

*Transcription of a copy of the original typewritten document held by the Landcare Research library in Lincoln. This version has been reformatted and some obvious typing and spelling errors have been corrected for easier reading, though smaller errors have been retained. There may also be minor errors in transcription. Original page numbers are given in pale blue.
(Attempts to contact Mr Parsons have not been successful.)*

THE FERAL SHEEP
(*Ovis aries* L.)
OF WOODSTOCK STATION
CANTERBURY, NEW ZEALAND

A project submitted in partial fulfilment of the requirements for the degree of Bachelor of Science with Honours in the University of Canterbury.

BY
S. R. PARSONS
1980

CONTENTS

		Page
Chapter 1	Introduction	1 [5]*
	Study Area	4 [6]
	a) Location	4 [6]
	b) Land use	4 [6]
	c) Vegetation	4 [6]
	d) Climate	5 [6]
Chapter 2	Methods	7
	A) Field Methods	7 [8]
	a) Shooting	7 [8]
	b) Autopsy	8 [8]
	B) Laboratory Methods	
	i) Skin sections	10 [9]
	ii) Microscopy of sections	10 [9]
	iii) Fibre diameter	11 [9]
	iv) Staple lengths	12 [10]
	v) Wool bulk and resilience	12 [10]
	vi) Parasites	13 [10]
	vii) Fleeces	13 [10]
	C) Aging Methods	14 [11]
	i) Tooth eruption	14 [11]
ii) Tooth annuli	14 [11]	
iii) Horns 1	15 [11]	
iv) Aging of Foetuses	15 [11]	
[Page ii]		Page
Chapter 3	Some observations on Sheep Behaviour	19 [13]
	A) Habitation	19 [13]
	B) Group size	19 [13]
	C) Wariness	20 [14]
	D) Interaction between feral and domestic sheep	21 [14]
Chapter 4	Physical Characteristics and Growth	23 [14]
	A) Appearance	23 [14]
	B) Pigmentation	23 [15]
	C) Hornedness	25 [15]
	D) Growth	27 [16]
Chapter 5	Wool and Skin Characteristics	
	i) Wool fibre diameter	34 [19]

** Page numbers in light blue refer to the original manuscript, in dark blue to this transcript.*

	ii) Fibre medulation	34 [20]
	iii) Shed fibres	37 [21]
	iv) Crimp, bulk and follicle genotype	37 [21]
	v) The follicle population	38 [21]
	vi) Wool growth	41 [23]
	vii) Clean wool yield	43 [26]
	Discussion	46 [27]

Chapter 6	Notes on Reproduction	53 [30]
-----------	-----------------------	---------

[Page iii]

		Page
Chapter 7	Health	57 [32]
	A) Teeth, feet and horns	57 [32]
	i) Teeth	57 [32]
	ii) Feet	57 [32]
	iii) Horns	59 [33]
	B) Parasites	
	i) Sheep keds	59 [33]
	ii) Lungworm	59 [33]
	iii) Hydatids	59 [33]
	iv) Examination of the abomasum and contents	61 [34]
	v) Brucellosis, Leptospirosis and Johne's disease	61 [34]
	C) Fatness	61 [34]
	Summary	62 [34]
Closing Comments		64 [35]
Summary		68 [36]
Acknowledgements		70 [36]
References		71 [36]
Appendices	1 Woodstock runholders 1855-1980	80 [40]
	2 Present known feral sheep flocks of New Zealand	81 [40]

[Page iv]

LIST OF FIGURES

Figure	Page No.
1 Map of study area	6 [7]
2 Jaws of a lamb and an adult showing teeth	17 [12]
3 Badger face variations	28 [17]
4 Sheep weights	31 [18]
5 Body length and tail length	32 [19]
6 Shoulder height and elbow height	32 [19]
7 Chest girth	32 [19]
8 The range of fibre diameter in individual sheep	35 [20]
9 Major variations in fibre diameter	36 [20]
10 Clean wool yield	45 [27]
11 Tooth abnormalities and jaw foramen variation	56 [31]

LIST OF PLATES

Plate	Facing Page No,
1 Wool fibres including one with fragmented medulation from a lamb	40 [23]
2 Arrangement of follicles and fibres in the skin	40 [24]
3 A Primary follicle with a group of secondary follicles	41 [24]
4 Groups of primary and secondary follicles showing triad line arrangement in the skin	41 [25]

[Page v]

LIST OF TABLES

Table	Page No.
1 Tooth eruption	16 [12]
2 Tooth annuli in relation to tooth eruption	18 [13]
3 Horn growth in rams	29 [17]
4 Wool fibre diameter, bulk and resilience and follicle ratios, density and depth	39 [22]
5 Expected mean values for skin biopsy data of some breeds and strains of sheep	40 [22]
6 Mean staple length and variance	42 [23]
7 Greasy fleece weights	44 [26]
8 Group size and composition	56 [31]
9 Levels of lungworm infestation	60 [33]

[There is no Table 10 but there is a Table 11 on page 34]

CHAPTER I

INTRODUCTION

The feral sheep of Woodstock station are Merinos and the present population probably stems from sheep released into the area from about 1855 when the more accessible areas of Woodstock station were first leased. The most rugged and inaccessible country was leased to D. Kinnebrook in 1858 (Acland 1975). The use of natural boundaries to mark run limits and few fences to keep the sheep out of what is now Oxford State Forest, did little to prevent the sheep disappearing into the bush, much of which was included within the run. Appendix 1 provides a list of Woodstock run holders.

Musters for shearing or tailing the lambs were often at rare intervals in high and inaccessible country in the early run days and wild sheep were common in the mountainous districts of the South Island by 1880 (Thomson 1928) and some North Island areas (Guthrie Smith 1953). Due to the frequent transferring of leases of the Woodstock runs between 1853 and 1902 (Appendix 1) there may have been periods of no management between different lease holders when the sheep were left to their own devices for some time, so there have probably been wild sheep in the Woodstock back country since the early years.

Merinos formed the main part of the Australian flock in the 1850s and became the dominant breed in New Zealand as settlement got underway as it was an ideal breed for the hills of Nelson, Marlborough, Canterbury and Central Otago (Stevens 1961). Due to the closeness and convenience of transport of sheep from Australia, Merinos were imported from Tasmania, South Australia, Victoria and New South Wales, though a few European imports were made (Austin 1944).

[Page 2] The Merino breed which has Spanish and possibly North African origins (Ziegler undated) consists of several distinct types which were exported to other countries from 1765 and formed into other distinct types due to environmental influences and the requirements of breeders in those countries (Austin 1944)

In the 19th century Merino sheep imported from Spain, Saxony, England, France and America (Cox 1936) were developed into several strains to suit local conditions and breeding preferences throughout Australia (Ryder and Stephenson 1968).

Thus the Merinos imported into New Zealand from Australia in the early settlement days were probably far from uniform in type. As New Zealand's feral flocks probably derive from these early importations and because they have survived under relatively normal free breeding conditions it is possible that they carry advantageous genes which have been lost in commercial flocks. Feral flocks therefore represent not only a possible new gene pool to improve commercial sheep but also a means of determining how past artificial selection has altered commercial sheep.

Despite extensive culls by runholders, Government shooters and bounty hunters this century (Howard 1966) several feral populations still exist (Appendix 2). Most research to date has been concentrated on the feral populations of Campbell Island and Arapawa Island, with some lesser attention to the Omahaki flock. The Campbell Island flock is the only feral sheep population known for certain not to be pure Merino (Whitaker and Rudge 1976).

Unfortunately the niches suitable for wild ungulates in New Zealand were unoccupied by mammals prior to their introduction, so the native plants have not evolved to be particularly browse resistant and many are easily decimated [Page 3] by uncontrolled populations of goats, deer, sheep, thar and chamois. Wodzicki (1950) described the damage to Campbell Island's subantarctic flora by sheep as irreparable, though they have improved the nesting conditions for the albatross (Wilson and Orwin 1964).

The Woodstock population has been substantially reduced in recent times and I estimate the present population to be 2-300 animals within the confines of Woodstock, but possibly as high as 500 if areas of surrounding forest are included. It seems that groups of wild sheep are scattered throughout much of the Oxford State Forest which borders Woodstock.

Attempts have been made in the past to capture groups of Woodstock sheep using men and dogs, even to the extent of building a wild sheep trap on the flats of Area II (Fig. 1), but with little success due to the contrary nature of the sheep and unwillingness to be mustered out of their territory (S. Spencer-Bower pers. comm.). However the sheep were shot for some years by Woodstock station staff as a convenient source of dogmeat.

At present feral sheep are only supposed to be shot under authorisation of the Secretary for Internal Affairs, for wildlife hunting or because of damage to any land, leasees and licensees of Crown land are supposed to eradicate any wild animals on the land (Whitaker and Rudge 1976).

[Page 4]

STUDY AREA

a) LOCATION.

Woodstock station is bounded to the North and East by the Oxford State Forest and to the South and West by the Waimakariri River (Fig. 1). Most sheep were shot or observed in the two areas marked in Fig 1. These two areas can be scanned for sheep relatively quickly using binoculars from several vantage points and were the two areas most easily reached where sheep can generally be found. A jetboaters' hut is in Area II, and there is a good station hut at the end of the four wheel drive track.

b) LAND USE – introduced animals.

All the area past Coal Creek has been closed to domestic sheep for 3 years though a few stragglers are still present. 200 head of domestic cattle (*Bos taurus*) are free to roam over the area North of Coal Creek. The domestic stock were seen to remain in the grassed areas. Feral Merino sheep (*Ovis aries*) are found on some grassed areas and in the forest, pigs (*Sus scrofa*), feral cats (*Felis catus*), hares (*Lepus europaeus*) and rabbits (*Oryctolagus cuniculus*) are also present. Possums (*Trichosurus vulpecula*), the feral sheep and deer (*Cervus elaphus*) are the major influences on the indigenous forest. A few chamois (*Rupicapra rupicapra*) inhabit the open tops.

c) VEGETATION.

Short tussock (*Poa, Festuca*) and native and introduced grasses cover the open areas of the study area. The rest is covered by indigenous Beech forest (*Northofagus solandri*) and a palatable small tree and shrub tiers (broadleaf and small leafed *Coprosma* species).

[Page 5] There is a dense mass of gorse (*Ulex europaeus*) covering the Smuggler Cove area and small plots in Area I and near the lower reaches of Kinnebrooks Stream. Some scrubby growths of matagouri (*Discaria toumatou*) occur on some open parts of Area II and along the spur between Coal Creek and Foster Stream.

d) CLIMATE,

The nearest meteorological stations to Woodstock are at View Hill (rain only), Eyrewell, Rangiora and Hororata. The mean annual rainfall at View Hill from 1941-1970 was 1103mm which is probably similar to the Woodstock rainfall. The winter months having slightly less rain than other months. The mean annual number of snow days between 1951 and 1970 was 2.5 for Eyrewell and Rangiora and 5.5 for Hororata, but Woodstock probably has > 5.

The monthly mean temperature for Woodstock probably resembles that for Eyrewell about 20km to the South-east which on average ranges from 5.0°C in July to 16.6°C in February, with the total incoming radiation ranging on average from 109 Langleys/day in June to 526 Langleys/day in December.

A. Field Methods

(a) Shooting. On the first trip into the area sheep were shot with a .22 semi-automatic Ruger 10/22 rifle with a 3.9 varipower scope. This rifle was effective at close range only. On hot days when sheep are often lying down and resting it was possible to get very close, within 10m, and shoot the animals in the head or neck with the .22. However these sheep are generally very wary and when on open faces often could not be approached within 100m without them running off.

For this reason the .22 was abandoned on subsequent trips into the area in favour of high powered rifles loaded with light projectiles to minimise body damage. Thus the use of high powered rifles on these sheep saves a lot of time involved in cautious stalking.

As this project was started in February there was not time to encompass a whole year's observations. For this reason and the small size of the population only sufficient sheep for the purpose of studying body, wool and skin characteristics, and general health and condition were shot. Some observations on reproductive behaviour, sheep impact on the environment and preferred habitats were made on subsequent trips into the area till September.

Sheep were deliberately selected from groups and shot to establish an adequate range of ages and sex for skin and wool samples, body measurements and health inspection. Shooting of sheep exhibiting the 'Badger face' pattern of pigmentation was avoided, except on two occasions due to the apparent rarity of the gene for 'Badger face' in the population.

[Page 8] (b) Autopsy. Sheep were autopsied as soon after shooting as possible. Autopsy of shot sheep was carried out with the following procedure.

(i) 20ml blood samples were taken from some sheep to test for Brucellosis, Leptospirosis, and Johne's disease.

(ii) The following standard body measurements were taken to the nearest centimetre: The carcass was laid on its left side and with its back gently arched a straight line measured from the top of its nose to the base of the tail. This was body length. Still on its left side the right foreleg was straightened and measured from the top of the scapula to the tip of the hoof and from the tip of the olecranon of the ulna bone to the tip of the hoof. This was shoulder height and elbow height respectively. Knee height of the straightened hindlimb was measured from the proximal extremity of the tibia to the tip of the hoof. Tail length was measured. Chest girth was measured around the heart region. Rams had horn lengths measured along the anterior keel and horn spread measured from tip to tip.

(iii) The whole sheep was suspended from a 100kg scale to obtain a live weight reading. The sheep was then eviscerated from oesophagus to rectum and weighed again to record the eviscerated weight. This includes the fleece, feet and head, but not testis or udders.

(iv) The lungs were examined for hard lumps and loss of sponginess due to lungworm, and assigned to a class from 0–4 of an arbitrary scale according to degree of infection. Lesions from some lungs were fixed in 10% formalin.

[Page 9] (v) The liver was examined for lesions or scars caused by hydatid cysts. Livers were assigned to a class from 0–4 according to an arbitrary scale of degree of infection. Lesions from some liver were fixed in 10% formalin.

(vi) The abomasum was cut open and given an on the spot examination for gut nematodes. The abomasum contents from a ewe hogget and a 4 tooth ewe shot in April were taken back to the laboratory for closer examination.

(vii) The rumen was opened and the contents noted whether predominantly grass or native plants.

- (viii) The lactation state of ewes was noted. Any foetuses were removed from the placenta and weighed whole and had length, shoulder height, and tail length taken. In addition near full term pre-natal lambs had knee and elbow height and chest girth measurements taken.
- (ix) Mid side wool samples of at least 30g were plucked from some dead animals, put in a plastic bag and labelled.
- (x) A 1cm² section of skin from the mid side area was removed from some dead animals and stored in individually labelled glass vials containing 10% formalin.
- (xi) Sheep were examined for any external parasites, examples of which were stored in 70% ethanol.
- (xii) Sheep were examined for flyblow, footrot and mange.
- (xiii) The presence of subdermal fat deposits, kidney fat and the sheep's general appearance were noted.
- (xiv) The jaws were removed, labelled and bagged. The skulls and fleeces of some sheep were also taken.

