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ASPECTS OF THE BIOLOGY OF CAMPBELL
ISLAND FERAL SHEEP (Ovis aries L.)

A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Science in zoology
at Massey University.

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FRONTISPIECE - field work, Campbell Island style.

ABSTRACT

The feral sheep population of Campbell Island was studied between April and August 1984. Data were collected from 2529 of the 4000 sheep killed in the south-east of the island, and the population described. Productivity and timing of lambing are examined. A survivorship curve and the age:sex characteristics are plotted to illustrate mortality and population structure. Changes in population size and lambing rates since 1895 are presented.

Attributes such as wool colour, occurrence of horns, body size and lambing dates are described. In several respects these differed significantly between localities, and the existence of distinct sub-populations is suggested. The presence of these sub-populations is related to home range behaviour.

Observations were made of 70 tagged sheep in the area around Menhir during April-June 1984, and it is suggested that they adhere to a home range, the mean size of which was 43.3 ha. Sheep were found associated in groups of up to 65, although mean size was 6.31. There was no constancy in group composition, although several hogget:dam associations were noted. Groups comprised both rams and ewes.

Time activity observations showed that in winter the sheep spent 70.2% of the time grazing, and 16.6% ruminating, with ruminating peaking around midday.

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CHAPTER ONE

INTRODUCTION

1.1 FERAL SHEEP

1.1.1 POPULATIONS AND STUDIES

A feral animal is one whose lineage was once domesticated but which now exists in an unmanaged and self-sustaining state. Rudge (1984c) recognizes three classes of feral Caprinae : A. ancient populations, including the Soay sheep. B. recent populations dating from periods of exploration and settlement, or from changes in land use. These comprise the majority of feral populations. C. strays from domestic populations. These tend to mix with domestic animals and have a transient existence.

Rudge (1983, 1984a, 1984c) lists 39 known populations of feral sheep in the world, of which 21 are in the Pacific Basin. Of these, 11 are in New Zealand. Of the New Zealand populations the following have been the focus of various studies : Pitt Island (Rudge 1983); Arapawa Island (Ricketts 1977; Orwin and Whitaker 1984); Woodstock (Parsons 1980); and Campbell Island (refer section 1.2). Small captive populations of sheep from Campbell Island, Arapawa Island, Raglan, and Hokonui are held by the Ministry of Agriculture and Fisheries at the Whatawhata Hill Station (Cockrem 1980), and by the Wool Research Organisation of New Zealand at Lincoln.

The feral sheep of Mauna Kea on the island of Hawaii have been studied by Giffin (1976), while the Soay sheep on St. Kilda island in the New Hebrides, off northern Scotland, have been the focus of a number of studies (Boyd et al. 1964; Grubb and Jewell 1966; Grubb 1974; Jewell et al. 1974). The Scottish black-faced sheep of Boreray Island in the St. Kilda group have also been studied (Morton Boyd 1981), and Van Vuren (1981) has examined feral sheep on Santa Cruz Island off California.

Also relevant to studies on feral sheep is the resume by Geist (1971) on the bighorn sheep of Canada.

1.1.2 VALUE AND STATUS OF FERAL SHEEP

Although feral sheep have long been regarded as pests, with a large amount of effort put into eradication programmes, over the last ten to fifteen years there has been an upsurge of interest in them. The FAO of the United Nations has included feral farm animals in its programme on vanishing livestock, and the IUCN has included significant feral animals in its conservation programmes (Rudge 1982).

Various scientific, cultural, and economic values have been put forward to support the idea of conserving at least some feral populations (Ryder 1976; Whitaker 1976; Bowman 1981; Bigham and Cockrem 1982; Rudge 1982 and 1984; Wodzicki and Wright 1984).

A scientific reserve for feral sheep was created in 1981 on Pitt Island in the Chatham Group (Rudge 1983),

but none of the other feral populations in New Zealand have legal protection. The Campbell Island population is tolerated in a portion of the nature reserve, with a decision on the future of the remaining sheep expected by 1990 (Rudge 1983).

