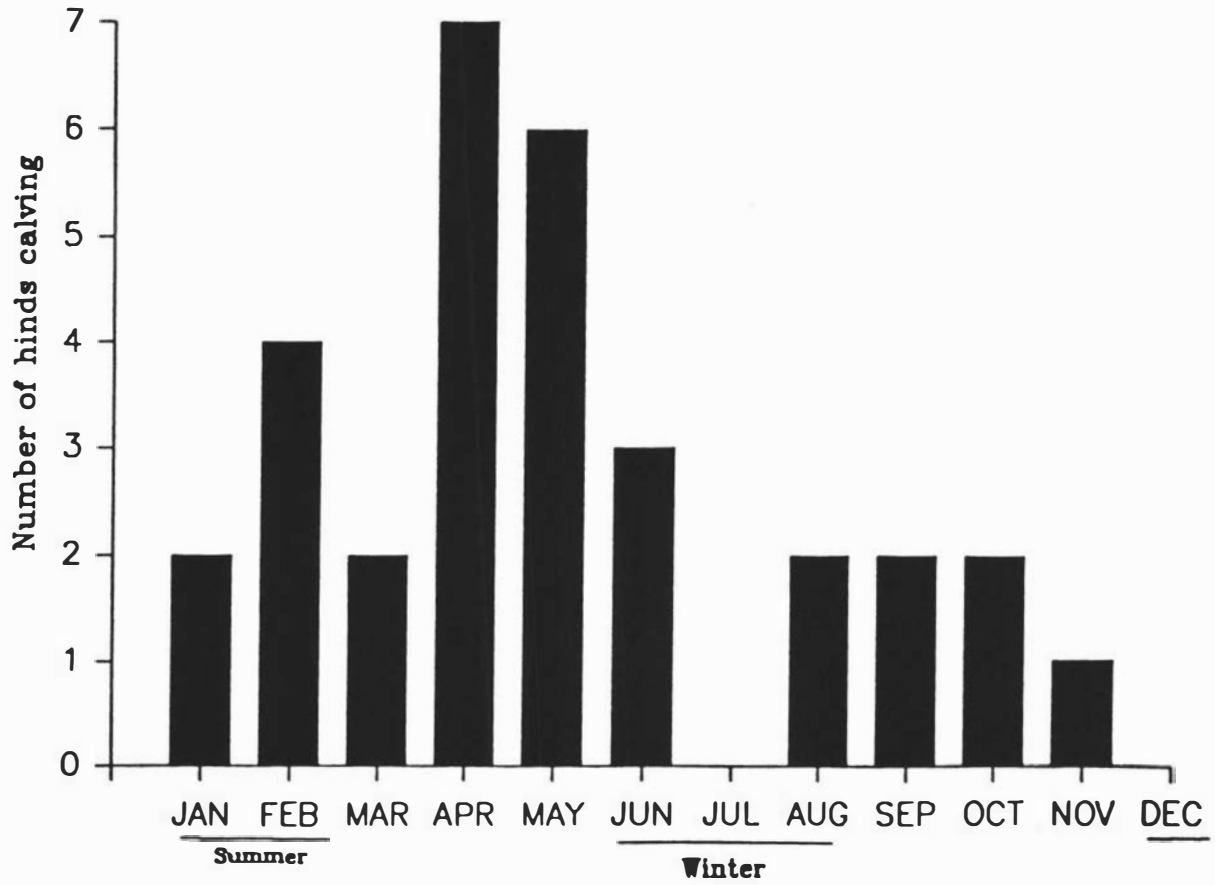


Figure 1.1 Monthly calving distribution in captive sambar under New Zealand conditions, from 1989-1992

**Antler status & dimension**

Table 1.2 shows a tendency for stags to be synchronized in hard antler, with the majority being in velvet antler between January (summer) and April (autumn) and in hard antler between May (autumn) and November (spring). January to April (summer) was the time when most stags were in velvet antler.

Table 1.2 Antler status from captive adult (≥ 3 years of age) and young (< 3 years of age) sambar stags under New Zealand conditions, between 1990 and 1992.

| Stag | Year | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Adult** | | | | | | | | | | | | | |
| 1 | 1990 | | V | V | H | H | H | H | H | H | H | H | H |
| | 1991 | H | H | V | V | V | H | H | H | H | H | H | H |
| | 1992 | V | V | V | H | H | H | H | H | H | H | H | V |
| 5 | 1990 | | V | V | H | H | H | H | H | H | H | H | V |
| | 1991 | V | V | V | H | *) | | | | | | | |
| 7 | 1990 | | V | V | H | H | H | H | H | H | H | H | H |
| | 1991 | V | V | V | H | H | H | H | H | H | H | H | V |
| | 1992 | V | V | V | H | H | *) | | | | | | |
| 4 | 1990 | | | | | | | | | | | | V |
| | 1991 | V | V | V | V | H | H | H | H | H | H | H | V |
| | 1992 | V | V | V | H | H | H | H | H | H | H | V | V |
| **Young** | | | | | | | | | | | | | |
| 37 | 1991 | | | | | | | | | | | V | V |
| | 1992 | V | V | V | H | H | *) | | | | | | |
| A | 1990 | | | | | V | V | V | V | S | S | S | S |
| | 1991 | V | V | V | H | H | H | H | H | H | H | H | H |
| | 1992 | V | V | V | V | H | *) | | | | | | |
| 965 | 1991 | V | V | V | V | V | S | S | S | S | S | S | S |
| | 1992 | S | S | S | V | V | *) | | | | | | |

V= velvet antler, H = hard antler, S= hard spike antler, *) = no recording, stags removed from area

Mean date of velvet stripping in adult stags (≥ 3 years of age) was 54 days earlier than in young stags (< 3 years of age; Table 1.3). Younger stags tended to have a variable period of time in velvet antler and their period of hard antler coincided with the time when the majority of adult stags

were in hard antler. Adult stags carried their hard antlers for 26 days longer than young stags. Mean date of hard antler casting in adult stags was 45 days earlier than in younger stags. Hard antler weight in adult stags was approximately double that of young stags.

Table 1.3 Mean date of hard antler commencement (mean, SD) in captive adult (≥ 3 years of age) and young (< 3 years of age) sambar stags, and length of time (days, SD) in velvet and hard antler conditions, under New Zealand conditions (n= number of observations).

| | Adult | n | Young | n |
|---|---|---|---|---|
| Mean date of velvet stripping[1)] | 17 April (14.9) | 11 | 10 June (84.6) | 4 |
| Mean length of time in hard antler (days) | 231 (40.0) | 8 | 205 (107.8) | 3 |
| Hard antler[2)]: | | | | |
| length (cm) | 50.8 (6.92) | 8 | 39.5 (4.45) | 6 |
| circumference (cm) | 11.9 (1.48) | 8 | 10.1 (1.00) | 6 |
| weight (g) | 817 (297.6) | 8 | 402 (79.7) | 6 |
| Mean length of time after antler casting to the first sign of velvet stripping (days)[3] | 125 (22.6) | 8 | 136 (29.8) | 3 |
| Mean date of antler casting | 7 December (35.4) | 8 | 21 January (45.2) | 3 |

[1)] Calculated from one side of antler
[2)] From individual antlers and individual animals were not identified
[3)] Period of velvet antler growth

**Behaviour**

Regardless of origin, all sambar were found to be very alert, cautious and nervous animals. Their disquiet was exhibited in the stamping of their front hooves on the ground whilst keeping their tails erect. They would stand still for briefly, walk away step-by-step and then run with their heads lowered and later form several small groups. In a very stressful situation, the leader would bark, causing all members of the group to run spasmodically, and the animals would than lie down after running. Because of their alert behaviour, sambar would notice any slight change within their paddock and they would avoid the area in which they had been disturbed for some time.

Despite the sensitive temperament of sambar, it was possible to quieten them in a farming situation through regular daily contact and handfeeding, daily, with maize or hay (0.5 kg/head/day) for four months. Table 1.4 shows the changing behaviour of group B when humans were present in their paddock. In the first month, the mean number of groups formed by the animals was 2.2, with the mean number of animals per group averaging 10. As the animals became accustomed to the presence of humans, the mean number of groups formed by the animals was reduced to 1.7, and the mean

number of animals per group increased to 12. Initially, the flight distance between the animals and humans was as far as possible. It took only 2.5 months to settle group A, with the flight distance reduced from 100 m to 10-15 m (main paddock area 1.7 ha); with group B it took almost 4.5 months, with the flight distance reduced from 140 m to only 25 m (main paddock area 2.4 ha).

Table 1.4 Number of groups (mean, SD) and number of animals per group (mean, SD) formed by group B (18 sambar), during the period when they were accustomed to the presence of humans in their paddock.

| Month | Mean number of groups | Minimum number of groups | Maximum number of groups | Mean number of animals per group | Minimum number of animals per group | Maximum number of animal per group |
|---|---|---|---|---|---|---|
| Feb. 1991 | 2.2 (0.55) | 1 | 3 | 9.7 (5.07) | 1 | 18 |
| Mar. 1991 | 2.0 (0.60) | 1 | 3 | 10.8 (5.47) | 3 | 18 |
| Apr. 1991 | 1.9 (0.67) | 1 | 3 | 10.7 (5.84) | 1 | 18 |
| May 1991 | 1.7 (0.49) | 1 | 2 | 12.0 (5.51) | 2 | 18 |

The onset of active rutting behaviour in sambar stags was observed during late May/early June and concluded in late October/early November. Rutting behaviour in stags was marked by wallowing, threshing the ground with their antlers, head rubbing on posts and trees and urinating on their head and antlers. Rutting sambar stags did not produce strong body odours, as commonly found in red stags, and roaring was never heard during daytime.

Daytime observations (0900-1000 or 1500-1600 h) showed that the dominant rutting stag collected a harem, but the stag showed a high degree of tolerance toward the presence of other stags in hard antler within the harem. The dominant stag always stayed close to the hinds, sometimes approaching hinds during urination and licking the hinds urine, presumably to detect hinds in oestrus. On four occasions the dominant stag was seen chasing a rival stag from the vicinity of the harem. On four other occasions, both dominant and rival stags were observed to be mode-fighting (pushing each other), while the hinds were either grazing or lying nearby. Although there was an impression of harmony between stags in hard antlers, two deaths were recorded from fighting injuries. Antler casting apparently did not change the behaviour of a dominant stag in keeping the harem, providing there were still hind(s) in oestrus. A dominant stag was observed chasing a hind, both before and after antler casting. Dominant stags were not aggressive towards stags in velvet antler.

**Health status**

Over a 12-month period of monthly faecal checks, no lungworm larvae or strongylate eggs were found in faeces from either group. On one occasion did an artificially reared sambar stag (5

months of age), grazing with mixed sex young artificially reared red deer (7 months of age), became heavily infested with lungworm. The symptoms were heavy coughing, restlessness, refusal to eat and substantial loss of body weight, -9.4 kg within 27 days. The number of lungworm larvae/g in faeces was 3350 and strongylade eggs 150/g, whilst in red deer, in the same group, the number of lungworm larvae/g in faeces ranged from 40-350 and strongylade eggs ranged from 0-50/g. Treatment of sambar was conducted by drenching with Ivermectin (IVOMEC, Merck, Sharp & Dohne, New Zealand) at 1/3 of the full dosage (5 ml; 1000 ug) for three consecutive days, and a booster of full dosage (15 ml; 3000 ug) on day four. Three deaths caused by MCF were recorded during the three years; one adult hind (> 3 years of age) in late winter 1991, one yearling stag (378 days) in late autumn 1992, and one yearling hind (382 days) in late winter 1992.

## DISCUSSION

The calving patterns of sambar in the present study show a peak in autumn (April-May), with a very large spread (Figure 1.1). A similar wide spread of sambar calving was also reported in Nepal (Mishra 1982). This suggests that sambar in NZ have retained their ancestral calving pattern and the reproductive pattern of tropical deer are not strongly linked to daylength, as found in temperate deer. Several studies support this view. Loudon & Curlewis (1988) found chital stags in Great Britain did not respond to melatonin treatment and calved throughout the year. Unmated chital hinds in Victoria, Australia, had continuous oestrous cycles throughout the year (Mylrea 1992). In a tropical environment, peak sambar calving occurs just prior to the monsoon season. This provides high quality roughage at weaning time, during a cool season which in turn reduces heat and humidity stress. In NZ a wide spread of calving could cause problems for deer calves born during late autumn and winter, because of severe cold and low availability of pasture.

The uncontrolled mating of tropical deer in the present study had resulted in a high mortality (28%) with inclement weather and aggressiveness of adult animals as the main factors. Death due to inclement weather was also experienced by rusa and chital deer in Australia (Mylrea 1991). It was suggested that lack of shelter and high stocking rate were the main cause of the mortalities in farm red deer calves (Kelly & Drew 1977). The present aggressive behaviour was probably more related to the presence of adult stags, as some of them were in the rut when the calves were born. Because calving in sambar occurs at any time of the year, and the presence of several adult stags in one group causes

mortality in both stags and calves, single sire mating should be practised with farmed sambar deer.

As the onset of rutting behaviour from the present sambar stags commenced in late May/early June, and assuming the gestation period of sambar hinds to be eight months (Schaller 1967; Bentley 1978), onset of calving should commence in January. Calving did in fact commence at this time and continued to November, with a peak in April/May. This indicates that onset of oestrous hinds varies between individuals and that stags were capable of mating in any month of the year. A study from Nepal indicates that the approximate peak mating activity of wild sambar is between October-November (local time), when stag population is in a transition from a high number in velvet antler (October) to a peak number in hard antler (December) (Mishra 1982). This suggests that mating by sambar stags in velvet antler in the wild is likely. Mylrea (1992) also notes that chital stags in velvet antler are still producing fertile spermatozoa and would mount an oestrous hind. Other reports also support the finding of tropical deer stags fertility at any stage of antler development (Goss 1983; English 1992; G.W Asher, personal communication). The present study also shows stag mating behaviour after antler casting.

In contrast to tropical deer, temperate red deer are not fertile while in velvet antler condition (Wilson 1984b), while Clutton-Brock & Albon (1989) showed that although wild red stags are in hard antler for more than seven months, the active breeding season lasted only for 1.5 months. This suggests that, compared to temperate stags, tropical stags have a much longer period of mating capability. Continuous oestrous cycles of tropical hinds and the ability of tropical stags to produce fertile spermatozoa and to mount hinds at any stage of antler development would explain such a wide spread of calving.

Tropical hinds also show a high ability to conceive soon after parturation. Chapple (1989) notes that chital hinds conceived only 18 days after parturition, whilst in the present study, identified sambar hinds had a mean conception time of 89 days, with the shortest time to conception noted as 50 days after parturition.

There has been historical debate on the length of time some sambar stags in NZ carry antlers. However, annual hard antler casting, in this study, supports the observations of Rudd (1978) of wild NZ sambar stags, and the findings of Acharjyo (1983) in India. In the present study the longest time a stag carried hard antler was 314 days. Chapple (1989) reports that chital stags could carry their hard antler for more than a year. Similarly, with rusa stags (van Mourik 1985). How this phenomenon occurs needs to be further evaluated. In the present study, sambar antler dimensions were smaller than those reported from India (Acharjyo 1983), suggesting environmental and genetic factors may be involved.

Sambar have long been known as shy and cunning deer (Harris 1966). In their natural environment, sambar live in dense habitat, where natural predators are present at all times (Kitchener 1961; Johnsingh 1983; Rice 1986). An alert and cautious behaviour was retained in NZ even after

being translocated to a place where natural predators, other than humans, do not exist. Despite all negative temperamental behaviour, quietening of sambar under farmed condition is still possible, by regular (daily) contact and handfeeding with maize or hay. Further development would be to train the animals for regular management, as commonly practised with farmed red deer.

Several cases have been reported which indicate that tropical deer are susceptible to MCF (Saroja et al. 1987; Hindmarsh 1991; G.W Asher, personal communication). How deer contract MCF is still unclear, but there is a strong link between the presence of sheep and MCF in deer (Hindmarsh 1991; Reid 1992). Therefore, reducing contact between sheep and deer should reduce the incidence of infection. Despite the susceptibility of tropical deer to MCF, no significant health problem were evident with set stocked sambar, where they were not in contact with other deer species. This indicates that adult sambar may have a mechanism which can eliminate the present of internal parasites. High resistance to internal parasites is also reported in rusa (Chardonnet 1988; Woodford 1991). The incident of one young stag being infected with an extremely high number of lungworm was an exception and suggests a degree of tolerance. Normal worm burden levels for farmed red deer are 0-72/g faeces for the lungworm larvae and 0-150/g faeces for the strongylate eggs (Wilson 1985).

Because calving time of NZ farmed red deer is November/December, the pattern of feed requirement for the deer generally does not coincide with the NZ pasture production profile. Advancing the calving season of red deer through hybridization with other deer species is one available alternative. Hybridizing red deer to tropical deer are two means of advancing the calving season in red deer (Short 1985). Present observations indicate that sambar, on average, calve seven months earlier than red deer in NZ, as shown in Table 1.5. Since the gestation period and birth weight are similar for sambar and red deer, artificial breeding of red hinds with sambar semen should be evaluated. Any such hybrid produced may have an advanced calving compared to red deer and could be of value in the NZ deer industry.

Table 1.5 Some comparisons of the biology of reproduction and antler growth (mean, SD) in captive adult sambar and red deer.

| | Sambar | Author | Red deer | Author |
|---|---|---|---|---|
| Mean calving date (SD) | 6 May (32.3) | present study | 8 December (12)[1)] | Moore et al. 1988a |
| Mean time of hard antler commencement (SD) | 17 April (14.9) | present study | 9 February (6.1) | Fennessy & Mackintosh 1992 |
| Days in hard antler | 231 | present study | 249 | Fennessy & Mackintosh 1992 |
| Mean hard antler casting date (SD) | 7 December (35.4) | present study | 25 September | Muir & Sykes 1988 |
| Gestation period (days) | 240 | Bentley 1978 | 234 | Fennessy & Mackintosh 1992 |
| Birth weight (kg) | 7.8-8.1 | present study | 8.8-9.2 | Fennessy & Mackintosh 1992 |
| Oestrous cycle length (days) | 17 | English 1988 | 18.8 | English 1988 |

[1)] recalculated

## CONCLUSIONS

From the present study it was concluded that :

I. The calving pattern in sambar has a wide spread, from January to November, with a peak in April/May. The mean calving date is 6 May (SD 32.3 days).

2. The calving interval (parturation to parturation) is 329 days (SD 29.7 days), with all hinds calving annually. Birth weight of stag and hind calves were similar, being 8.1 kg (SD 1.37 kg) and 7.8 kg (SD 1.72 kg), respectively.

3. Inclement weather and the aggressiveness of adult sambar were the major cause of death in new born calves (25%). Mortality of stag calves is 41% and of hind calves 6%.

4. Sambar stags in hard antler seem well synchronized, with younger stags adjusting timing of hard antler by lengthening or shortening the time in velvet. Hard antler in adult stags is carried for 231 days (SD 40.0 days), and cast annually. In young stags hard antlers were carried for 205 days (SD 107.8 days). The time from antler casting to velvet stripping in adult stags was 125 days (SD 22.6 days), compared with 136 days (SD 29.8 days) for younger stags.

5. Sambar are very cautious and nervous animals, but can quieten under farmed conditions, by regular (daily) visits and handfeeding with maize or hay.

6. The dominant rutting sambar stag demonstrated a high tolerance toward the presence of rival stags near the harem, although the death of two stags indicated that serious fighting did occur.

7. Malignant catarrhal fever was the main health problem in sambar, but they appeared to have some mechanism in controlling the internal parasites when out of contact with red deer.

8. The possibility of hybridizing sambar and red deer needs to be evaluated as a possible reasons of advancing the calving time of farmed deer.

# CHAPTER 2

## GRAZING PATTERNS OF SAMBAR AND RED DEER IN CAPTIVITY

### INTRODUCTION

Sambar are native to tropical South-East Asia (Whitehead 1972; Grzimeck 1990), and have been successfully liberated in Australia (1857), the USA (1908) and NZ (1870) (Wodzicki 1950; Bentley 1978; Lewis et al. 1990). They are the largest of the tropical Asian deer preferring a habitat of thick and dense cover (Whitehead 1972; Bentley 1978). Sambar usually avoid direct contact with humans (Harris 1966), and because of their secretive nature, little is known about their natural feeding pattern. In NZ, the habitat of wild sambar includes dense cover such as pampas (Cortaderia sp.), flax (Cordyline australis), willow (Salix sp.) and pine (Pinus sp.) (Kelton 1981; Douglas 1983).

The general view of sambar feeding behaviour is that they are nocturnal (Kitchener 1961; Harris 1966; King 1990), but this has never been precisely observed and documented. As a result, no quantitative information is available to describe their grazing behaviour. A report concerning one adult captive sambar hind in Thailand shows that feeding occurred mainly in early morning, late evening and at night (Ngampongsai 1978), whilst observations from wild sambar in Nepal show most were sighted in early morning and late afternoon (Mishra 1982), which was assumed to represent their grazing times.

The objectives of this study were to construct time budgets of feeding activities of sambar over the full 24 h period, to establish if these changed with season, and to compare these measurements with those of age matched temperate red deer grazing identical pasture. This study thus compares grazing behaviour of deer that evolved in tropical and temperate regions of the world, and which were liberated at similar times in NZ.

### MATERIALS AND METHODS

#### Experimental design

Nine sambar and nine age matched red deer grazed separate but adjoining areas of pasture for a 12-month period. Measurements of grazing behaviour were recorded continuously over 24 h periods using scan sampling at 12-min intervals, at 2-monthly periods from March 1990 to March 1991.

#### Animals

Sambar from group A comprising two adult stags (2-4 years of age), four adult hinds (2-4 years of age) and three juveniles (8-12 months of age). The young sambar were all born on the Flock

House deer farm. Nine red deer of similar sex and age were compared with the sambar.

After the first month of observation (March 1990), one adult sambar hind died as a result of an injury but no subsequent adjustment was made to the red deer group size. As the hinds calved, the calves were removed for an artificial rearing study (Chapter 4); hence the present study was not complicated by lactation in either deer species. Some sambar were fitted with ear tags, but these were too small for consistent observation. However, both sambar and red deer could be reliably identified by either their size, sex or distinctive markings.

**Paddock layout**

The paddock for group A sambar was divided into two equal parts and allocated to sambar (0.85 ha) and red deer (0.85 ha, Figure 2.1) on 2 February 1990. In addition, an extra 0.1 ha of pine trees (Pinus radiata) adjoining the sambar paddock was provided for sheltering purposes. This was considered necessary because sambar do not appear to have a good coat insulation, compared to red deer. The paddocks were surrounded by two metre high double layer deer netting fence, with a divider fence of single netting, so all animals, from both groups, could make visual but limited body contact.

The deer were observed from an elevated observation room, located at the end of the paddock, at the junction of the sambar and the red deer areas. The presence of the operator in the room did not disrupt the grazing activities. The room was well sealed, had a window and was kept dark at night, with a torch being used while recording data.

**Pasture vegetation**

The sward was an unimproved pasture, to which fertiliser and irrigation had never been applied and no other animals had ever been introduced. The major botanical composition (%mean, SE), determined in January 1991 was Trifolium sp. 13.6 (2.09%), Bromus sp. 6.9 (2.01%), Agrostis sp. 15.0 (3.40%), Holcus lanatus 18.8 (3.74%), Ranunculus sp. 4.9 (1.81%), Cynodon dactylon 11.3 (1.62%) while the remaining were Hypochaeris sp., Sporobolus africanus, Rumex acetocella, Erodium sp., Corex sp., Cerasium sp. and Taraxacum afficinale. Areas grazed by sambar were of similar botanical composition to those grazed by red deer.

**Observation techniques**

The activities of the deer were divided into three major categories, namely: grazing, defined as searching for and ingesting forage; ruminating, defined as regurgitating, masticating and swallowing the bolus (Fierro & Bryant 1990), and resting, defined as any other activity.

Rate of prehending biting (ROB) was characterized by a distinctive upward jerk of the head while pulling the plants. Measurements were made by recording the time needed to complete 20 uninterrupted bites and was expressed as bites per minute (Jamieson & Hodgson 1979).

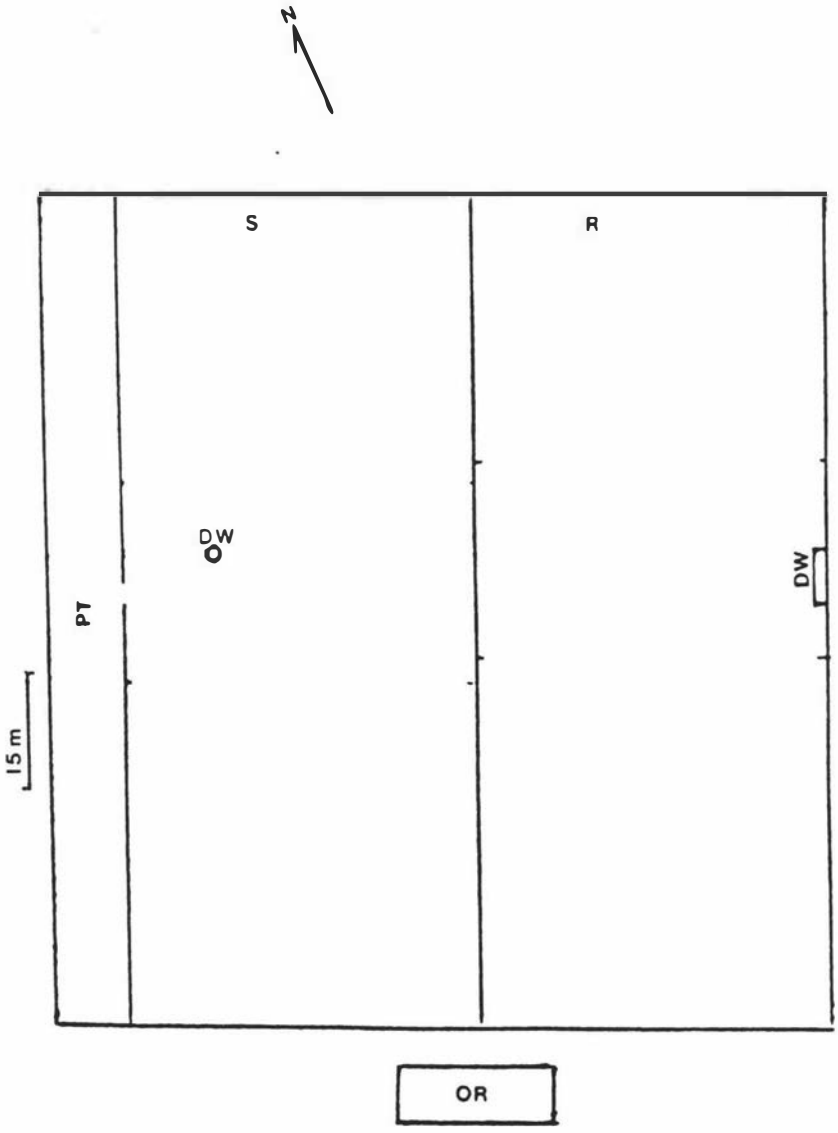


Figure 2.1 Layout of the paddock being grazed by sambar (S) and red deer (R) during grazing behaviour observations (DW= drinking water through, PT= pine trees, OR= observation room).

Two typical adult stags and two hinds from each deer group, balanced for age, were chosen to record ROB.

The three defined foraging categories and ROB were all recorded during daytime, but during the night only grazing activity was recorded. A telescope (Bisley Deluxe, D: 40 mm, zoom 10-40x, Japan) and binoculars (Nikon, 10 x 40 mm magnification, Japan) were used during the daytime observations. Observations after dark used a light gathering night-scope (Noctron V, 132 mm, Japan), powered by two AA batteries to intensify the images.

**Data collection**

At each recording period, duplicate 24 h measurements were made one week apart, except in October 1990, when only one 24 h observation was made. Observations took place during the weekend and commenced at 1000 h on Saturday, when other activity near the deer unit was at a minimum. Operators were located in the observation room 30-60 min before commencing the measurements.

The behaviour of each animal was recorded every 12 min, by scanning each paddock from left to right. During the day, the total number of animals in each activity category was recorded. At night, data were collected only on the total number of animals grazing. Two operators were used, to allow continuous 24 h recording.