[Page 10] B Laboratory Methods

(i) Skin Sections

Transverse and longitudinal skin sections were made using the technique outlined below, developed from Preece (1959): Mid side skin samples were washed in distilled water. Transverse sections 20–30mm thick and longitudinal sections about 100mm thick were cut using a freezing microtome with a 'Frigister' head.

Sections were a) stained with Mallory's Methylene blue-azure II working stain for five minutes.

- b) washed and decolourised in 95/b alcohol.
- c) stained with 2.5% Phloxine.
- d) dehydrated in absolute alcohol and washed in Xylene.
- e) mounted in Euparal on a glass slide and covered with a glass coverslip.

Transverse sections were obtained from 11 sheep. Longitudinal sections were obtained from 8 sheep. A number of sections were obtained from each sheep sample.

(ii) Microscopy of Sections.

a) Transverse sections. The clearest section showing primary and secondary follicles was selected and placed under a Reichert microscope at 50x magnification under transmitted light. An eyepiece with a grid of constant dimensions (0.7cm x 0.7cm) was inserted. At least 10 non overlapping counts of the number of follicles within the grid were made for the best section from each animal. Primary follicles were distinguished from secondary follicles by their association with a duct from a sweat gland and a bilobed sebaceous gland. [Page 11] By dividing the total number of secondary follicles thus counted, by the total number of primary follicles counted, a secondary : primary follicle ratio was arrived at for each sheep (S/P).

b) Longitudinal Sections. Slides were placed under a microscope and viewed under reflected light at 20x magnification. A calibrated eyepiece was used to measure follicle depth from the lowest point of a follicle to the skin surface. 10 follicle depths were measured for each sheep. Only one follicle depth in a group of follicles was measured. Measurements were converted to microns.

The degree of tanglement of wool fibres in groups were classified according to Nay (undated).

(iii) Fibre Diameter.

a) Preparation of Fibres.

The following method was used to obtain the fibre diameter of each sheep.

- (i) Several staples were selected at random from the scoured and conditioned mid side sample of wool.
- (ii) About 1mm lengths of wool fibres were obtained from the middle portions of the wool staples using a hand held microtome and a razorblade.
- (iii) The lengths of wool fibres were fixed horizontally in cedarwood oil on a glass slide, covered with a glass coverslip and labelled.
- (iv) The preparations were left to set overnight.

b) Fibre diameter readings. Each slide was placed under a projection microscope and the diameters of 500 fibres measured with a transparent ruler. Measurements were converted to microns.

[Page 12] By measuring the diameter of fibres in profile, the difficulty of cutting cross sections of fibres absolutely at right angles to their vertical component is bypassed.

Generally one edge of a fibre is out of focus when using the profile technique and appears as a diffuse black or white Becke line. To measure the diameter of these fibres the focus is altered until one edge of the fibre is sharply in focus and the other edge has a white Becke line. The true diameter is then obtained by measuring the distance from the sharp edge to the inside of the white Becke line (Ryder and Stephenson 1968).

(iv) Staple Lengths.

Accurate measurement of staple length for the mid side wool samples of 11 sheep were obtained by selecting at random, 100 staples from each sample and feeding them through a W.R.O.N.Z. Staplemeter which printed out each staple length and gave a mean for each 100 samples. The standard deviation and variance of staple lengths for each sheep was also obtained. Staple lengths for other sheep were obtained with a tape measure in the field.

(v) Wool Bulk and Resilience.

- a) Mid side wool samples from 11 sheep were scoured, conditioned and had all vegetable matter removed to yield 10g of clean wool from each sheep.
- b) Bulk and resilience for each 10g sample was recorded using a W.R.O.N.Z. Loose Wool Bulkometer 77/135. Samples were compressed with the standard 10g and 30g weights. The calibrated scale on the bulkometer was read to the nearest 0.1 of a unit.

[Page 13] c) Calculations.

Bulk = 10gf x 0.5

Resilience = (10gf - 50gf) x 0.5

(vi) Parasites.

Sheep keds were identified by Professor R. L. C. Pilgrim of this Department.

Blood samples and parasitic lesions from the lungs and livers were kindly examined by the Ministry of Agriculture and Fisheries.

Abomasum contents were sieved and inspected in petri dishes under a binocular microscope for nematodes.

(vii) Fleeces.

The skins from some sheep were removed in the field and brought back to town. These were tanned with a chrome alum solution ($K_2SO_4 \cdot CR_2(SO_4)_3 \cdot 24H_2O$) plus washing soda ($Na_2CO_3 \cdot XH_2O$).

These preserved skins provide examples of fleece type and structure for posterity.

Greasy fleece weights were calculated for these tanned skins by subtracting a tanned skin factor of $1.57kg/m^2$ of skin from the total weight of the skin with fleece attached.

[Page 14] C Aging Methods

To enable the construction of simple growth curves and the comparison of wool and skin characteristics to age, sheep were put into approximate age classes by tooth eruption status and growth lines in the cementum of the 1st incisor.

(i) Tooth Eruption.

The 20 temporary teeth of the lamb are gradually replaced over about 4 years by 52 permanent teeth (Fig 2). Age classes were developed from Ryder and Stephenson (1968) and May (1964). However these authors refer to generalised sheep tooth eruption times, though this varies with the breed of sheep. For this reason and the increased variability of eruptions along the sequence, the age classes are approximations only, but I consider them adequate for the requirements of this project.

The sequence of tooth eruptions is shown in Table I. A tooth was considered erupted once it had broken through the gums, as for Caughley (1965).

(ii) Tooth Annuli.

Layered structures of the teeth (dentin and cement) and of the periosteal zone of the bones can be good indicators of the age (in years) of mammals (Kevezal and Kleinenberg 1969).

Method: One of the first permanent incisors (I_1) was removed from the jaws of 17 sheep and the root tips progressively ground transversely on 180 and 500 grit wet and dry carborundum paper and polished on hard cardboard and hardboard.

The surface was examined repeatedly as grinding progressed, in reflected light under a binocular microscope. This method was found to yield the best results for [Page 15] known age Romney cross sheep by Rudge (1976).

Result: The first boundary between dentine and cementum was very clear in all the teeth, but subsequent dark bands representing winter cementum growth were less easily distinguished and were indeterminable in some teeth. Lines were not continuous around the section and were clearest on the lateral and lingual sides. Between 2–4cm of the root tip needed to be ground before growth lines became clear.

From Table 2 it can be seen that growth lines in the cementum of the 1st incisor give a good indication of age for most of the sheep and substantiates the age classes established by tooth eruption state (Table 1).

(iii) Horns.

Annual growth rings on ram horns as found for Soay sheep (Jewell et al 1974), Rocky Mountain Bighorn sheep (*Ovis canadensis canadensis*), Stones sheep and Dalls sheep (*O. dalli*) (Geist 1971), cannot be distinguished from the general convolutions of the horn surface of the Woodstock Merinos.

Aging of Foetuses.

Foetal growth curves were constructed from prenatal growth data of Stephenson (1952) and Stephenson and Lambourne (1960) for Australian Merinos.

Woodstock sheep foetal data was fitted to these curves and an age in days from conception assigned to each foetus. Allowing for population variation and any seasonal affects I consider the ages to be accurate to within 10 days. Thus the month of conception and month of birth can be derived for each foetus.

TABLE 1 TOOTH ERUPTION

a. Eruption States

I ₁	I ₂	I ₃	I ₄	P ₂	P ₃	P ₄	M ₁	M ₂	M ₃	N
							x			3
							x	x		5
x							x	x	x	3
x	x						x	x	x	1
x	x				x	x	x	x	x	1
x	x			x	x	x	x	x	x	5
x	x	x		x	x	x	x	x	x	1
x	x	x	x	x	x	x	x	x	x	7

b. Eruption Sequence

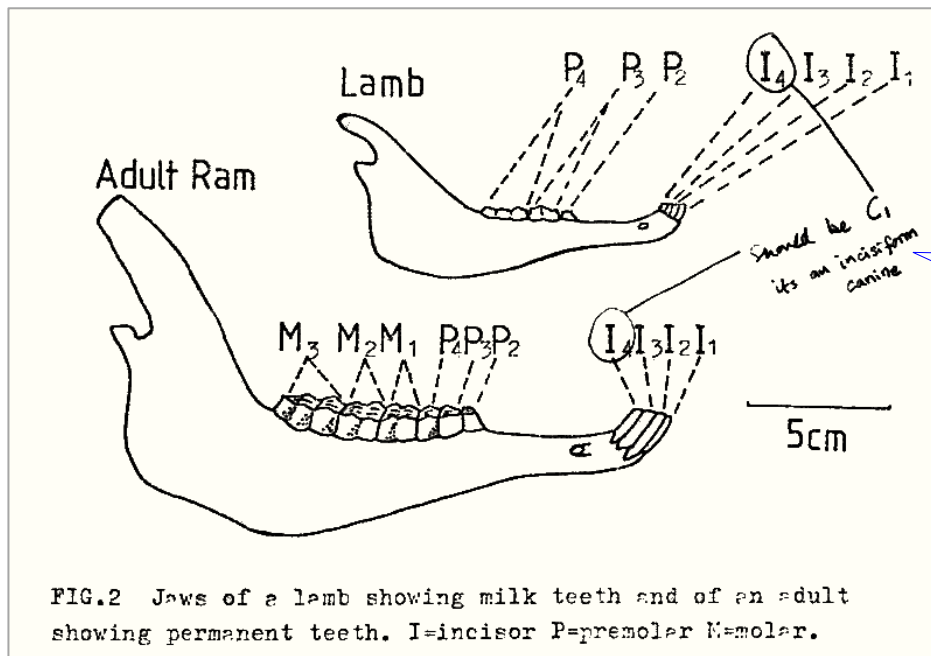
$$M_1 > M_2 > I_1 > \underbrace{M_3}_{24-30} > (P_3 \ P_4 > P_2) \cong I_2 > I_3 > I_4$$

3
9
18
24-30
30-36
36-42

N.B. The above ages (in months) are estimates only of age at the full eruption of each tooth.

KEY:

I=incisor P=premolar M=molar



Added comment

FIG.2 Jaws of a lamb showing milk teeth and of an adult showing permanent teeth. I=incisor P=premolar M=molar.

TABLE 2

TOOTH ANNULI IN RELATION TO TOOTH ERUPTION

Tooth eruption	No. sheep	Growth rings in I ₁				
		1	2	3	4	5
I ₁	3	5				
I ₂	6	0	3	1		
I ₃	2		1	1		
I ₄	6		0	1	2	2

○ Probably too few growth rings
 □ Probably too many growth rings

CHAPTER 3

SOME OBSERVATIONS OF SHEEP BEHAVIOUR

A. Woodstock feral sheep are found in the indigenous forest areas and the open tussock and grass faces of the area. Most sheep were seen on hill sides with a North, North East or East facing aspect. Bush fringed grassy clearings are common feeding areas though many sheep were seen up to 500m away from significant forest or bush cover.

B. GROUP SIZE.

Group size ranged from 2–23 and there appears to be some seasonal variation (Table 8). Sheep were not seen alone, though 1 ewe with its lamb was seen alone. The larger groups of 13–23 were seen mostly from the beginning of my observations in February till the end of April, but not from May through to September when I concluded my observations for this report, though a group of 3 was seen in February, and a group of 13 in September. From May through to August all sheep seen were in groups of 3–8.

The summer mobs of 13–23 all consisted of large adult rams, ewes and hoggets, with the occasional young lamb. The smaller groups generally consisted of ewes, hoggets and lambs with the occasional adult ram. The smaller groups may be 'family' groups of ewes with their offspring. No groups of only rams were seen (Table 8).

As the breeding season of these sheep seems to commence about January (Chapter 6) these larger mobs of sheep may be formed at this time and function as breeding groups during the breeding season. When most of the ewes are pregnant and cease to come on heat these mobs may fragment into the smaller groups observed later in the year. [Page 20] No full fights between adult rams were seen, though some nudging and blocking behaviour occurred between rams in the large mobs. Chipped horns and broken teeth in some rams suggests that some fighting does occur.

C. WARINESS.

Woodstock feral sheep are particularly wary animals especially when on open faces, and need to be approached cautiously to prevent them running off. The sheep can easily spot movement 200m away across open areas in good light .

Adult rams were seen to be the most wary animals. They constantly survey their surroundings and will stare for some minutes in the direction of possible intruders.

Domestic cattle and sheep wandering into view do not evoke any response from the feral sheep, which generally run off if a man approaches within 100m. They will often stamp their forelegs, look from one to another and give goat like warning cough's before running off as a group after seeing or scenting anything unusual.

The first sheep to run were followed by the rest of the group though if adult rams were present, one would often take over the lead. But some of the rams in the larger mobs were seen to run at the back of the group when disturbed and constantly stop and check the area behind them while the ewes and younger sheep kept moving.

The sheep generally run off along or towards established animal tracks if nearby. Thus it is often possible to predict the direction in which a group will run when disturbed, which aids shooting success.

Sheep on open faces are much easier to stalk from above than below as the area below the sheep is more easily [Page 21] viewed while feeding than the hillside above.

On hot sunny days groups of sheep were often found to be lying down and dozing out in the open or in the shade of trees. In these circumstances it is possible to approach the group to within a few meters if some cover is available. But if disturbed the sheep will get up and run off remarkably fast.

The sheep generally keep on running until they are out of sight. Occasionally some young sheep become separated from the group when disturbed and would only run a few metres at a time before bleating if the group could not be seen. These were always hoggets.

D. INTERACTION BETWEEN FERAL AND DOMESTIC SHEEP:

The area of feral sheep habitation is closed off to domestic sheep at present, though some stragglers still remain in the area. They have very long fleeces and the hoggets still have their tails. These sheep were seen to keep to the lower country and were never seen within feral sheep groups.

According to former Woodstock Station manager, Mr L. Latter, when domestic stock were run in the area, feral rams would service domestic ewes.

The same problem is presently being experienced at the Mt. White Station north of Woodstock where there is also a feral Merino population (G. Roberts pers. comm.). Woodstock domestic ewes with lambs sired by feral rams were always recovered in the muster (Latter pers. comm.). During mustering the feral sheep were often rounded up with the domestic stock, but always escaped when attempts were made to drive the mob out of the feral sheep's territory (S. Spencer-Bower pers. Comm.).

[Page 22] These features plus the fact that most of the hack country occupied by the feral sheep usually only had wethers run on it suggests relatively little if any genetic influence on the feral flock by domestic sheep, at least in recent times.

[Page 23]

CHAPTER 4

PHYSICAL CHARACTERISTICS AND GROWTH

A. APPEARANCE.

Woodstock feral sheep are very open faced and have long woolless legs. The face and legs having a short hair coverage. Most adult rams have horns which spiral out from the head, but most ewes do not have horns. Rams have a distinct 'Roman nose' hut ewes are fairly straight nosed. The

sheep generally have a tidy appearance with relatively even wool coverage over the woollen areas of the body. Most are dag free despite long woolly tails and woolly rumps.