1.2 CAMPBELL ISLAND SHEEP

1.2.1 HISTORY

Farming began on Campbell Island in 1895 with the introduction of 300-400 sheep. Sheep previously liberated on the island between 1865 and 1895, in association with the Government castaway depots, failed to survive. The next introductions were of 2000 sheep in 1901, and 1000 in 1902. The breed of these founding flocks is uncertain. Kerr (1976) believed the 1901 introductions were Leicester-Merino and Lincoln-Merino crosses (Corriedales), while Wilson and Orwin (1964) thought the 1901 introductions were Merinos, and those of 1902 either Leicester-Merinos, half-bred Merinos and Romneys, or Corriedales. Thirty unidentified rams were introduced in 1923, and three Cheviot rams were released in 1953. Wilson and Orwin (1964) judged from appearance and wool that the sheep were a Merino-Longwool breed cross, with breed ranging from half to quarter bred types.

Sheep numbers peaked at 8540 in 1909-1910, and remained high until 1916 when the wool clip also peaked at 131 bales. During the 1920's sheep numbers dropped

rapidly, although this was due in part to the export of 2000 sheep in 1917-1918, and another 200 in 1923 and 1925 (Kerr 1976). As well, the shepherds were killing at least 30 sheep a year. When the farming venture was abandoned in 1931 sheep numbered about 4000.

During the farming era the sheep were not intensively managed. They were rounded up once a year for shearing, an operation which began in October or November and would take until March or April. On at least one occasion shearing had not been completed by August. Timms (Kerr and Judd 1978) describes four or five main musters of each of the main areas, with the shearing taking place next to the homestead in Tucker Cove.

A 1910 stock inspector reported that the ewes and rams ran together, and that lambing was taking place over six months of the year (Kerr 1976). Rams comprised "about 5%" of the population in 1911, and wethers a further 30%.