ROB was recorded between 12 min scanning intervals, during daytime only. Each selected animal was recorded for 2 x 20 bites, before moving to other animal. Ambient air temperature was recorded hourly and any specific weather conditions noted.

**Pasture sampling & chemical analysis**

At the end of each recording period, pasture height was assessed in both paddocks using 30 measurements per paddock with a falling plate meter (Hammond Doyle Co. Pty. Limited, Australia), and herbage mass was measured by cutting 15 quadrats (0.01 $m^2$) from each paddock. Prior to cutting, the height of each quadrat was also measured.

Subsamples of forages, cut to soil level, were taken from each paddock for laboratory analyses of dry matter (DM), total nitrogen (N) and in vitro digestibility. All samples were stored at -20°C, freeze dried, and ground to pass a one mm diameter sieve (Willey mill, USA) prior to laboratory analysis. Dry matter was measured by drying the samples in an oven at 110°C for 16 h. Total N was determined by the Kjeldhal procedure in a Kjeltec Auto 1030 Analyzer (Tecator A.B. Sweden), using a selenium catalyst with sulphuric acid digestion. Ammonia was then determined by automatic titration against 0.1 M HCl. In vitro digestibility followed the method described by Roughan & Holland (1977).

**Calculation of data & statistical analysis**

Percentage of animals grazing was defined as number of animals grazing x 100/number of animals present. The percentage of both sambar or red deer that were either grazing, ruminating or resting was calculated for each 12 min interval. These were then averaged over hourly intervals, to determine if the foraging behaviour of sambar deer differed from that of red deer over a 24 h period. The percentage data were transformed to arcsin (Zarr 1974) and analyzed by general linear models using Statistical Analysis System (SAS 1987), with the factors fitted being type of deer (2), time of the day (24), month of the year (7), and their interactions.

A grazing cycle was defined as the period where a gradual increase in the percentage of animals grazing occurred, followed by a gradual decline. The length of grazing (h/24h) for each deer species was calculated using the following equation :

$$\text{Grazing time (h/24h)} = \frac{\text{Total animal observed as grazing in 24h}}{\text{Total animal observed as grazing, ruminating and resting in 24h}} \times 24$$

Total time (h/24h) spent grazing, ruminating and resting during daytime only was calculated in a similar manner (Hodgson 1982). Daytime was taken as the time between 0600 to 1800 h (12 h), the remainder representing night time (12 h).

## RESULTS

**Air temperature**

Highest temperatures were noted in January, whilst the coldest weather occurred in July, coinciding with NZ summer and winter seasons, respectively. The lowest hourly temperature during winter occurred in early morning (6° C) and the highest hourly temperature in summer occurred during midday (23° C).

**Herbage mass, height & nutrient quality**

In Figure 2.2, the seasonal patterns for the herbage mass and pasture height show a common trend, being lowest towards the end of winter and highest in spring. Total N and organic matter digestibility (OMD) were significantly higher ($p<0.05$, Figure 2.3) in the sambar area than in the red deer area in July (winter) and September (spring); however, these were lower in the sambar area during May ($p<0.10$; autumn).

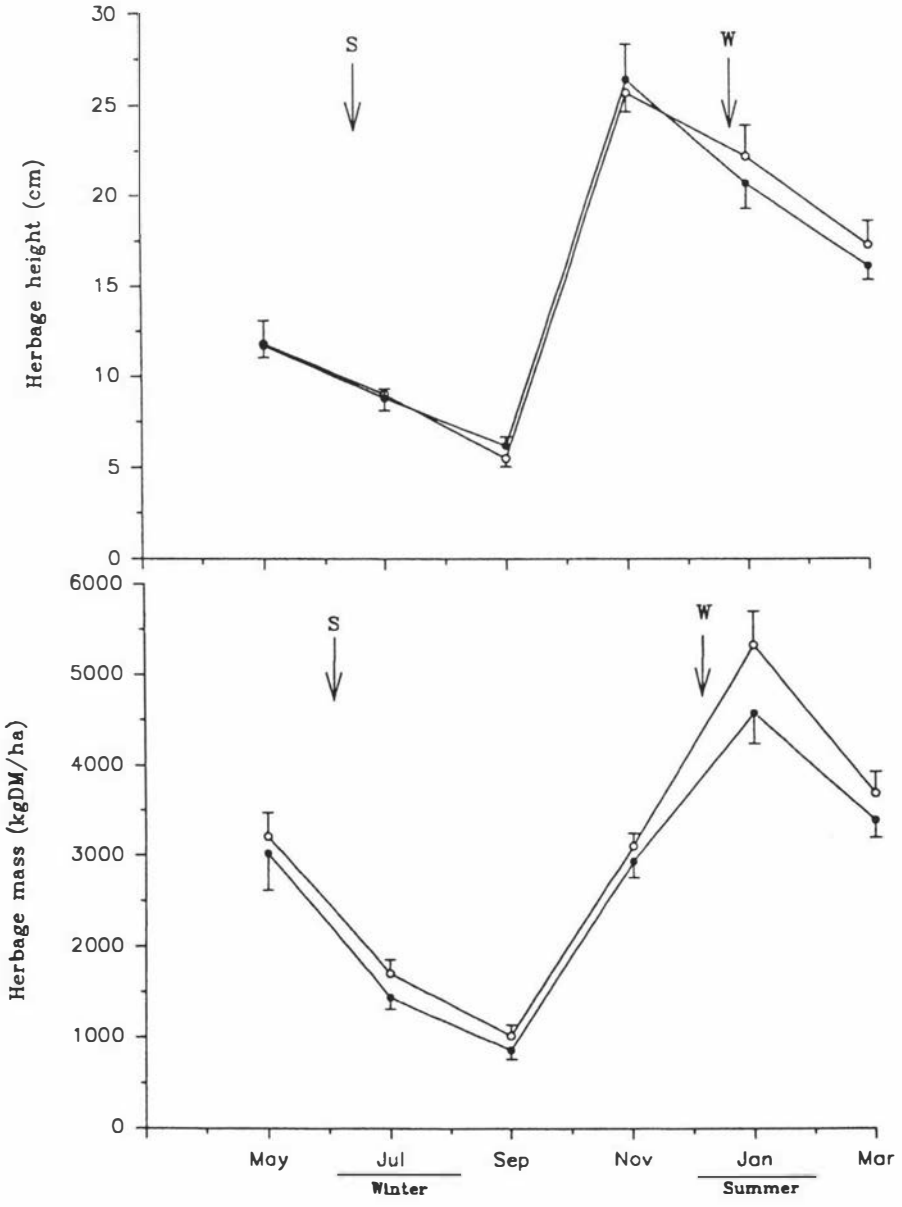


Figure 2.2 Mean herbage height (cm) and standing herbage mass (kgDM/ha) of pasture grazed by sambar (●) and red deer (○) during the study. Vertical bars represent SE. (S= summer solstice; W= winter solstice).

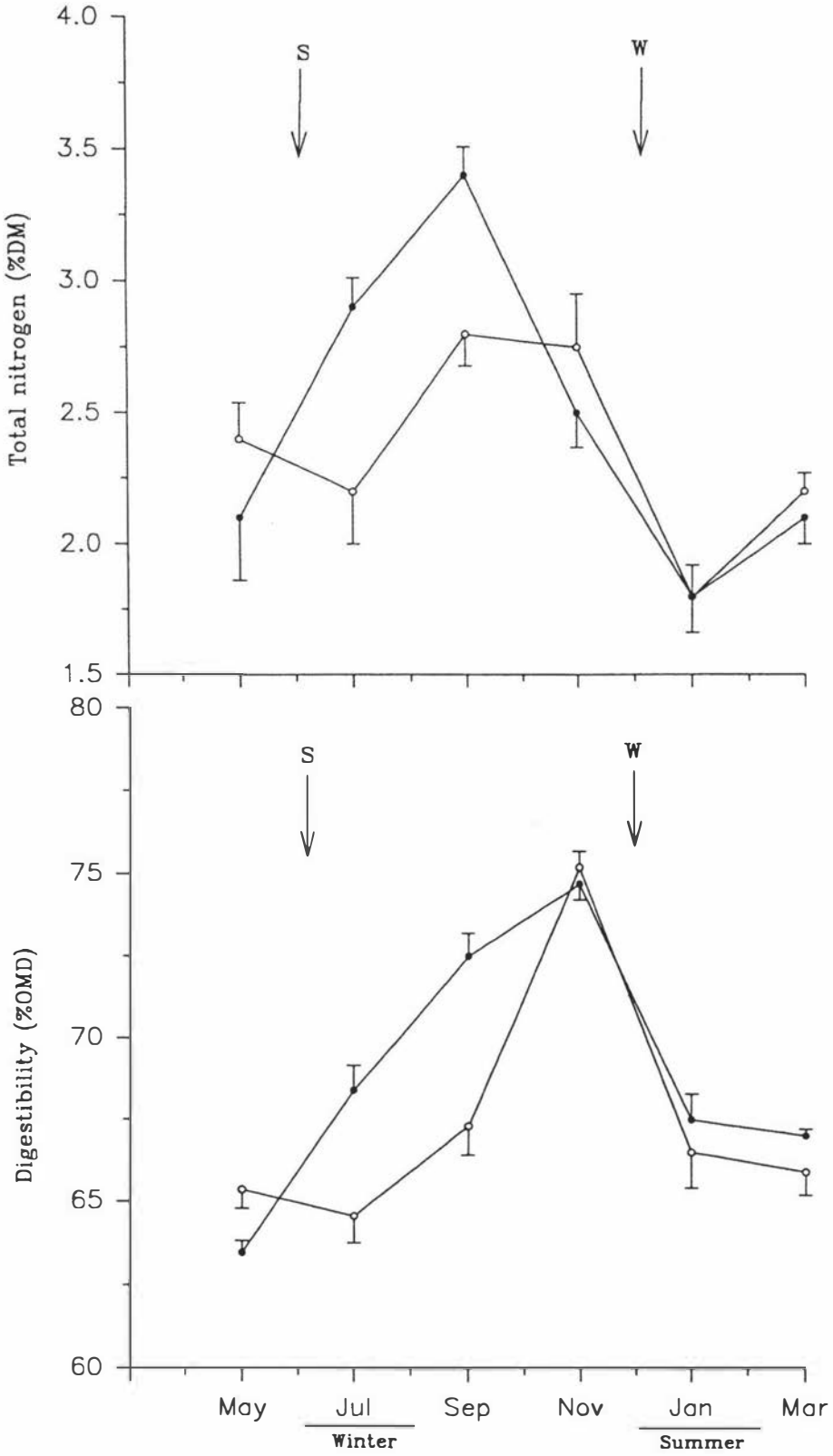


Figure 2.3 Mean total nitrogen content (%DM) and organic matter digestibility (%DM) of pasture grazed by sambar (●) and red deer (○) during the study. Vertical bars represent SE (S= summer solstice; W= winter solstice).

**Grazing observations**

Figure 2.4 shows the 24 h grazing pattern averaged over all observations. There was a significant interaction between deer species and time of day ($p<0.001$). Sambar actively grazed at night (0100-0500 h) and in the late afternoon and late evening (1700-2100 h), with only a few sightings during the morning and the middle of the day. By contrast, red deer actively grazed during the morning (0600-0700 h) and in the afternoon/early evening (1500-2000 h). Both species showed less active grazing during late morning/early afternoon (1000-1400 h).

Sambar and red deer had similar total grazing time (day + night, Table 2.1), with this being evident in all seasons, but grazing time for both species was less in spring ($p<0.05$) than in other seasons. Sambar grazed significantly longer at night (+1.3 h, $p<0.01$), and significantly less during the daytime (-1.6 h, $p<0.01$) than red deer. The ratio night:day grazing was much higher for sambar (2.3:1.0) than for red deer (1.1:1.0, $p<0.001$) and there was no interaction between species of deer and season. During daytime, sambar spent more time resting (6.4 h/11 h, $p<0.001$) compared to red deer (5.1 h/11 h), but there was no difference between the two species in ruminating time (2.1 v 1.9 h).

Table 2.1 Annual and seasonal grazing time (h/24 h) of sambar and red deer grazing unimproved pasture in New Zealand.

| | Sambar | Red deer | SEM |
|---|---|---|---|
| **Mean over all seasons**[1)] | | | |
| day time | 2.9 | 4.5 | 0.25 |
| night time | 6.2 | 4.9 | 0.25 |
| (day + night) | 9.1 | 9.4 | 0.28 |
| **Season** | | | |
| Spring | 7.8 | 7.1 | 0.41 |
| Summer | 9.4 | 10.7 | 0.65 |
| Autumn | 9.9 | 9.9 | 0.46 |
| Winter | 9.3 | 10.1 | 0.65 |

[1)] Mean values over all seasons

In spring, sambar tended to have a greater number of grazing cycles (day+night) than red deer ($p<0.05$, Table 2.2). Sambar also had more grazing cycles at night (+0.9, $p<0.05$) and less (-0.3, $p<0.10$) during daytime than red deer. Although mean ROB was greater in sambar than in red deer, the difference was consistent in all months (Table 2.3).

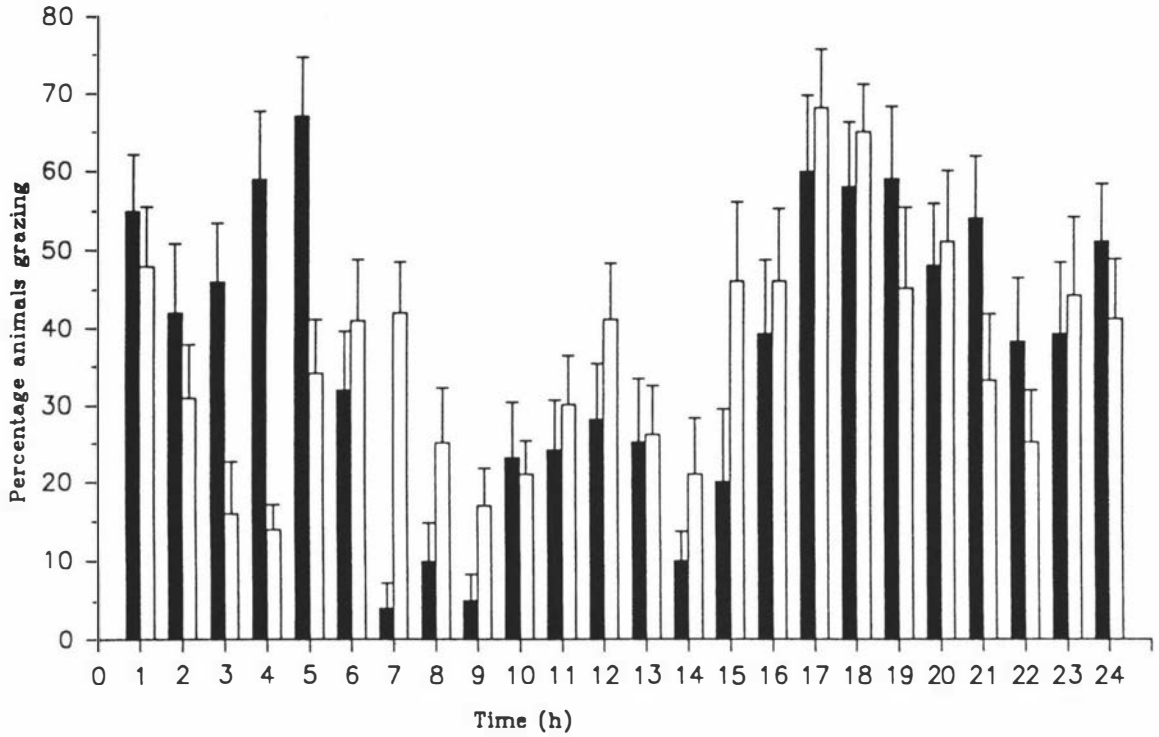


Figure 2.4 The percentage of sambar (■) and red deer (□) observed to be grazing at hourly intervals, over a 24 h period. Data are the means of observations made at bimonthly intervals, over a 12 month period. Vertical bars represent SE.

Table 2.2 Annual and seasonal grazing cycles per 24 h of sambar and red deer grazing unimproved pasture in New Zealand.

| | Sambar | Red deer | SEM |
|---|---|---|---|
| **Mean over all seasons**[1)] | | | |
| day time | 1.4 | 1.7 | 0.14 |
| night time | 3.2 | 2.3 | 0.19 |
| (day + night) | 4.6 | 4.0 | 0.27 |
| **Seasonal** | | | |
| Spring | 5.2 | 3.2 | 0.51 |
| Summer | 4.0 | 4.0 | 0.81 |
| Autumn | 4.0 | 4.5 | 0.57 |
| Winter | 3.5 | 4.5 | 0.81 |

[1)] Mean values over all seasons

Table 2.3 Rate of prehending biting (number/min, SE) of sambar and red deer grazing unimproved pasture in New Zealand.

| Month | Sambar | Red deer |
|---|---|---|
| May 1990 | 61.7 (1.31) | 42.8 (0.99) |
| July 1990 | 68.0 (1.49) | 49.9 (1.08) |
| September 1990 | 72.4 (1.45) | 50.8 (1.19) |
| October 1990 | 69.3 (1.28) | 47.6 (1.09) |
| November 1990 | 52.4 (1.13) | 39.9 (1.01) |
| January 1991 | 59.7 (1.14) | 51.0 (0.89) |
| March 1991 | 67.7 (1.11) | 52.1 (0.97) |
| Mean | 64.5 (0.48) | 47.7 (0.39) |
| Stags | 66.2 (0.67) | 44.2 (0.57) |
| Hinds | 62.7 (0.68) | 51.3 (0.53) |

## DISCUSSION

The present study shows that sambar and red deer have different grazing patterns. Sambar graze mainly at night, late afternoon and late evening, whereas red deer graze mainly during the morning and afternoon/early evening. These patterns were consistent within season and month of the year. The commencement and cessation of grazing in sambar was closely related to sunset and sunrise, as reported by Kitchener(1961) and Bentley (1978). On the other hand, the grazing behaviour of red

deer did not show a close relationship with the sunset/sunrise cycle.

Belovsky & Slade (1986) in the USA, and Clutton-Brock et al. (1982) in Scotland found similar foraging behaviour to the red deer in the present study. Such a marked behavioural difference between sambar and red deer in the same environment may reflect the evolution of different strategies for survival in their natural habitats. Nocturnal activity is characteristic of tropical deer such as chital (Dinnerstein 1979; Mishra 1982) and Bawean deer (Axis kuhli, Blouch & Atmosoedirdjo 1987), and has been inferred for sambar in Sri Lanka (Santiapillai et al. 1981). Nocturnal foraging by large African herbivores appears to be, in part, a thermoregulatory adaptation (Owen-Smith 1988), avoiding grazing in the heat of the day. Thus nocturnal foraging patterns may have reduced the thermoregulatory challenge for sambar evolving in their normal tropical habitat. Behavioural selection to avoid predators may also have contributed to nocturnality in sambar (Kitchener 1961; Johnsingh 1983; Rice 1986). The discovery that red deer may be nocturnal in the Mediterranean area (Carranza et al. 1991) indicates that temporal foraging patterns in this species may vary with environmental conditions.

The amount of time spent grazing by both species was within the range found for domesticated ruminants (Table 2.4), but less than for wild red deer recorded by Clutton-Brock et al. (1982). Day length, ambient air temperature, pasture availability and the composition, maturity and water content of pasture all influence grazing time (Black 1990). The shorter grazing time found here for red deer is probably due to a higher food availability compared with that on Rhum Island (Clutton-Brock et al. 1982) and Belovsky & Slade (1986). The finding in this study that sambar completed 4.6 cycles/24 h is the first record of grazing cyclicity in tropical deer. Both species spent least time grazing in spring when pasture mass and nutritional value were highest.

Table 2.4 Time spent grazing (h/24 h) for several domesticated animals and wild deer compared to the present study.

| Species | Grazing time (h/24 h) | | Methods of study | Authors |
|---|---|---|---|---|
| | Mean | Range | | |
| Suckling cows | | 5-12 | ? | Dulphy et al. (1980) |
| Dairy cows | | 6-11 | | |
| Sheep | | 3-13 | | |
| Sheep | 8 | 7.8-11 | focal | Bueno & Ruckebusch (1979) |
| Sheep | 9 | 4.4.-10.6 | scanning | Arnold (1984/85) |
| Horses | 11.3 | 4.1-16 | | |
| Cattle | 7.7 | 2.3-12.7 | | |
| Red deer | | | | |
| Hinds | | 11.1-11.8 | focal | Clutton-Brock et al. (1982) |
| Stags | | 10.4-12.9 | | |
| Red deer | 7.4 | 6.9-7.9 | scanning | Present study |
| Sambar | 8.5 | 8.1-9.0 | scanning | Present study |

The ROB was 35% faster in sambar than in red deer, and comparable with rates measured in cattle, whereas red deer exhibited rates similar to sheep (Table 2.5). Prehending biting does not change greatly with sward type in domestic sheep and cattle (Forbes 1982), and did not vary with changes in the sward in wild red deer (Clutton-Brock et al. 1982). As there was no difference in pasture height or mass between areas grazed by either sambar or red deer in any season of the year, it seems that eight sambar and nine red deer produced similar grazing pressure, accounting for the larger size of sambar. However, grazing by sambar at the time of lowest herbage availability (winter) produced pasture of higher OMD and total N content than pasture grazed at this time by red deer. The difference in bite rate may further reflect differences in grazing strategy between sambar and red deer, perhaps including bite depth and bite size, which should be measured in future studies and related to diet selection.

Table 2.5 Rate of prehending biting (number/min) for several domesticated animals compared to the present study.

| Species | Mean | Range | Authors |
|---|---|---|---|
| Sheep | | 48-52 | Forbes (1982) |
| Cattle | | 60-62 | |
| Red deer | | | |
| Stags | | 50-68 | Clutton-Brock et al. (1982) |
| Hinds | | 54-66 | |
| Red deer | | | |
| Stags | 44.2 | 43.6-44.7 | present study |
| Hinds | 51.3 | 50.8-51.8 | |
| Sambar | | | |
| Stags | 66.2 | 65.5-66.9 | present study |
| Hinds | 62.7 | 62.9-63.4 | |

# CONCLUSIONS

From the present study it was concluded that :

1. Sambar graze during the night, late afternoon and late evening, whilst red deer grazed mainly during the morning and afternoon/early evening. This pattern was not altered by season or month of the year. Sambar and red deer had similar total grazing time (9.1 v 9.4 h/24 h), but sambar had a higher rate of prehending biting (64.5 v 47.7 bites/min, $p<0.01$), and a relatively higher number of grazing cycles (4.6 v 4.0/24 h) than red deer. A faster ROB suggests that sambar are more selective in their diet than red deer.

2. During daytime, sambar spent less time grazing (2.9 v 4.5 h/24 h, $p<0.01$), but longer time during the night (6.2 v 4.9 h/24 h, $p<0.01$) than red deer. During daytime, rumination time equal in both species (2.1 v 1.9 h/11 h).

3. It is suggested that the night grazing pattern of sambar may have developed as a defensive strategy against attack by predators, and to avoid activity during hot daytime temperatures in the tropics. It seems that sambar, which have lived for more than 120 years in NZ, have retained their nocturnal feeding habit.

# CHAPTER 3

## DIETARY PREFERENCES OF SAMBAR AND RED DEER

### INTRODUCTION

Wild red deer are intermediate feeders which can adapt well to browse and grazing (Kay et al. 1980; Hoffman 1985). In the wild, red deer are noted for selecting plants more in relation to their abundance rather than specific plant species (Kay & Staines 1981). However, wild red hinds select feed higher in total N than stags (Kay & Staines 1981). Domesticated red deer prefer legumes to grasses and herbs, and have a high preference for red clover (Hunt & Hay 1990).

In spite of a substantial number of studies of wild sambar, the dietary preferences are not well documented. For example, Burke (1982) categories sambar as browser for most of the year. On the other hand Dinnerstein (1983) categorizes sambar as a grazer. This view is supported by Nair & Jayson (1988), while Ngampongsai's (1987) study suggests that sambar could be categorized as an intermediate feeder. Ngampongsai (1987) in Thailand, and Kelton (1981) in NZ, found that wild sambar selected plants in proportion to their availability.

The objectives of the present study were to determine the dietary preferences of sambar and red deer given access to a range of legume, browse and grass species.

### MATERIALS AND METHODS

#### Experimental design

Dietary preferences of sambar and red deer was determined on three occasions, at two monthly intervals, by offering a free choice of seven different plant species (legumes, browse & grasses). Nutritive quality of plant on offer and diet selected, plant height, plant species purity, plant preference, and stem diameter selected were subsequently determined.

#### Animals

Sambar from group A comprising one adult stag and six adult hinds, and a similar number of age matched red deer were used in the study. The sambar were familiar with movement between paddocks, and to the presence of the operator.

#### Plant species & paddock

The plant species comprised two legumes (red clover, Trifolium pratense var. Colenso and lotus, Lotus corniculatus var. Goldie), two browse shrubs (lupin, Lupinus arboreus and willow, Salix

matsudana x alba var NZ 1040 Tangoio) and three grasses (Yorkshire fog, Holcus lanatus; prairie grass, Bromus willdenowii; perennial ryegrass, Lolium perenne, with three levels of endophyte: low, medium and high). Sowing rate for prairie grass was 28 kg/ha, Yorkshire fog 7 kg/ha, lotus 8 kg/ha, white lupin 120 kg/ha, red clover 7 kg/ha and perennial ryegrass 20 kg/ha. Willow stems (30 cm long) were planted at one m intervals.

The experimental paddock consisted of four replicated blocks, with two replicated blocks per experimental area. Each block contained six main plots, sized 20 x 2 m per plot, for the six main plant species, with perennial ryegrass sown in the spaces between plots (0.6 m). Each experimental area (A & B) was separated by a two m high deer fence, as shown in Plates 3.1A&B.

**Paddock management**

Before cultivation, the experimental paddock was sprayed with glycophos (Roundup, Monsanto, New Zealand) at the rate of 12 l/ha. All species, except willow, were sown three months later, on 2 May 1991. Willow poles were planted on 15 June 1991. Reactive superphosphate was applied at the sowing rate of 150 kg/ha, and again on 4 October 1991. Nitrogen, in the form of urea, was applied one month after sowing, and then regularly every two months, at the rate of 25 kg N/ha. On 27 July 1991, legume and sweet lupin plots were sprayed with propyzamide (Kerb Flo, Rohm and Hass Ltd., New Zealand) at a rate of 3 l/ha, to remove the non-legume plants. Grass plots were sprayed with a mixture of MCPA and mecoprop (Turfix, Yates, New Zealand) at the rate of 12 l/ha, to remove any legumes and broadleaf weeds. On 6 September 1991, willow plots were sprayed with diuron and linuron mixture (Cohort, Ciba Geigy Ltd.,New Zealand) at a rate of 4 l/ha, to eliminate weeds. Three to four weeks before each observation was conducted, grass and legume plots were cut to maintain herbage in a vegetative state. In the willow and lupin plots, weeds were cut using a sickle.

**Data collection**

Observations were conducted during weekends in December 1991, February 1992 and April 1992, when other activities on the farm were minimal. Sambar and red deer groups were selected at random to go to area A first and were followed by the second group the following day. The following weekend, the second replicate (area B) was grazed and the order of grazing was reversed.

The animals were introduced to each experimental area half-an-hour before observations commenced, to allow them to adapt to the area. Observations commenced between 0830-0930 h, by recording, at one minute intervals, the number of animals grazing specific plots until 300 recordings were made. Observations were made from a hide sited 50 m from the experimental paddock using binoculars (Nikon, Japan, 10 x 50 magnification), or a telescope (Bisley Delux, Japan, D= 40 mm, 10-40 magnification).

A

B

Plate 3.1 (A). Experimental paddock (area B, replicate 1), during December 1991. From left to the right, lotus, medium endophyte perennial ryegrass, red clover, low endophyte perennial ryegrass and lupin. (B). Experimental paddock (area B, replicate 2), during December 1991. From left to the right, high endophyte perennial ryegrass, willow, low endophyte perennial ryegrass and Yorkshire fog.

At the time of the second observation (February 1992), lupin showed the effects of competition from broadleaf plants, and at the third observation (April 1992) the lotus area had been invaded by weeds. Observations of animals grazing these areas were excluded from the data.