There is some variation in the cleanliness of the wool (Chapter 5). Some sheep were very clean indeed, but most have a grey appearance due to the collection of dirt, sand, and vegetable material in the wool.

Most sheep seen were white. A few were seen with the odd black patches on the fleece, black or exhibiting the badger face pattern.

The Woodstock feral sheep give the impression of a wild animal coping well with its environment rather than being the worse for lack of management by man.

B. PIGMENTATION.

Of 150 sheep sightings, 146 were white, 5 were black or predominantly black, 5 were badger faced and 3 had black patches. Many of the white sheep examined had small black spots on the ears and one ewe also had a black spot on the top of its nose.

The gene for white is completely dominant in the Merino (Hayman and Cooper 1965).

[Page 24] Black sheep are recessive homozygotes. The badger face pattern was considered by Roberts and White (1930 – cited in Ryder and Stephenson 1968) to depend on the presence of a single dominant gene that changes recessive colour into badger face, but has no effect on white sheep or on dominant colours.

Ryder and Stephenson (1968) described the badger face pattern as having the main characteristic of a white area between the eyes which shades into a pigmented lower jaw and belly, but the pattern showing considerable variation. The rest of the body is white.

Two Woodstock variations were seen. Both have a pigmented lower jaw and mouth area, ears, belly and legs. But one variation has pigmentation above the eyes while the other has black stripes across the eyes (Figure 3). The badger face pattern is found in many other sheep breeds including the Soay, Cheviot and Welsh Mountain breeds (Ryder and Stephenson 1968). A reversed badger face gene which gives a mirror image of the badger face pattern can also be found in Merinos (Dolling 1970).

The black sheep at Woodstock were all seen in Area I and all the badger faced sheep were seen in Area II (Fig. I). If the badger face gene does change recessive black to badger face, then the badger face gene cannot be very prevalent in Area I. Badger faced individuals or those carrying the gene may have been shot out of this area, have never reached it or have been unsuccessful in spreading it through the sheep population of this area. The genetics of sheep pigmentation types is very complex (Ryder and Stephenson).

[Page 25] Three sheep were seen with black patches of wool on the shoulder and one prenatal lamb had a pigmented area on the ventral side of the neck. These effects are probably due to some recessive gene belonging to a series of genes for irregular spotting, patches of pigment and piebald effects (Ryder and Stephenson). I saw no good examples of pie-baldness in these sheep, though Mr L Latter recalls seeing some in the past. It is possible that the incidence of badger face, black and piebald sheep in the Woodstock feral population has been reduced over the years as hunters and cullers may have been biased towards shooting the more striking individuals or may just be a natural loss as population numbers have dwindled.

I do not know of the badger face phenotype being identified and reported in any of the other feral Merino flocks of New Zealand. One possible badger face sheep out of 907 was reported in the Campbell Island feral flock by Wilson and Orwin (1964).

C. HORNEDNESS.

The incidence of horn growth in males and female sheep varies with the breed. Merino rams are generally horned, but hornedness in Merino ewes varies from flock to flock. Dolling (1960b) found horned ewes varied from 6–25% of the ewe population in a number of unselected Australian Merino flocks. Merino ram horns are triangular in cross section, but ewe horns are flat and goat-

like and don't grow very long. Merino rams and ewes occasionally have scurs. Horns grow continuously throughout the life of the sheep, though the rate of horn growth decreases with age.

[Page 26] Three genes: P, P¹, and p effect hornedness in Merinos. These alleles are at one locus or 2 pairs of alleles are at closely linked loci (Dolling 1961).

P is the gene for polledness in both males and females. P¹ is the gene for horns in both males and females. The gene p gives horns in males but only knobs or scurs in females.

P is incompletely dominant to P¹, but dominant to p. P¹ is dominant to p (Dun and Marrant 1962). P may also be incompletely dominant over p (Dolling 1960a).

All large rams seen at Woodstock were horned. But 3 male hoggets were shot which had no horn expression. Other rams of the same age had significant horn growth (Table 3). Only 1 ewe was seen to have horns. This ewe was also black. All other ewes examined had short bony knobs on the skull at the horn sites which indicates a homozygous pp condition (Dolling 1950b).

The hornless hoggets examined had bony knobs also at the horn sites which indicates a polled heterozygous Pp condition: as homozygous PP rams usually have clean depressions in the skull at the horn sites (Dun and Marrant). However it is generally accepted that there is some variation in appearance with each gene combination. The low incidence of true ewe horns in the Woodstock population indicates that the P¹ gene is rare in these sheep or fails to express itself in a heterozygous condition. Woodstock rams with horns are therefore probably homozygous pp.

Table 3 shows horn length and spread for each ram shot and shows that most horn growth occurs in the first year. Horn spread varies with the closeness of horn curl to the head. Left and right ram horns were symmetrical to the nearest cm for length and spread in all cases. However 1 young ram [Page 27] was seen with only one horn. It was a member of a mob of 19 sheep including 4 more mature rams with greater horn growth and may have lost the horn in a fight with one of the heavier rams.

D. GROWTH.

Four foetuses estimated to be at least 140 days old weighed 3.5kg (2 females) and 4.0kg (1 female and 1 male). These lambs would have had birth weights close to any well-bred fine woolled Merino.

A lamb shot when about 6 weeks old weighed 20kg. From Figs. 4–7 the most rapid growth rate occurs until the sheep are 8-9 months old and rams are generally larger and heavier than ewes though there is some overlap. There is no significant sex difference in Merino foetal weights (Stephenson and Lambourne 1960). From Fig. 4 rams reach maximum weight by about 2 years. Adult ram weight varied from 43kg–52kg.

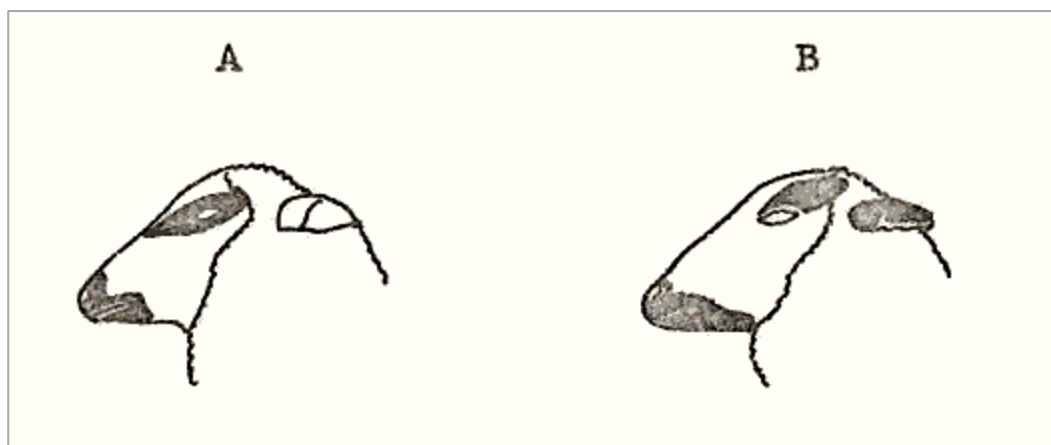
Coop and Clark (1960) found that Merino ewes of South Island high country flocks do not increase their body weight after the first mating. High country ewes first mate as 2-tooths but most Woodstock ewes probably first mate as hoggets (Chapter 6), so probably attain their maximum weight in their first year. But the mean Woodstock ewe body weight of 44kg is in excess of the 33kg–39kg means for high country ewe flocks found by Coop and Clark.

Wilson and Orwin (1964) found a body weight range of 32kg–45+kg for feral ewes of Campbell Island. The lightest Woodstock ewes I weighed were 34kg each. One was weighed in July and 2 in August and all 3 had young lambs.

[Page 28] The heaviest female was a pregnant 3-year old of 56kg (foetal wt. = 4kg) weighed in May. Figure IV shows considerable weight variation between pregnant and lactating ewes of 15kg or 30% of the mean live pregnant weight, discounting all visceral organ and foetal weights carried by the ewes (eviscerated weight) the body weight of lactating ewes is 35% less than pregnant ewes. Lactating ewes had the least fat reserves.

This loss is due to the added stress of foraging enough feed for maintenance of the ewe and production of milk for the lamb(s). Ewes with lambs need to increase their grazing time to meet this demand (Arnold 1960). From Figures 5–7 the sheep obtain their adult body height, length and chest girth measurements between about 1–1.5 years.

FIG.3 BADGER FACE VARIATIONS



[Page 29]

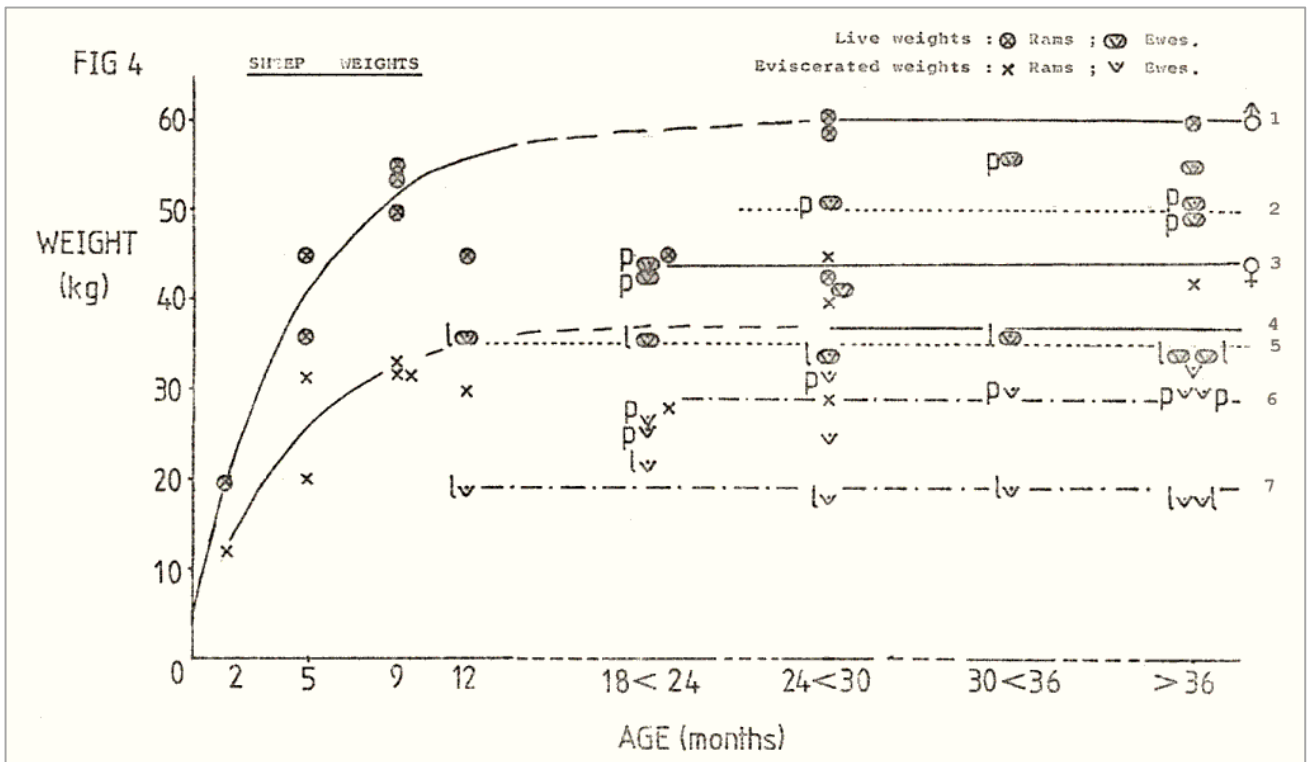
TABLE 3

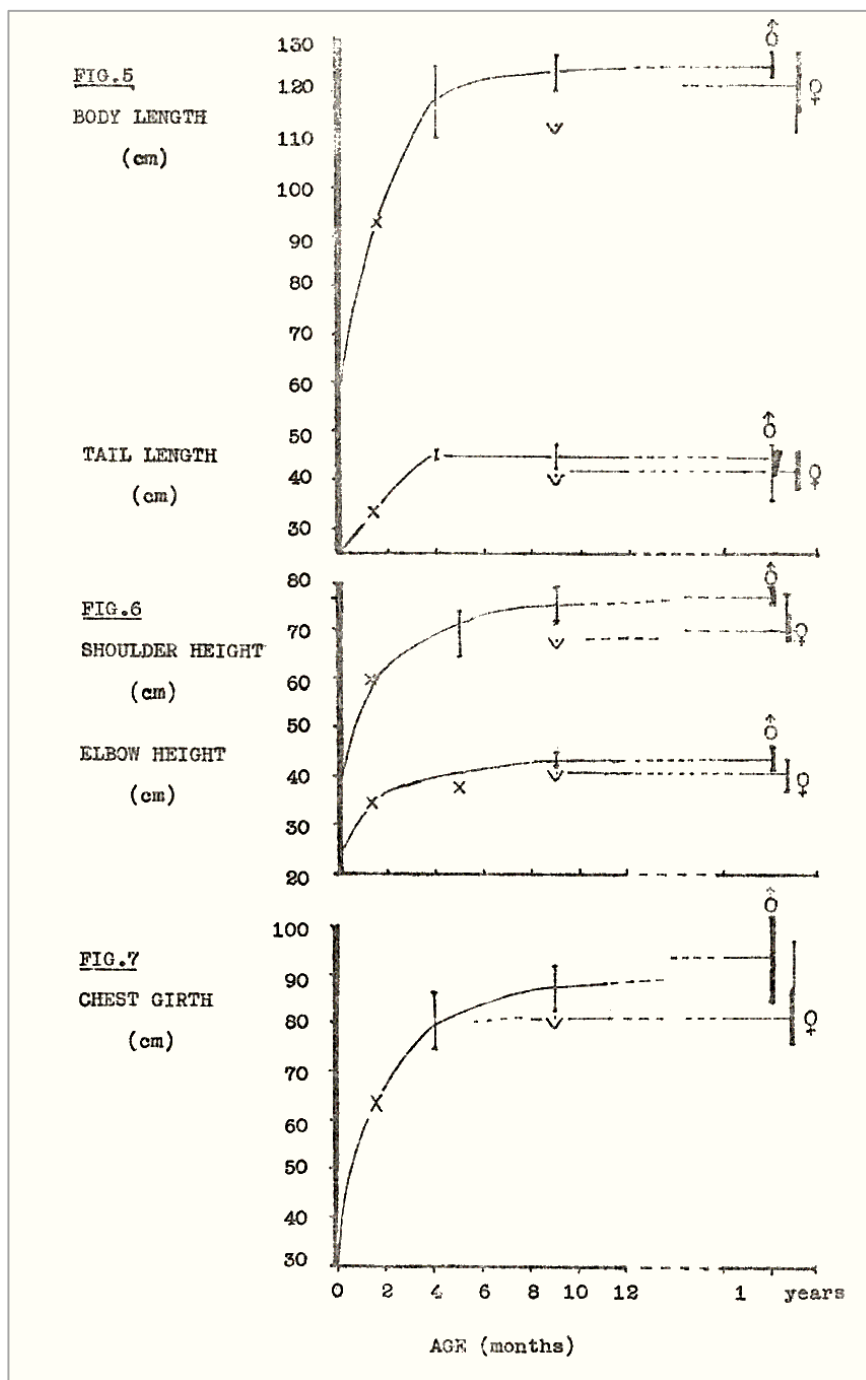
<u>HORN GROWTH IN RAMS</u>						
No.	Approximate Age by Tooth eruption state (Months) and Annuli		Horn length (cm)	Horn span (cm)	Single horn: Spread/length	
(i)		(1.5)	-	-	-	
(ii)	}	M_1	(5)	25	31	0.6
(iii)				0	0	0
(iv)				0	0	0
(v)	}	M_{12}	(8-12)	0	0	0
(vi)				36	40	0.6
(vii)				41	50	0.6
(viii)				46	42	0.5
(ix)	}	$I_{12} M_{12}$	(22-30)	53	40	0.4
(x)				62	60	0.5
(xi)				67	62	0.5
(xii)				72	49	0.3
(xiii)	Full Mouthed	3-4 yrs	67	50	0.4	

Rams (iii) - (v) are hornless.