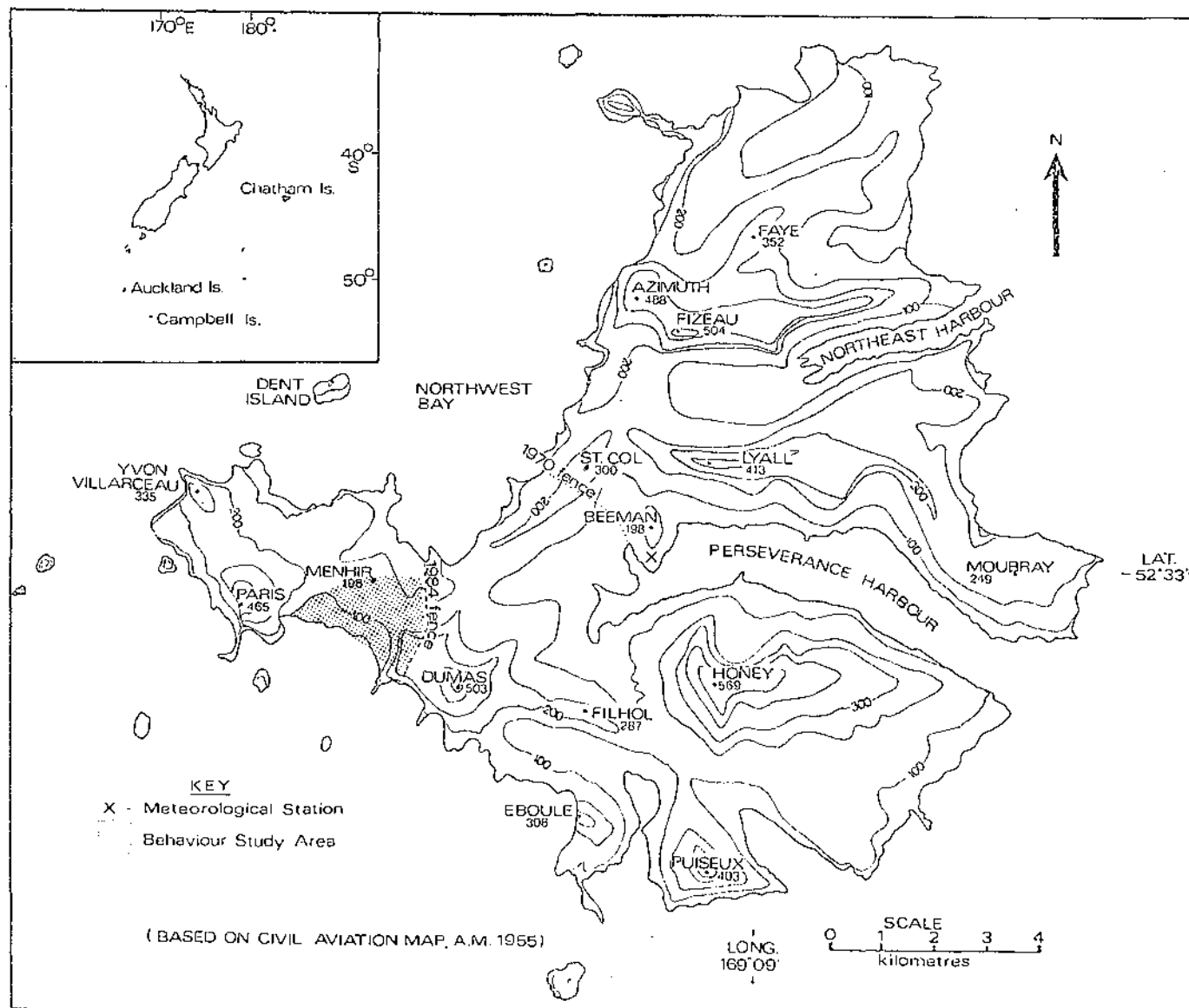
Sheep and wool were initially in good condition but they began to deteriorate after about 1904. This decline may have been due, in part, to the regrowth of less palatable species in the burnt-off vegetation. By 1931 some of the sheep were already described as double-fleeced with hairy wool, and Spence (1969) estimated there were more than 1000 'wild' sheep. The death and loss rate of stock was high, particularly after shearing and lambing. Lambing percentages for the whole island were in the range 20-24%.

After the farming era the number of sheep continued to decline. From 1941 onwards approximately 50 sheep a year were shot for meat, a factor contributing further to the decline. Wilson and Orwin (1964) recorded a low of 907 sheep in 1961, with a lambing percentage of only 11. The rate of decline was thus approximately 3% per annum (cf. Wilson and Orwin's figure of 5% which fails to take into account the export of at least 2000 sheep from the population). By 1969 the population trend had reversed, and the population count was about 3000 (Taylor et al. 1970).

A decision was then made to eradicate sheep from half of the island (Wilson and Orwin 1964; Taylor 1968), and Kenworthy (1980) has detailed the circumstances involved. The conflicting pressures from plant and animal ecologists on the one hand, and from the Meteorological Station, for whom the sheep were of value as a source of meat, on the other, were therefore partially resolved. In addition, several scientists had been interested in preserving the herd for genetic and agricultural values. In January and February 1970 a fence was erected across the middle of the island (figure 1.1), and 1281 sheep were shot from the northern portion. A further 105 sheep were shot in the succeeding year (Bell and Taylor 1970; Rudge in prep.).

Since 1975 population censuses have been carried out by Ecology Division, DSIR (Dilks and Dunn 1978;

FIGURE 1.1 - map of Campbell Island.



Dilks and Wilson 1979; Wilson 1980; Wilson and Elliot 1981; Dilks and Grindell 1983; Wilson and Gaze 1983).

The sheep population and vegetation changes since the exclusion have also been studied in several summer expeditions : 1975-1976 (New Zealand Department of Lands and Survey 1980), and 1984 (Orwin 1984).