**Plant sampling & chemical analysis**

Pre-grazing height of plants, other than willow and lupin, was measured using a rising plate meter (Ashborn, Palmerston North, NZ), for 30 counts per plot. Willow and lupin were measured using a conventional wooden two metre ruler. Plant species purity was measured using point-analysis (50 counts per plot). Representative samples of plants on offer, other than willow and lupin, were cut to ground level for nutritive quality. Willow and lupin were cut in the tip area, at the approximate height where the animals would browse. Willow and lupin stem diameter were measured using microcallipers. After the determination of dietary preference, representative samples of the plants selected by the animals were collected for nutritive quality analysis. All samples were stored at -20° C for further analysis.

Samples of forages were analyzed for DM, total N, *in vitro* digestibility, total fibre, lignin and condensed tannin (CT). Total fibre and lignin contents were analyzed following the detergent procedures of Goering & van Soest (1970). Condensed tannins were determined by the butanol/HCl procedure described by Terill *et al.* (1992), which measures extractable, protein-bound and fibre-bound CT.

**Statistical analysis**

Plant height, plant species purity, nutritive value, and number of animals grazing particular plants, which reflected dietary preference, were analyzed using SAS (1987). A generalized linear model was used, with variables used being deer species, plant species and month of observation. Lupin and lotus grazing observations during February and April observations were included as missing values. Analysis of dietary preference was conducted by grouping the plant species into browse, legume and grass categories. Nutritional values for diet selected were presented only from December 1991 sample, as the others were missing during storage.

## RESULTS

**Plant height & species purity**

There was no interaction between plant species and month of observation for plant height and no significant effect of time of observation, as shown in Figure 3.1A. The interaction between plant species purity and month of observation was significant ($p<0.001$; Figure 3.1B).

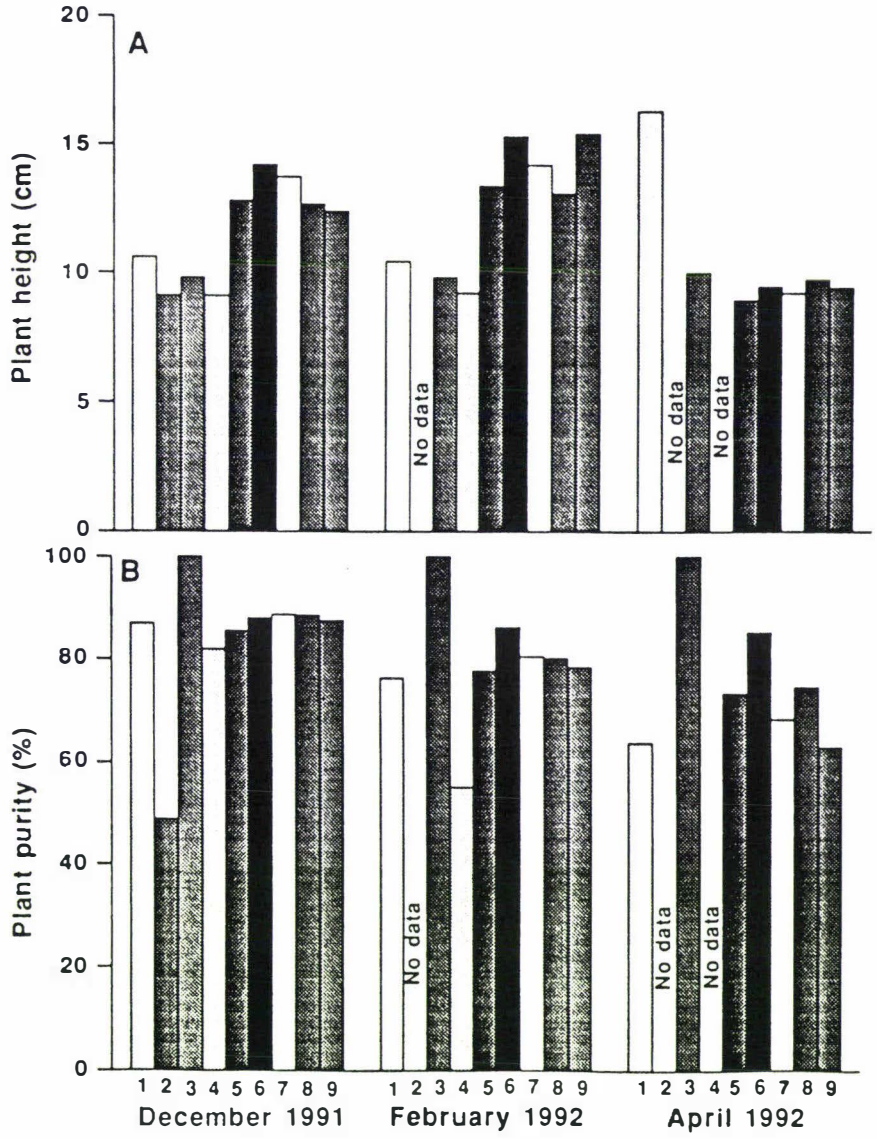


Figure 3.1 (A) Mean herbage height (cm, willow= height * 10) and (B) plant purity (%) of plants on offer, prior the introduction of animals during December 1991, February 1992 and April 1992 (1= Red clover, 2= Lotus, 3= Willow, 4= Lupin, 5= Prairie grass, 6= Yorkshire fog, 7= Low endophyte perennial ryegrass, 8= medium endophyte perennial ryegrass, 9= high endophyte perennial ryegrass).

Except for willow, each plant species showed a decline in purity from December to April, due mainly to competition from native grasses and weeds.

**Dietary preference**

The interaction between plant species and animal species was significant ($p<0.001$), as shown in Table 3.1. The dietary preferences of sambar was, in descending order: willow, high endophyte perennial ryegrass, low endophyte perennial ryegrass, lotus, red clover, lupin, medium endophyte perennial ryegrass, Yorkshire fog and prairie grass. In contrast, red deer showed a preference for red clover, followed by lotus, low endophyte perennial ryegrass, lupin, medium endophyte perennial ryegrass, high endophyte perennial ryegrass, prairie grass, Yorkshire fog and willow.

Table 3.1 Mean number of observations for sambar and red deer grazing a range of plants over three observation times; December 1991, February 1992 and April 1992.

| Plant species | Sambar | | Red deer | | SEM |
|---|---|---|---|---|---|
| | Observation | Preference ranking | Observation | Preference ranking | |
| Willow | 44.0 (25.8)[1] | 1 | 7.4 (4.2) | 9 | 5.66*** |
| Lupin | 17.0 (9.9) | 6 | 20.5 (11.6) | 4 | 5.17 |
| Red clover | 20.3 (11.9) | 5 | 49.8 (28.4) | 1 | 6.74** |
| Lotus | 20.6 (12.0) | 4 | 26.4 (15.0) | 2 | 4.17 |
| Yorkshire fog | 8.5 (5.0) | 8 | 8.0 (4.5) | 8 | 2.70 |
| Prairie grass | 5.0 (2.9) | 9 | 9.4 (5.3) | 7 | 2.08 |
| Perennial ryegrass | | | | | |
| low endophyte | 21.3 (12.4) | 3 | 21.5 (12.2) | 3 | 4.59 |
| medium endophyte | 10.5 (6.1) | 7 | 17.5 (9.9) | 5 | 2.59 |
| high endophyte | 24.0 (14.0) | 2 | 15.7 (8.9) | 6 | 3.34 |

*** $p<0.001$, ** $p<0.01$

[1] Percentage of total observations

When the plant species were grouped into browse, legume and grass categories (Table 3.2), second degree interaction (plant group*animal species*time) and the interaction between time and animal species were not significant, however the interaction between plant group and animal species was significant ($p<0.001$). Grass was selected at similar rate by both groups, however browse was selected more by sambar and red clover was selected more by red deer. The summation of total observations in Table 3.1 did not add up into 150, as it was in Table 3.2, this was due to the missing

values occuring in individual plants (lotus, lupin) during February 1992 and April 1992.

Table 3.2 Mean number of observations for sambar and red deer grazing browse, legume and grass in December 1991, February 1992 and April 1992.

| | Sambar | Red deer | SEM |
|---|---|---|---|
| Browse | 54.4 (36.3)[1] | 20.2 (13.5) | 7.29* |
| Grass | 69.3 (46.2) | 72.1 (48.0) | 6.57 |
| Legume | 26.3 (17.5) | 57.8 (38.5) | 6.56* |

* $p<0.01$

[1] Percentage of total observations

**Stem diameter**

Visual observations indicated a large difference between the two deer species in selecting browse. Sambar selected both leaves of willow and stems less than 36 mm diameter from near the tip. Red deer mainly chose leaves. With lupin, there was no noticeable difference in stem selection, with sambar selecting stems less than 29 mm diameter, and red deer selecting stems less than 27 mm. However, red deer selected slightly more lupin leaves than sambar.

**Nutritive value**

Plants on offer

Total N and OMD did not differ between species with month of observation although there were differences between plant species ($p<0.001$; Table 3.3). Legumes were significantly higher in total N ($p<0.05$) than in grass and browse, with grass and browse being of similar total N content. Grasses were significantly lower in OMD ($p<0.05$) than browse tips and legumes, but similar between browse and legumes. Condensed tannin concentration was high in willow, intermediate in lotus and non-detectable in the other species (Table 3.4).

Plants selected

Limited data, collected in December 1991, suggests that sambar tended to select plants higher in CT and lignin, and lower in digestibility, than red deer (Tables 3.4 & 3.5). Lower OMD for willow selected by sambar (Table 3.5) compared to OMD on offer (Table 3.3) was due to sambar selected more stem parts. The same occurred with lupin. Of the species preferred by sambar, willow had the highest concentration of CT (4.88 %), whilst none of the preferred diet of red deer had CT concentration as high as in sambar.

Table 3.3. Mean total nitrogen content (%DM) and organic matter digestibility (%DM) of plants on offer, over three observation times in December 1991, February 1992 and April 1992.

| Plant species | Total N | OMD |
|---|---|---|
| **Browse** | | |
| Willow[1)] | 2.4 | 81.5 |
| Lupin[1)] | 2.4 | 79.6 |
| **Legumes** | | |
| Red clover | 3.6 | 82.4 |
| Lotus | 2.8 | 79.0 |
| **Grasses** | | |
| Yorkshire fog | 2.6 | 72.7 |
| Prairie grass | 2.2 | 74.6 |
| Perennial ryegrass: | | |
| low endophyte | 2.2 | 75.5 |
| medium endophyte | 2.1 | 73.7 |
| high endophyte | 2.1 | 76.7 |
| SE | 0.40 | 2.80 |

[1)] plant parts sampled approximately 20 cm from the tips, at a maximum of one m above the ground

Table 3.4 Condensed tannin concentrations and its fractions (%DM) in plants on offer and plants selected by sambar and red deer, during December 1992.

| Forage | Extractable | Protein-bound | Fibre-bound | Total |
|---|---|---|---|---|
| | | **Feed on offer** | | |
| Willow | 4.43 | 1.97 | 0.44 | 6.84 |
| Lotus | 1.45 | 0.54 | 0.07 | 2.06 |
| Red clover | <0.001 | 0.04 | 0.001 | 0.04 |
| Yorkshire fog | 0.002 | <0.001 | <0.001 | 0.002 |
| Prairie grass | <0.001 | 0.05 | <0.001 | 0.05 |
| PRG, HE[1)] | <0.001 | 0.005 | <0.001 | 0.005 |
| | | **Diet selected** | | |
| Sambar | | | | |
| Willow | 4.08 | 0.53 | 0.27 | 4.88 |
| Lotus | 1.42 | I/S[2)] | I/S | I/S |
| Red clover | <0.001 | 0.02 | 0.002 | 0.022 |
| PRG, HE | 0.01 | 0.01 | <0.001 | 0.02 |
| Red deer | | | | |
| Red clover | <0.001 | 0.01 | <0.001 | 0.01 |
| Yorkshire fog | 0.04 | 0.01 | 0.04 | 0.09 |
| Prairie grass | 0.03 | 0.01 | 0.04 | 0.08 |

[1)] high endophyte perennial ryegrass
[2)] insufficient sample

Table 3.5 Nutritive value of plant species selected by sambar and red deer in December 1992.

| Plant species | Total N (%DM) | NDF (%DM) | Lignin (%DM) | OMD (%) |
|---|---|---|---|---|
| Willow : | | | | |
| sambar | 1.9 | 58.9 | 12.9 | 66.9 |
| red deer | N/D[1)] | N/D | N/D | N/D |
| Lupin : | | | | |
| sambar | 3.8 | 21.1 | 3.2 | 85.0 |
| red deer | 2.6 | 23.0 | 3.0 | 86.5 |
| Red clover : | | | | |
| sambar | 4.6 | 18.3 | 1.3 | 85.4 |
| red deer | 3.1 | 23.2 | 1.2 | 85.6 |
| Lotus : | | | | |
| sambar | 3.6 | 18.3 | 1.3 | 83.9 |
| red deer | 2.0 | 23.2 | 1.2 | 73.3 |
| Yorkshire fog | | | | |
| sambar | N/D | N/D | N/D | N/D |
| red deer | 1.8 | 44.7 | 0.8 | 74.1 |
| Prairie grass : | | | | |
| sambar | N/D | N/D | N/D | N/D |
| red deer | 2.0 | 43.6 | 1.4 | 74.1 |
| PRG, LE[2)] : | | | | |
| sambar | 1.8 | 45.4 | 1.2 | 78.4 |
| red deer | 1.5 | 44.3 | 1.1 | 79.9 |
| PRG, ME[2)] : | | | | |
| sambar | N/D | N/D | N/D | N/D |
| red deer | 1.5 | 44.2 | 1.1 | 78.9 |
| PRG, HE[2)] : | | | | |
| sambar | 1.4 | 46.9 | 1.3 | 75.8 |
| red deer | N/D | N/D | N/D | N/D |

[1)] not determined, because of missing samples
[2)] PRG= Perennial ryegrass
LE= low endophyte
ME= medium endophyte
HE= high endophyte

# DISCUSSION

The present study indicates that sambar had a preference for grass followed by browse and legume, whilst red deer selected grass followed by legume and then browse. Wild sambar in Florida, USA, selected browse as the first choice in all seasons, followed by forbs and grasses. Indeed, forbs and grasses are considered as an important diet for wild sambar, accounting for as much as 33% of their total diet during summer, spring and autumn, and 12% in winter (Shea et al. 1990). It is reported from Thailand that wild sambar have 21 preferred species of forest plants and seven preferred species of grassland plants (Ngampongsai 1987). However, the present study conflicts with the findings of Kelton & Skipworth (1987), where wild sambar in NZ selected 79% of their diet as coarse grasses, of low nutrient quality. This may have been due to the very limited grass available for selection. In NZ, wild sambar have concentrated around areas of flax swamp (Phormium tenox), but can also be found in both poplar (Populus sp.) and willow plantation areas (Kelton 1981). Sambar can occupy a range of habitat types and regional differences may therefore account for the differences in observed sambar feeding habits (Riney 1957; Schaller 1967; Kelton 1981; Dinnerstein 1983; Ngampongsai 1987; Shea et al. 1990).

The preference of red deer for red clover supports the findings of Hunt & Hay (1990). Selection of legumes by red deer also supports the findings of Bootsma et al. (1991), in which domesticated red deer tended to select more legume (white clover) relative to grass (perennial ryegrass). Clutton-Brock & Albon (1989) also found that wild red deer avoid diets with high fibre, high lignin and low digestibility. This was confirmed in the present study, where domesticated red deer selected plants high in nutrient value, such as legumes (red clover). A calculation of the composition of the total diet selected by both sambar and red deer indicates that the sambar diet would have contained 19 %, 135% and 188% more NDF, lignin and CT, respectively, than the red deer diet (Table 3.6). Thus, sambar selectively preferred a diet high in CT and low in digestibility, while red deer selected a diet with a high nutritive value. The figures for total diet composition should be taken as a general guide only, as the calculation used (Appendix 3.1) assumes intake to be proportional to the time spent on each plant species. There could be deviations from this, as bite weight may differ between plant species.

Sambar appear to select a total diet higher in fibre, lignin and N, but lower in OMD than red deer. Studies of jaw activity show that sambar ruminate for longer periods than red deer and have more rumination bolus/h than red deer (Chapter 5). This may be an evolutionary adaptation to more efficiently reduce particle size and recycle N to the rumen when sambar are consuming high fibre diet.

Table 3.6 Composition of total diet selected by sambar and red deer.

| Animal species | Total N | NDF | Lignin | CT | OMD |
|---|---|---|---|---|---|
| Sambar | 2.51 | 40.04 | 4.45 | 1.51 | 63.87 |
| Red deer | 2.21 | 33.53 | 1.89 | 0.53 | 79.69 |

In the present study, willow was the preferred diet by sambar, and although the CT content of willow on offer was as high as 8.6% DM, sambar selected shoot tips with a CT concentration of 6.0%. On the other hand, red deer selected against a high level of CT.

Differences in dietary preference between the two animal species may have evolved with the ability of the animals to neutralise secondary compounds present in plant species, such as CT. Condensed tannin present in plants is thought to have evolved as a self-defence against attack by pathogenic bacteria, fungi, insects and grazing herbivores (Barry 1989). The result of an inability to neutralized ingested tannin would be a depression in rumen degradation of soluble protein, rumen carbohydrate digestion and VFI (Barry & Manley 1986; Waghorn et al. 1987).

Recent study has shown that herbivores, adapted to consume tanniferous forage, may cope with the presence of such secondary compounds by producing salivary proteins that bind tannin in a highly specific manner (Robbins et al. 1987b), and the presence of such proteins has been confirmed in the saliva of several deer species (browsers), but is absent in cattle and sheep (grazers) (Austin et al. 1989). Indeed, a later study indicates that the ability of animals to counter tannin is correlated with their feeding habit, whereas salivary tannin-binding proteins in animals are produced very specifically for the types of tannin that are consumed in the preferred diet (Hagermann & Robbins, personal communication). Further study is needed to determine the type of salivary tannin-binding proteins present in sambar and red deer.

## CONCLUSIONS

From the present study it was concluded that :

1. Sambar preferred willow and red deer preferred red clover over other plants offered. Yorkshire fog and prairie grass had very low preference rankings with both deer species.

2. Sambar selected both willow leaves and stems less than 36 mm in diameter, whereas red deer selected leaves only.

3. Sambar selected plant components higher in lignin, condensed tannin and N, but lower in OMD than the red deer. Red deer selected plants for high nutrient quality, and against plants containing high levels of condensed tannin.

4. Sambar may have evolved a physiological mechanism for coping with high levels of dietary condensed tannin.

## APPENDIX 3.1

## CALCULATION OF COMPOSITION OF TOTAL DIET SELECTED BY SAMBAR AND RED DEER

The calculation was based on the assumption that the amount of nutrient consumed by the animals was proportional to the time spent eating a particular plant and the nutrient quality of that plant selected. Thus, it can be derived through an equation :

Composition of total diet selected =

$$\sum [\%\ \text{animal grazing on plant X} \cdot \text{nutritive value of plant X selected}] + [\%\ \text{animal grazing on plant Y} \cdot \text{nutritive value of plant Y selected}] + \ldots\ldots$$

Because of the limited data obtained from the present study, several conditions were applied in the way the total diet selected was calculated :

1. The percentage of total animal grazing (see Table 3.1).
2. The nutrient value of the feed selected (see Table 3.5).
3. Where the nutrient value of the feed selected for one deer species was not available, the value of plant selected from the other deer species was then used.
4. Where the nutrient value of the feed selected by both deer species was not available, the value of the feed on offer was used.

# CHAPTER 4

## MILK INTAKE, GROWTH AND BEHAVIOUR OF ARTIFICIALLY REARED SAMBAR AND RED DEER CALVES

### INTRODUCTION

Following the commercialisation of deer farming in NZ, the practice is now spreading worldwide. In NZ, the predominant temperate species farmed is red deer, with a smaller number of wapiti and fallow deer (GIB, personal communication).

Diversification into farming tropical deer is still in a very early stage, with limited commercialisation in Australia (Mackenzie 1985; English 1988; Woodford & Dunning 1992; rusa, sambar and chital), New Caledonia (Chardonnet 1988; rusa), Papua New Guinea (Stewart 1985; rusa), Taiwan (Hsia et al. 1987; sambar), Mauritius (Lalouette 1985; rusa) and Thailand (de Vos 1990; chital). To date, rusa appear the most widely farmed tropical deer. However sambar not only are the largest of the tropical deer, but they appear to have a good conformation. The velvet antlers from adult sambar stags could also be a valuable product.

Sambar were liberated in NZ in 1875 (King 1990), and have adapted to a wild environment in the coastal Manawatu (Arowhenua-Wanganui), Rotorua and Whakatane regions, North Island (P.D Muir, personal communication). However, the farming of sambar has not commenced in NZ, as numbers are low and they are known for their very temperamental and aggressive nature. This, together with their large size, has made yarding and handling of wild sambar virtually impossible.

Artificial rearing of several deer species has been undertaken with a high degree of success (Long et al. 1961; Robbins & Moen 1975, white-tailed; Fennessy et al. 1981, red; van Mourik 1983; Sookhareea & Dryden 1993, rusa; Parker & Wong 1987, black-tailed deer). There is now a need to develop similar rearing procedures with sambar. This study also aimed to produce animals that can be readily handled and used for further study.

The objectives of the present study were thus to develop procedures for the artificial rearing of sambar calves, determine the normal body dimensions at birth, measure milk intake and growth rate, in comparison with artificially reared red deer calves under similar conditions. Some behavioural observations of sambar and red deer calves during the period of artificial rearing were also documented.

## MATERIALS AND METHODS

### Experimental design

Ten sambar and nine red deer calves were removed from their dam within 24 h of birth and were artificially reared with ewe milk replacer until weaning age at 70 days. Body dimensions at birth (weight, height, girth and length), milk consumption, liveweight gain and behavioural aspects during artificial rearing were recorded.

### Animals

Red deer calves

Between 8 December 1990 and 27 December 1990, nine red deer calves (6 stags and 3 hinds) were removed from their dams within 24 h of birth. Calves were ear tagged, put into individual pens (1.5 x 2.0 x 0.9 m high), and left undisturbed for 18-24 h before the first ewe milk replacer was offered. The four pens were made from aluminium pipe and located inside a building (23.0 x 12.0 x 3.5 m high) with a concrete floor. Each pen floor was covered with sawdust, and two bales of meadow hay were put in each pen in an L shape, as a hiding place. The sawdust was replaced weekly and any wet or dirty areas of sawdust, due to urination or defecation, were removed daily.

After three days in the pens, calves were allowed daytime access to an outside grassed area (20 $m^2$). At 3.0-3.5 weeks of age, all calves were transferred to a small paddock (300 $m^2$), outside the building. Three weeks later they were transferred to a large paddock (0.55 ha) on the deer farm.

Sambar calves

Between 2 January 1991 and 3 September 1991 ten calves (7 stags and 3 hinds) were removed from their dam within 24 h of birth and ear tagged. The rearing procedure was as for red deer calves, although some sambar calves were born during the winter (June-August), and a 250 watt infra-red bulb was hung approximately 80 cm above the sawdust area, as a heater.

For the first three days, the calves were kept inside the shed. Thereafter, they were allowed access to 100 $m^2$ of fenced grassed area during daytime only. After day eleven, the calves had total access to the fenced area, but were kept inside during frosty nights. At four weeks, all calves were transferred to a 0.75 ha fenced paddock on the deer farm.

### Feeding

Calves were bottle-fed with ewe milk replacer (Anlamb, Anchor Dairy Company Ltd, Hamilton, NZ), by diluting the milk powder (30% w/v) into boiled water which had been cooled to 30° C. The ewe milk replacer was given either in a 300 cc bottle (day 1 to day 14) or a 1.5 litre bottle (day 15 onward), fitted with an artificial rubber lamb teat (length 4.5 cm, slit length approx. 0.35 cm).

For the first three days, the calves were fed a restricted amount of ewe milk replacer (65% of

normal intake), to prevent stomach upsets. From then until weaning age (70 days) they were fed the ewe milk replacer ad libitum. This feeding regime is shown in Table 4.1.

Table 4.1 Milk feeding regime during artificial rearing for both sambar and red deer calves.

| Week | Number of feed/day | Time |
|---|---|---|
| I | 4 | 0600-0700; 1200-1300; 1700-1800; 2200-2300 |
| II | 3 | 0600-0700; 1500-1600; 2200-2300 |
| III | 2 | 0800-0900; 1700-1800 |
| IV | 1 | 0900-1000 |

A small quantity (300 g) of moist soil was made available to each calve and was replaced when dry. For the first 10 days, the rectum area was rubbed with a damp cloth, after each feed, to stimulate defecation. Samples of ewe milk replacer powder were taken from individual batches for laboratory analysis. As individual calves were released into the paddock, pasture samples were cut to ground level and stored at -20° C for nutritive analysis.

**Health**

After removal from their dam, calves were given two ml of liquid vitamin supplement (Hydrovit, Rhone Poulec Ltd. NZ) orally, and because of the presence of ticks, all calves were treated with two ml Flumethrin (Bayticol, Bayer New Zealand Ltd.).

When scouring occurred, calves were fed solely with high energy electrolyte solution (Life Aid-P, Vetco Products Ltd. Manukau City, NZ) for two feeds. A mixture of ewe milk replacer and commercial homogenized cow's milk was then gradually replaced the electrolyte solution, until normal concentration was reached. After feeding, all utensils were washed and immersed in an antibacterial solution (Milton, Procter & Gamble Ltd., NZ).

When the calves were transferred to the deer farm they were drenched every three weeks with Ivermectin (IVOMEC, Merck, Sharpe & Dohme Ltd., N.Z), as protection from internal parasites and lungworm (Dictyocaulus viviparus). At weaning, all animals were vaccinated against clostridial infections using Tasvax Convax 5 vaccine (Coopers Animal Health Ltd., N.Z)

**Data collection**

Body dimensions at birth: liveweight, body length, body height and body girth, were measured at commencement of artificial rearing. Body length was measured across the body, from pinbone of the front leg to the lateral tuberosity on the rear leg scapula. Body height was measured vertically from the ground to the shoulder, and body girth was measured just behind the shoulder

(Sharples & Dumelow 1990). Liveweight was measured weekly for the first four weeks, and every two weeks thereafter. Intake of ewe milk replacer was recorded daily. The behaviour of calves was observed and recorded, particularly when the activities shown in Table 4.2 commenced.

Table 4.2 The descriptions of the behaviour observed during artificial rearing of sambar and red deer calves.

| Subject | Description |
|---|---|
| | **Related to feeding behaviour** |
| Licking soil | Licking or gnawing the soil (ground) surface, or the moist soil provided. |
| Nibbling dead forage | Light biting, to taste any dead matter of plant parts (dead leaves, stems, or hay). |
| Eating fresh forage | Light grazing, where head jerking was observed (plucking of grasses). |
| Light ruminating | Rumination for short periods of time (2 min), as indicated by clear upper and lower throat movements during mastication and regurgitation. |
| Light browsing | Actively eating fresh plant leaves. This applied only to sambar calves. |
| Gnawing bark chips | Gnawing available bark chips. This applied only to sambar calves. |
| Meconium disappearance | When this yellowish gelatinous substance is no longer present in the rectum. |
| Defecate alone | Defecated automatically. No stimulation of the rectum area required. |
| Urinating | Urination. |
| Faecal granule | Faces produced in a pellet form. |
| | **Related to environment** |
| Bound to operator | Actively standing up or coming towards the operator, when called for feeding. |
| Running | Running, jumping or chasing each other. |
| Jumping the fence | Jumping the protecting fence (0.95-1.15 m height). |
| Socializing | Forming a group with adults. This applied only to sambar calves. |

**Laboratory analysis**

Ewe milk replacer powder samples were analyzed for DM, total N and gross energy, while forage samples were analyzed for DM, total N and in vitro digestibility. Gross energy was determined through heat of combustion using an adiabatic bomb calorimeter (Gallenkamp Autobomb, Watson Victor Ltd., U.K). Samples were pelleted (0.5-0.8 gDM, 12 mm diam.) prior to combustion.

**Statistical analysis**

Body dimensions at birth and behavioral data were analyzed using Student t-test. Milk replacer intake, and liveweight gain data were analyzed by analysis of variance using a General Linear Model procedure (SAS 1987). The liveweight gain was grouped into three categories, based on growth patterns; 0 to 7 days, 7 to 28 days and 28 to 70 days. For the latter two categories liveweight gain was calculated as the slope of regression of weight (kg) on age (days). Growth curves up to 70 days of age in both deer species indicated a linear line.