- P Pregnant ewe.
- l Lactating ewe.
- 1 Mean ram live weight.
- 2 Mean pregnant ewe live weight.
- 3 Mean ewe live weight.
- 4 Mean eviscerated ram weight.
- 5 Mean lactating ewe live weight.
- 6 Mean pregnant ewe eviscerated weight.
- 7 Mean lactating ewe eviscerated weight.

FIGURE 4





CHAPTER 5

WOOL AND SKIN CHARACTERISTICS

This chapter deals with the wool and skin characteristics of the Woodstock feral sheep and some comparisons with commercial Merinos are made.

(i) WOOL FIBRE DIAMETER.

The mean fibre diameter for the sample was $20 \pm 2 \mu\text{m}$. No trends due to age or sex are apparent (Table 4) though the lamb (a) had the highest fibre diameter variation due to the retention of some kempy birth coat fibres which are generally shed within a few months after birth. The coefficient of variation of fibre diameters for the older sheep in the sample varied from 14-23% which is low to high but encompasses the expected commercial Merino range of 15-20% (Whitaker and Rudge 1976).

There is some variation in the distribution of fibre diameters for individual sheep and the degree of skewness to fine of fibres (Fig. 8).

Most fibres varied in diameter by 1 or 2 microns along their length, but some fibres showed considerable variation in diameter along their length associated with bumps and kinks in the fibre (Fig. 9).

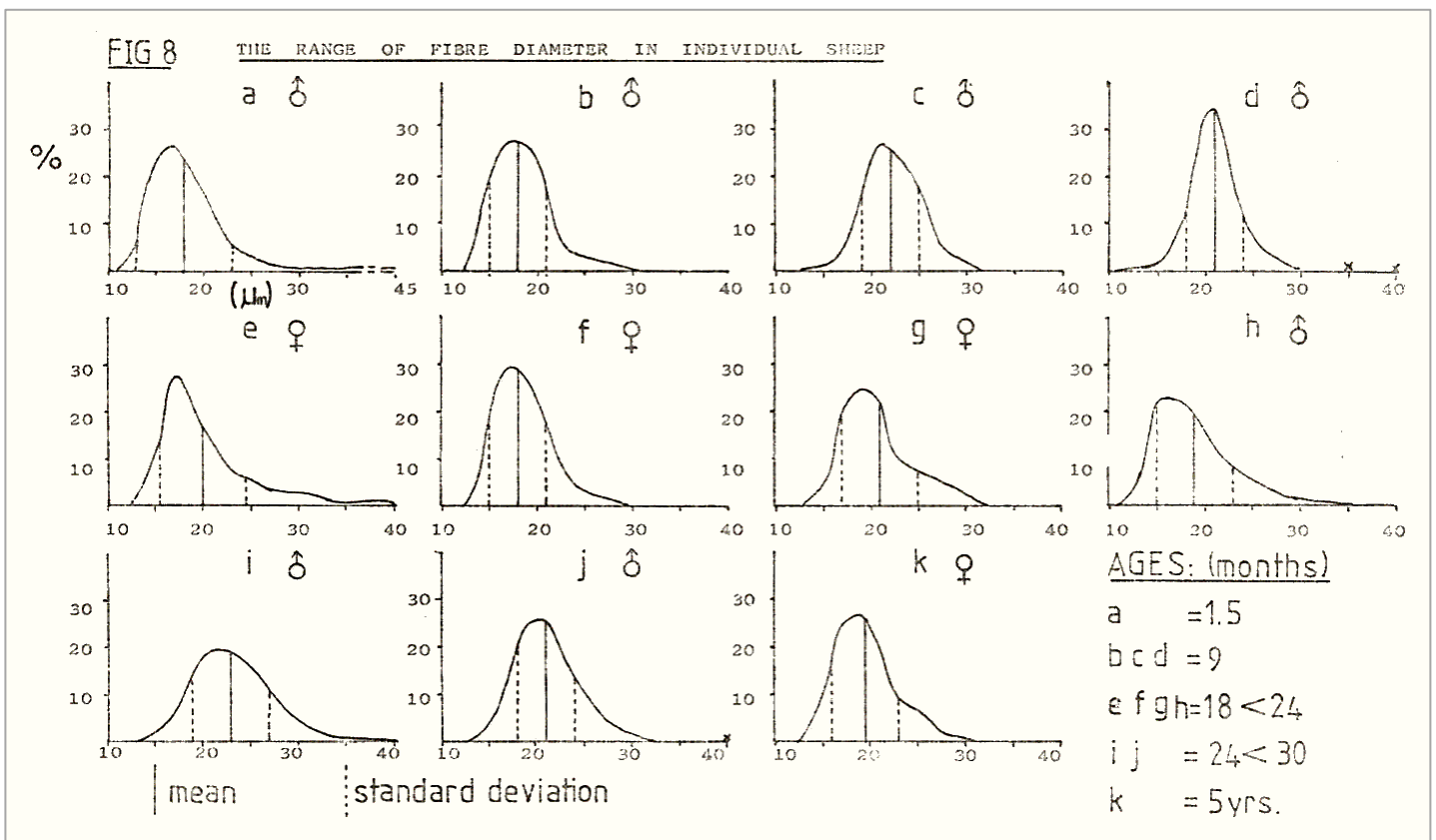
These fibre types may be due to some change in the follicles crimping or growth mechanisms and were not counted in the construction of mean fibre diameter data (Table 4).

The mean fibre diameter for these sheep is compared with that of other breeds and strains in Table 5.

(ii) FIBRE MEDULATION AND PIGMENT.

The occasional fragmented medulation type fibres (<1%) were found in some wool samples. The most were seen in the lambs' wool sample and were generally thick, probably primary fibres which are normally shed 2-3 months after birth (Plate 1).

[Page 34] FIG 8. THE RANGE OF FIBRE DIAMETER



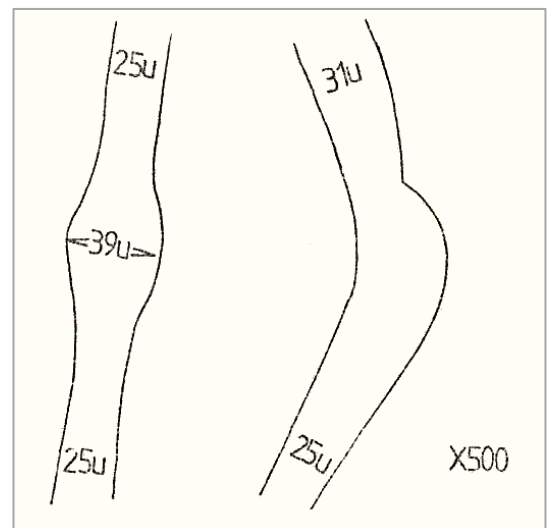
[Page 35]

FIG.9 MAJOR VARIATIONS IN FIBRE DIAMETER

Some wool fibres have bumps and kinks in them as shown [on the right]. Most fibres vary in diameter along their length by one or two microns.

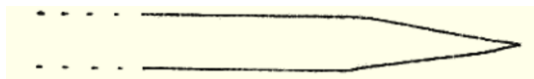
[Page 36]

A few pigmented fibres (< 1%) were found in some of the mid side wool samples. But up to 3% of the sample fibres from the 2 badger faced sheep (b, f) were pigmented.



(iii) SHED FIBRES.

Wool fibres taken from a ewe in the process of shedding its fleece were found to have attenuated roots indicating gradual cessation of fibre growth by the wool follicles. Shed fibres 'break off' at skin level.



Drawing of the attenuated root tip of a shed fibre, (X 500).

(iv) CRIMP, BULK AND FOLLICLE GENOTYPE.

Individual wool fibres are highly crimped but typical Merino staple crimp is lacking. Different wool types vary in their ability to resist compression primarily due to the crimp structure of individual fibres which is set by the wool follicle curvature genotype (Watson, Jackson and Whiteley 1977).

The results of bulk (resistance to compression) and resilience (ability of wool to return to original form after compression) tests for individual sheep are shown in Table 4.

The sample mean for bulk compression = $31.4 \pm 2.7 \text{ gcm}^3$ and resilience = $10.2 \pm 0.7 \text{ gcm}^3$ which are high wool values. The wool follicles were generally found to be at an angle of between 45° and 90° from vertical with the fibres forming discrete bundles which protrude from the skin surface at a common orifice (Plate 2).

Though the bulbs of neighbouring follicles are deflected in different directions, the fibres of a bundle tend to bend in [Page 37] the same plane in unison with low degree of tanglement (Plate 2) and are also crimped in the same dimensions outside the common orifice. However, fibres from adjacent orifices do not bend in the same direction at similar levels above the skin surface, hence the lack of staple crimp in the fleece.

The follicles of lamb skin were found to be more vertical than in the older sheep and the fibre bundles were generally straighter and more tangled. This arrangement appears to be associated with lower bulk properties, though resilience is normal (Table 4(a)).

(v) THE FOLLICLE POPULATION.

The mean ratio of secondary to primary follicles (S/P) for the population sample of 10.5 ± 1.0 is low for commercial Merinos and is associated with a low follicle density of 50.9 ± 8.7 per mm^2 . However there is considerable individual variation in S/P ratio and follicle density as shown in Table 4. When analysing wool follicle population data the age and nutritional state of the sheep must be considered as the abdominal fullness of an animal at the time the midside biopsy is made will affect the inter-follicle distance and so the follicle density per mm^2 of skin. Optimal feed conditions were available to the sheep at the time of sampling and all sheep were in good condition.

The total complement of wool follicles of a sheep does not change after birth, thus young sheep have higher follicle densities per mm^2 than older sheep, as shown for the lamb (a) in Table 4. But the S/P ratio remains constant throughout the life of the sheep.

Primary follicles (which are the first to develop in the foetus) were generally readily distinguished in transverse skin sections from secondary follicles by their association

[Continued on page 40]

[Page 38] TABLE 4. WOOL FIBRE DIAMETER BULK AND RESILIENCE AND FOLLICLE RATIOS, DENSITY AND DEPTH

TABLE 4

WOOL FIBRE DIAMETER BULK AND RESILIENCE AND FOLLICLE RATIOS, DENSITY AND DEPTH

AGE (months)	SEX	MEAN FIBRE DIAMETER (u)	COEFFICIENT OF VARIATION	FOLLICLE S/P	FOLLICLE DENSITY (mm ²)	FOLLICLE DEPTH (u)	RESISTANCE TO COMPRESSION (BULK) (gcm ²)	RESILIENCE (gcm ²)	
(a)	1.5	M	18.5 ± 4.54	24.6	9.2	61.4	1355 ± 98	23.7	9.8
(b)	9	M	18.3 ± 2.99	16.3	11.0	42.7	-	30.9	9.4
(c)		M	20.9 ± 2.92	13.9	9.6	34.0	1311 ± 107	33.7	10.6
(d)		M	22.3 ± 3.18	14.2	11.0	40.6	1346 ± 156	34.7	11.8
(e)	18-24	F	19.9 ± 4.60	23.1	11.8	37.6	1329 ± 127	32.4	10.3
(f)		F	18.1 ± 2.77	15.2	10.1	35.0	1078 ± 110	32.4	10.4
(g)		F	20.6 ± 4.03	19.5	8.5	29.2	1355 ± 132	32.5	10.5
(h)	24-30	M	18.8 ± 4.03	21.4	12.0	44.0	1302 ± 159	30.8	9.0
(i)		M	23.2 ± 4.22	18.2	10.5	24.0	-	30.8	9.6
(j)		M	20.9 ± 3.32	15.9	10.4	39.1	1170 ± 122	31.6	10.5
(k)	5 years	F	19.5 ± 3.45	17.7	11.2	29.9	-	32.0	9.8
No.=11 sample mean			20.1 ± 1.59	18.2 ± 3.6	10.5 ± 1.05	38.0 ± 9.9	1281 ± 85	31.4 ± 2.7	10.2 ± 0.7

[Page 39] TABLE 5. EXPECTED MEAN VALUES FOR SKIN BIOPSY DATA OF SOME BREEDS AND STRAINS OF SHEEP

TABLE 5

EXPECTED MEAN VALUES FOR SKIN BIOPSY DATA OF SOME BREEDS AND STRAINS OF SHEEP

BREED AND STRAIN	FIBRE DIAMETER (u)	SECONDARY/ PRIMARY FOLLICLES	FOLLICLE DENSITY per mm ²	SOURCE	
MERINO	fine 20-22	20	70	Adapted from : Ryder and Stephenson (1968). Clark and Carter (1957a). KrishnaRao, Schinckel and Clarke (1960).	
(commercial)		medium 23-26	22		65
		strong 27-30	17		55
feral Woodstock	20 ± 2	10.5 ± 1	38.0 ± 9.9	This report.	
feral Arapawa I.	21	5.2		Whitaker and Rudge (1976).	
CORRIEDALE (Merino X British)	32	10.8	29	Ryder and Stephenson (1968).	
CAMPBELL ISLAND (Merino X British)	20	4.5		Whitaker and Rudge (1976).	
ROMNEY MARSH (British)	35	5.5	20	KrishnaRao, Schinckel and Clark (1960).	
Indian Breeds	26-60	1.2-3.5	6-16	Narayan (1960).	

[Page 40] with a bilobed sebaceous gland and sweat duct (Plate 3). From Table 4 there is some variation in follicle depth in the skin so follicle population counts are best facilitated by taking transverse sections of skin at different depths and finding the section which shows the most follicles clearly.

In the foetus primary follicles develop in groups of 3 (triads) with secondary follicles developing later clustered in groups between the primary follicles of a triad (Ryder and Stephenson 1968).