In 1983 a decision was made by the Outlying Islands Reserve Committee to further limit the numbers of sheep on the island. The numbers of sheep were increasing rapidly, and vegetation to the south of the fence was deteriorating further. In January-February 1984 a Department of Lands and Survey team erected a new fence across the south-western corner of the island (figure 1.1), an idea first proposed by Taylor (1980). A population of approximately 700-800 sheep was left in this area, which comprises about 10% of the island's total area. The sheep in the south-eastern corner of the island, between the two fences, were shot in June and July 1984.

1.2.2 PREVIOUS STUDIES

Data from the previous cull are being analysed with a view to determining reasons for the decline and subsequent rapid increase in sheep numbers to 1969 (Rudge 1984b, Rudge in prep.). Members of the 1975-1976 summer expedition looked at the disease status of the population (Hutton 1976, 1980), and at ectoparasites (Heath 1976, 1979). Holmes (1976) made comments on behaviour,

and Cockrem and Clarke (1976) remarked on physiology. Regnault (1976, 1980) examined wool and made some general observations. Bigham and Cockrem (1982,1984) looked at skin and wool in one of the captive populations, and Orwin (1984) looked at wool during the 1984 summer expedition. Both Regnault and Orwin currently hold wool and skin samples collected during the 1984 cull. General works concerned with the future of the sheep population on Campbell Island include Wilson (1979), Taylor (1980), and Wilson and Rudge (1982).

1.2.3 RATIONALE FOR PRESENT STUDY

With the construction of the fence in 1970 a research programme was adopted with the aims of studying the status of, and changes in, the flora and fauna (Wilson 1979, Taylor 1980, Rudge 1982). Aim 4 reads : "to allow further study of the biology, population ecology and agricultural value of the long isolated feral sheep and cattle".

Management policy 3.2 of the Management Plan for Campbell Island (New Zealand Department of Lands and Survey 1983) suggested the limiting of sheep to a small area, and encouraged research relating to the sheep.

Although work carried out to date goes some way to meeting these aims, the present study was instigated to allow a more intensive ecologically oriented study, which could take advantage of the amount of data that was expected from the large number of sheep.

1.3 CAMPBELL ISLAND

1.3.1 LOCATION AND STATUS

Campbell Island is New Zealand's southernmost island territory, lying 663 kilometres south of Bluff at latitude 52°33'S, longitude 169°09'E (figure 1.1).

The island covers an area of 114 square kilometres. Its greatest length from north to south is 14 kilometres, and from east to west is 14 kilometres.

Since 1954 Campbell Island and its outlying stacks have been gazetted as a Flora and Fauna Reserve, with a change of classification under the 1977 Reserves Act to Nature Reserve. They are all administered by the New Zealand Department of Lands and Survey, and entry to the reserve is by permit only.

1.3.2 GEOLOGY AND TOPOGRAPHY

The geology of Campbell Island has been described by various workers beginning with Filhol in 1885. A fairly complete geological survey carried out by R.L. Oliver in 1944 was published as "The Geology of Campbell Island" (Oliver 1950) as part of the Cape Expedition Series. Fleming (1980) presents the most recent summary of the known geology. A simple geological map is included in the management plan (New Zealand Department of Lands and Survey 1983), but a detailed map is still being prepared.

Campbell Island is the dissected remnant of a basaltic volcanic dome some 6-8 million years old (Adams 1981), which had its centre to the north of North-west

Bay. Most of the western half of the original island has been removed by marine erosion, resulting in a coastline characterised by steep precipitous cliffs up to 300m in height. The island slopes more gently to the east, and the "drowning" of radial valleys has created several large inlets, the most prominent being North-east Harbour and Perseverance Harbour. The volcanic rocks overlie mudstone, sandstone and limestone, with a basement of metamorphic schist.

The present topography of the island is the result of the interacting processes of glacial erosion, sea erosion and eustatic sea-level changes. The topography is rugged, with 15 peaks higher than 200m. Mount Honey is the highest peak at 569m.