## RESULTS

**Feeding**

The nutritive value of the ewe milk replacer powder and pasture grazed by both sambar and red deer calves from two to 70 days of age is given in Table 4.3.

Table 4.3 The nutritive value of milk powder and pasture grazed during the period of artificial rearing for both sambar and red deer calves, from two to 70 days of age.

| Content | Milk powder | Pasture |
|---|---|---|
| Lactose[1)] | 38.5% | - |
| Milk fat[1)] | 24.0-30.0% | - |
| Vegetable oil[1)] | 3.0% | - |
| Minerals[1)] | 6.0% | - |
| NaCl[1)] | 1.2% | - |
| Total nitrogen[2)] | 4.6% | 3.0% |
| Gross energy[2)] | 23.6 KJ/gDM | - |
| In vitro organic matter digestibility[2)] | - | 80.3% |

[1)] Approximate composition provided by ANLAMB-The New Zealand Co-operative Dairy Ltd.
[2)] Nutrition Laboratory, Animal Science Department, Massey University, New Zealand.

**Date of birth & birth body dimensions**

The mean calving date of the red deer was 14 December 1990 (SD 3.8 days, Table 4.4), which was 10 days later than the mean calving date of red deer at the Flock House deer farm, 4 December 1990. Sambar calved over a wide interval, stretching from January to September, with the mean calving date 10 June 1991 (SD 68.5 days).

During the period of artificial rearing, one red hind calve died from severe scouring at the age of three days. The birth weight of 4.5 kg was also very light. Two sambar stag calves died from abomasal bloat, one at 12 days of age (8.5 kg) and the other from severe scouring at nine days of age (9.0 kg). Data from dead calves were not included. Sambar calves tended to be bigger in their body girth at birth (+1.9 cm, Table 4.4), shorter in their body length (-1.1 cm), and lighter in their birth weight (-0.6 kg) than red deer calves, but none of these differences were significant. The body height of sambar was significantly shorter (-3.9 cm, $p<0.10$) than that of red deer calves.

Table 4.4 Mean calving date and birth body dimensions (mean,SE) of sambar (n=8) and red deer calves (n=8) that were artificially reared in 1991.

| Dimension | Sambar | Range | Red deer | Range |
|---|---|---|---|---|
| Calving date | 10 Jun. 1991 | 6 Jan.-1 Sep. 1991 | 14 Dec. 1990 | 9-20 Dec. 1990 |
| Birth weight (kg) | 6.8 (0.40) | 5.5 - 8.5 | 7.4 (0.32) | 6.5 - 9.0 |
| Height (cm) | 49.8 (1.43) | 44.4 - 55.0 | 53.7 (1.19) | 49.3 - 58.5 |
| Body girth (cm) | 48.2 (1.26) | 44.2 - 54.3 | 46.2 (1.69) | 41.3 - 54.3 |
| Body length (cm) | 39.1 (0.97) | 36.0 - 43.1 | 40.2 (1.60) | 34.8 - 46.9 |

**Liveweight**

All red deer calves and six of the eight sambar calves were weaned off ewe milk replacer at 70 days of age. Early self-weaning occurred with two sambar calves, when they refused to take any ewe milk replacer for three consecutive days: a hind (26.2 kg) at 61 days and a stag (32.5 kg) at 62 days, respectively.

The liveweight gain pattern of both species shows a similar trend, with three phases being recognized: very slow growth for the first week, increased growth from the second until the fourth week but slower growth thereafter. Rate of gain in the three phases was not significantly different between sambar and red deer calves (Table 4.5).

Table 4.5 Liveweight gain (g/day) for both sambar and red deer calves from two to 70 days of age.

| Phase | Week | Sambar | Red deer | SE |
|---|---|---|---|---|
| 1 | 0-1 | 241 | 161 | 140.8 |
| 2 | 1-4 | 387 | 403 | 66.2 |
| 3 | 4-10 | 322 | 318 | 47.1 |
| | Overall | 347 | 330 | 18.8 |

**Milk replacer consumption**

Averaged over 70-day rearing period, red deer calves consumed significantly more ewe milk replacer than sambar calves ($p<0.05$, 359 gDM/head/day v 312 gDM/head/day, respectively, Figure 4.1). Even though there was no interaction between deer species and age, there was a trend which suggested differences in milk replacer intake with time. Milk intake in red deer calves increased from the first until the fourth week, followed by steady consumption until the eighth week, and then declined sharply. In contrast, sambar calves had highest milk consumption during week three and progressively declined thereafter, with values for week seven ($p<0.10$), week eight ($p<0.01$) and weeks nine and 10 ($p<0.05$) being significantly lower than for red deer calves.

**Behaviour**

The age at which both deer species commenced selected behavioural activities was not different (Table 4.6), except that red deer calves commenced fence jumping earlier (-5 days, $p<0.01$) than sambar calves. Even though there was no significant difference between sambar and red deer calves in the age at which running commenced, by the age 10 days red deer calves tended to spend more time running and walking than sambar calves. From day four, red deer calves walked around before settling after feeding; in contrast, sambar calves would go straight to their hiding place after feeding.

**Health**

Scouring occurred in seven sambar calves (3 acute, 4 very mild) and in four red deer calves (2 acute, 2 very mild). On average, sambar calves showed symptoms of scouring 5.4 days (range 2-9 days) after was removed from their dam, and red deer calves after 4.3 days (range 2-6 days). Those animals observed consuming soil tended to have only minor scouring problems. Mixing the ewe milk replacer with commercial homogenized cow milk (50:50) for the first week, followed by a 70:30 ratio for the second and third weeks, then returning to 100% ewe milk replacer by the fourth week, proved to be helpful in preventing the occurrence of scouring in sambar calves. Two sambar calves experienced abomasal bloat. One died within nine h after bloating, but the other was saved after being treated with 2 x 10 ml doses of liquid paraffin, given orally.

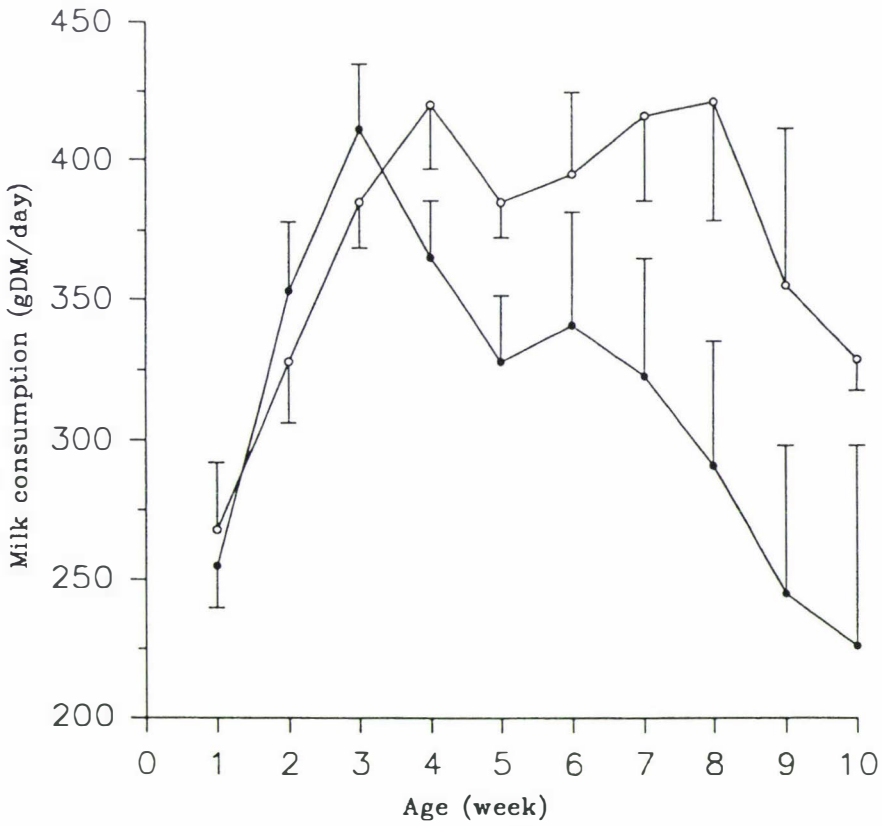


Figure 4.1 Mean daily milk consumption of sambar (●) and red deer calves (○) during artificial rearing. Vertical bars represent SE.

Table 4.6 Mean age at which sambar and red deer calves commenced selected activities during artificial rearing. Unless otherwise stated, age was measured from the date of birth of individual animals (mean, SE).

| Activity | Sambar | N | Range | Red deer | N | Range |
|---|---|---|---|---|---|---|
| **Related to feeding behaviour** | | | | | | |
| Licking soil | 3.3 (0.37) | 8 | 2-5 | 3.4 (0.33) | 8 | 2-5 |
| Nibbling dead forage | 10.0 (1.10) | 8 | 5-14 | 9.7 (0.99) | 6 | 7-13 |
| Eating fresh forage | 19.0 (1.51) | 7 | 13-23 | 20.0 (1.15) | 6 | 17-25 |
| Light ruminating | 36.0 (2.21) | 5 | 30-42 | 33.2 (2.48) | 5 | 25-38 |
| Gnawing bark chips | 18.0 (3.42) | 4 | 11-27 | N/A[1)] | | |
| Light browsing | 21.3 (2.06) | 4 | 16-26 | N/A[1)] | | |
| Meconium disappearance | 5.0 (0.45) | 6 | 4-7 | 5.0 (0.37) | 6 | 4-6 |
| Defecate alone | 5.4 (0.38) | 8 | 4-7 | 5.1 (0.35) | 8 | 4-7 |
| Urinating | 3.1 (0.34) | 7 | 2-4 | 3.4 (0.26) | 8 | 2-4 |
| Faecal granule | 29.4 (2.29) | 5 | 24-36 | 26.2 (2.65) | 5 | 17-32 |
| **Related to environment** | | | | | | |
| Bound to operator[2)] | 3.3 (0.49) | 8 | 2-6 | 3.0 (0.38) | 8 | 2-5 |
| Running | 10.0 (1.53) | 6 | 6-16 | 9.5 (1.34) | 6 | 6-14 |
| Jumping the fence | 25.3 (0.88) | 3 | 24-27 | 20.3 (0.33) | 3 | 20-21 |
| Socializing | 37.6 (1.67) | 5 | 33-43 | N/A[1)] | | |

[1)] No observations were made
[2)] The time counted from the first day of the calves being acquired

# DISCUSSION

In present study, the success of artificially reared of sambar calves, where eight out of 10 survived, was similar to that of artificially reared red deer calves, where eight out of nine survived. It also indicates early development of grazing behaviour in both sambar calves (20 days of age) and red deer calves (19 days of age). The present study differs to other artificial rearing systems in that the calves were allowed to develop their grazing behaviour at an early age, by allowing them access to pasture as early as three days of age.

The lack of major differences in body dimensions at birth was surprising, considering that in the wild, adult sambar are bigger than red deer. So far, no comparable data are available from other studies. However, a comparison with data from sambar calves born in an Indian Zoo, shows that the sambar calves in the present study were shorter in their body height (50.5 v 55.1 cm, respectively) and lighter in their birth weight (6.2 v 9.7 kg, respectively) (Acharjyo & Mishra 1980). Comparisons of liveweight with other tropical deer indicates that the ratio of fawn birth weight to dam liveweight appears to be lower for sambar than for red deer (Table 4.7).

The low sambar birth weight found in the present study may be related to nutritional status. The earliest sambar calve, born in January (summer), had a birth weight of 8.5 kg which was 1.9 kg heavier than mean birth weight of sambar calves born in June-September (winter-early spring). Temperate deer naturally mate in late autumn, when the feed availability is relatively low, and graze on lush green pasture in spring, when the foetus is in a stage of rapid growth. This does not occur with sambar in NZ. Indeed, the calving time of the sambar in the present study was concentrated close to the end of winter (Table 4.4), and during late pregnancy, their nutritional status may have been poorer than in red deer at a similar stage of pregnancy. This may have contributed to reduced size and lower birth weight.

The present study shows the following growth for both sambar and red deer calves: slow growth in the first week, increasing in the second to fourth weeks and slowing thereafter. Lower liveweight gain for both sambar and red deer calves in the first week could possibly be due to restricted feed intake in the first three days of their life. The decline in liveweight gain in the third phase corresponded to the higher forage consumption and less milk replacer. The overall liveweight gain of red deer calves, in the present study, was close to the liveweight gain of red deer calves nursed naturally on improved pasture in England (330 g/day v 324-369 g/day, respectively; Loudon et al. 1984), or from improved pasture in NZ farms (342 g/day; Muir 1988), but below the liveweight gain of red deer calves reared naturally on red clover swards (450 g/day; Niezen et al. 1993). This suggests that the genetic potential for growth was not attained in the present study.

Table 4.7 Comparative birth weight (kg) and the proportion (%) of calf birth weight to dam liveweight in temperate and tropical deer.

| Species | Calve birth weight | | Authors | Approximate dam liveweight (kg) | Calve birth weight / Dam liveweight | |
|---|---|---|---|---|---|---|
| | Mean | Range | | | | |
| | | | **Temperate deer** | | | |
| Red deer (Cervus elaphus) | | | | | | |
| Hinds | 7.9 | | Loudon et al. 1983 | 84.9 | 9.3 | |
| | 7.6 | | Loudon et al. 1984 | 86.0 | 8.8 | |
| | 9.2 | | Loudon et al. 1989 | 100[1)] | 9.2 | |
| | 7.4 | 6.6-9.0 | Fennessy et al. 1981 | 100[1)] | 7.4 | 7.8 |
| | 6.0 | 3.9-8.3 | Kelly & Whateley 1975 | 100[1)] | 6.0 | |
| | 6.5 | | Present study | 102[2)] | 6.4 | |
| Stags | 9.4 | 7.4-12.0 | Fennessy et al. 1981 | 100[1)] | 9.4 | |
| | 6.4 | 4.1-9.1 | Kelly & Whateley 1975 | 100[1)] | 6.4 | 7.8 |
| | 7.8 | 7.0-9.0 | Present study | 102[2)] | 7.7 | |
| | | | **Tropical deer** | | | |
| Sambar deer (Cervus unicolor) | | | | | | |
| Hinds | 6.2 | 5.5-7.5 | Present study | 143[3)] | 4.3 | |
| Stags | 7.2 | 6.0-8.5 | Present study | 143[3)] | 5.0 | 4.7 |
| Javan rusa (Cervus timorensis) | | | | | | |
| Hinds | 4.0 | 3.5-4.5 | Mylrea 1991 | 75 | 5.3 | |
| Stags | 5.0 | 3.0-7.0 | | 75 | 6.7 | 6.0 |
| Chital (Axis axis) | | | | | | |
| Hinds | 3.4 | 3.1-3.9 | Mylrea 1991 | 50 | 6.8 | |
| Stags | 3.6 | 3.3-4.0 | | 50 | 7.2 | 7.0 |

[1)] Typical value assumed for NZ farmed red hinds
[2)] Typical value for Flock House red hinds
[3)] Weight of the present sambar hinds in 1989

A comparison with previous trials conducted by Fennessy et al. (1981) shows that at a similar age (9 weeks) the liveweight of red deer calves in the present study was heavier (28.0 v 23.0 kg). This could be due to the difference in milk replacer being used. The previous study used simulated deer milk containing a high proportion of cow milk. In general, deer milk is rich in fat, protein, lactose and dry matter contents compared to cow milk (Robbins & Moen 1975; Robbins et al. 1987a), with sambar milk containing 11.1 % fat and 9.8 % protein (Slee & Presidente 1981), and red deer milk containing 8.5 % fat and 7.1 % protein (Arman et al. 1974).

The milk replacer intake pattern for red deer in the present study showed a sharp decline at eight weeks of age, which differed from the general trend of milk replacer intake in artificially reared deer (Arman et al. 1974; Robbins et al. 1987a; Parker & Wong 1987). These authors reported that peak milk replacer consumption occurred over the first 3-4 weeks, and then declined. Relative to red deer calves, sambar calves showed a reduced dependency on milk replacer, with a lower overall level of milk replacer intake, earlier peak intake, faster rate of decline and earlier self-weaning. This suggests that sambar calves consume more forage earlier than red deer calves. In contrast, tropical Burmese brow-antlered calves had milk consumptions twice that of the present sambar calves (Martinet et al. 1991), even though the liveweight was much lower than the sambar. It is also reported that the declining milk intake in the tropical Burmese brow-antlered calves occurred after eight weeks.

The present study indicates, that in general, both species commenced the selected activities at a similar time (Table 4.1). Among several published reports on artificial rearing of deer, very few mention the provision of soil/dirt. The present study shows that after milk, soil is the first solid matter consumed by the calves. Indeed, some calves start licking the soil as early as two days of age. Some calves of both species show a high appetite for soil and often continued licking soil after feeding. Soil/dirt could play an important role in the early development of rumen function. Facultative microbes could be introduced into the rumen, and the presence of soil in the rumen may stimulate the development of rumen microbes. Rusa calves showed an interest in consuming lucerne hay, freshly cut grass and soil at approximately 12 days of age (van Mourik 1983), while black-tailed deer calves started nibbling solid matter between 5-8 days, with actual solid consumption at 25 days of age (Sadleir 1980). In the present study, calves consumed soil as the first solid matter, followed by dead forage and bark chips (in sambar), grazing grasses and later browsing (in sambar).

Very little work has been undertaken on the development of rumen/reticulum function in deer. An early study with white-tailed deer shows that the rumen is fully functional by four months of age (Short 1964), whilst in black-tailed deer, ruminating activity is first detected at 50 days with a range of 36-58 days (Parker & Wong 1987). In the present study, sambar calves commenced light ruminating at 36 days and red calves at 33 days. Observations of ruminating could be used as a rough guide in detecting functional rumen/reticulum activity. At this point, during artificial rearing, milk replacer consumption could be restricted. The condition of faecal granules could also be used as an indicator

that the animals are consuming increasing amounts of solid matter.

Shyness in sambar calves could be due to the natural instinct to hide from predators until the ability for rapid flight is fully developed. In the present study, sambar calves started to socialize at 38 days of age. At this time they were capable of kicking, jumping, struggling and running with speed and strength. Red deer calves tended to be much more active in walking, running, jumping and chasing each other than sambar. Wild red deer calves were reported to join with the hind group at three weeks of age, and at 10 to 15 days of age some calves had started to follow their dam to feeding areas (Moore et al. 1985).

The present study shows a considerably higher proportion of animal scouring in sambar (70%) than in red deer (44%), but heavy scouring only occurred in 30% of total calves, in both species. From a management viewpoint, mild scouring should be considered as a threat to the success of artificial rearing. Indeed, several authors have mentioned scouring as the primary health problem faced during artificial rearing of deer (Robbins et al. 1987a; Silver 1961). Some causes of scouring are believed due to the unbalanced composition of the milk replacer relative to natural deer milk, especially for lactose. Van Mourik (1983) emphasizes undigested fats and sugar entering the hind gut as the cause. The high occurrence of scouring in the present sambar calves may be due to intolerance to the milk replacer used, as there is limited data available on the composition of sambar milk.

Abomasal bloat was the second problem faced during the period of artificial rearing and appeared to happen when the animals drank too much and too fast. The size of the nipple slit relative to the milk outflow may therefore be important for the prevention of bloat. Administration of liquid paraffin to stimulate defecation, may, indirectly, release some of the gas from the stomach.

## CONCLUSIONS

From the present study it was concluded that :

1. It is possible to artificially rear sambar calves with a similar high degree of success as for red deer calves. Scouring and abomasal bloating were two major concerns in artificial rearing sambar calves. Until the milk composition of sambar is known precisely, care has to be taken during feeding in the first three weeks of age.

2. Sambar calves were smaller in their birth body dimensions than red deer calves, but no significant

differences are found, except for height (49.8 v 53.7 cm, $p< 0.10$). It is calculated that calve birth weight as a proportion of dam liveweight is lower for sambar than for red deer. This is probably a general difference between tropical and temperate deer.

3. Sambar calves consumed less milk than red deer calves (312 gDM/head/day v 359 gDM/head/day, $p<0.05$). Relative to red deer calves, sambar calves showed an earlier peak in milk consumption, a faster rate of decline, and earlier self-weaning. This data indicates that sambar calves are less dependant upon milk consumption than red deer calves.

4. Both sambar and red deer calves showed a similar growth pattern, being slow during the first week, faster between weeks two and four, and slower thereafter. In general, sambar calves have a higher growth rate than red deer calves (347 g/day v 330 g/day, respectively), but the difference was not significant. These figures are close to natural growth of red deer on improved pasture, but below the growth rate of red deer on a red clover sward.

5. The age both deer species commenced selected activities was similar, except that red deer calves commenced fence jumping earlier (-5 days, $p< 0.01$) than sambar calves. Sambar calves spent less time running and walking after feeding, compared to red deer calves.

# CHAPTER 5

## A COMPARISON OF DIGESTION, CHEWING EFFICIENCY, EATING AND RUMINATING TIME IN SAMBAR AND RED DEER

### INTRODUCTION

The VFI pattern in red deer is marked by seasonal fluctuations, being low in winter and high in summer (Suttie et al. 1989; Barry et al. 1991; Domingue et al. 1991a). Other seasonal changes from winter to summer are increases in rumen pool size of both dry matter and liquid, due to a slowing of fractional outflow rate (FOR), and an increase in the rate of ammonia production (Domingue et al. 1991b; Freudenberger et al. 1993). The digestive efficiency of red deer does not change between winter and summer, in spite of a marked increase in feed intake from winter to summer (Milne et al. 1978; Freudenberger et al. 1993).

To achieve a high probability of feed leaving the rumen, feed particle size should be reduced to a critical size (Reid et al. 1977), identified as less than one mm sieve size for red deer, goats and sheep (Ulyatt et al. 1986; Domingue et al. 1991a). Particle size reduction occurs through chewing during both eating and ruminating (Ulyatt et al. 1986). Since no post-rumen particle reduction occurs (Poppi et al. 1980), faecal particle size can be used as an index of material leaving the rumen.

There are no data available regarding the digestive efficiency of tropical deer. Data from field studies (Chapter 3), indicates that sambar have a tendency to be nocturnal grazers, whereas red deer graze mainly during morning and evening. However, it was not possible to record the actual time sambar and red deer spent eating and ruminating in the paddock. These activities were recorded in the present study under controlled conditions using automated jaw recording.

The objectives of the present study were to compare the feed intake, digestive and chewing efficiency, eating and ruminating time (h/24 h), and feed and faecal particle distributions of sambar and red deer during winter and summer.

### MATERIALS & METHODS

#### Experimental design

Measurements of VFI, water intake, apparent digestibility, faecal particle size and eating and ruminating times were made during summer (S: January-February 1992) and winter (W: July-August 1992), with sambar and red deer fed chaffed lucerne hay. All animals had been artificially reared and kept indoors in metabolism cages. Within each season, experiments were conducted on the time spent eating and ruminating, efficiency of chewing during eating and efficiency of chewing during rumination.

**Animals**

Initially, during summer (January-February 1992), five stags and one hind from each deer species, and during winter (July-August 1992), four red stags and one red hind and three sambar stags and two sambar hinds were used for digestion trials. All animals were part of a previous study (Chapter 4). As the study progressed, two sambar were lost: one sambar stag from a neck injury, and one sambar stag from MCF. During winter, one red stag was not used for temperament reasons. Thus, apparent digestibility, VFI and faecal particle size distribution were determined using five red deer (four stags and one hind) and four sambar (three stags and one hind). Because of behavioural problems, voluntary water intake was determined using only three red stags, and four sambar (three stags and one hind). These were the same animals used in both the summer and winter periods.

Because of deaths and behavioural problems, jaw recording data was conducted using only three sambar during summer and winter, and four red deer in summer and three red deer in winter. Animals were not necessarily the same for both summer and winter periods.

The sambar were approximately five months younger than the red deer in both experiments, because of the differences in birth date as discussed in Chapters 1 and 3 (Table 5.1). The model and specification of the cages were similar to that described by Milne et al. (1978).

Table 5.1 Mean age (days, SE) and liveweight (kg, SE) of sambar and red deer used in the digestion trial, during both summer and winter.

| | Summer | | Winter | |
|---|---|---|---|---|
| | Sambar | Red deer | Sambar | Red deer |
| Age (days) | 249 (42.4) | 393 (5.0) | 397 (45.4) | 545 (2.3) |
| Liveweight (kg) | 67 (6.7) | 96 (3.5) | 102 (5.6) | 111 (6.2) |
| n | 4 | 5 | 4 | 5 |

**Diet**

Throughout the digestion and jaw recording periods, all animals were fed chaffed lucerne hay (2-6 cm in length) which had been harvested from the same paddock. A small multimineral salt block (Summit Multimineral Salt Block, Dominion Salt, NZ.Ltd.) was available in each feed bin. Drinking water was available at all times.

Adjustment to chaffed lucerne hay commenced one week before the animals were placed in metabolism cages. At this stage, the animals allocated to jaw recording were also fitted with leather jaw harnesses. Once animals were in the metabolic cages, a further 7-day period of adjustment was allowed, with feed offered being 15% greater than the previous day's consumption.

**Digestion trial**

Digestibility was measured over a 7-day period, with feed on offer, feed refusals, undercrate feed residues, faeces, and drinking water being weighed daily and pooled per animal for each digestion period. For each digestion period samples of feed on offer were pooled. Animals were fed once per day, between 0800-0900 h. Water containers were refilled twice daily and the quantity corrected to allow for evaporation loss. Drinking water consumption was calculated by subtracting the weight of residual water from the weight of the water offered. The result was converted to a volume basis by multiplying by specific gravity. Total water intake was calculated as the summation of drinking water and water consumed with the feed.

Duplicate samples of feed on offer were taken daily. Approximately 10% of feed residue for each animal was collected daily and pooled per animal for each digestion period. Faecal samples were collected and weighed daily and stored at -20°C. At the end of the trial, faecal samples were thawed and pooled per animal, mixed thoroughly, and sub-sampled. A sample of 200 g of the mixed faeces from each animal was taken for particle size analysis. All samples were stored at -20°C until required for analysis.

**Jaw recording**

At the end of each digestion period, the animals selected for jaw recording were retained in metabolism cages. One side of the cage wall was adjusted so that the animals could only move backward or forward, thus minimising damage to the jaw recording equipment. A 2-day period of adjustment was allowed before chewing activities were recorded.

Each animal was fitted with a jaw harness with a balloon attached under the lower jaw. Jaw movements were obtained by sensing the compression of a balloon connected to a pressure transducer. Records of jaw activity were made on multi-channel heat sensitive chart paper, as described by Domingue (1989). Plates 5.1A&B show the position of the animal during the recordings. Three sub-experiments were conducted during jaw recording:

Experiment 1. Time spent eating and ruminating

During this period the paper chart drive speed was set at 25 mm/min and records were made for four consecutive days with each animal. Animals were fed once per day, ad libitum, at 0800-0900 h. Feed on offer, feed refusals and undercrate feed residues were collected and recorded daily. The sampling procedure was similar to that described for digestion trials.


Plate 5.1 Recording of jaw movements for chewing efficiency during summer. (A) Jaw harness attached to a sambar stag, and (B) Position of animal during recording.

Information from the chart paper was read and tabulated during the 4-day recording period, so that the time spent eating or ruminating, number of bolus during rumination, number of bouts of eating or ruminating and the time spent per bout eating or ruminating could be measured. A "bout" was defined as a combination of at least three boluses regurgitated and chewed or continuous eating/ruminating lasting at least three minutes (K.J Stafford, personal communication).

Experiment 2. Efficiency of chewing during eating

The morning after Exp.1 was completed, all experimental animals were fasted for three h, from 0800-1100. A test meal of 30 min duration using 1.1 kg of chaffed lucerne hay was given, and jaw movements during eating were recorded. During this period, the paper chart drive speed was set at 60 mm/min to enable the number of chews during eating to be calculated. At the end of recording, unconsumed feed was weighed. Data were then expressed as the number of chews/min and number of chews/gDM eaten. The procedure was repeated at 2100 h, where fasting took place from 1800-2100 h. Between repeat trials, the animals were fed with 0.5 kg chaffed lucerne hay. Mean values were then calculated from both morning and evening trials.