Plate 4 shows a typical transverse section of these follicle groups in Woodstock Merinos. The primary follicles are arranged in rows across the skin with the sebaceous glands and sweat ducts arranged on the same side of each follicle and the secondary follicles clustered in groups on the opposite side of the primary follicles, though it is difficult to distinguish distinct triad groups.

This Merino type follicle arrangement is also found in other sheep breeds such as the Drysdale, Romney and Mouflon (*O. ammon*) (Ryder and Stephenson 1968).

The follicle density and S/P ratio of Woodstock sheep are compared with other breeds and strains in Table 5.

(vi) WOOL GROWTH.

The mean staple lengths for midside samples from 11 sheep are shown with standard deviation and variance in Table 6. These sheep were shot in February, March and April. Note the large variance in the staple lengths from 3 ewes (f, g, k) compared to the rest of the sample.

[Facing page 40]

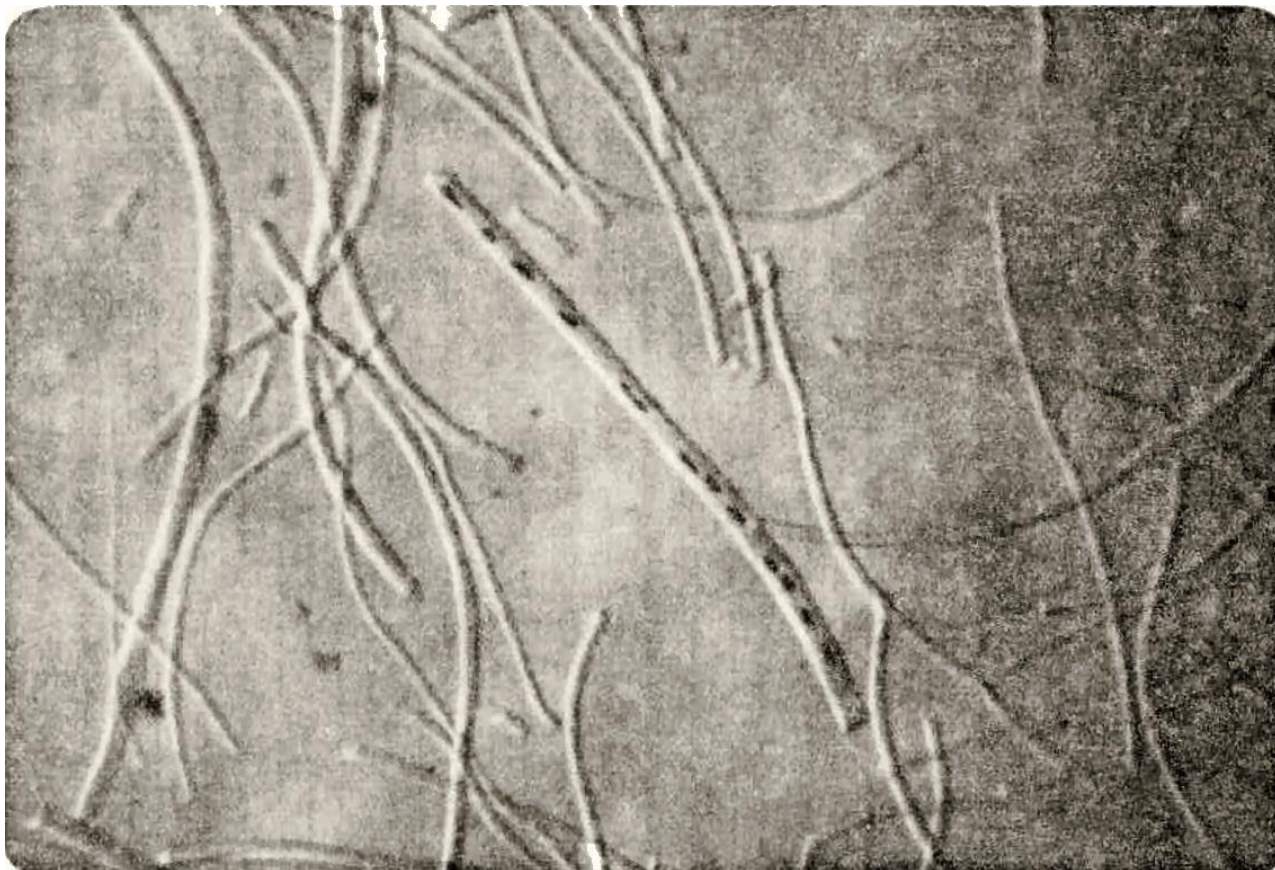


PLATE 1. Wool fibres in profile (modulated fibre @ centre) (X82)

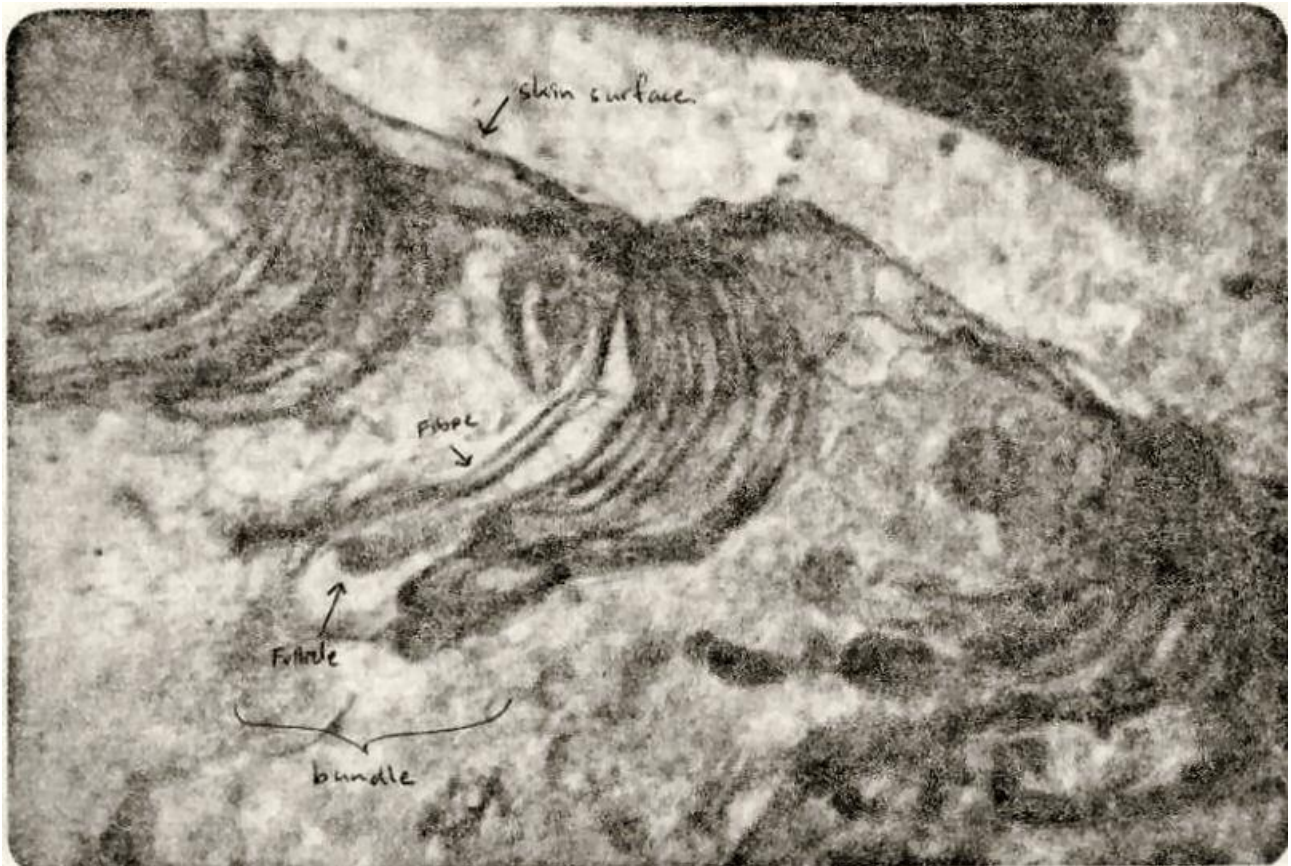


PLATE 2. Groups of follicles and fibres in profile. (X 82)

[Facing page 41]

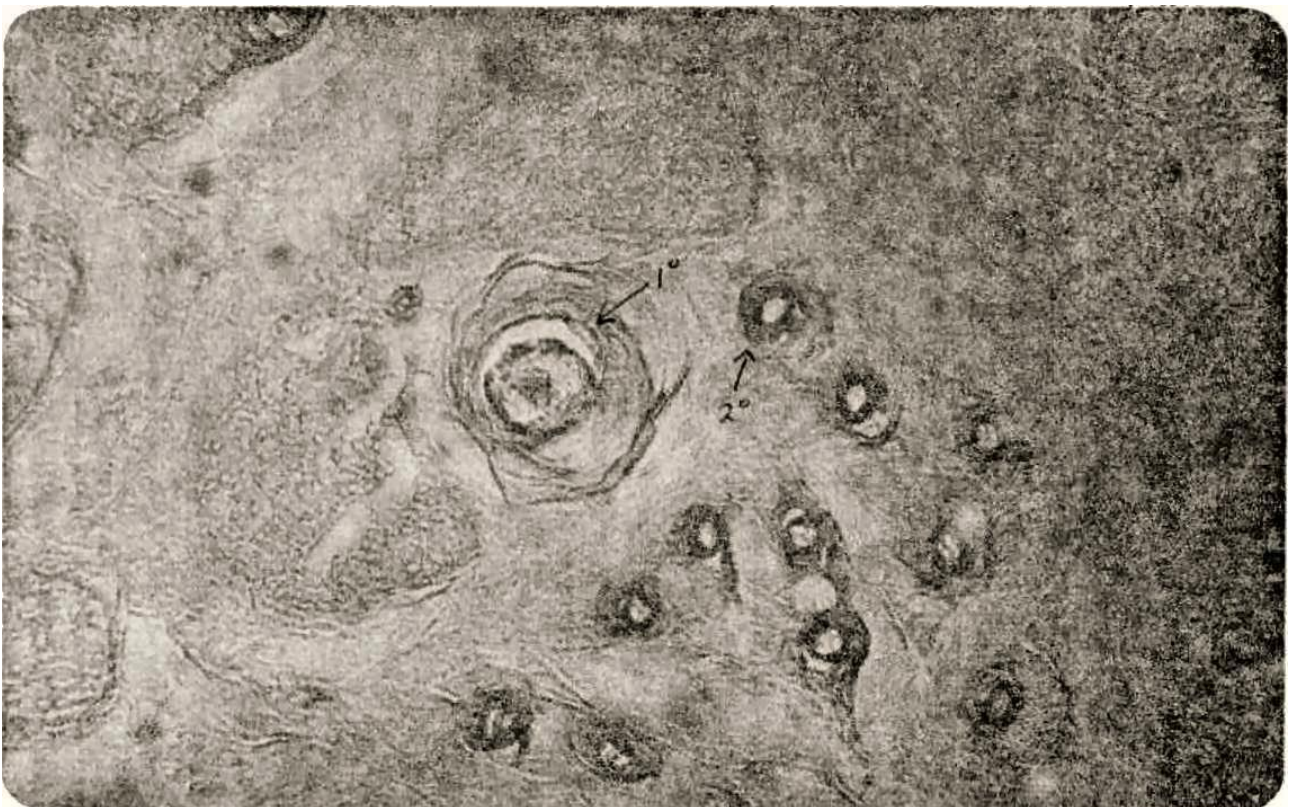


PLATE 3. A group of 13 secondary follicles and 1 primary. (X 280) T. S.

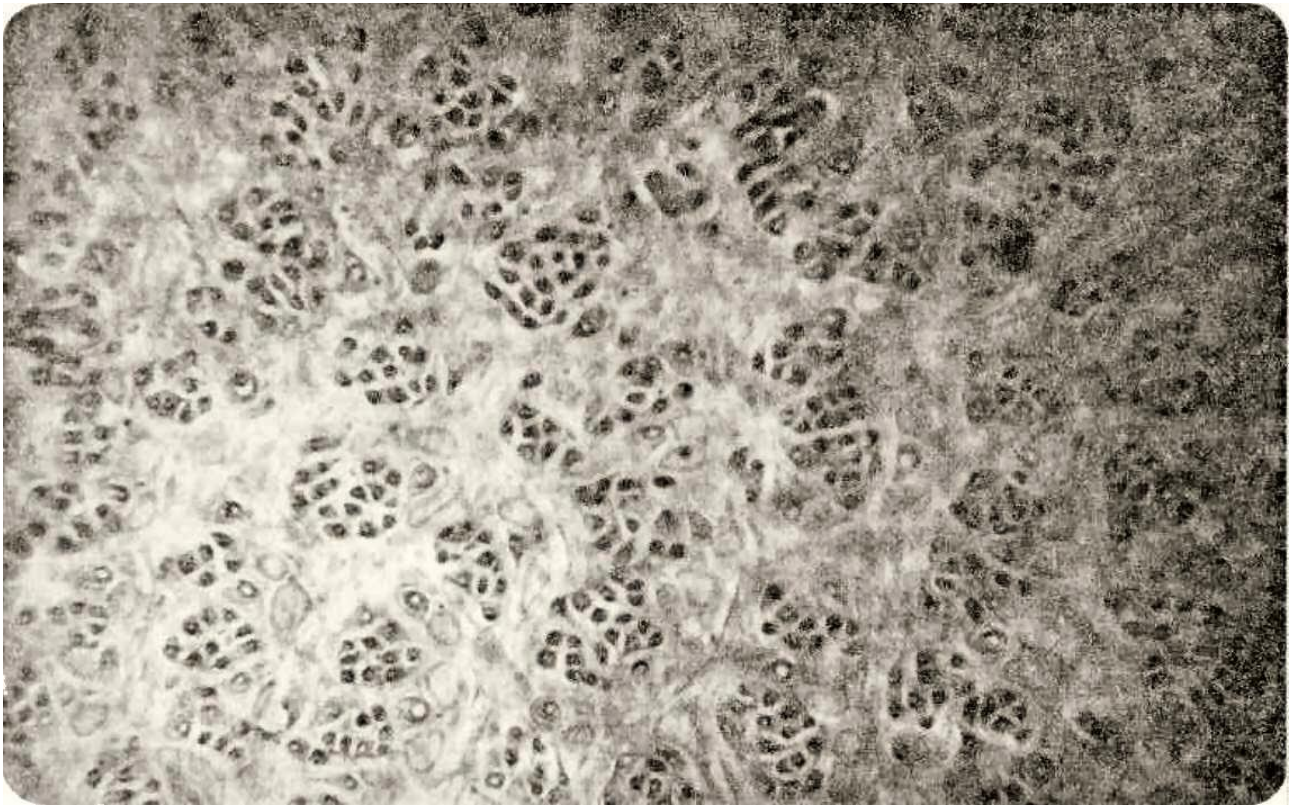


PLATE 4. Groups of primary and secondary follicles. T. S. (X33)

[Page 41]

TABLE 6. MEAN STAPLE LENGTH AND VARIANCE

<u>TABLE 6</u>				
<u>MEAN STAPLE LENGTH AND VARIANCE</u>				
SAMPLE		SEX	MEAN STAPLE LENGTH (mm)	VARIANCE
Lamb	a	M	36 ± 6	35
Hoggets	b	M	37 ± 8	61
	c	M	43 ± 5	23
	d	M	41 ± 5	29
	e	F	27 ± 4	19
2 Teeths	f	F	71 ± 11	113
	g	F	45 ± 15	224
	h	M	49 ± 6	38
	i	M	54 ± 8	58
4 Teeths	j	M	79 ± 9	73
	k	F	39 ± 16	251
Full Mouthed				
Sample mean = 49 ± 15				

From Table 6 sheep e-k were older than 18 months when shot (see Key Fig. 8) and are therefore expected to have shed their fleeces in the previous spring. The variation in mean staple lengths of these sheep probably reflects when they shed their flank wool as well as individual variation in rate of wool growth.