Experiment 3. Efficiency of chewing during ruminating

The morning after Exp. 2 was completed, the animals were fed for 3 h (0800-1100 h) with 1.5 kg of chaffed lucerne hay as a test meal. Feed and water were then removed, and ruminating activity was recorded for five h, with chart drive speed set at 60 mm/min. Feed on offer and the residue were recorded. Data were then expressed as the number of chews/bolus during ruminating, number of chews during ruminating/min, time spent chewing per bolus ruminated (sec) and time elapsed between each rumination bolus (sec). Traces of jaw activity during eating, ruminating and idling in both deer species are shown in Figure 5.1.

**Sample processing & chemical analysis**

All feed and residue samples were freeze dried in duplicate, and faeces in triplicate for dry matter content determination. Samples were analyzed for organic matter (OM), total N, hemicellulose, cellulose, lignin and energy contents. Organic matter content was measured by ashing the samples in a furnace at 500°C for 16 h.

Pelleted faecal samples prepared for particle fractions analysis were thawed in water for 12 h, before being wet sieved, to pass five sizes (4,3,2,1 & <1 mm) (Domingue 1989). Particle size distribution feed on offer and refusals were determined using the dry sieving technique, to pass five sizes (5.6,4,2,1,0.5 & <0.5 mm). Each fraction was then oven dried at 100°C for 16 h, and reweighed. Data are expressed as percentages.

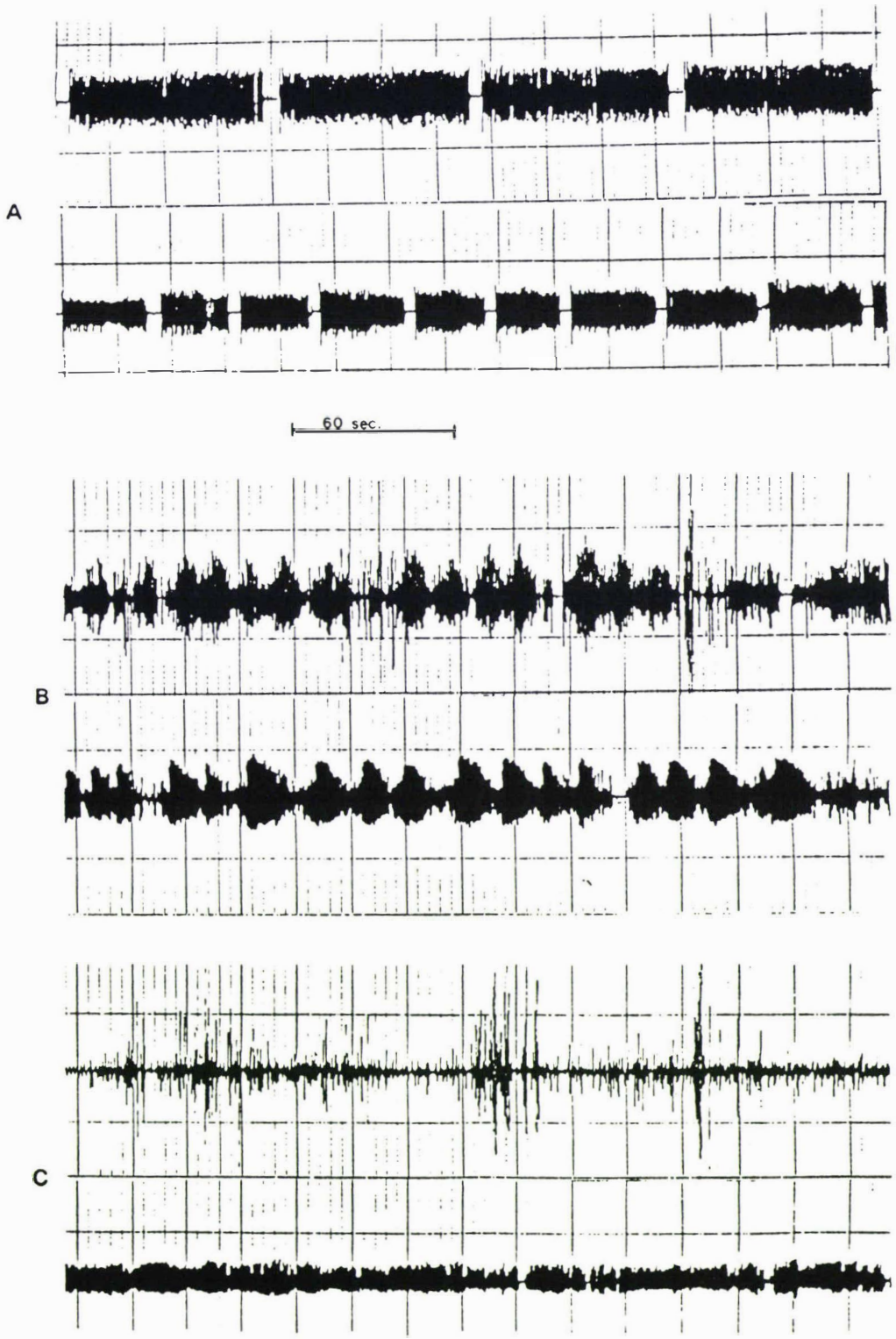


Figure 5.1 Traces of jaw activity during summer from the same animal in each species. (A) Ruminating patterns in red deer (upper) and sambar (lower). (B) Eating patterns in red deer (upper) and sambar (lower). (C) Idling patterns in red deer (upper) and sambar (lower).

**Statistical analysis**

Effects of season and season v deer species interactions for digestibility, faeces particle size data and water intake were assessed using repeated measure analysis of variance (Gill & Hafs 1971), with summer and winter as two time periods, using Statistical Analysis System package (SAS 1987). Due to different animals of the same species being used for summer and winter in the jaw recording experiments, the data were analyzed separately, per season, using one-way analysis of variance.

## RESULTS

**Voluntary feed intake & digestibility**

The chemical composition (g/kg DM) of the chaffed lucerne hay was relatively constant between seasons (Table 5.2). Voluntary feed intake (kgDM/day) showed a weak interaction ($p= 0.085$) between deer species and season (Table 5.3), with the VFI of sambar increasing slightly from summer to winter, and that of red deer decreasing markedly. When expressed as $g/kgBW^{0.75}$ per day, VFI was significantly lower in winter than in summer ($p<0.01$), but the deer species x season interaction was not significant. It appears that the decline in VFI from summer to winter was greater for red deer (-35%) than for sambar (-18%). This difference, depending on how VFI is calculated, is due to sambar liveweight increasing more from summer to winter than that of red deer (Table 5.1).

Table 5.2 Chemical composition (g/kgDM) of chaffed lucerne hay fed to sambar and red deer during the digestibility trials conducted during summer and winter.

| | Summer | Winter |
|---|---|---|
| Organic matter | 916 | 908 |
| Heat of combustion (KJ/kgDM) | 18.5 | 18.7 |
| Total nitrogen | 28.8 | 27.8 |
| Cellulose | 257 | 246 |
| Hemicellulose | 163 | 177 |
| Lignin | 78 | 80 |
| Total fibre[1)] | 501 | 503 |

[1)] = cellulose+hemicellulose+lignin

Table 5.3 Voluntary feed intake and apparent digestibilities of sambar (n= 4) and red deer (n=5) fed chaffed lucerne hay ad libitum during summer and winter.

| | | Sambar | Red deer | SEM |
|---|---|---|---|---|
| **Voluntary DM intake** | | | | |
| kg/day | S[1)] | 1244 | 1898 | 199.2 |
| | W | 1404 | 1345 | 275.2 |
| g/kgBW$^{0.75}$/day | S | 53.5 | 61.7 | 5.94 |
| | W | 43.9 | 40.0 | 8.84 |
| **Apparent digestibility** | | | | |
| Dry matter | S | 0.581 | 0.596 | 0.0076 |
| | W | 0.581 | 0.575 | 0.0167 |
| Organic matter | S | 0.589 | 0.609 | 0.0077 |
| | W | 0.593 | 0.589 | 0.0166 |
| Total fibre[2)] | S | 0.468 | 0.500 | 0.0092 |
| | W | 0.484 | 0.486 | 0.0255 |
| Cellulose | S | 0.524 | 0.549 | 0.0071 |
| | W | 0.538 | 0.556 | 0.0336 |
| Hemicellulose | S | 0.567 | 0.604 | 0.0168 |
| | W | 0.563 | 0.572 | 0.0242 |
| Lignin | S | 0.074 | 0.089 | 0.0126 |
| | W | 0.087 | 0.078 | 0.0150 |

[1)] S= summer, W= winter
[2)] = cellulose+hemicellulose+lignin

**Water consumption**

There were no significant differences between deer and season species in drinking water consumptions (Table 5.4). Sambar tended to drink more water than red deer in summer, but the deer species x season interaction did not attain significance.

**Particle size**

The distribution of particle size in feed on offer was similar between summer and winter (Table 5.5). There was no significant interaction between deer species and season for the distribution of faecal particle sizes. The distribution of faecal particle sizes showed no significant difference between species at any sieve size during both summer and winter. The distribution of faecal particle size less than one mm in summer for sambar and red deer was 98.7 and 98.5%, respectively, and in winter was 98.9 and 98.5%, respectively.

Table 5.4. Water consumption (ml/day) in sambar (n=4) and red deer (n=3) fed chaffed lucerne hay ad libitum during summer and winter.

| | | Sambar | Red deer | SEM |
|---|---|---|---|---|
| Drinking water(ml/day) | S[1)] | 7057 | 6257 | 1940.8 |
| | W | 6076 | 5856 | 1635.6 |
| Drinking water | S | 316.0 | 209.4 | 92.64 |
| (ml/kgBW$^{0.75}$/day) | W | 193.3 | 173.0 | 51.21 |
| Total water intake[2)] | S | 7186 | 6481 | 1945.6 |
| (ml/day) | W | 6305 | 6127 | 1669.4 |
| Total water intake[2)] | S | 321.5 | 216.9 | 92.99 |
| (ml/kgBW$^{0.75}$/day) | W | 200.5 | 181.3 | 52.45 |
| | W/S | 0.67 | 0.85 | 0.12 |
| Total water intake /feed | S | 5.9 | 3.2 | 1.46 |
| intake ratio | W | 4.6 | 3.5 | 0.72 |

[1)] S= summer, W= winter
[2)] = drinking water intake+water consumed with the feed

**Eating & ruminating time**

Sambar spent consistently longer eating than red deer, during both summer and winter, and day and night, but none of these effects attained significance (Table 5.6). However, total eating time/gDMI was greater for sambar than for red deer during summer ($p<0.01$), but there was no species difference during winter. Eating time/gDMI was similar for red deer in both summer and winter, but declined markedly in sambar between seasons.

Sambar also tended to spend more time ruminating than red deer, during both summer and winter and day and night, with the effects attaining significance during winter for both total (24h) ($p<0.01$), and daytime ruminating time ($p<0.001$). Total time spent ruminating (min/gDMI) was greater for sambar than for red deer, in both summer ($p<0.001$) and in winter ($p= 0.089$). Total time spent ruminating/gDMI seemed to be constant between seasons in red deer, but to decline in sambar from summer to winter.

The ratio night:daytime eating was consistently greater for sambar than for red deer, whilst the ratio of night:daytime ruminating was consistently less for sambar than for red deer. The ratio night:daytime ruminating attained significance only in winter ($p<0.01$).

Table 5.5. Distribution of particle size (%DM), retained in sieved, of feed on offer and faeces in sambar and red deer fed chaffed lucerne hay ad libitum during summer and winter (Sambar n=4; Red deer n=5).

| Sieved (mm) | Summer | | | Winter | | |
|---|---|---|---|---|---|---|
| **Feed on offer**[1)] | | | | | | |
| 5.6 | | 34.6 | | | 29.8 | |
| 4.0 | | 20.6 | | | 24.2 | |
| 2.0 | | 22.6 | | | 21.8 | |
| 1.0 | | 13.5 | | | 14.1 | |
| 0.5 | | 6.3 | | | 7.0 | |
| <0.5 | | 2.3 | | | 3.1 | |
| | Sambar | Red deer | SEM | Sambar | Red deer | SEM |
| **Faeces** | | | | | | |
| 2.0 | 0.47 | 0.46 | 0.07 | 0.24 | 0.34 | 0.08 |
| 1.18 | 0.12 | 0.42 | 0.17 | 0.52 | 0.61 | 0.21 |
| 1.0 | 0.74 | 0.67 | 0.03 | 0.67 | 0.55 | 0.08 |
| 0.5 | 27.3 | 26.9 | 0.92 | 25.5 | 26.2 | 1.53 |
| 0.25 | 37.6 | 38.3 | 2.02 | 38.9 | 36.4 | 1.45 |
| <0.25 | 33.8 | 33.3 | 1.66 | 34.2 | 35.9 | 2.76 |
| < 1.0 | 98.7 | 98.5 | 0.20 | 98.6 | 98.5 | 0.23 |
| > 1.0 | 1.3 | 1.5 | 0.20 | 1.4 | 1.5 | 0.23 |

[1)] = Feed on offer to both species

Table 5.6 (Exp.1) Time (min) spent eating and ruminating by sambar (S) and red deer (R) fed chaffed lucerne hay ad libitum during summer (S n=3; R n=4) and winter (S n=3; R n=3).

| | | Sambar | Red deer | SEM |
|---|---|---|---|---|
| Voluntary feed intake | | | | |
| DMI (gDM/day) | S[1)] | 1373 | 2122 | 90.8** |
| | W | 1802 | 1447 | 220.4 |
| DMI (gDM/kgBW$^{0.75}$/day) | S | 58.7 | 70.9 | 2.82** |
| | W | 55.9 | 44.8 | 9.53 |
| **Eating (min)** | | | | |
| min[2)]/gDMI | S | 0.28 | 0.16 | 0.016*** |
| | W | 0.14 | 0.16 | 0.018 |
| min/24h | S | 383 | 332 | 17.4*) |
| | W | 254 | 221 | 24.2 |
| min/06.00-18.00 (day) | S | 208 | 197 | 23.3 |
| | W | 124 | 113 | 10.8 |
| min/18.00-06.00 (night) | S | 175 | 135 | 19.4 |
| | W | 130 | 108 | 21.3 |
| Eating ratio (night/day) | S | 0.84 | 0.69 | 0.168 |
| | W | 1.05 | 0.96 | 0.193 |
| **Ruminating (min)** | | | | |
| min[2)]/gDMI | S | 0.41 | 0.25 | 0.018*** |
| | W | 0.30 | 0.25 | 0.020*) |
| min/24h | S | 554 | 520 | 37.5 |
| | W | 544 | 355 | 42.6** |
| min/06.00-18.00 (day) | S | 240 | 214 | 23.8 |
| | W | 238 | 101 | 19.8*** |
| min/18.00-06.00 (night) | S | 314 | 306 | 18.4 |
| | W | 306 | 254 | 25.6 |
| Ruminating (night/day) ratio | S | 1.31 | 1.43 | 0.168 |
| | W | 1.29 | 2.52 | 0.187** |

[1)] S= summer; W= winter

[2)] refers to total time eating or ruminating/24 h

*** $p<0.001$, ** $p<0.01$, *) $p<0.10$

**Eating & ruminating bouts**

There was little difference between the two deer species in number of eating bouts (Table 5.7). The number of daytime ruminating bouts were significantly greater for sambar than for red deer, in both summer ($p= 0.078$) and in winter ($p<0.01$), but there was no species difference in terms of ruminating bouts at night. Ruminating time (min/bout) during 24 h was similar for sambar and red deer, with no significant differences during either day or night.

**Efficiency of chewing**

Within season there were no differences between sambar and red deer in the number of chews/gDMI during eating (Table 5.8), although chewing rate/time tended to be lower for sambar than for red deer in summer ($p<0.01$), but not during winter.

Sambar had a lower number of chews ruminated/bolus and a lower chewing time/ruminated bolus than red deer, in both summer ($p<0.01$) and in winter ($p= 0.080$), but had more rumination boli/h than red deer ($p<0.01$). There was no species difference in chewing rate during rumination.

Table 5.7 (Exp.1) Number of eating and ruminating bouts in sambar (S) and red deer (R) fed chaffed lucerne hay ad libitum during summer (S n=3; R n=4) and winter (S n=3; R n=3).

| | | Sambar | Red deer | SEM |
|---|---|---|---|---|
| **Eating:** | | | | |
| Number eating bouts | | | | |
| 24 h | S[1)] | 11.8 | 12.3 | 1.39 |
| | W | 10.8 | 12.9 | 1.70 |
| 06.00-18.00 (day) | S | 6.8 | 7.3 | 0.59 |
| | W | 5.3 | 7.1 | 0.50[*)] |
| 18.00-06.00 (night) | S | 5.0 | 5.0 | 1.06 |
| | W | 5.4 | 5.8 | 1.25 |
| Minute/bout eating | | | | |
| 24 h | S | 32.7 | 30.4 | 3.54 |
| | W | 25.1 | 17.7 | 4.14 |
| 06.00-18.00 (day) | S | 32.1 | 28.2 | 4.30 |
| | W | 23.3 | 16.2 | 3.45 |
| 18.00-06.00 (night) | S | 33.4 | 34.8 | 5.83 |
| | W | 27.0 | 19.4 | 5.04 |
| **Ruminating** | | | | |
| Number ruminating bouts | | | | |
| 24 h | S | 14.5 | 13.4 | 0.66 |
| | W | 15.9 | 11.6 | 2.71 |
| 06.00-18.00 (day) | S | 7.8 | 5.9 | 0.72[*)] |
| | W | 8.0 | 4.6 | 1.33[**] |
| 18.00-06.00 (night) | S | 6.8 | 7.5 | 0.57 |
| | W | 7.9 | 6.9 | 1.47 |
| Minute/bout ruminating | | | | |
| 24 h | S | 38.3 | 38.9 | 1.82 |
| | W | 36.4 | 34.0 | 4.26 |
| 06.00-18.00 (day) | S | 33.5 | 37.9 | 1.68 |
| | W | 31.4 | 27.5 | 3.57 |
| 18.00-06.00 (night) | S | 43.8 | 40.5 | 2.98 |
| | W | 42.0 | 37.8 | 5.45 |

[1)] S= summer, W= winter; [**] $p<0.01$, [*)] $p<0.10$

Table 5.8 (Exp. 2 & 3) Chewing efficiency during eating and chewing during ruminating in sambar (S) and red deer (R) fed chaffed lucerne hay ad libitum during summer (S n=3; R n=4) and winter (S n=3; R n=3).

| | | Sambar | Red deer | SEM |
|---|---|---|---|---|
| **Eating (Exp.2)** | | | | |
| Intake rate (gDMI/min) | S[1)] | 8.0 | 8.8 | 0.78 |
| | W | 14.3 | 12.5 | 1.32 |
| Intake rate | S | 12.0 | 11.0 | 0.10 |
| (mgDMI/kgBW$^{0.75}$/min) | W | 23.0 | 24.0 | 0.40 |
| Number of chews/min eating | S | 84.1 | 100.3 | 2.54$^{**}$ |
| | W | 104.1 | 100.6 | 7.5 |
| Number of chews/gDMI | S | 11.0 | 11.7 | 0.93 |
| | W | 7.4 | 8.6 | 1.05 |
| **Ruminating (Exp.3)** | | | | |
| Number of chews/bolus | S | 59.6 | 94.1 | 6.27$^{**}$ |
| ruminating | W | 63.8 | 85.2 | 8.05$^{*)}$ |
| Chewing time/bolus | S | 40.7 | 61.7 | 3.62$^{**}$ |
| ruminated (sec) | W | 42.5 | 59.6 | 5.84$^{*)}$ |
| Number of boli/h | S | 68.0 | 48.0 | 3.83$^{***}$ |
| | W | 72.5 | 50.6 | 4.47$^{**}$ |
| Number of chews/min | S | 89.9 | 91.5 | 7.30 |
| ruminating | W | 92.2 | 86.9 | 3.63 |
| Pause between bolus | S | 5.2 | 5.1 | 0.29 |
| ruminating (sec) | W | 5.6 | 5.1 | 0.16$^{*)}$ |

[1)] S= summer, W= winter

$^{***}$ $p<0.001$, $^{**}$ $p<0.01$, $^{*}$ $p<0.05$, $^{*)}$ $p< 0.10$

# DISCUSSION

The best indicator of seasonal changes in VFI is considered to be absolute intake (kgDM/day), as this is not complicated by changes in liveweight. Using this parameter, it was found that the endogenous cycle of VFI in growing sambar was greatest in autumn and least in spring, with the amplitude of the cycles being lower than for red deer (Chapter 6). The VFI obtained for sambar in the present study supports this trend, with summer VFI (January/February) increasing towards its maximum in April (autumn), and winter VFI (July/August) decreasing towards its minimum in September (spring). It seems that sambar achieved their high winter VFI with a decrease in eating time/DMI, perhaps by increasing intake rate/min and by increasing chewing frequency during eating.

A seasonal trend of VFI in the present red deer confirm previous studies of highest intake in summer and lowest in winter (Suttie et al. 1989; Domingue et al. 1991a; Barry et al. 1991), being strongly linked to photoperiod (Barry et al. 1991). The mechanism for reducing VFI from summer to winter in red deer appears to be a reduction in time per eating bout, whilst keeping the number of eating bouts/h and the chewing rate/min during eating relatively constant between seasons. As a result, eating time (min/gDMI) in red deer did not change between summer and winter.

The present study showed that passage through a one mm sieve was the critical particle size for material leaving the rumen in both species of deer. This is similar to sheep (Ulyatt 1983), and confirms findings in red deer (Domingue et al. 1991a). Studies in mule deer and elk also show a similar trend, with 92% and 89%, respectively, of feed particles sized >2.8 mm being reduced to <1.0 mm by rumination (Spallinger & Robbins 1992). Apart from particle size, efficiency of feed utilization by the rumen is also dependent on the shape of the feed particles. The rumen of browsing animals are more tolerant to larger cuboidal shaped particles, rather than long fibrous particles, as present in mixed feed (Renecker & Hudson 1990). The distribution of faecal particle size did not significantly change over the season, similar to finding with moose (Alces alces) and wapiti (Renecker & Hudson 1990). Chai et al. (1984) concluded that the efficiency of chewing during rumination in breaking down feed particles is greater than during eating, whilst Spallinger & Robbins (1992) found in elk and mule deer that the principle mechanism for breaking down feed particles was chewing during rumination rather than microbial digestion.

Although there were changes between seasons in VFI, apparent digestibility did not change between season in either deer species. Constant digestibility in red deer is due to a reduction in rumen fractional outflow rate during summer, leading to an increase in rumen pool size, allowing longer time for rumen microbial fermentation and increased ammonia production (Domingue et al. 1991a; Freudenberger et al. 1993). Digestive function in sambar and how this differs from that of red deer, is an area that requires future study.

One of the major differences between sambar and red deer was in rumination behaviour, with sambar spending more time ruminating/gDMI, having shorter time per ruminated bolus than red deer, but having more ruminating bouts and boli/h. Such differences might be expected to lead to a more efficient rate of particle breakdown during rumination in sambar, a faster rate of turnover of rumen contents during rumination and increased saliva production and rumen N recycling. If this is true, it might be expected that digestive efficiency in sambar could be greater than for red deer with diets high in fibre and, hence, low in digestibility are offered. This hypothesis needs to be tested experimentally, as tropical forages are known to be of lower digestibility than temperate forages (van Soest 1982), and it may well be that sambar have evolved a rumination pattern designed for efficient breakdown of such forage.

Relative to red deer, sambar did more ruminating during daytime. This may complement their nocturnal grazing behaviour under field conditions (Chapter 2), and be part of an evolutionary mechanism allowing them to ruminate during daytime whilst hiding from predators.

## CONCLUSIONS

From the present study it was concluded that :

1. Sambar showed less seasonality of VFI than red deer. This could indicate a different physiological control of intake in tropical deer. A pronounced decrease in water intake from summer to winter may indicate the importance of water for sambar during summer.

2. Digestibility of lucerne hay was similar in sambar and red deer (OMD 59%) and the distribution of faecal particle size showed that the critical particle size was one mm sieve size for both species.

3. Eating time tended to be slightly greater for sambar than for red deer, in both summer and winter, and during both day and night, but none of these effects attained significance. Eating time (min/gDMI) was greater for sambar during summer, with the slower rate of chewing during eating being a contributing factor. There were no differences between the two deer species in winter in eating time (min/gDMI) or in number of chews/min during eating.

4. Short term intake rate (gDMI/min) and chews/gDMI during eating were not significantly different

between sambar and red deer.

5. Red deer appeared to achieve a decline in VFI from summer to winter by reducing the number of minutes per eating bout, whilst keeping the number of eating bouts/h and the chewing rate per minute time during eating relatively constant. Sambar appeared to use the same mechanism, with the magnitude of the changes being less pronounced.

6. Both absolute ruminating time (min) and ruminating time per unit of feed (min/gDMI) were consistently greater for sambar than for red deer, in both summer and in winter. Sambar consistently had less ruminating chews/bolus and spent less time ruminating/bolus than red deer, but had more ruminating boli/h than red deer.

7. Differences between sambar and red deer were more pronounced in ruminating behaviour than in eating behaviour. Sambar may have evolved a different ruminating pattern to red deer in order to effectively break down low quality tropical forages.

# CHAPTER 6

## A COMPARISON OF ENDOGENOUS PATTERNS OF GROWTH, VOLUNTARY FEED INTAKE AND PLASMA HORMONE CONCENTRATIONS IN SAMBAR AND RED DEER

### INTRODUCTION

Studies of the growth, VFI, hormonal profile and reproductive physiology of tropical deer are limited to extensive studies conducted in non-tropical environments. These studies have been unable to demonstrate an endogenous cycle in tropical deer or a link with photoperiod. The highest growth rate for rusa living in a sub-tropical grazing environment was recorded during winter, while the lowest growth rate occurred in summer (Woodford 1991). There was no marked fluctuation of body loss in chital stags over a 3-year period (Chapple 1989). Suttie et al. (1992a) clearly showed no seasonal effect on growth rate when rusa were compared to red deer in a sub-tropical environment.

Rusa stags living in Victoria, Australia, show an elevated concentration of PRL during long day periods (summer) and low concentration at other times. This indicates a certain degree of response to photoperiod (van Mourik & Stelmasiak 1985). However, the interrelationship among plasma LH, T and PRL concentrations, that occurs in temperate deer, does not exist in rusa stags (van Mourik et al. 1986). This is confirmed in chital stags in Great Britain which showed no photoperiodic pineal link to the reproductive axis in temperate environments (Loudon & Curlewis 1988). No information is available concerning endogenous patterns of VFI, body growth and plasma hormone concentrations in sambar.

On the other hand, temperate deer have a clearly defined seasonal pattern of VFI and body growth, being high in spring and summer and low in winter (Suttie et al. 1989; Domingue et al. 1991a). These patterns are closely related to daylength (Suttie et al. 1984), with the endogenous cycles cued to photoperiod by the hormone melatonin (Barry et al. 1991). Seasonal patterns of both body growth and VFI are greatest in adult stags (Kay 1985; Suttie & Simpson 1985). The profile of reproductive hormones in temperate deer is also well documented (Lincoln 1985), with the release of plasma LH and T being both seasonal and pulsatile (Suttie et al. 1989 & 1991).

The objectives of this study were to investigate cycles of body growth, VFI and plasma hormone concentrations in sambar and to compare these with annual endogenous cycles in red deer.

## MATERIALS AND METHODS

### Experimental design

Artificially reared sambar and red deer were randomly selected and placed in individual indoor pens for a 16-month period. All animals were fed a pelleted diet ad libitum, and the two deer species were compared for rate of body growth, VFI and blood profiles of the hormones prolactin, progesterone, testosterone and luteinizing hormone. During the rut, scrotal circumference of the stags was also measured, and any rutting behaviour noted. The study for red deer commenced on 21 July 1991 and concluded on 28 November 1992 and for sambar commenced on 12 October 1992 and concluded on 28 February 1993.

### Animals

Apart from one red hind, all animals (5 stags and 3 hinds of each species) were artificially reared (Chapter 4). In January 1992, one sambar stag had to be euthanised due to a neck injury sustained during the digestion trial (Chapter 5), and in July 1992 and September 1992 one sambar stag and one sambar hind, respectively, died from MCF. No replacements were made.