The large variance in staple lengths for f, g and k is due to a proportion of exceptionally long but narrow staples in the individual samples which were probably not shed with the rest of the fleece and thus represent more than one year's wool growth.

[Page 42] Field measurements of staple lengths from various body regions of autopsied sheep revealed different rates of wool growth for different body regions with the variations more marked in ewes than rams.

Back and flank wool was generally shorter than shoulder, neck or rump wool. For different ewes, shoulder wool was estimated to be between 0-50% and rump wool 30-300% longer than midside flank wool. Ewes generally only had 1 or 2 cm of belly wool growth. Some ewes had long trailing rump wool which probably had not been shed for some years. The occasional ewe also had very long shoulder wool as well as rump wool but relatively short flank and back wool. It therefore seems that some ewes have a greater ability than others to shed wool annually and the most susceptible regions to wool loss by shedding or fibre breakage are the back, flanks and belly.

Rams generally had a more even wool coverage with shoulder wool 0-20% and rump wool 30-100% longer than midside flank wool. Belly wool was generally about the same length as flank wool.

Greasy fleece weights of 6 sheep are given in Table 7.

(vii) CLEAN WOOL YIELD.

The percentage by weight of wool, grease, dirt and sand, and vegetable matter for midside wool samples from 11 sheep are shown in Fig. 10. The lambs clean wool yield is high as only negligible amounts of sand, dirt and vegetable matter had accumulated in its fleece between birth and when it was shot.

The mean clean scoured wool yield for the older sheep of the sample is 38±9% by weight.

Grease, dirt and sand account for 51±8% and vegetable matter 11±4% by weight of the greasy fleece weight.

[Page 43] Dirt and sand combine with the wool grease and cause the fibres to matt together which gives the fleece a grey appearance. The variation in dirt and sand content probably reflects the time spent by individual sheep on erosion sites.

Vegetable matter in the wool consisted mainly of grass *Agropyron scabrum*, *Marrubium vulgare*, *Acaena* sp, hook grass (*Acinia* sp) [*Uncinia?*], gorse thorns (*Ulex europaeus*) and bits of seeds; grass stems, twigs and small leaves of shrubs and trees which get caught in the fleece as the sheep pass through bush, scrub and tussock grass area.

Sex	Age	Greasy fleece wt. (kg)
F	} 5-12 months	1.7
M		2.4
M		2.2
F	} 3-4 years old	2.0
M		2.9
F		3.6

fibre in the skin (Fraser and Short 1958) so the variation in follicle depths within individual sheep shown in Table 4 may be sufficient to account for the variability in fibre diameter within each sample. Excluding the lamb data (a), from Table 4 there is the suggestion of a trend of increased fibre diameter standard deviation with increased follicle depth standard deviation but the sample size is too low to state this with any certainty.

Larger fibre producing breeds have deeper follicles than fine woolled sheep (Fraser and Short 1958) so a relationship between mean fibre diameter and mean follicle depth in individual sheep of a population could be expected but the small sample size excludes any clear relationship here.

From Table 4, a high variation in follicle population data within the Woodstock flock is apparent.

The sample mean S/P value of 10.5 ± 1.05 is low when compared to the expected ratio of present day commercial Merino types (Table 5). However when sampling sheep from 22 different Australian flocks Carter and Clarke (1957) found individual S/P values to range from 10.7–46.1, though the fine Merino range was 11.2–32.8. Turkish Merinos also have a low S/P value of 10.7 (Ryder and Stephenson 1968).

The standard deviations for Carter and Clarke's populations ranged from ± 0.20 to ± 1.41 using 30 and 20 specimens per population respectively.

[Page 47] So Merinos show considerable variation in interpopulation S/P values with the Woodstock population exhibiting a low S/P type.

Carter and Clarke found individual Australian fine Merino follicle densities to range from 30–118 per mm^2 , but the standard deviation for a population sample never rose above ± 2.43 . Therefore the Woodstock mean of 38.0 ± 9.9 though low for a fine Merino population is not exceptional, but the high standard deviation probably is.

Fleece weights, fibre diameter, fibre population density, the degree of fibre and staple crimp, staple length and many other wool and body characteristics are highly heritable traits (Young, Newton Turner and Dolling 1960a & b). Therefore the present wool and skin traits of the Woodstock sheep may resemble the original Merino type run in the area 120 years ago.

The higher density fleeces with more uniform fibre diameter and strong crimp of the present commercial Merinos may therefore reflect the extent of modification of the original 19th century Australian fine Merino by artificial selection for fleece type over the last 100 years. Thus the high intrapopulation variability of the Woodstock sheep of fibre diameter, S/P ratio and follicle density and the variability of fibre diameters within individual samples probably reflects the lack of artificial management for fleece type.

Rather than being culled for poor wool characteristics by man, natural selection has operated to improve the flock for survival as a wild population.

Environmental factors, especially poor nutrition may influence fibre diameter and length (Ryder and Stephenson 1966) though Schinckel and Short (1961) considered that poor nutrition in the foetus or in early post-natal life severely [Page 48] restricts the follicles ability to produce fibres, but doesn't have a significant effect on the fibre diameter of Merinos. Other factors may influence wool growth variation in sheep but much of the variation in wool production traits in different strains of Australian Merinos in different environments is attributed largely to genetic variation (Dunlop 1962, Dolling and Moore 1961).

Wilson and Orwin (1964) reported hunger fineness in some poorly nourished feral Merino cross sheep on Campbell Island which are subject to severe winter stress due to lack of feed and a cool wet climate. Poor diet can also reduce skin thickness in Merinos (Lyne 1964) but the climate and nutrition plane at Woodstock are not considered poor enough for any length of time to be major influences on the wool type of the Woodstock population.

The tendency of these sheep to shed their fleeces in the spring or early summer indicates that this ability is important in the fitness of feral sheep, as it is for true wild sheep (*Ovis ammon*, *O. canadensis*). Sheep less encumbered by long continuously growing fleeces will be more agile and probably have a breeding advantage as the main breeding season for Woodstock sheep appears to be over the summer months (Chapter 6) after shedding when most wool round the genitalia will

have been lost. Short wool over the hot months also allows the sheep to sweat more effectively, though panting is the principle method of evaporative cooling in sheep (Brooke and Short 1960).

Certain characteristics of the fleece and skin must be important for the mechanisms of fleece shedding to operate, therefore some of the Woodstock Merino fleece and skin traits [Page 49] of fine, high fibre crimp, high bulk, low fibre density wool and low S/F value may be associated with the sheading ability in Merinos. Commercial Merinos also seem to have a tendency to shed wool fibres in the spring, though generally <1% of the fibres are lost (Ryder and Stephenson 1968). The feral sheep of Arapawa Island tend to shed their entire fleeces in spring and have similar wool and skin characteristics to Woodstock sheep (Whitaker and Rudge 1976).

How the shedding mechanism works in these sheep is not yet fully understood, though as Section (iii) shows shed fibres have attenuated roots and not the bulbous brush ends of cast fibres from wild sheep (*O. ammon*, *O. canadensis*). Attenuated ends resemble stress shed fibres, but the apparent lack of stress factors suggests a distinct process of fibre shedding.

No feral sheep were seen with complete double fleeces, in contrast to several miss-mustered domestic sheep in the area which had very long heavy fleeces and showed no evidence of fibre shedding on any region of the body.

Fibre shedding in wild Merinos may be influenced by environmental factors such as increasing temperature and day length as for true wild sheep (Jewell et al 1974). From Section (vi) shedding may not be complete or even occur regularly in some sheep and some sexual dimorphism in shedding abilities is apparent. The wild Soay sheep of St. Kilda are not always successful in shedding the entire fleece either and exhibit some sex differences in the rate of fibre sheading and regrowth of new fibres (Jewell et al 1974).

Wool production is not high in Woodstock Merinos (some greasy fleece weights are given in Table 7). The lower wool production of ewes to rams of similar age is attributed to [Page 50] retarded wool growth due to the nutritional drain of lactation. Wool growth in Merino rams may occur at a relatively even rate (Ryder and Stephenson 1968) or have seasonal variations (Wodzicka 1960). Early Australian Merinos produced about 3kg of wool annually (Cox 1936) but different strains now vary in wool production which may reflect differences in the efficiency of conversion of food to wool of different strains (Dunlop, Dolling and Kennedy 1960). Wool growth variation may also reflect differences in utilisation or digestion of foods or differences in maintenance requirements or both (Daly and Carter 1955).

The most wool productive sheep within a population tend to have the highest levels of feed intake as well as the highest efficiency of conversion of feed to wool (Schinckel 1960) thus some of the staple length variations between sheep in Table 6 may be explained.

Ewe fleece weights (Table 7) approach the range of fleece weights of 2.3–3.4kg found by Coop and Clarke (1966) for South Island high country Merino ewes. However from Fig. 9 and Section (vii), dirt, sand and vegetable matter adds to the greasy fleece weight of some sheep more than others which is attributed to the range of habitats available. The mean clean scoured yield of $33\pm 9\%$ is comparable to the present day Spanish Merino yield of 35–40% (Ryder and Stephenson 1968).

In summary Woodstock feral Merinos are considered to reflect the early Australian Merino types in their fleece and body characteristics, though some genetic drift due to the particular genetic potentials of the original sheep which became wild at Woodstock and some environmental influence on gene expression must be considered.

[Page 51] Some natural inbreeding may occur in these sheep but this may not affect the wool and skin characteristics in Merinos (Doney 1961).

The wool is not high class by present commercial standards and any sheep with this fleece type, recognised by its blocky appearance and lack of staple crimp, have probably been ruthlessly culled from commercial flocks. However it is interesting to note that the Woodstock sheep have a high bulk fleece type (Section (iv)) which is a valued property as it adds to the appearance and handle of woollen fabrics but has been reduced in the development of some modern Merino strains such as the medium woolled Peppin Merino (Watson et al 1977) which was developed for the dry

inland areas of South Australia, New South Wales and Queensland (Ryder and Stephenson 1968). But selection for higher resistance to compression appears [to] result in the reduction of other desirable traits in Peppin Merino (Watson et al 1977).

By the study of wild Merino populations it may be possible to determine the genetic associations of certain wool and body characters and thus save time in artificial breeding experiments. Herein, may lie one of the values of feral sheep.

[Page 52]

CHAPTER 6

NOTES ON REPRODUCTION

There appears to be some seasonal variation in lambing times, as the most young lambs per ewe were seen in March and April, and July and August (Table 8). Observations over many years by L. Latter and R. Carmichael indicate a peak of births in June and July which may also be true for the feral sheep of Arapawa Island and Omahaki Station (Whitaker and Rudge 1976) and King Country goats (Clark 1974) indicating a January-February breeding season. The normal Merino gestation period is 151 days (Ryder and Stephenson 1968).

Wild sheep of the northern Hemisphere mate in Autumn (November-December) and give birth in the spring (April-June) (Geist 1971) which seems similar to the behaviour of some feral Merinos in New Zealand.

Australian merino ewes appear to have a natural ovulation and oestrus period from January to July though some have isolated periods of ovulation and oestrus at other times of the year (Radford 1964a). The rutting season of Soay and American wild sheep appear to be synchronised by the seasonally changing light regime (Jewell et al 1974, Geist 1971). But constant day length experiments do not seem to abolish the general oestrus rhythm of Merino ewes (Radford 1964b).

The incidence of lambs of similar age in the sheep groups observed (Table 8) suggests that ewes in the same group may come into oestrus at similar times.

Woodstock sheep may be stimulated to form the larger summer groups (Table 8) by ewes coming into oestrus. The adult rams in these groups may stimulate the onset of oestrus in other ewes in the group (Watson and Radford 1960). When most of the ewes in the group have become pregnant and cease to be in [Page 53] oestrus, the larger mobs may fragment into smaller groups observed in the winter months (Table 8).

The formation of larger groups by breeding individuals would reduce the tendency for small groups to become inbred which can have an adverse effect on many fitness characters (Doney 1961).

Woodstock ewes probably first mate as hoggets as Merinos can breed and conceive at 6 months (Ryder and Stephenson 1968) though fertility can be low in ewes that mate when young due to non-conception or high prenatal mortality (Watson and Gamble 1961). The sample of Woodstock sheep shot was too small to evaluate breeding ages and lambing percentages, but of 17 ewes shot (which were not selected for pregnancy or lactation state) 14 were either pregnant or lactating. The only ewe hogget shot was milking a lamb of about 6 weeks.

Commercial Merinos generally exhibit a lambing percentage of between 50–90% depending on climate, season and husbandry practices (Dun 1961). The Woodstock sheep's lambing success probably lies within this range and varies with the severity of winter storms.

Two sets of twins were seen; one in March and the other in April, and a ewe shot in May had foetal twins. While this does not represent a high twinning rate, which in any case is unexpected in Merinos, it is an indication of ewe fertility and level of feed available. All other pregnant ewes shot had only 1 foetus and other lactating ewes appeared to have only one lamb.

The breeding season of other wild ungulates in New Zealand such as thar, chamois and deer have developed short and distinct breeding seasons 6 months out of phase with their Northern Hemisphere counterparts (Caughley 1967, Dixon 1975). [Page 54] New Zealand wild sheep populations including the Woodstock flock have extended breeding seasons but why they tend to

have a peak of births almost in phase with wild Northern Hemisphere ungulates in unclear. However this behaviour does allow for ewes to make the most use of spring and summer growth during their recovery from the stress of lactation.

Though environmental factors such as temperature and light may be involved in the onset of sexual activity in these sheep it seems that these factors do not operate in sheep as well as some goat populations as they do in New Zealand big game mammals. This may reflect the evolution of Merino sheep and goats in equatorial latitudes or the effects of domestication.