The red deer were placed in individual pens on 7 July 1991. Because of temperaments problems, in September'91 and October'91 one red hind and one red stag were replaced. Due to the wide range of sambar calving dates (Chapter 4), the sambar were introduced to pens gradually, from 23 September 1991 to 2 January 1992. The mean age and liveweight of sambar and red deer when penned are shown in Table 6.1. Data collection commenced after a two-week period of adjustment to the diet and surroundings. First year velvet antlers were removed when the animals were transferred to metabolic cages for digestion trials (Chapter 5).

Table 6.1 Mean age (days, SE) and liveweight (kg, SE) of sambar and red deer when they were placed in individual indoor pens.

| | STAGS | | HINDS | |
|---|---|---|---|---|
| | Sambar | Red deer | Sambar | Red deer |
| Age (days) | 160 (55.4) | 219 (18.6) | 128 (25.5)[1)] | 232 (27.9) |
| Liveweight (kg) | 49.5 (7.70) | 51.2 (2.09) | 36.6 (2.85)[1)] | 44.6 (5.62) |
| n | 3 | 5 | 2 | 3 |

[1)] where n=2, range (±) is given

**Health**

One week before the animals were placed in individual pens, they were drenching with Ivermectin (IVOMEC, Merck, Sharp and Dohme, NZ) to remove intestinal parasites. This drenching was repeated one week and three weeks after the animals were penned. When one sambar stag died of MCF (July 1992), all animals were injected with Teramycin Q-100 (10% w/w Oxytetracyline, Pfizer, New Zealand) at a dose rate of 10 mg/kg, to prevent further infection. During the rut and when stags were too flighty for blood sampling, mild anaesthesia (2-3 cc, 2% Xylazine; Rompun, Bayer Ltd. N.Z) was administered, without any antidote. The use of this drug only applied to red stags and only comprised 5% of total red stag blood samples.

**Housing**

Sixteen individual indoor pens measuring 4.0 m x 2.0 m, with 2.7 m high sides were used. Three-quarters of the pen floor length comprised slatted wood and the remainder concrete. Drinking water was available through automatic drinking nipples. The bottom half of the pen walls was made of metal bars, with the upper half made of wood. Each animal could make visual contact and limited physical contact with neighbouring animals. Pens were cleaned daily. Natural ambient temperature and illumination were used, but artificial lights were also provided, synchronized with natural daylength.

**Feeding**

All animals were fed a pelleted diet, comprising barley (39.8%), bran/pollard (23.0%), brewers grain (5.0%), soya (10.0%), lucerne (15.0%), molasses (4.0%), salt (1.0%), lime (1.5%), dicalcium phosphate (0.5%) and ruminant millmix vitamin (0.2%). The pellet dimensions were five cm in length and nine mm in diameter, and was produced in two tonne batches by Harvey Farms, Wanganui. All animals were fed once daily, at 0800-0900 h, at 120% of the previous day's consumption. Feed intake and feed refusal were recorded weekly. Samples of feed on offer and feed refusals were collected daily, and pooled weekly. A representative sample of feed on offer and residue from the pooled sample were taken weekly and analyzed for DM. Nutritive value of feed on offer was monitored every second batches, for DM, total N, gross energy and *in vitro* digestibility.

**Weighing, scrotal measurement, blood & fibre sampling**

All animals were weighed and blood sampled from the jugular vein every two weeks. Additional weekly samples were taken from hinds as they approached puberty. Blood sampling was conducted under hand restraint in a dark room, and samples collected in 10 ml heparinised-vacutainer tubes (Nippro Medical Industries Ltd. Japan), stored on ice box (5°C) for further processing. Within 50 min of collection all samples were centrifuged at 2000 g (gravity) for 15 min. Plasma was transferred to one ml plastic tubes and stored at -20°C until required for analysis.

Fibre was sampled at two monthly intervals, from the rump area, approximately three mm above the skin. Fibre samples were then separated into primary fibres and secondary fibres, which act as underwool during winter in red deer (A. Parry, personal communication). Ten hair fibres from each category sampled were then measured for length, using a ruler. As the rut approached, scrotal circumference of stags was measured every two weeks, using a flexible polypropylene tape around the middle of the scrotum.

**Hormonal assays**

Prolactin (PRL)

The PRL assay was conducted in the Physiology Laboratory, Department of Animal Science, Massey University, using a standard double-antibody competitive binding radioimmunoassay, based on the method of van Landehem & van de Weil (1978). Ovine prolactin, NIADDK-oPRL-18(AFP-8277E, 30 IU/mg) from National Institute of Health (NIH), Bethesda, Maryland USA was used as the reference standard, and ovine prolactin NIADDK-oPRL-I-2 (AFP-7150B) from NIH, Bethesda, Maryland USA for iodination. The first antibody used was NIADDK-anti-oPRL-1 (AFP-973269) rabbit and was donated by the NHPP University of Maryland School of Medicine, Baltimore, USA, and second antibody was Donkey anti-rabbit serum (IDS, Washington, Tyne and Wear, England, Code APPT1, Lot 11656). Intra assay and inter assay coefficients of variation were 9.7 and 16.6%, respectively. The least amount significance from zero was 0.841 ng/ml.

Testosterone (T)

The T assay was conducted in the Immunology Laboratory, Department of Physiology & Anatomy, Massey University, using a standard double-antibody competitive binding radio-immunoassay (Barrell & Lapwood 1978). The antiserum was raised against testosterone-3-(O-carboxymethyl)-oxime-bovine-serum albumin. The labelled ligand was 2,4,6,7-[$^{3}$ H] testosterone (84-109 Ci/mol; Amersham International plc, Amersham, Bucks, U.K). The inter-assay coefficients of variation for the three pools of plasma containing 0.50, 2.45 and 9.71 ng/ml were 10.8, 15.5 and 18.4%, and the intra-assay coefficients of variation were 43.2, 18.1 and 18.4%.

Progesterone (P)

The P assay was conducted at the Ruakura Agricultural Centre, New Zealand Pastoral Agricultural Institute, Hamilton, as described by Morrow (1992). The antiserum (R1) was raised in a rabbit against progesterone -11-BSA conjugate and used at a final dilution of 1:34,000 in PVP buffer, with the addition of normal rabbit serum (NRS) at 1:400. The second antibody was raised in a goat against rabbit (GAR) and used at a final dilution 1:65 in PVP buffer. The radio active label $I^{25}$-progesterone-11-hemisuccinate (Amersham International plc, U.K) was diluted in PVP buffer to 10,000

cpm/ul. Progesterone standards were prepared by volumetrically diluting 1.0 ml of 0.1 progesterone/ 100 ml ethanol (1 mg/ml) in 100 ml PVP buffer, and diluting further in charcoal-stripped plasma collected from castrated red stags. The inter-assay coefficients of variation for the three pools of plasma containing 1.96, 10.42 and 18.06 ng/ml were 14.3, 8.3, 2.2% with the intra-assay coefficients of variation were 2.5, 16.7, 6.4%, respectively.

Luteinizing hormone (LH)

The LH assay was conducted at the Ruakura Agricultural Centre, New Zealand Agricultural Institute, Hamilton, using a heterologous radioimmunoassay procedure described for sheep by Scaramuzzi et al. (1970) and validated for use with fallow deer plasma (Asher et al. 1986). The antiserum was raised in a rabbit using NIH-LH-S11 as the antigen and used at a final dilution of 1:40,000 in EDTA-PBS buffer with the addition of normal rabbit serum (NRS) at 1:400. The second antibody was raised in a goat against rabbit (GAR) and used at a final dilution of 1:650 in micro granular cellulose solution. The radioactive ligand was iodinated NIAMDD oLH-24 AFP. All samples were run in one assay, with the coefficients of variation within the assay for the three pools of plasma containing 0.73, 11.5 and 14.2 ng/ml were 6.3, 6.7 and 3.7%, respectively.

**Data collection & statistical analysis**

Because of the six months age difference between sambar and red deer, and the low number of animals of each sex, no statistical comparisons were made at individual time points (ie months). Rather, the data were examined for evidence of endogenous cycles and the times at which these occurred in the two deer species. Data from dead animals were not included. All red deer data recording was concluded on 29 November 1992, while data collection from sambar continued until 28 February 1993, in order to compare data on animals at the same age. Mean values and standard errors are presented. Metabolisable energy (ME) was calculated as digestible organic matter (kg/kgDM) multiplied by 16.3.

To estimate energy requirements, regression equations were calculated of liveweight gain (g) per day per kg metabolic weight ($W^{0.75}$) on calculated ME intake (MJ) per day per kg metabolic weight, as described by Fennessy et al. (1981), using data from the same age periods for each deer species. For each sex of each deer species, values for each animal calculated over four consecutive three-month periods were used in each regression. Voluntary feed intake (VFI), liveweight gain (LWG) and feed conversion efficiency (FCE; kgDMI/kgLWG) for the two deer species were statistically compared over corresponding complete 12-month periods (sambar, Nov'91-Nov'92; red deer, Jul'91-Jul'92), when the two deer species were of similar age, using a 2 x 2 factorial model, to examine effects of deer species, sex and any species x sex interaction. A similar analysis was also performed with FCE, calculated from the start of the experiment to the attainment of a target

liveweight (stags 100 kg; hinds 80 kg).

## RESULTS

### Diet quality & monthly voluntary feed intake

The pelleted diet used during the study contained 2.9% total N, organic matter digestibility was 83.2% and gross energy was 18.3 KJ/gDM. Calculated metabolisable energy was 12.2 MJ/kgDM.

Figure 6.1 shows changes with time in VFI (kgDM/day) of sambar and red deer of both sexes. Sambar tended to consume less feed than red deer, with the latter showing a more pronounced seasonal fluctuation. Sambar stags had a peak VFI in April (autumn), remaining relatively constant until July (winter), declining thereafter until September (spring) and then slowly increasing.

Peak VFI in sambar hinds also occurred in April, gradually declining until November (spring) and then slowly increasing. In contrast to sambar, red stags showed a peak VFI in January (summer), which declined sharply thereafter, reaching its lowest level in June (winter), before increasing again in spring. In red hinds, peak VFI occurred in February (summer), a month later than in red stags, declining until its lowest level in June, and rising thereafter. A drop in VFI in both sexes of red deer was coincided with the breeding season. Collectively, the data show maximum and minimum VFI in red deer in summer and winter, respectively, whereas in sambar maximum and minimum VFI occurred respectively in autumn and spring.

### Liveweight change, seasonal feed intake, efficiency of feed conversion & energy requirements

Both sexes of sambar showed a slowing of growth in their first spring, followed by rapid growth over summer/autumn (Figure 6.2). Sambar hinds showed a continuous but slow body growth throughout winter and their second spring, but sambar stags showed slow growth over winter and no growth during their second spring. In contrast, red deer showed a slowing of growth in their first winter, and a continuous increase in liveweight over their second spring and summer. A drop in liveweight occurred in the second autumn for red deer, being more pronounced in stags than in hinds. During the autumn breeding season, red hinds lost 4.4% of liveweight compared to 6.8% in red stags.

A comparison of the seasonal (ie 3 monthly) pattern of VFI and LWG in sambar and red deer is shown in Table 6.2. For both sexes, sambar showed highest VFI and LWG in autumn and minimum values in spring, whereas red deer showed maximum VFI and LWG in spring/summer and minimum values in winter.

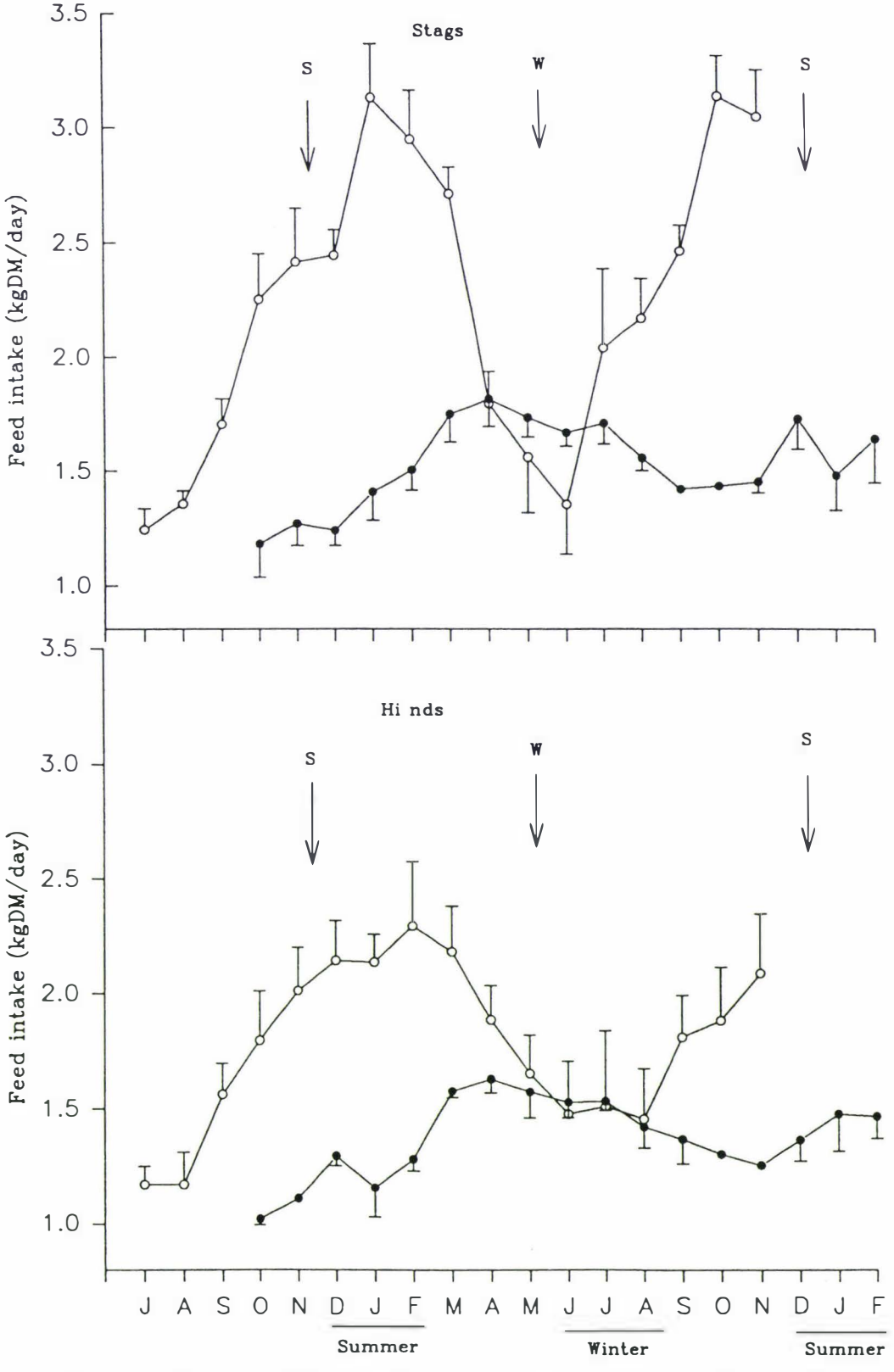


Figure 6.1 Voluntary feed intake (kgDM/day) of young sambar (●) and red deer (○) fed indoors on a pelleted diet ad libitum. Vertical bars represent SE (range, for sambar hinds) (S= summer solstice; W= winter solstice).

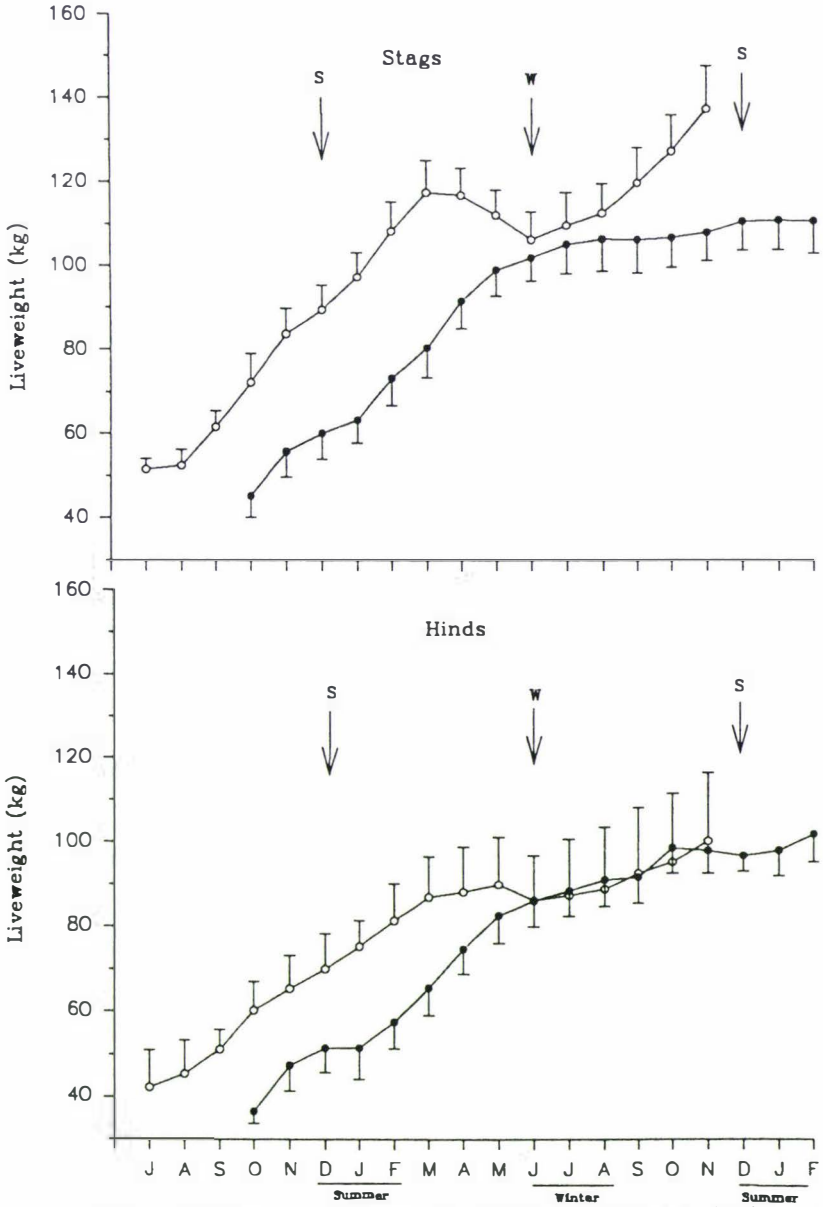


Figure 6.2 Liveweight changes (kg) of young sambar (●) and red deer (○) fed indoors on a pelleted diet ad libitum. Vertical bars represent SE (range, for sambar hinds) (S= summer solstice; W= winter solstice).

Table 6.2 Seasonal patterns of voluntary feed intake, liveweight gain (mean, SE) and feed conversion efficiency in young sambar and red deer, fed indoors on a pelleted ad libitum, under New Zealand conditions. At the start of summer'92 sambar were six months and red deer were 12 months of age.

| | Sambar stag (n=3) | Red stag (n=5) | Sambar hind (n=2)[3] | Red hind (n=3) |
|---|---|---|---|---|
| | | **Spring'91** | | **Spring'91** |
| VFI | | | | |
| (kgDM/day) | | 2.13 (0.164) | | 1.79 (0.168) |
| (gDM/$BW^{0.75}$/day) | | 85.7 (3.41) | | 84.1 (1.77) |
| LWG[1] (g/day) | | 348 (23.9) | | 219 (35.1) |
| FCE[2] | | 6.1 | | 8.2 |
| | **Summer'92** | **Summer'92** | **Summer'92** | **Summer'92** |
| VFI | | | | |
| (kgDM/day) | 1.31 (0.06) | 2.75 (0.176) | 1.31 (0.044) | 2.19 (0.191) |
| (gDM/$BW^{0.75}$/day) | 59.2 (2.27) | 87.8 (1.44) | 63.4 (1.66) | 85.5 (1.75) |
| LWG (g/day) | 199 (44.8) | 291 (17.7) | 192 (35.5) | 191 (13.0) |
| FCE | 7.0 | 9.3 | 6.8 | 11.5 |
| | **Autumn'92** | **Autumn'92** | **Autumn'92** | **Autumn'92** |
| VFI | | | | |
| (kgDM/day) | 1.79 (0.185) | 2.02 (0.109) | 1.64 (0.093) | 1.91 (0.171) |
| (gDM/$BW^{0.75}$/day) | 62.1 (3.24) | 57.3 (1.28) | 61.3 (12.5) | 66.6 (2.64) |
| LWG (g/day) | 260 (31.8) | 40 (17.5) | 254 (12.5) | 90 (23.9) |
| FCE | 6.9 | 50 | 6.3 | 31.7 |
| | **Winter'92** | **Winter'92** | **Winter'92** | **Winter'92** |
| VFI | | | | |
| (kgDM/day) | 1.62 (0.047) | 1.93 (0.258) | 1.52 (0.078) | 1.48 (0.259) |
| (gDM/$BW^{0.75}$/day) | 51.0 (1.28) | 56.0 (5.67) | 50.6 (0.28) | 51.4 (4.07) |
| LWG (g/day) | 71 (22.0) | 4 (16.3) | 78 (26.0) | 23 (7.5) |
| FCE | 22.5 | 475 | 19.2 | 65.2 |
| | **Spring'92** | **Spring'92** | **Spring'92** | **Spring'92** |
| VFI | | | | |
| (kgDM/day) | 1.43 (0.019) | 2.88 (0.122) | 1.31 (0.044) | 1.93 (0.219) |
| (gDM/$BW^{0.75}$/day) | 43.5 (2.54) | 76.3 (2.11) | 42.3 (0.11) | 63.3 (1.74) |
| LWG (g/day) | 25 (5.8) | 268 (28.1) | 25 (13.5) | 131 (0.02) |
| FCE | 56.0 | 10.8 | 52.0 | 14.5 |
| | **Summer'93** | | **Summer'93** | |
| VFI | | | | |
| (kgDM/day) | 1.64 (0.096) | | 1.43 (0.104) | |
| (gDM/$BW^{0.75}$/day) | 47.7 (1.44) | | 45.7 (1.43) | |
| LWG (g/day) | 31 (6.1) | | 33 (12.5) | |
| FCE | 52.0 | | 39.3 | |

[1] LWG= liveweight gain, [2] feed conversion efficiency (kgDM/kgLWG), [3] where n=2, range (±) is given. Summer= Dec.-Feb; Autumn= Mar-May; Winter= Jun.-Aug; Spring= Sep.-Nov.

Feed conversion efficiency was most efficient (ie lowest value) at the times when both deer species showed high VFI and LWG, as might be expected. When comparisons were made at maximum VFI (sambar, autumn'92; red deer, summer'92) it seems that FCE was more efficient for sambar than red deer.

When calculated over a 12 month period (from similar initial ages) no interaction between species x sex or effects of sex on VFI, FCE and LWG were found (Table 6.3). However, between species, sambar had significantly lower VFI ($p<0.01$) and more efficient FCE ($p<0.05$) than red deer, with growth rate being similar for both sambar and red deer.

The two deer species were also compared from the start of the experiment to the attainment of specified target liveweights (stags 100kg; hinds 80 kg; Table 6.4). Sambar deer tended to attain this objective earlier than red deer, and with improved FCE ($p<0.01$). The interaction between species and sex was significant ($p<0.05$) for FCE, indicating that efficiency of the sambar hinds was greater than for stags.

Table 6.3. Voluntary feed intake, liveweight gain and feed conversion efficiency (mean, SE) in young sambar and red deer, fed indoors on a pelleted diet ad libitum, over corresponding 12 month periods (sambar: Nov'91-Nov'92; red deer: Jul'91-Jul'92).

| | Sambar stag (n=3) | Red stag (n=4) | Sambar hind (n=2)[1] | Red hind (n=2)[1] |
|---|---|---|---|---|
| Initial age (days) | 198 (64.0) | 201 (2.5) | 169 (39.0) | 204 (2.5) |
| VFI (kgDM/day) | 1.63 (0.072) | 2.21 (0.131) | 1.42 (0.081) | 1.82 (0.293) |
| LWG (g/day) | 138 (24.5) | 159 (17.8) | 139 (1.3) | 126 (33.2) |
| FCE | 12.2 (2.21) | 13.9 (1.09) | 10.3 (0.70) | 15.0 (1.66) |

[1)] where n=2, range (±) is given

For both sexes of both deer species, liveweight gain (g) per day per $kgW^{0.75}$ was strongly related to ME intake (MJ; MEI) per day per $kgW^{0.75}$ (Table 6.5 & Figure 6.3). The regression slopes were higher for sambar deer than for red deer ($p<0.05$) in both sexes. Maintenance energy requirement (MER), calculated as MEI corresponding to zero LWG, was consistently lower for sambar than for red deer, whilst LWG per MJ MEI was higher for sambar than for red deer.

Table 6.4 Age, liveweight gain, voluntary feed intake and feed conversion efficiency in young sambar and red deer growing to target liveweights (stags 100 kg; hinds 80 kg), fed indoors on a pelleted diet ad libitum (mean,SE[1]).

| | STAGS | | HINDS | |
|---|---|---|---|---|
| | Sambar (n=2) | Red deer (n=5) | Sambar (n=2) | Red deer (n=2) |
| Initial liveweight (kg) | 52.7 (12.10) | 51.2 (2.09) | 36.6 (2.85) | 50.2 (0.80) |
| Initial age (days) | 186 (85.5) | 219 (18.6) | 128 (25.50) | 248 (40.50) |
| Target liveweight (kg) | 100.3 (0.25) | 100.7 (0.44) | 80 (0) | 80.8 (0.40) |
| Age at target liveweight (days) | 371 (67.5) | 413 (24.05) | 310 (25.0) | 401 (46.50) |
| Total liveweight gain (kg) | 47.6 (11.85) | 49.5 (2.31) | 43.4 (2.85) | 30.6 (1.20) |
| Days on experiment | 185 | 194 | 182 | 153 |
| Total VFI (kg) | 264 (38.3) | 342 (20.0) | 235 (20.5) | 306 (43.5) |
| FCE | 5.7 (0.62) | 6.9 (0.26) | 5.4 (0.12) | 9.9 (1.03) |

[1] where n=2, range (±) is given

Table 6.5. Regression equations of liveweight gain (g) per day per $kgW^{0.75}$ on MEI (MJ) per day per $kgW^{0.75}$ for young sambar and red deer between similar ages (sambar: 8-20 months, autumn'92-summer'93; red deer: 9-21 months, spring'91-winter'92).

| | Sambar deer | Red deer |
|---|---|---|
| Stags | LWG= 37.71MEI-20.14<br>SE 5.09 3.20<br>$R^2$= 0.85 n=12<br>p<0.001<br><br>MER[a]=0.53 MJME/$kg^{0.75}$/day | LWG= 26.45MEI-16.75<br>SE 3.43 3.08<br>$R^2$= 0.78 n=20<br>p<0.001<br><br>MER= 0.63 MJME/$kg^{0.75}$/day |
| Hinds | LWG= 40.09MEI-20.80<br>SE 4.70 2.90<br>$R^2$ = 0.92 n=8<br>p<0.001<br><br>MER= 0.52 MJME/$kg^{0.75}$/day | LWG= 21.63MEI-13.56<br>SE 3.76 3.37<br>$R^2$= 0.78 n=12<br>p<0.001<br><br>MER= 0.62 MJME/$kg^{0.75}$/day |

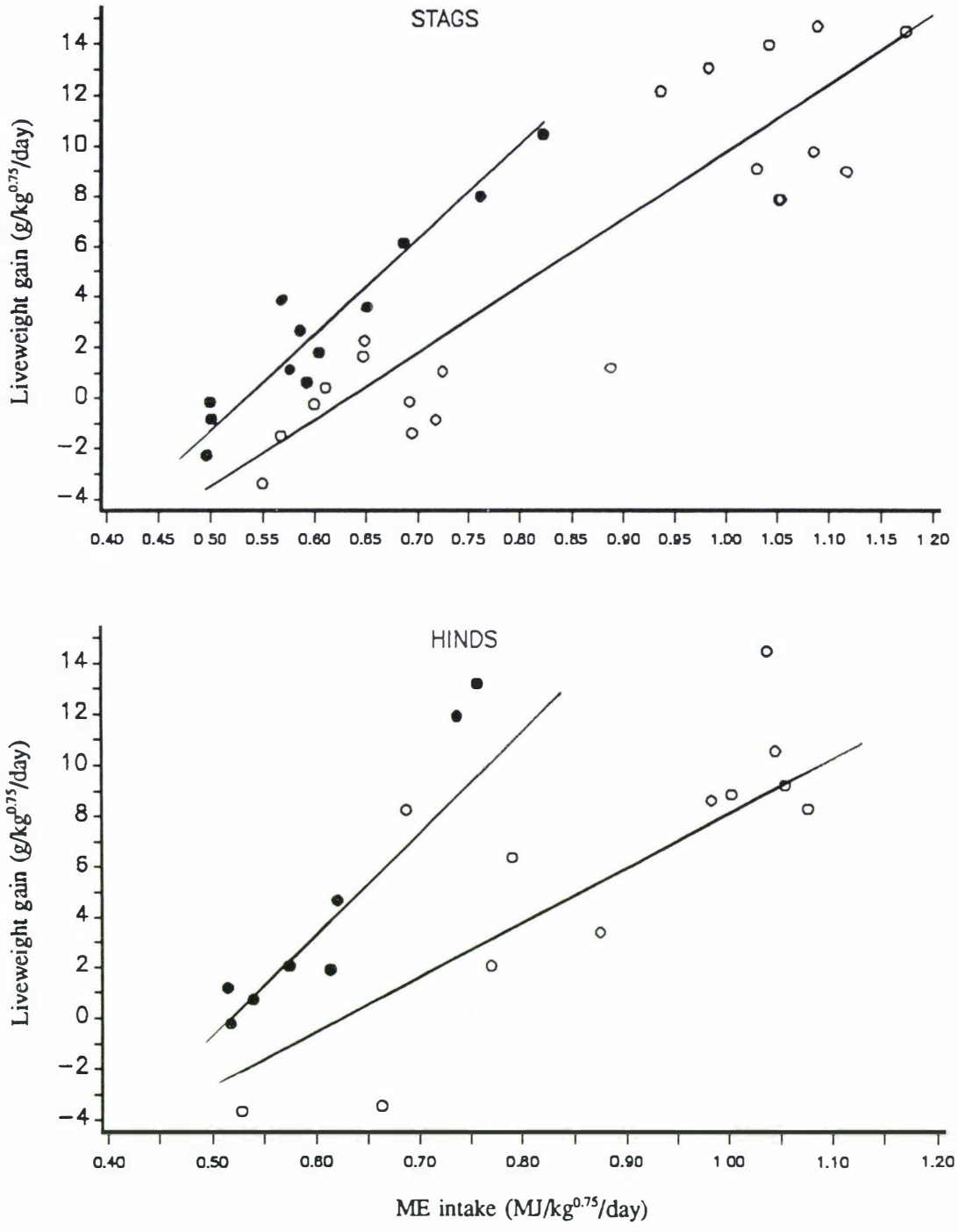


Figure 6.3 Relationship between metabolisable energy intake and liveweight gain for sambar (●) and red deer (○)

**Scrotal circumference & hard antlers**

Scrotal size in sambar stags increased slowly but progressively over summer, autumn and winter, reaching a maximum size in October (spring), before declining (Figure 6.4). In contrast, scrotal circumference in red stags increased rapidly over summer, with maximum average size being recorded in March (autumn), and decreasing thereafter.