[Page 55] TABLE 8

Month seen	No. in Group	AR	Ewes [†]	Hogs	UN	L
February	23	4	8+	6+	4	1
	15	4	5+	5+	3	0
	14	3	5+	4+	2	0
	3	0	2	1Ram	0	0
March	19	5	7	3	0	4 *
	13	3	4+	2+	4	0
April	18	5	6+	3+	2	3 *
	15	0	9	2	0	4
May	8	2	2+	0+	3	1
	6	0	6-	0+	0	0
	3	0	2	1Ram	0	0
June						
July	7	0	4	0	0	3
	4	1	2	0	0	1
August	8	1	1	3Rams	0	3
	4	0	2	0	0	2
September	2	0	1	0	0	1
	8	0	4	1	0	3
	13	0	6	5	0	2
	8	0	3	3	2	0

AR : adult rams, UN : unknown, L : young lambs

† : May include a few hogget ewes. * includes 1 set of twins.

Adult rams were easily recognised even at a distance by their large horns but ewes and hoggets were less easily distinguished. No sheep were seen over 2 days in June when there were some snow storms and low dense mists.

HEALTH

A. TEETH, FEET, AND HORNS.

(i) TEETH.

There was no evidence of paradontal disease in any of the autopsied sheep.* Some sheep had gaps between the teeth where herbage had lodged preventing close contact between teeth. These gaps were generally between premolar 3 and molar 1 of the lower jaws.

One sheep had greatly uneven wear on the lower 3rd temporary premolars due to abnormally long upper premolars grinding them down. Two rams had 1 broken 2nd permanent incisor. The older sheep generally had slightly chipped and cracked crowns on the incisors. 1 ram had a broken 1st molar in the lower left mandible.

No sheep had lost any teeth. However 1 ewe had a short extra tooth jammed between the 3rd premolar and 1st molar of the right mandible. The same ewe had the 3rd incisor of the left mandible erupting abnormally. This tooth was branched, with the main branch erupting between the 1st and 2nd incisors and the other branch erupting up through the palate (Fig. 10).

(ii) FEET,

No sheep had overgrown or deformed hooves. But some had the pasterns bent laterally with elongated nails. This damage was probably incurred coming down the steep shingle screes and rocky outcrops that these sheep travel over. There was no evidence of clinical footrot about the feet or interdental spaces which is often a cause of underrun hooves in sheep (Thomas 1962).

* Suckling (1975) provides a photographic record of the progress of paradontal disease in a sheep.

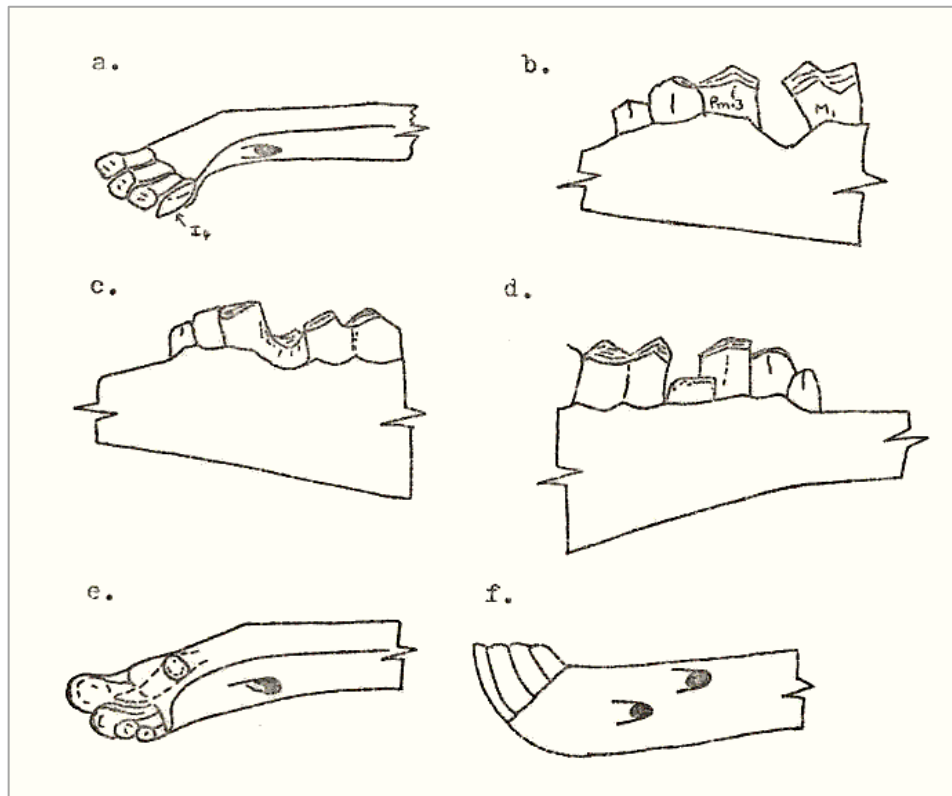


FIG.11 Tooth abnormalities and Jaw foramen variation. (a) I4 twisted 90°. (b) Gap between permanent teeth due to lodgement of foliage. (c) Uneven wear on 3rd temporary premolar. (d) Extra tooth between P3 and M1 in adult ewe. (e) Extra incisor erupting through the palate and between I1 and I2 in same adult ewe as for d. (f) An extra anterior jaw foramen was found in 2 ram hoggets.

Some rams had chipped horns, probably as a result of fighting. One ram had lost one horn completely.

B. PARASITES.

(i) SHEEP KEDS.

All Woodstock feral sheep have sheep keds (*Melophagus ovinus*) which were found all over the woollen area of the sheep but seemed to be most concentrated on the rump.

(ii) LUNGWORM

All sheep except a 6 week old lamb had lung lesions. The lesions were focuses of collapsed lung with numerous eosinophils typical of focal parasitic type lesions caused by the smaller sheep lungworm *Muellerius capillaris* (Hutton pers. comm.).

Generally the level of infestation was low to moderate (Table 9).

(iii) HYDATIDS.

Of the seep autopsied, 8 had small lesions in the liver typical of parasite migratory tracts. The most likely parasite is *Cysticercus tenuicollis*, the larval stage of the hydatid tapeworm *Taenia hydatigena*, which migrates briefly in the liver, and then encysts attached to the peritoneum where it waits to be eaten by a carnivore.

Taenia hydatigena has been found in the cat (Whitaker and Rudge 1976) and feral cats (*Felis catus*) are present at Woodstock.

Growth Stage (and approximate age)	Arbitrary Scale of Infestation					No.
	0	1	2	3	4	
Lamb ~ 6 wks	1	0	0	0	0	1
Hoggets < 1.5yrs	0	7	1	0	0	8
2 Teeth 1.5 < 2	0	3	1	1	0	5
4 Teeth 2 < 2.5	1	2	2	2	0	7
6 Teeth and full mouthed 2.5- 5	0	4	5	0	0	9
<hr/>						30

[Page 60] (iv) EXAMINATION OF ABOMASUM AND CONTENTS.

No parasitic ulcerations of the abomasum were found. The abomasum contents from 2 sheep were inspected in the laboratory but no nematode worms were found.

(v) BRUCELLOSIS LEPTOSPIROSIS AND JOHNES DISEASE. [There is no Table 10.]

Serology	No. samples	Result
<i>Brucella ovis</i>	14	All negative
<i>Leptospira pomona</i>	12	All negative
<i>L. hardjo</i>	12	All negative
Johnes (CF and GD Tests)	8	7 negative 1 suspicious

C. FATNESS.

Hoggets had thick layers of subdermal fat especially round the rump. Older sheep had thinner layers. Some lactating ewes had little or no subdermal fat deposits.

All sheep hid renal deposits with hoggets having the most and lactating ewes the least.

[Page 61] D. SUMMARY.

No lame or sick animals were seen. The sheep keds (*M. ovinus*) were the only external parasites found. Keds have a world wide distribution and also infest the Soay sheep of St Kilda (Jewell et al 1974) and the Campbell Island feral flock (Whitaker and Rudge 1976). Keds are blood sucking wingless flies, the maggots of which are retained in the parents uterus till full grown when they are deposited close to the skin and pupate almost immediately (Toop, Jenkins and McGarry 1955). Infestation was found to be low or zero on shed sheep or shed body regions. Adult keds cling to the wool fibres and the pupae are held in the wool only by the density of the fibres so much of the ked infestation may be lost with the shed fleece, though reinfestation must be fairly rapid.

No lice were found on the sheep which suggests that the population has never been exposed to lice, though sheep can vary in their susceptibility to infestation (Scott 1952). The biting louse *Damalinia ovis* has been found on Campbell Island feral sheep (Whitaker and Rudge 1976).

The lack of gut nematodes and generally low to moderate lungworm (*M. capilaris*) infestation probably reflects the low population density and browsing over reasonably large areas. Grassed feeding areas were not seen to be closely cropped indicating the abundance of feed in the form of grasses and palatable native shrub and small tree tier which the sheep browse on. These conditions are not conducive to large gut nematode infestations. However the extent of my examinations for gut parasites cannot be claimed to show these sheep are clean, but suggests at least a low gut parasite load. Many types of common internal parasites can be hosted by domestic sheep (Cameron 1951).

[Page 62] The lack of lice, disease (Table 11) afflictions such as footrot and mange, and the apparent lack of gut parasites and low level of *M. capilaris* infestation indicates that these sheep are not a serious health threat to local domestic sheep flocks. One sheep returned a suspicious result for the Johnes C.F. (complement fixation) test, though not for the G.D. (gell diffusion) test. Normally for this type of result the tests would be repeated with another blood sample (Hutton pers. comm.) but in this case it was impossible as the sheep was dead.

Some wild Merinos shot by the Forestry Service on Mt Oxford some 10km east of Woodstock were reported to have rickets (Roberts pers. comm.). A deficiency of calcium or phosphorus or vitamin D and magnesium on which they depend could cause rickets (Osteomalacia in adults) in sheep (Nat. Acad. Sci. 1975). No rickety sheep were seen at Woodstock.

When this project was started I knew very little about the Woodstock feral sheep except that they did exist and there was no written information on them. Those involved in feral sheep research were either unaware of the sheep's existence or considered them extinct (Whitaker and Rudge 1976).

Hopefully this project presents some of the interesting characteristics of these sheep which may be of some use in comparison to other feral flocks and to stimulate further research into feral sheep.

The value of the Woodstock population lies in the fact that it is not only one of the countries' oldest and most established flocks but is readily accessible from research centres in Christchurch or Lincoln. The sheep probably resemble the early Australian Merino type brought here in the 18th *[sic]* century and thus give an indication of the extent of modification of this type that has since taken place due to artificial breeding conditions.

As a result of natural selection in wild populations certain genetic wool and body traits which confer some advantage on wild sheep such as the wool shedding ability, reduced wool growth, long legs and light body are expected to appear or remain. Some such traits though interesting to biologists, may not be of much use to commercial sheep breeders interested in high wool and meat production. However once the natural wool casting ability of these wild Merinos is understood, the development of commercial strains with wool that could be plucked by hand at certain times of the year may be possible. But introducing this apparently genetic trait into commercial sheep may be detrimental to the quality or quantity of wool produces. Some other traits such as open facedness seen in the feral sheep which is associated with better hogget growth and higher fertility than woolly faced strains (Whitaker and Rudge 1976) should be noted by [\[Page 64\]](#) sheepbreeders. So the study of wild populations where a ready gene pool of certain associations of traits already exists, may save time in sheep development programmes involving breeding experiments.

Wild sheep populations are also of interest in their own right in their abilities to cope with the environment, parasites, disease and competition with other animals. So a more detailed study of internal parasites, fecundity and shedding mechanisms than allowed for by the time available for this report may be of interest.

The role of feral sheep in the destruction of native forests and the spreading of noxious plants such as gorse (*Ulex europaeus*) are of importance when assessing the merits of maintaining these populations. However, most Woodstock sheep were seen to be feeding on grass and examination of the rumen contents of autopsied sheep indicated that grasses were cropped most of the time. But some sheep were found to have been browsing on the shrub and tree tier (especially *coprosma* sp. leaves and fruits and beech (*Nothofagus*) seedlings) within the forested areas.

How much of the browsed plants seen in the forest were eaten by sheep rather than by deer is difficult to assess, though I consider the present wild sheep population too low to be a real threat to native plant regrowth. The sheep do not appear to heavily browse the vegetation of an area before moving on, but seem to range over the Woodstock back country fairly extensively, though the grassy faces of Areas I and II often have sheep on them.

Feral and domestic animals may be responsible for the occurrence of pockets of gorse especially in the Coal Creek and [\[Page 65\]](#) Foster Stream area. However gorse and sheep were probably brought into the area at the same time by Kinnebrook before 1860, so it hasn't really spread very far. The original lines of Kinnebrook's gorse fence around his hut site can still be seen amongst the gorse cover of the Smuggler Cove area (Fig. 1).

From my observations of the wild sheep groups there appears to be about three times as many adult ewes as adult rams which suggests a high ram mortality, though many ram hoggets were seen. In an attempt to determine longevity I shot the rams with the greatest horn growth from some groups, yet the oldest ram was just erupting its last incisors (I_4) and had 4 growth rings in the cementum of I_1 . Soay rams have a much higher mortality than ewes, which may be accounted for by different growth rates, metabolic rates, nutrient requirements and rutting activity (Jewell et al 1974). However extreme sex differences in mortality are not found in most true wild sheep.

Mortality in American Bighorn sheep (*Ovis canadensis canadensis*) is close to unity for the sexes (Geist 1971).

Rams were seen to feed normally and have full paunches throughout my observations and do not cease feeding over any 'rutting' period. The availability of feed throughout the year is good so there is no reason why rams that have serviced many oestrus ewes cannot recover fully at any time. It is possible that the apparent high adult ram mortality is artificially induced by hunters after good heads, though hunting pressure on the area is not high. But there seems no natural reason why ram mortality should be higher than for ewes.

The oldest ewes shot were 5 years old by tooth annuli-count, however from tooth wear, I am tempted to add 2 or 3 years.

[Page 66] As the Woodstock population does not seem high enough at present to warrant extensive culling, a policy of maintenance of the flock of an acceptable level to the Forestry Service, station management and researchers is recommended as it may serve little purpose in the long run to follow an eradication plan. Wild sheep in, or adjacent to, other parts of the Oxford State forest may pose a more serious threat to the forest but any control or eradication shooting should, involve the Forestry Research Institute and other interested research groups from Christchurch and Lincoln so as much use as possible can be made from culled wild sheep.

[Page 67]

SUMMARY

1) A population of feral Merinos occupy the back country of Woodstock station between the Oxford State Forest and the Waimakariri River gorge in Canterbury. The population is estimated at 2-300 within the boundaries of Woodstock station, but feral sheep are also found within the Oxford State Forest and on other stations bordering the forest.

A total of 30 sheep (13 males and 17 females) of various ages were shot and autopsied. The sheep were observed from February to September.

2) The sheep are light bodied, leggy, open faced, fine woolled Merinos which tend to shed their fleeces in spring or early Summer. The majority of the sheep are white but a few black and badger faced were seen.

3) The sheep are fully grown by 1.5–2 years with rams generally bigger and heavier than ewes. Rams grow curling horns, though the occasional ram and most ewes are hornless.