Hard antler in sambar stags was noted as quite variable compared to red stags. Animal number 77 came into hard antler spike in May, while animals number 85 and 87 came into hard antler spike in June and July. In contrast, all red stags developed hard antler spikes in March.

**Fibre**

Visual examination indicated that sambar primary fibres were coarser and more sparse than red deer primary fibres. The presence of secondary fibres in sambar was limited and varied between individuals (Figure 6.5).

Growth of red stag primary fibre showed a slow rate from the first July to the July of the second year, before increasing rapidly until September, and moulting. Maximum length of red stag primary fibre was 73 mm. Red stag secondary fibres measured in July of the second year showed a rapid growth until November, with a maximum length of 34 mm. In sambar stags, the primary fibres growth showed a slow/static rate throughout the study, with the maximum length being 48 mm. Secondary fibres were noted in November, but only from one animal, characterised as very sparse and short, 14 mm.

Primary fibre growth in red hinds showed a faster growth only from July of the second year until November, with a maximum length of 68 mm. Secondary fibres measured from July of the second year showed a continuous growth until November, with a maximum length of 36 mm. In sambar hinds, there was a decreasing trend of growth in length of primary fibres from September '91 to January '92, with a maximum length of 45 mm. The pattern was associated with the moulting process in one of two sambar hinds. Down-like fibre in sambar hinds was noted in only one animal and was very sparse, with the maximum length of 16 mm.

Moulting of the coat was observed in all red deer, beginning in early September and concluding in early November. Only one sambar stag and one sambar hind showed signs of moulting, in early September and early October, respectively.

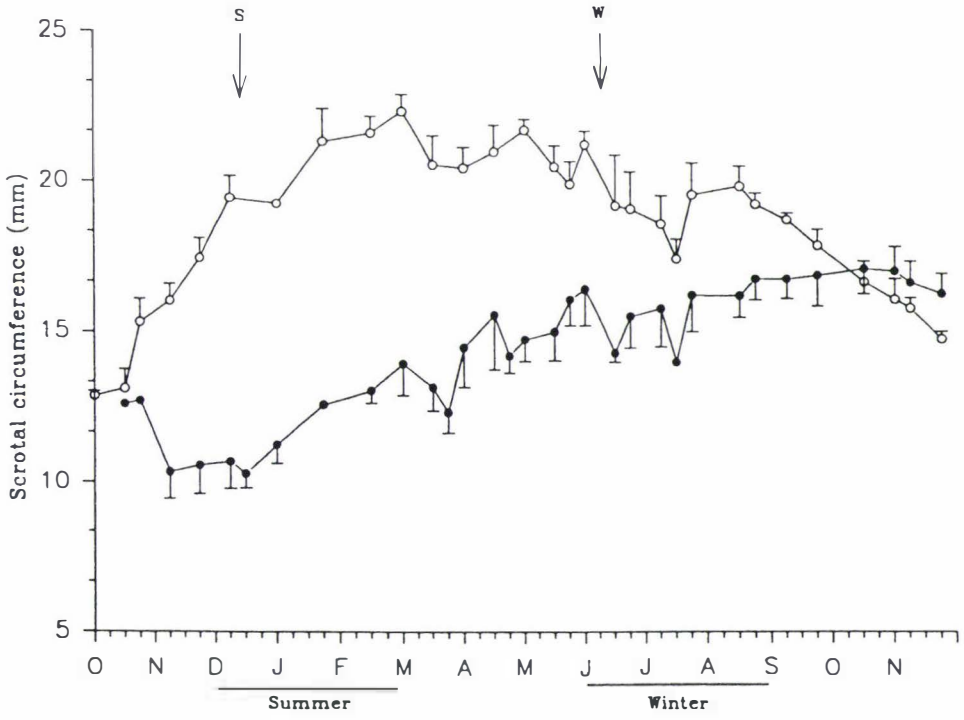


Figure 6.4 Scrotal circumference (mm) pattern of young sambar (●) and red stags (○) fed indoors on a pelleted diet ad libitum. Vertical bars represent SE (S= summer solstice; W= winter solstice).

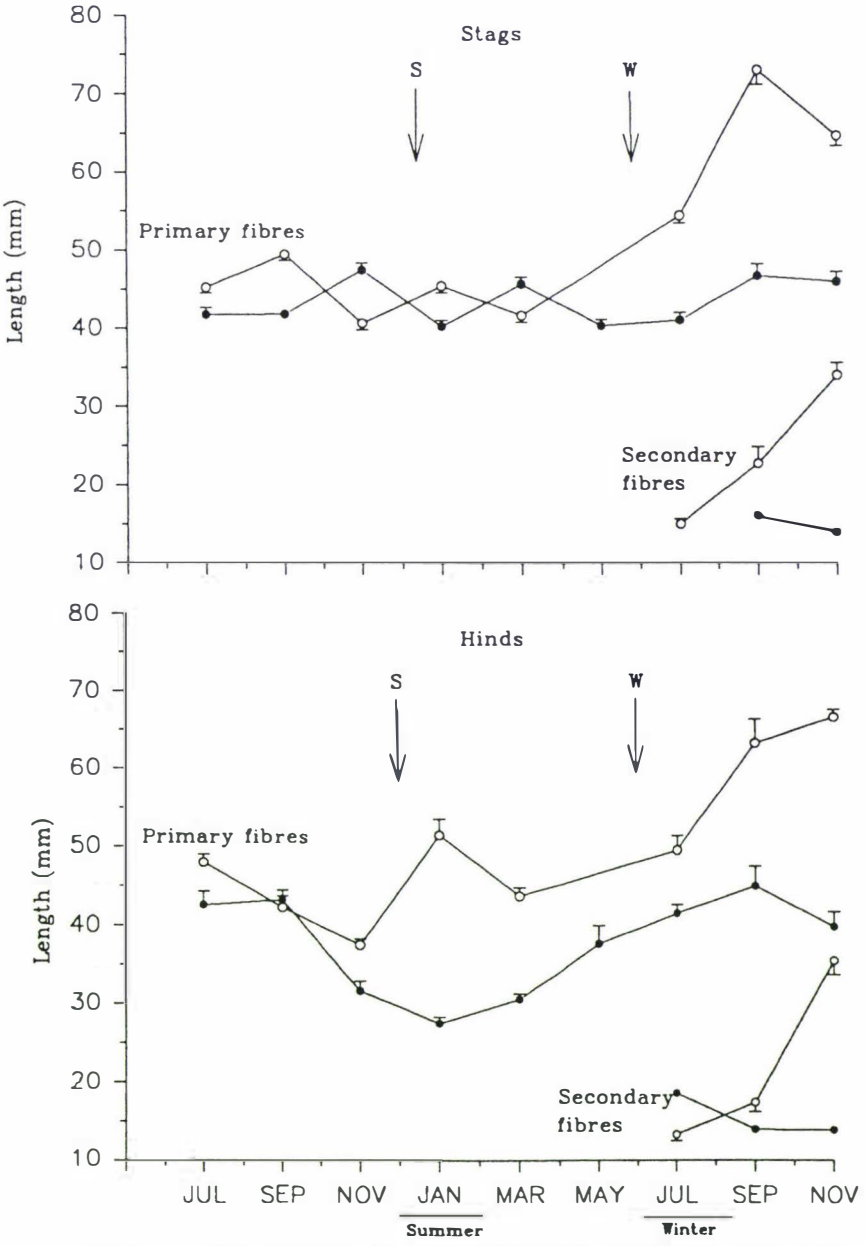


Figure 6.5 Fibre length of primary fibres and secondary fibres in young sambar (●) and red deer (○) fed indoors on a pelleted diet ad libitum. In red deer, moulting of secondary fibres commenced in early September and concluded in early November. Vertical bars represent SE for stags and range for hinds (S= summer solstice; W= winter solstice).

**Hormonal patterns**

Prolactin

High levels of plasma PRL concentrations in red stags and hinds were noted from spring to mid-summer, before declining to a low level in autumn and winter (Figure 6.6). A similar trend was also shown by sambar stags and hinds, with a minor difference in autumn, when sambar tended to have higher levels of plasma PRL concentrations than red deer. In general, sambar stags had slightly higher levels of plasma PRL concentrations than red stags during autumn and winter, but lower peak levels in summer.

Luteinizing hormone

Sambar stags tended to have highest plasma LH concentrations during autumn, winter and early spring, but these were of lower magnitude than the peak values for red stags, and were maintained over a longer time period (Figure 6.7). Sambar hinds showed low plasma LH concentrations during summer and autumn, and commencement of a spike release towards the end of winter .

In contrast, high levels of plasma LH concentrations in red stags were noted from mid-spring to the end of summer, before declining and remaining low through late autumn, winter and early spring. In red hinds, plasma LH concentrations pattern fluctuated less than in red stags, while spike release in plasma LH concentrations did not commence until the end of their second winter.

Testosterone

Low plasma T concentrations in sambar stags were noted from mid-October until April, with higher values from April to September (Figure 6.8A). However, the pattern was actually an accumulation of three stags at three different ages. Individual variation of plasma T concentrations in sambar stags indicated a wide spread of T spikes. During hard antler, the oldest stag (Tag 77) experienced up to three T spikes, tag 87 experienced two T spikes while tag 85 had only one T spike.

By comparison, red stags had their high levels of plasma T concentrations concentrated during March/early April, before declining. Peak levels of plasma T concentrations in red stags occurred in their second autumn with lowest levels in spring. In contrast, sambar stags had peak levels of plasma T concentrations for a longer period, from autumn to spring but at a lower magnitude than for red deer.

Progesterone

Spike release of plasma P in sambar hinds were not detected until winter and their second spring (Figure 6.8B). By contrast, plasma P profile in red hinds showed three peak levels, the first occurring in summer, with the second and third peaks during autumn and winter.

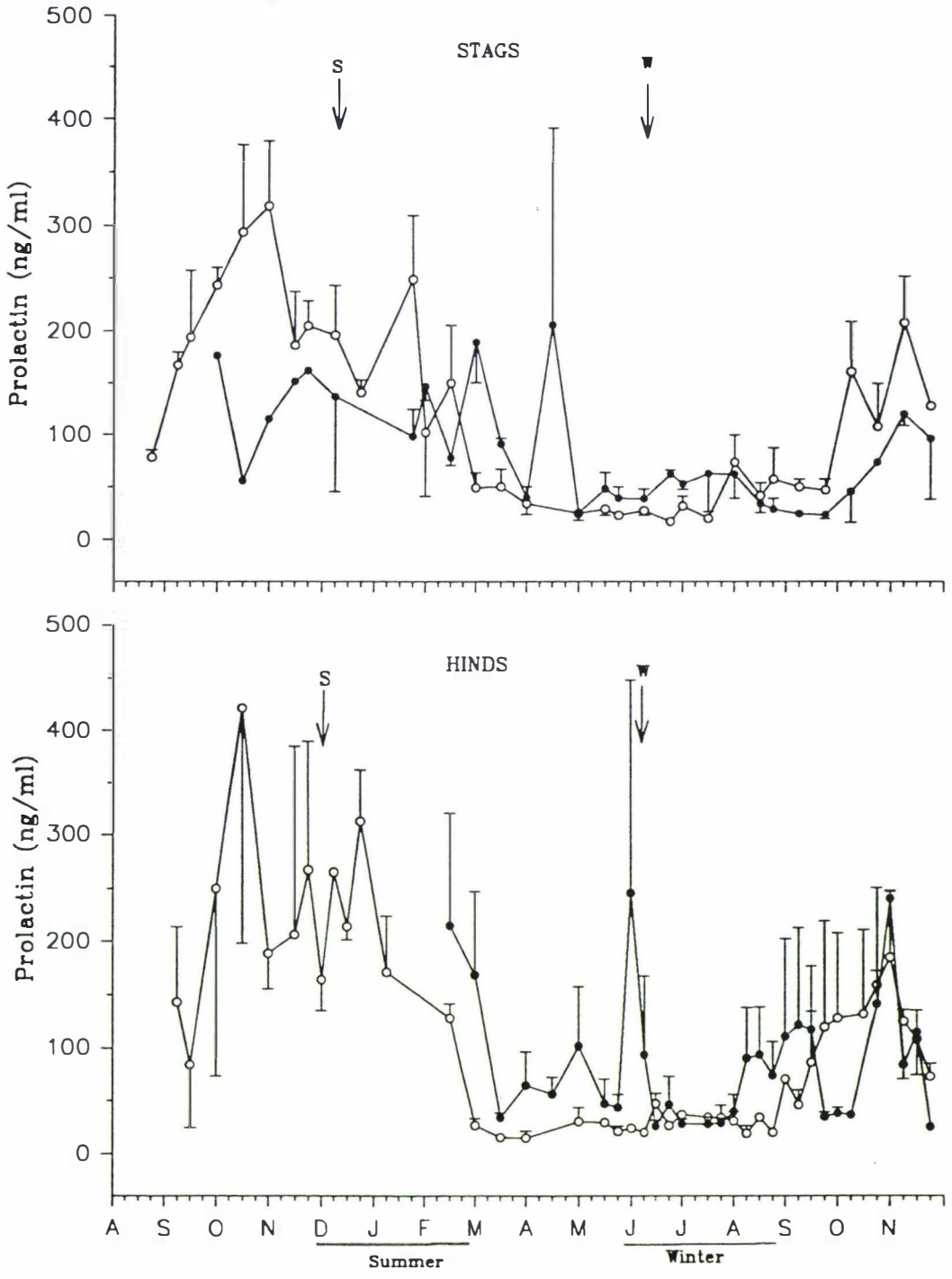


Figure 6.6 Plasma prolactin profile of young sambar (●) and red deer (○) fed indoors on a pelleted diet ad libitum. Vertical bars represent SE for stags and range for hinds (S= summer solstice; W= winter solstice).

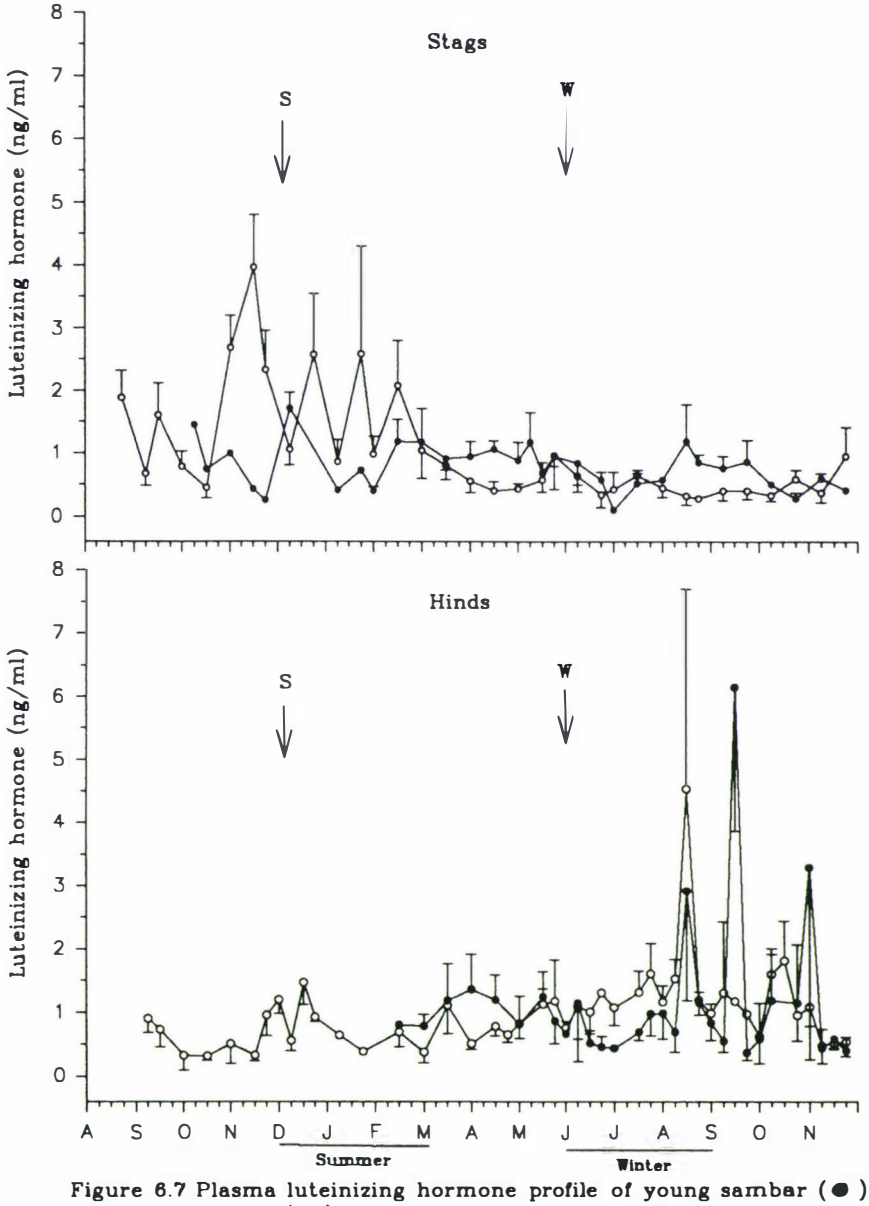


Figure 6.7 Plasma luteinizing hormone profile of young sambar (●) and red deer (○) fed indoors on a pelleted diet ad libitum. Vertical bars represent SE for stags and range for hinds (S= summer solstice; W= winter solstice).

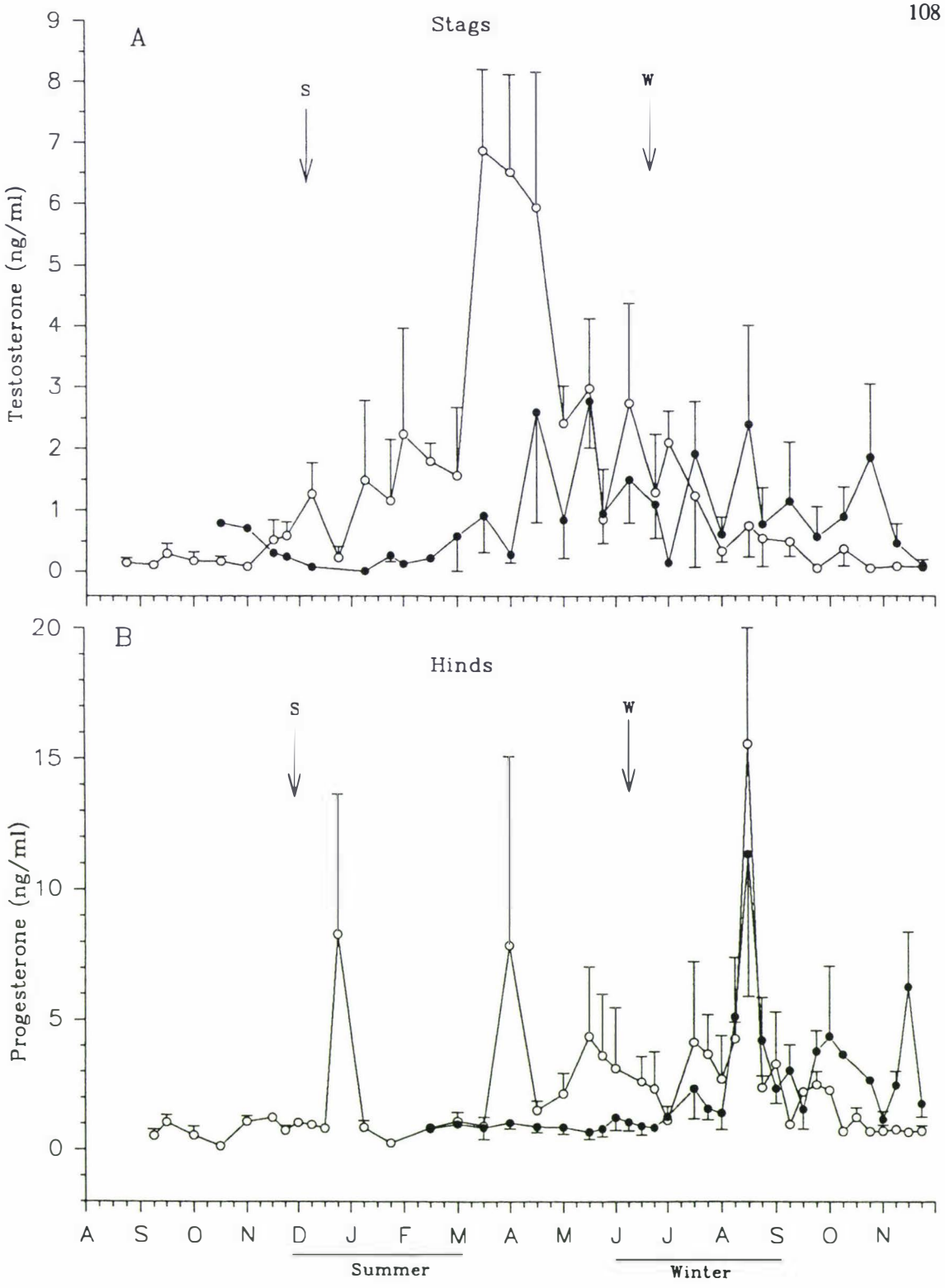


Figure 6.8 (A) Plasma testosterone profile of young sambar (●) and red stags (○), and (B) Plasma progesterone profile of young sambar (●) and red hinds (○) fed indoors on a pelleted diet ad libitum. Vertical bars represent SE for stags and range for hinds (S= summer solstice; W= winter solstice).

# DISCUSSION

This is the first study to show seasonal cycles in sambar, which were evident in VFI, body growth and plasma T levels in stags. In general, the cycles were of much lower amplitude than observed for red deer, with maximum and minimum VFI occurring in autumn and spring, respectively. While sambar stags did not vocalise during the rut, plasma T values suggest that late autumn, winter and early spring are the peak breeding season. Comparisons between species in the present study are complicated by the difference in calving time (Chapter 4), meaning that the young sambar went through only one winter in this study, but young red deer went through two winters. These cycles in sambar may become more pronounced in their second year of life, as they do in red deer, and this should be further researched.

The present study demonstrated a seasonal VFI in red deer with maximum VFI in both sexes during summer, gradually declining as the breeding season commenced, and reaching its lowest levels in winter. The red stags in the present study experienced a sharp decline in their VFI of up to 57% during the breeding season, and the red hinds up to 32%. Suttie et al. (1987) also found that although red hinds declined in their VFI during the breeding season, the drop was not as rapid and/or as great as in red stags. The overall pattern was similar to other studies (Suttie et al. 1989), although a greater decline in VFI occurred in the red hinds in the present study.

Peak liveweight in red stags occurred in March, or at around 15 months of age and thus was similar to the findings of Suttie et al. (1987). From March, liveweight declined as a result of a drop in VFI, then increased during spring. The present unmated young red stags decreased in liveweight during the rut by as much as 7% and red hinds 3%. In contrast, sambar of both sexes had no liveweight loss during the period of this study, but rather a slower/static growth during winter and their second spring. Similar patterns of growth were shown by rusa aged 3 to 15 months, in a sub-tropical environment (Suttie et al. 1992a). As indicated in Table 6.2, sambar only experienced a faster growth rate up to 12 months of age (autumn'92), before experiencing a steady growth but at a slower rate. Further studies are needed to quantify growth patterns in sambar during their second year of life and to compare these with red deer.

Maximum liveweight after the initial period of rapid growth was less for sambar stags than for red stags (Table 6.6), but the sambar achieved this earlier than red deer (-60 days in stags, -52 days in hinds). An arbitrary target liveweight (100 kg in stags and 80 kg in hinds) was achieved earlier (-42 days in stags, -91 days in hinds) in sambar than red deer (Table 6.3). Collectively, the VFI, LWG and FCE data indicate that whilst the total amount of weight gained over a complete 12-month period is similar for young sambar and young red deer, less total feed is eaten and hence sambar have an improved FCE. Better FCE values in young sambar compared to red deer suggests a difference

between the two deer species in either efficiency of energy utilisation above maintenance or lower maintenance energy requirements.

Table 6.6 Maximum voluntary feed intake and liveweight attained in young sambar and red deer, in the period following their initial period of slow growth (sambar, spring; red deer, winter), when fed indoors on a pelleted diet ad libitum (mean, SE)[1].

| | Sambar stag (n=3) | Red stag (n=5) | Sambar hind (n=2) | Red hind (n=3) |
|---|---|---|---|---|
| **Maximum VFI** | | | | |
| kgDM/day | 1.93 (0.104) | 3.02 (0.198) | 1.70 (0.105) | 2.33 (0.251) |
| Age attained (days) | 355 (57.5) | 424 (9.5) | 322 (54.5) | 415 (10.1) |
| **Maximum liveweight** | | | | |
| kg | 105.0 (7.30) | 120.0 (6.85) | 96.9 (6.65) | 90.3 (11.2) |
| Age attained (days) | 407 (57.7) | 467 (3.8) | 445 (53.0) | 497 (19.3) |

[1)] where n= 2, range (±) is given

When ME requirements for maintenance and gain (above maintenance) were calculated (Fennessy et al. 1981), it appears that sambar require less ME for both maintenance and gain than do red deer (Table 6.7). This needs to be followed up with calorimetric studies, measuring maintenance ME requirement and the efficiency of conversion of ME to net energy (NE) above maintenance in young growing deer of both species.