4) Group size varied between 2 and 23, though mobs of 13-23 were generally seen in summer and early autumn and smaller groups of 2-15 in the winter months. Seasonal variations of group size may be associated with a main summer breeding season which results in a tendency for lambing to occur in winter.

5) From wool and skin samples of 11 sheep mean fibre diameter = $20.1 \pm 1.59 \mu$, mean secondary to primary follicle ratio = 10.5 ± 1.05 , mean follicle density = $38.0 \pm 9.9 \text{mm}^2$, mean follicle depth = $1281 + 85 \mu$, resistance to compression of fibre = $31.4 \pm 2.7 \text{gcm}^3$ and resilience = $10.2 \pm 0.7 \text{gcm}^3$.

Individual fibres are highly crimped but staple crimp is lacking.

[Page 68] 6) The general health of the sheep is good though they are infested with sheep keds (*Melophagus ovinus*), most have the lungworm (*Muellerius capillaris*) and some showed evidence of hosting the larval stage of the hydatid tapeworm *Taenia hydatigena*.

7) It is considered that feral sheep populations such as the Woodstock flock should be maintained at some acceptable level for research purposes.

[Page 69]

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to Mr L. S. Latter and Mr R. K. Losshagen for allowing ready access to the sheep population and to Dr D. F. G. Orwin for making available the facilities of the Wool Research Organisation, Lincoln, and helpful advice in the construction of this report. I am also grateful for the assistance in field work given by Mr G. Hume and M. Bristow. I thank Mr

J. B. Hutton of the Animal Health laboratory, Lincoln, for identifying internal parasites and Professor R. L. C. Prilgrim who identified the sheep keds.

Thanks also go to Mr G. Roberts of the Ashley Forestry Service, Mr C. J. Peckelharing of the Forestry Research Institute, Miss J. Woods and other staff of the Wool Research Organisation, the Spencer-Bower family and Miss R. Henderson.

[Page 70]

REFERENCES.

- Acland L. G. D. 1975 *The Early Canterbury Runs*. Whitcoulls, Christchurch. 4th edition 417p.
- Arnold G. W. 1960 The effect of the quality and quantity of pasture available to sheep on their grazing behaviour. *Australian Journal of Agricultural Research*. 11 : 1034-1045.
- Austin H. B. 1944 *The Merino, Past, Present and Probable*, Grahame Book Co., Sydney. 2nd edition. 247p.
- Brook A. H. and Short B. F. 1960 Regulation of body temperature of sheep in a hot environment, *Australian Journal of Agricultural Research*. 11 : 402-407.
- Cameron T. W. M. 1951 *Parasites of domestic animals : a manual for Veterinary students and surgeons*. Adam and Charles Black, London. 420p.
- Carter H. B. and Clarke W. H. 1957a The hair follicle group and skin follicle population of Australian Merino sheep. *Australian Journal of Agricultural Research*. 3 : 91-108.
- 1957b The hair follicle group and skin follicle population of some non-Merino Breeds of sheep. *Australian Journal of Agricultural Research*. 8 : 109-120.
- Caughley G. 1965 Horn rings and tooth eruption as Criteria of age in the Himalayan Thar *Hemitragus jemlahicus*. *New Zealand Journal of Science*. 8 : 333-351.
- [Page 71] Caughley G. 1967 Growth, Stabilisation and decline of New Zealand population of the Himalayan Thar (*Hemitragus jemlahicus*). Unpublished PhD thesis. Canterbury University. 155p.
- Clark J. M. 1974 Ecology of feral goats (*Capra hircus* L.) in the Southern King country, New Zealand. Unpublished MSc thesis. Canterbury University. 116p.
- Coop I. E. and Clark V. R. 1966 The influence of live weight on wool production and reproduction in high country flocks. *New Zealand Journal of Agricultural Research*. 9 : 165-181.
- Cox E. W. 1936 *Evolution of the Australian Merino*. Angus and Robertson, Sydney. 171p.
- Daly R. H. and Carter H. B. 1955 The fleece growth of young Lincoln, Corriedale, Polwarth and fine Merino maiden ewes under housed conditions and unrestricted and progressively restricted feeding on a standard diet. *Australian Journal of Agricultural Research*. 6 : 476-513.
- Dixon E. H. 1975 *Red deer farming in New Zealand*. Millwood Press, Wellington. 52p.
- Dolling C. H. S. 1960a Hornedness inheritance and polledness of sheep. I The inheritance of polledness in sheep in the Merino. *Australian Journal of Agricultural Research*. 11 : 427-43S.
- 1960b Hornedness and polledness in sheep. II The inheritance of horns in Merino ewes. *Australian Journal of Agricultural Research*. 1 : 618-627.
- 1961 Hornedness and polledness in sheep. IV Triple alleles affecting horn growth in the Merino. *Australian Journal of Agricultural Research*. 12 : 353-261.
- [Page 72] Dolling C. H. S. 1970 *Breeding Merinos*. Rigby Ltd. Adelaide. 266p.
- Dolling C. H. S. and Moore R. W. 1961 Efficiency of conversion of food to wool. II Comparison of the efficiency of the same Merino ewes on two different rations. *Australian Journal of Agricultural Research*. 12 : 452-451.
- Doney J. M. 1961 Effects of Inbreeding on four families of Peppin Merinos. IV The expression of heterosis. *Australian Journal of Agricultural Research*. 12 : 302-569.

- Dunlop A. A., Dolling C. H. S., and Kennedy J. P. 1960 Efficiency of conversion of food to wool in five Merino strains. *Australian Journal of Agricultural Research*. 11 : 576-584.
- Dunlop A. A. 1962 Interactions between heredity and environment in the Australian Merino. I. Strain x location interactions in wool traits. *Australian Journal of Agriculture Research*. 13 : 503-531.
- Dun R. B. 1961 Breeding Merino sheep for higher lamb production. *Wool Technology*. 8 4 9-15.
- Dun P. B. and Marrant A. J. 1962 Identification of Merino rams homozygous for the poll gene. *Australian Journal of Agricultural Research*. 13 : 69-81.
- Fraser A. S. 1952 Growth of wool fibres in sheep. *Australian Journal of Agricultural Research*. 3 : 410-343.
- [Page 73] Fraser A. S. and Short B. F. 1958 Studies of sheep mosaic for fleece type. I. Patterns and origin of mosaicism. *Australian Journal of Biological Science*. 11 : 200-208.
- Geist V. 1971 Mountain sheep a study in behaviour and evolution. *University of Chicago Press*, Chicago. 383p.
- Guthrie Smith H. 1969 *Tutira - the story of a New Zealand sheep station*. A. H. and A. W. Reed, Wellington. 4th edition. 464p.
- Hayman R. H. and Cooper D. W. 1964 The inheritance of black pigmentation in a family of inbred Peppin Merinos. *Australian Journal of Agricultural Research*. 15 : 453-460.
- Howard W. E. 1966 *Control of introduced mammals in New Zealand*. D.S.I.R. information series no. 45. 95p.
- Jewell P. A., Milner C., Morton Boyd J. 1974 *Island survivors : The ecology of the Soay sheep of St. Kilda*. Athlone Press, London. 386p.
- Klevezal G. A. and Kleinenberg S. E. 1967 *Age determination of mammals from annual layers in teeth and bones*. Translated from Russian by J. Salkind, I.P.S.T. Press, Jerusalem. 128p.
- Krishnarao M. V., Schinckel P. G. and Clark W. H. 1960 The wool follicle population of some Indian breeds of sheep. *Australian Journal Agricultural Research*. 11 : 97-104.
- [Page 74] Lyne A. G. 1964 Effect of adverse nutrition on the skin and wool follicles in Merino sheep. *Australian Journal of Agricultural Research*. 15 : 788-801.
- May N. D. S. 1964 *The anatomy of sheep*. University of Queensland Press, Brisbane. 2nd edition. 369p.
- Meteorological observations 1969-1978. New Zealand Meteorological Service.
- Narayan S. 1960 Skin follicle types, ratios and population densities in Rajasthan sheep breeds. *Australian Journal of Agricultural Research*. 11 : 408-426.
- Nay T. (undated) *Technique for examining wool follicles in the skin of sheep*. Division of animal genetics CSIRO Epping.
- National Academy of Sciences, Washington D C 1975 Nutrient requirements of sheep. 5th edition.
- Preece A. 1959 *A manual for histological technicians*. Little, Brown and Co. Boston. 21Sp.
- Radford H. M. 1964a Photoperiodism and sexual activity in Merino ewes I. The effect of continuous light on the development of sexual Activity. *Australian Journal of Agricultural Research*. 15 : 139-146.
- 1964b Photoperiodism and sexual activity in Merino ewes II. The effect of equinoctra light on sexual activity. *Australian Journal of Agricultural Research*. 15 : 147-153.
- [Page 75] Rudge M. R. 1976 Aging domestic sheep (*Ovis aries* L.) from growth lines in the cementum of the first incisor. *New Zealand Journal of Zoology*. 3 : 421-424.
- Ryder M. L. and Stephenson S. K. 1968 *Wool growth*. Academic Press, London and New York. 805p.
- Schinckel P. G. 1958 The relationship of lamb birth coat to adult fleece structure in a strain of Merino sheep. *Australian Journal of Agricultural Research*. 9 : 567-578.

- Schinckel P. G. 1960 Variation in feed intake as a cause of variation in wool production of grazing sheep. *Australian Journal of Agricultural Research*. 11 : 585-594.
- Schinckel P. G. and Short B. P. 1961 The influence of nutritional level during prenatal and early postnatal life on adult fleece and body characteristics. *Australian Journal of Agricultural Research*. 12 : 178-202.
- Scott M. T. 1952 Observations on the bionomics of the sheep body louse (*Damalinia ovis*). *Australian Journal of Agricultural Research*. 3 : 60-67.
- Stephenson S. K. and Lambourne L. S. 1960 Prenatal growth in Romney cross Southdown cross and Australian Merino sheep I. Introduction and external growth patterns in the two breeds. *Australian Journal of Agricultural Research*. 11 : 1043-1063.
- [Page 76] Stephenson S. K. 1962 Prenatal growth in Romney cross, Southdown cross and Australian Merino sheep. II Carcass conformation in the two breeds. *Australian Journal of Agricultural Research*. 15 : 733-766.
- Stevens P. G. 1961 *Sheep Part 2 - Sheepfarming Development and Sheep Breeds in New Zealand*. Whitcombe and Tombs.
- Suckling G. W. 1975 A photographic record of the progress of periodontal disease in one sheep. *New Zealand Journal of Agricultural Research*. 18 : 131-2.
- Thomas J. H. 1962 The bacteriology and histopathology of footrot in sheep. *Australian Journal of Agricultural Research*. 13 : 723-732.
- Thomson G. M. 1921 *Wildlife in New Zealand, Part 1. Mammalia*. Government Printer, Wellington. 112p.
- Toop C. R., Jenkins C. F. H. and McGarry V. L. 1955 *Lice and Ticks in sheep*. Department of Agriculture W. Australia. Bulletin No. 2233.
- Watson R. H. and Gamble L. C. 1961 Puberty in the Merino ewe with special reference to the influence of season of birth upon its occurrence. *Australian Journal of Agricultural Research*. 12 : 124-138.
- Watson N., Jackson N., Whitely K. J. 1977 Inheritance of the resistance to compression property of Australian Merino wool and its genetic correlation with follicle curvature and various wool and body characters. *Australian Journal of Agricultural Research*. 28 : 1083-1094.
- [Page 77] Watson R. H. and Radford H. M. 1969 The influence of rams on the onset of oestrus in Merino ewes in the spring. *Australian Journal of Agriculture Research*. 11 : 65-71.
- Whitaker A. H. and Rudge M. R. (editors) 1976. *The value of feral farm mammals in New Zealand*. New Zealand Department of Lands and Survey information series. Vol. 1. 84p.
- Wilson P. R. and Orwin D. F. G, 1964 The sheep population of Campbell Island. *New Zealand Journal of Science*. 7 : 460-490.
- Wodzicka M. 1960 Seasonal variations in wool growth and heat tolerance in sheep I-II. *Australian Journal of Agricultural Research*. 11 : 75-84.
- Wodzicki K. A. 1950 *Introduced mammals of New Zealand : an ecological and economic survey*. D.S.I.R Bulletin No. 98. 255p.
- Young S. S. Y., NewtonTurner H. and Dolling C. H. S. 1960a Comparison of estimates of repeatability and heritability for some production traits in Merino rams and ewes I. Repeatability. *Australian Journal of Agricultural Research*. 11 : 257-275.
- 1960b Comparison of estimates of repeatability and heritability for some traits in Merino rams and ewes II. Heritability. *Australian Journal of Agricultural Research*. 11 : 607-617.
- Ziegler O. L. editor (undated) *The Australian Merino*. Ziegler Publications. Australia. 167p.

WOODSTOCK RUNHOLDERS 1853-1980

1853	Run 109 allotted to George Batson.
1855	Run 109 transferred to Capt. James Row.
1857	Transferred to Robert Chapman who disposed of it to George P. Day.
1858	Run 260 allotted to John W. Smart.
May	Run 270 occupied by David Kinnebrook ,
Aug.	Run 260 taken over by Day and run with 109.
1860	Run 260/109 sold to Wilson and Co. (R.Wilson, W.Eckersley, W.Welch).
1865	Kinnebrook dies in snowstorm on Run 270.
1866	Run 270 taken over by Capt. William Foster.
	Runs 260/109 taken over by James Drummond MacPherson.
1869	Runs 260/109 and 270 taken over by Mathesons Agency.
1873	All run licences cancelled and run licence 653 issued to cover original 3.
1878	Woodstock sold to Fitch and sons.
1885	Passed to National Mortgage and Agency Co. (advertised as 10,000 ac leasehold, 700ac freehold with 5117 sheep).
188?	Sold to R. and W. McKay.
1902	Sold 81 at auction to Richard O Dixon.
Post WW1	Government resumes about half of Woodstock and settles Marmaduke Spencer Bower (returned soldier) on it.
1980	Spencer Bower family still own Woodstock.

PRESENT KNOWN FERAL SHEEP FLOCKS OF NEW ZEALAND
(Modified from Whitaker and Rudge 1976)

1. Arapawa Island (Marlborough Sounds)	Merino
2. Cambell Island (Subantarctic)	Merino X
3. Chatham Islands (i) Main Island	Merino
(ii) Pitt Island	Merino
4. Clarence River Catchment (Marlborough)	Merino
5. Hokonui Hills (Southland)	Merino
6. Omahaki Station (Hawkes Bay)	Merino
7. Oxford State Forest (Canterbury)	Merino
8. Mohaka River (Hawkes Bay)	Merino
9. Waianakarua Catchment (South of Oamaru)	Merino or Merino X
10. Wairau River Catchment (Marlborough)	Merino X
11. Woodstock (Canterbury)	Merino

N.B. The sheep at Oxford State forest can be extended to include feral flocks at Mt White, Coopers Creek and Woodstock.