For red stags, maintenance requirements for ME estimated in this study were slightly higher than those calculated by Fennessy et al. (1981, Table 6.7), perhaps due to slight overestimation of OMD values from laboratory analyses. Frisch & Vercoe (1977) and Vercoe (1970) conducted similar feed conversion efficiency studies with temperate (Shorthorn x Hereford; SH) and tropical (Brahman) cattle as reported here for temperate and tropical deer. They reported better feed conversion efficiency and a lower fasting metabolic rate in the tropical cattle (Table 6.8), implying lower maintenance heat production. This gives further emphasis to the need for calorimetric studies comparing efficiency of energy utilisation in tropical sambar and temperate red deer. To effectively combat hot tropical conditions, it may be that cattle and deer that evolved in the tropics have developed lower levels of heat production, and this hypothesis needs to be tested for deer.

The length of time that sambar stags had maximum scrotal circumference (5 months) was similar to that of chital stags (Mylrea 1992). In contrast, maximum scrotal circumference in red stags lasted for only three months. Thus, in sambar and chital stags the breeding season is likely to be longer than in red stags. Fertile sperm has been detected in chital and rusa stags at all stages of antler growth (Mylrea 1992; G.W Asher, personal communication). In red stags, spermatogenesis was

detected as early as nine months of age, but the reproductive tracts are not fully developed until 12 to 15 months of age, and this coincides with the rut in older stags (Webster et al. 1992). The pattern of semen quality in sambar stags during antler development and the rut needs to be further evaluated.

Table 6.7 A comparison of estimated metabolisable energy requirements for maintenance (MER) and gain in young sambar and red deer.

| | Sambar | Red deer | Authors |
|---|---|---|---|
| | | **(MER;MJ ME/kgW$^{0.75}$/day)** | |
| Stags | | 0.57, 0.57 | Fennessy et al. (1981) |
| Stags | 0.53 | 0.63 | Present study[1)] |
| Hinds | | 0.52 | Suttie et al. (1987) |
| Hinds | 0.52 | 0.62 | Present study[1)] |
| | | **(ME for gain; MJ /kg LWG)** | |
| Stags | | 33.8, 39.2 | Fennessy et al. (1981) |
| Stags | 26.5 | 37.8 | Present study[1)] |
| Hinds | | 55 | Suttie et al. (1987) |
| Hinds | 24.9 | 46.2 | Present study[1)] |

[1)] Calculated from the equations in Table 6.5

Table 6.8 A comparison of voluntary feed intake, liveweight gain, feed conversion efficiency and fasting metabolism between Brahman (Bos indicus) and Shorthorn x Hereford (Bos taurus) cattle fed chaffed lucerne hay.

| | Brahman (Tropical) | Shorthorn x Hereford (Temperate) | Difference (SH= 100) |
|---|---|---|---|
| DMI (kg) | 514 | 556 | 92 |
| Liveweight gain (kg) | 49.9 | 48 | 104 |
| FCE (kgDMI/kgLWG) | 10.3 | 11.5 | 90 |
| Fasting metabolism (KJ/kgW) | 87 | 101 | 86 |

Frisch & Vercoe (1969), Vercoe (1970).

The lack of secondary fibres in most sambar was not surprising, as, in their native tropical habitat, this fibre is not required because of a relatively high ambient temperature. For sambar living in a temperate environment, a lack of natural protection (secondary fibres) during winter means that shelter is imperative. Because sambar do not develop secondary fibres and the primary-fibres are coarser and sparser than red deer, there would be a greater tendency of body heat loss occurring in sambar during winter, compared to red deer. Although conducted indoor, the present study suggests that sambar did not seem to suffer from excessive body heat loss during winter, judging from the lack of liveweight loss and absence of shivering. However, there may be other mechanisms involved in preventing excessive body heat loss, such as increased skin thickness and lower daily activity. Coat insulation and critical temperature need to be defined in calorimetric experiments with both sambar and red deer.

The principle difference between temperate and tropical environments is that the former has a distinctive seasonal variation in temperature and daylength. To adapt the breeding season to those environmental changes, seasonal changes in daylength appear to be the principal environmental cue in temperate deer, whilst in tropical deer it is believed that seasonal changes in feed quality may influence the breeding time (Lincoln 1985).

The present red deer had a plasma PRL profile typical of seasonal animals responsive to photoperiod (Loudon & Brinklow 1992). Relative to red deer, higher levels of plasma PRL concentrations were noted in sambar from early autumn through winter, but levels were lower in summer. In general, sambar are less seasonal in terms of plasma PRL concentrations then temperate deer, as also shown by rusa stags (van Mourik & Stelmasiak 1985) and in both sexes of chital in Australia (Chapple 1989).

Assuming that the maximum plasma T levels in both sambar and red stags can be used as an indication of optimum mating ability, and that the first spike of plasma PG in hinds of both species is an indication of onset of puberty, then sambar of both sexes reached sexual maturity earlier and at lighter liveweights than red deer (Table 6.9).

Sambar hinds showed a peak of spike plasma P release in mid-August, 100 days earlier and 4.5 kg lighter than red deer Table (6.9). However, as the blood sampling regime was conducted at weekly intervals, the study may not have accurately identified the first spike of plasma P release in either of the two deer species. Woodford & Dunning (1992) indicated that farmed rusa hinds reached puberty age at eight months, while chital hinds attained puberty from nine months to 17 months of age (Acharjyo & Mishra 1980; Chapple 1989). The first peak of P in red hinds occuring in summer may have been due to the release of adrenal progesterone, experienced when the animals were in stress (G.W Asher, personal communication). English (1988) reported that red hinds reached their puberty at 15 months of age, while unmated hinds can still undergo repeated oestrous cycles for 160 days (Kelly & Moore 1987). In order to obtain more precise profiles of plasma T and P release in sambar, to

define age of puberty and length of the reproductive season, it is necessary to conduct a study with greater frequency of blood sampling.

Table 6.9 Mean age and liveweight when sambar and red deer first showed peak values in plasma testosterone and progesterone concentrations and the age when stags had their first hard antler (mean, SE; n= number of animals).

| | Sambar | Red deer |
|---|---|---|
| STAGS | | |
| Peak of testosterone : | | |
| Age (days) | 445 (108.1) | 469 (3.9) |
| Weight (kg) | 100.8 (8.87) | 116.7 (7.65) |
| n | 3 | 5 |
| Hard antler commencement : | | |
| Age (days) | 376 (28.3) | 443 (1.9) |
| Weight (kg) | 97.3 (4.48) | 112.7 (7.94) |
| n | 3 | 5 |
| HINDS | | |
| Peak of progesterone: | | |
| Age (days) | 407 (32.6)[1)] | 506 (25.0)[1)] |
| Weight (kg) | 90.0 (5.87)[1)] | 95.5 (13.05)[1)] |
| n | 2 | 2 |

[1)] where n=2, range (±) is given

## CONCLUSIONS

From the present study it was concluded that :

1. Both sexes of sambar showed a weak seasonal pattern in VFI and body growth, compared to red deer. Peak VFI occurred in autumn and lowest VFI in spring, whereas red deer had highest VFI in summer and lowest VFI in winter. The period of low VFI in sambar was longer than in red deer.

2. Highest growth rate in sambar occurred in autumn, and lowest growth rate in winter and early spring, whereas red deer had their highest growth rate in spring/summer and lowest growth rate in winter.

3. Young sambar appeared to be more efficient in converting feed to liveweight gain than young red deer, indicating a better utilisation of energy. This could be due to improved efficiency of energy utilisation above maintenance or lower maintenance energy requirements. This hypothesis needs to be explored further in calorimetry experiments.

4. Estimated requirements of ME for both maintenance and gain (above maintenance) in growing sambar tended to be lower than for growing red deer.

5. Sambar did not develop secondary fibres during winter, while the primary fibres of sambar were coarser, sparser and shorter than in red deer. Calorimetric experiments are needed to measure coat insulation and lower critical temperature in sambar and red deer.

6. Relative to red deer, sambar tended to have higher plasma PRL concentrations in autumn, while red deer in spring and summer.

7. Sambar stags had elevated levels of plasma T over a longer period (autumn-spring), but with a lower peak. Spike release of plasma P (suggesting puberty) was detected in red hinds in autumn and sambar hinds in spring, when they were aged 17 and 14 months, respectively, and weighed 95.5 and 90 kg.

8. It is concluded that young sambar, living in a temperate environment, have endogenous cycles of VFI, liveweight, scrotal circumference and plasma concentrations of PRL, LH and T. These appear to be seasonal, but of reduced amplitude compared to red deer. Plasma hormone concentrations suggest that reproductive activity in sambar extends over a longer period than in red deer and commences at an earlier age and lower liveweight. Endogenous cycles in sambar appeared to be less tightly entrained to time than was the case with red deer.

9. Further experiments are needed, with control lighting, to establish if sambar are responsive to photoperiod and to define the onset of puberty and duration of the breeding season in sambar hinds.

# CHAPTER 7

## HAEMATOLOGICAL VALUES IN CAPTIVE SAMBAR

### INTRODUCTION

There is little base data on the blood haematology of sambar. The limited data available has been obtained mainly from stressed animals, which could alter the actual values (Chapman 1977; Slee & Presidente 1981). A few reports have also discussed the haematology of chital (Chapple 1989) and rusa (Audige 1992a&b).

During the present study it was possible to obtain blood samples from healthy artificially reared sambar, to set a standard haematological value for sambar in a temperate climate.

### MATERIALS AND METHODS

#### Experimental design

Nine sambar were blood sampled without tranquilliser. In addition, four semi-domesticated, mixed age sambar stags were sampled, whilst under the influence of a tranquilliser. Blood samples were analyzed for haematological values.

#### Animals

Nine artificially reared sambar (5 stags, 4 hinds), used for the indoor study (Chapter 5), were jugular venipuncture blood sampled in May 1992 (late autumn) and September 1992 (early spring). In May, the stags were in velvet antler, whilst in September they were in hard antler. All animals had been fed a high quality pelleted diet, with 2.9 % total N (Harvey Farm, Wanganui) and were familiar with regular physical handling and blood sampling. In May 1992, four semi-domesticated adult sambar stags in hard antler were sedated using a mixture of 10% Xylazine hydrochloride ("Rompun", Bayer, NZ) and fentanylcitrate-azaperone ("Fentaz", Ethnor Pty.Ltd. North Ryde, Australia), at a ratio of 3:1, administered by a tranquillizer dart (Paxarms Ltd, Timaru, NZ). Blood samples were taken from deer after sedation.

#### Blood sampling

Blood samples were collected by venipuncture from the jugular vein into 10 ml heparinised-vacutainer tubes (Nippro Medical Industries Ltd. Japan). Air-dried blood smears were made within one hour of collection, to check for the normality of blood cells. All samples were sent to Batchelar Animal Health Laboratory (Ministry of Agriculture and Fisheries, NZ) within four h of collection, for standard haematological analysis.

**Statistical analysis**

No statistical analysis of data were conducted because of the small number of samples. Means and ranges of data collected are presented based on sex, time of collection (May v September) and methods of sample collection (unsedated v sedated).

## RESULTS

Red blood cell measurements and plasma protein concentrations of unsedated sambar are shown in Table 7.1. Haemoglobin (Hb), packed cell volume (PCV) and plasma protein concentrations in hinds were slightly higher then in stags, but there was not a significant variation between ages. White blood cell (WBC) counts were not different between age and sex, but the WBC fractions (%) varied with age and sex (Table 7.2). Neutrophil percentage was relatively low, whilst the lymphocyte, monocyte, eosinophil and basophil counts were higher in hinds than in stags. However, within sex there was little variation in WBC between age groups.

Haematological values from sedated, semi-domesticated adult sambar stags are given in Table 7.3. The only marked differences between the unsedated and sedated stags were the Hb, WBC concentrations and WBC fractions. Haemoglobin concentration was lower in sedated stags than in unsedated stags. The fractions (%) of neutrophil in the WBC of unsedated stags was 2.5 times higher, eosinophil seven times higher and lymphocyte three times lower than that in unsedated stags.

Table 7.1. A comparison of red blood cell values (mean, range) from unsedated sambar, kept indoors, during May and September 1992.

| Month | Age (days) | RBC (x $10^{12}$/l) | Hb (g/dl) | PCV (l/l) | MCHC (g/dl) | MCH (pg) | MCV (fl) | Plasma protein (g/l) |
|---|---|---|---|---|---|---|---|---|
| **Hinds** | | | | | | | | |
| May 1992 (n=3) | 302 (248-368) | N/A | 13.1 (11.7-14.2) | 0.42 (0.38-0.46) | 30.8 (30.8-30.9) | N/A | N/A | 85 (80-90) |
| September 1992 (n=2) | 466 (427-505) | 9.9 (9.8-10) | 14.2 (14.1-14.3) | 0.45 (0.44-0.46) | 31.6 (31.1-32.0) | 14.4 (14.1-14.6) | 45.5 (44-47) | 91 (86-96) |
| **Stags** | | | | | | | | |
| May 1992 (n=2) | 294 (290-298) | N/A | 12.4 (12.2-12.6) | 0.39 (0.38-0.40) | 31.5 (31.2-31.8) | N/A | N/A | 80 (78-82) |
| September 1992 (n=2) | 431 (427-435) | 9.2 (8.5-9.9) | 12.8 (11.6-13.9) | 0.40 (0.36-0.44) | 31.9 (31.6-32.2) | 13.8 (13.6-14.0) | 43 (42-44) | 86 (84-88) |
| **Overall** | | 9.6 (8.5-10) | 13.1 (11.6-14.3) | 0.42 (0.36-0.46) | 31.4 (30.8-32.2) | 14.1 (13.6-14.6) | 44.3 (42-47) | 85.4 (78-96) |

N/A = not sampled

Table 7.2 A comparison of white blood cell values (mean, range) from unsedated sambar, kept indoors, during May and September 1992.

| Month | Age (days) | WBC (x $10^9$/l) | Neutrophil (%) | Lymphocyte (%) | Monocyte (%) | Eosinophil (%) | Basophil (%) |
|---|---|---|---|---|---|---|---|
| **Hinds** | | | | | | | |
| May 1992 (n=3) | 302 (248-368) | 4.5 (3.5-5.6) | 11 (8-15) | 81.7 (63-92) | 0.33 (0-1) | 0.33 (0-1) | 0 |
| September 1992 (n=2) | 466 (427-505) | 4.4 (4.4-4.5) | 35.5 (29-42) | 60 (50-70) | 1 (0-2) | 2 (1-3) | 1.5 (0-3) |
| **Stags** | | | | | | | |
| May 1992 (n=2) | 294 (290-298) | 4.5 (4.3-4.8) | 36 (31-41) | 63.5 (58-69) | 0 | 0 | 0.5 (0-1.0) |
| September 1992 (n=2) | 431 (427-435) | 4.6 (4.4-4.9) | 27.5 (24-31) | 68.5 (65-72) | 0.5 (0-1) | 3.5 (3-4) | 0 |
| **Overall** | | 4.5 (3.5-5.6) | 25.7 (8-42) | 69.9 (50-92) | 0.4 (0-2) | 1.3 (0-4) | 0.4 (0-3) |

Table 7.3. Haematological values from mixed age semi-domesticated adult sambar stags sedated using a mixture of 10% Xylazine and Fentaz in September 1992 (n=4).

| | Mean | Range |
|---|---|---|
| Hb g/dl | 12.0 | 10.3-12.6 |
| PCV l/l | 0.39 | 0.33-0.41 |
| MCHC g/dl | 31.1 | 30.8-31.4 |
| WBC x $10^9$/l | 3.2 | 1.2-4.4 |
| Neutrophil (seg) x $10^9$/l | 2.3 | 0.96-3.52 |
| Neutrophil (%) | 70.5 | 48-80 |
| Lymphocyte x $10^9$/l | 0.65 | 0.23-1.31 |
| Lymphocyte (%) | 21.3 | 11-41 |
| Monocyte x $10^9$/l | 0 | 0 |
| Eosinophil x $10^9$/l | 0.30 | 0.12-0.56 |
| Eosinophil (%) | 7.3 | 1-14 |
| Basophil x $10^9$/l | 0.035 | 0-0.06 |
| Basophil (%) | 1.0 | 0-2 |
| Plasma protein g/l | 85.0 | 80-88 |

## DISCUSSION

The differences between sambar stag and hind red cell measurements were in Hb, PCV and plasma protein concentrations. Although the WBC counts were similar between age and sex, the WBC fractions showed a variation. Haematological values of unsedated red deer did not differ with age group: 3-8, 9-18 and >18 months, or with sex (Wilson & Pauli 1986). In contrast, haematological values of chital showed a significant difference between sex in adult animals, but not in neonates or juveniles (Chapple 1989). Red cell counts and mean cell volume (MCV) of rusa stags were significantly higher than rusa hinds, whilst mean cell Hb content was significantly lower in stags than in hinds (Audige 1992a). Coles (1986, as quoted by Chapple 1989) mentions that muscular exercise and apprehension could influence the leucocyte counts, but restraint of chital did not change the total leucocyte count, unless it was followed by high muscular activity (Chapple 1989). For the present study, the animals were settled and as they were familiar with the handling procedures, stress was

believed to be negligible.

Higher Hb concentrations in stags with hard antlers is believe to be a physiological adaptation to sustain intense activity during the rut (Audige 1992a). In contrast, the semi-domesticated sambar stags (in hard antlers) in the present study, had a lower Hb value than the artificially reared young stags in hard antler. This may have been due to the sedation drug used (10% Xylazine and Fentaz) or to differences in age. The effect of Xylazine in red deer is noted as decreasing platelet, lymphocyte and basophil concentrations, and red cell mass (Cross et al. 1992).

The present study is compared with other haematological values of sambar in Table 7.4. There were small variations in neutrophil and lymphocyte proportions, and large variations in Hb, MCV and MCH concentrations, particularly from the data of Chapman (1977). This could be due to the limited data obtained or to age or stress differences. Further study is needed with a larger sample size of animals.

Table 7.4. Comparisons of haematological values in sambar under different sampling conditions.

| | Chapman 1977 | Slee & Presidente 1981 | Present study | Present study |
|---|---|---|---|---|
| Method of collection | Unspecified, wild animals | shot, wild animals | unsedated, tame | sedated, semi-domesticated |
| **Red cell** | | | | |
| Hb (g/dl) | 18 | 13.6 | 13.1 | 12.0 |
| PCV (l/l) | - | 0.41 | 0.42 | 0.39 |
| RBC (x $10^{12}$/l) | 8.9 | 9.0 | 9.6 | - |
| MCV (fl) | - | 49 | 44.3 | - |
| MCHC (g/dl) | - | 33 | 31.4 | 31.1 |
| MCH (pg) | 19 | 16 | 14.1 | - |
| Plasma protein (g/l) | - | - | 85.4 | 85.0 |
| **White cell (x $10^9$/l)** | | | | |
| WBC | 4.5 | 3.5 | 4.5 | 3.2 |
| Neutrophil | 2.5 | 1.4 | 1.2 | 2.3 |
| Lymphocyte | 1.5 | 2.2 | 3.3 | 0.65 |
| Monocyte | 0.3 | 0.4 | 0.02 | 0 |
| Eosinophil | 0.2 | 0.12 | 0.06 | 0.3 |
| Basophil | 0.06 | 0 | 0.02 | 0.04 |

# CONCLUSIONS

From the present study it was concluded that :

1. Hb, PCV and plasma protein concentrations from unsedated sambar were slightly higher in stags than in hinds, but there were no age effects.

2. WBC counts for unsedated sambar were not different between age or sex, but the WBC fractions (%) varied between age and sex. Sambar hinds had higher percentage of lymphocyte, monocyte, eosinophil and basophil cells and a lower proportion of neutrophil than sambar stags.

3. Unsedated sambar stags had higher Hb concentrations, and higher neutrophil and eosinophil fractions, and lower lymphocyte fractions than sedated stags.

## GENERAL DISCUSSION

The present study suggests some distinctive differences in the reproductive biology of sambar and red deer. Under NZ conditions, captive sambar have a mean calving date of 6 May compared with 8 December in farmed red deer. Thus, on average, sambar calve 7 months earlier than red deer. The spread of calving in sambar is from January to November and in farmed red deer from early November to mid-January. Sambar stags tend to have a longer period of maximum scrotal circumference (5 v 3 months) and a longer period of high plasma T concentrations (20 v 5 weeks) than red stags. The onset of rutting in sambar stags commences in late May/early June and lasts until November (25 weeks). In the present study, sambar stag which had cast his antlers was still observed to exhibit rutting behaviour, and supports the finding with chital (Chapple 1989). In NZ, the onset of rutting in farmed red stags is from mid-March until late May (9 weeks). However, the peak breeding season usually lasts for five weeks for stags, with unmated red hinds still exhibiting oestrous cyclicity for a further 16 weeks after the peak breeding season (Kelly & Moore 1977). Collectively, this indicates that the reproductive season is longer in both sexes of sambar than in red deer, but further experiments are necessary to more accurately define the duration of the breeding season. Both sexes of sambar attain puberty earlier and at lighter liveweight than red deer; sambar stags at 445 days (101 kg) and red stags at 469 days (117 kg); sambar hinds at 407 days (90 kg) and red hinds at 506 days (95.5 kg).

Plasma concentrations of reproductive hormones in sambar indicate that under temperate environments the animals display endogenous reproductive cycles which appear to be seasonal. The cycles are of reduced amplitude compared to red deer, with high and low hormone concentrations occurring at different times in the two species. The degree to which the endogenous sambar reproductive cycles have been modified by photoperiod is not clear, and it would be interesting to examine the response of NZ sambar to changes in photoperiod. Studies with chital and rusa in Australia (van Mourik & Stelmasiak 1985; Mylrea 1992) and chital stags in the USA (Bubenik et al. 1991) suggest that both species could be responsive to photoperiod. In the USA, tropical Burmese brow-antlered hinds also exhibit oestrous cyclicity at the same time as the local temperate deer, suggesting a degree of responsiveness to the local environmental conditions (Wemmer & Grodinsky 1988).

The wide calving pattern in sambar, shown from a range of studies (Table 2, p 11), clearly indicates a long period of breeding. In their native habitat wild sambar search for feed by shifting their habitat from forest areas during the drought, to open grasslands in the monsoon season (Santiapillai et al. 1981). Thus, under tropical conditions, sambar are unlikely to experience extreme feed shortages, and because sambar stags in hard antler can be found at any time of the year, reproductive success is

likely. It is likely that the wide spread of calving in the present sambar is related to differences between hinds in the onset of oestrous, although further study is required.

Studies with chital hinds indicate that the time of birth influences the timing of puberty, with mean age of hinds in first oestrus being shorter for autumn-born animals compared to spring-born animals, 10 v 15 months, respectively (Mylrea 1992). The presence of oestrous hinds in the mixed sex group appeared to be a control over the stags reproductive cycle, but did not influence the peak rutting time in stags (Chapple 1989). From the present study it appears that the reproductive physiology of sambar stags (timing of hard antler) is not closely related to the time of birth. Younger stags tended to be in hard antler at a similar time as the majority of adult stags were in hard antler. This occurred by either lengthening or shortening the time in velvet antler. However, the data was gathered from a limited number of animals, and further study is required. A similar trend of well synchronised antler casting between young and adult animals has been shown in chital stags (Mylrea 1992).

The patterns of VFI and growth in sambar also indicates endogenous cycles, of reduced amplitude and with peaks and troughs occurring at different times compared to red deer. Sambar have maximum VFI and growth in autumn and minimum in spring, compared to red deer with maximum VFI in summer and minimum in winter. Sambar appear to have a faster growth rate only in the first 12 months, before steady but slower growth occurs. Peak growth rate in red deer coincides with peak feed abundance during both spring and summer. During the mating season, there was no decline in VFI or growth in either sex of sambar, as occurs in red deer. A drop in liveweight by chital stags occurred only during velvet antler growth rather than during the rutting season (Chapple 1989; Mylrea 1992).

Peak calving in both sambar and red deer was closely associated with peak VFI. With red deer, peak VFI and calving is associated with high pasture availability, under temperate conditions. Presumably the present peak calving time in sambar also reflects feed conditions under tropical environments. During tropical April and May (southern hemisphere), a transitional period occurs between wet and dry seasons, with mild and low humidity and a low number of insect parasites. Thus, during this period conditions are conducive to survival of young, as newborn calves are unlikely to face neither climatic discomfort nor parasite attack.

Young sambar were found to consume less feed than young red deer and have a better FCE than red deer at comparable age. From an early age, sambar tend to conserve energy, calves being less active and spend more time hiding. This may have evolved as a natural defence against predators. Early weaning from milk replacer also occurred and may be necessary for early independence from their dams because of the consistent threat from predators. Lower calculated metabolisable energy requirements for maintenance and gain in sambar compared to red deer indicate lower basal heat production and which is supported by differences found between Bos indicus v Bos taurus cattle (Frisch & Vercoe 1969). Further study of energy utilisation using respiration calorimetry is needed to

assess differences between sambar and red deer.

There were no differences in feed digestibility between sambar and red deer when high quality lucerne hay was fed. Eating time was similar for sambar and red deer, but sambar spent more time ruminating. Sambar also had more ruminating bolus/h with less ruminating chews/bolus than red deer. This could be an indication that an increased ruminating behaviour of sambar has evolved to more effectively break down low quality forage. In field observations, sambar preferred willow (browse) which had high levels of CT and fibre, but low levels of total N and OMD. Red deer preferred red clover which was high in total N and OMD but low in CT and fibre. The type of forage selected by sambar is typical of the quality of common tropical forage (van Soest 1982; Minson 1990). Studies indicate that the selection of plants with high concentration of secondary compounds, such as CT, is related to the ability of the animals' saliva proteins to bind/neutralize these compounds (Robbins et al. 1987b; Austin et al. 1989). This has been identified in mule deer, which produce CT-binding salivary proteins, while cattle and sheep do not (Robbins et al. 1987b). Selection of plants with higher CT by sambar could be due to their ability to counter CT, through the presence of salivary CT-binding proteins. This hypothesis needs further investigation, by conducting digestibility trials with both sambar and red deer offered low quality roughage containing CT (e.g Lotus corniculatus or Lotus penduculatus threshed straw).

In terms of commercial deer production, the use of sambar could, potentially, bring some advantages to the NZ deer industry and those of tropical countries. Farmed red deer in NZ are considered late calvers (mean date 16 December, Moore & Cowie 1986), and the highest market demand in the northern hemisphere corresponds to August/November in NZ. As a result, there is a constant pressure on the industry to produce bigger animals by August/November (ie. less than 12 months of age). Moreover, summer calving is often too late to synchronise with the spring peak of pasture dry matter production, and the high feed requirements for hinds during lactation is out of sequence with pasture growth. Pasture is also of low nutritional quality during summer. A desirable slaughter liveweight by 12 months of age is often difficult to obtain. A successful attempt to attain less than a 12-month slaughter liveweight has been conducted through better pasture management (Ataja et al. 1992) or providing new forage species (Niezen et al. 1993; Semiadi et al. 1993). Hybridizing larger sized temperate deer stags with red hinds has also been successfully conducted, either using wapiti (Fennessy et al. 1991) or Pere David's (Fennessy & Mackintosh 1992) as sires. The former aimed to increase growth rate, while the later aimed to advance the calving date and as well as increasing growth rate.

The present study provides an indication that as well as early calving potential, sambar have a better FCE with less winter growth depression than red deer. Thus, it may be beneficial to produce hybrid 0.5 sambar/0.5 red stags using artificial breeding, which should be evaluated for fertility and ability to naturally mate red hinds. Hybrid 0.25:0.75 sambar:red hinds might be expected to have a

more extended breeding season than pure red deer and open up the possibility of early calving, better FCE, faster growth rate and less winter depression of growth and VFI in commercial deer.

For tropical regions, the present study indicates that farming sambar is possible, although conventional management needs to be altered. As wild sambar are flighty and nervous animals, sambar farming can be initiated using artificially reared animals, as in this study. Those countries which have already developed tropical deer farming but using a smaller body size animals, such as rusa, could still benefit from an introducing of sambar blood through hybridization to improve the performance and production of the herd. This should be easier then hybridising with the temperate red deer, as sambar and rusa deer are known to hybridise using natural mating.

In summary, the present study indicates that sambar have adapted to utilise low quality forage. They also have a reduced amplitude of cycles of VFI and growth, supportive of the pattern of pasture production under a tropical environment. Tropical countries would be best advised to develop deer industries based upon their own indigenous deer, such as sambar, which have evolved in those environments.

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