The only maps of the island available prior to the time of the study result from a topographical survey by Clifton in 1942-1943. I used two maps - one produced by the Civil Aviation Department, Ministry of Transport, and the other obtained from Ecology Division, DSIR. Whilst largely comparable, these and other maps published in various books contain slight differences in the citation of heights. For example, Beeman is given a height of 198m on the Civil Aviation map, and 189m on the Ecology Division map. Other workers (Given 1980, Morris 1980) have bemoaned the lack of an accurate base map, and cast doubt upon the validity of some of the contours. Judd (1980) points out that Mt. Fizeau would appear to be

actually lower than Mt. Azimuth, although Mt. Fizeau's height is usually given as 16m higher than Mt. Azimuth. A small map obtained from the Royal New Zealand Air Force gives Mt. Fizeau's height as 475m (cf. the more usual 504m), which would align with Judd's comment.

A problem is the citation of all heights in imperial measurements. To maintain consistency throughout this study I have converted all figures to metric measurements, and have approximated contour lines from the nearest imperial equivalent (figure 1.1).

1.3.3 SOILS

Soils have been described by Campbell (1980). Soil formation has a strong relationship to topography, with deep peat deposits forming on flat and gently sloping surfaces. On moderate to steeply sloping land the peat mantle is shallower and generally less than 2m thick due to natural erosion processes. This thin peat at high altitudes has an increased mineral content.

The mass movement of peat is common, as evidenced by old slip scars. These slips are facilitated by the presence of impervious rocks providing a shear plane, and are triggered by periodic exceptional rainfall which causes soils to become saturated. Such slips are more prevalent in the lower and middle altitudinal zones where the accumulation of peat is most rapid. The most recent slips, which are a striking feature of the landscape, date from 23 May 1982 (Dilks and Grindell 1983).

1.3.4 VEGETATION

Campbell Island's vegetation is predominantly tussock grassland, shrubland and herbfield (Oliver and Sorenson 1951; Sorenson 1955; Given and Meurk 1980; Meurk 1982; New Zealand Department of Lands and Survey 1983). The subantarctic vegetation has been severely modified by burning, sheep grazing and the introduction of various herbs and grasses, since it was described by Hooker in 1844, Kirk in 1890, Cockayne in 1903, and Cheeseman in 1909. Two hundred and eighteen species of vascular plant have been recorded for the island (Meurk 1975; Given 1980). Of these, 81 are adventive species (Meurk 1977).

The original vegetation could be divided into 13 main formations (Meurk 1980), segregated by altitude, exposure, water table characteristics and/or proximity to maritime influences.

Meurk (1977, 1980) divides the island into two broad altitudinal zones, lower and upper. The lower alpine zone includes the following associations:

1. a dwarf forest of Dracophyllum scoparium and D. longifolium, attaining a height of 5m in sheltered places. This association includes Coprosma spp., Myrsine spp. and Polystichum vestitum, and reaches to 180m altitude.

2. Chionochloa antarctica tall tussock grasslands. Formerly widespread, but highly susceptible to grazing.

3. Poa litorosa-Bulbinella rossi meadows. This is

now the dominant mid-altitudinal formation. In a few places B. rossi exists in almost pure stands.

The dominant higher alpine zone association is:

4. a tall Marsippospermum rush-herbfield association.

The megaherbs, which include Pleurophyllum spp., Anisotome spp. and Stilbocarpa sp., were found in high altitude associations and in a tall tussock herb field with Poa foliosa. They had their range much restricted by sheep grazing, but have made a spectacular recovery in the north of the island since the exclusion of the sheep.

1.3.5 WILDLIFE

Campbell Island is an important breeding location for a number of marine mammals and seabirds. Hooker's sealion (Phocartos hookeri), fur seal (Arctocephalus forsteri), and sea elephants (Mirounga leonina) all breed on the island, although they have major breeding grounds on other subantarctic islands. The southern right whale (Eubalaena australis) congregates around Campbell Island from June to October to calve and mate (Bailey and Sorenson 1962).

About 62 species of birds have been recorded from Campbell Island, but only 29 are known to breed there (New Zealand Department of Lands and Survey 1983). It is the major breeding ground of the southern royal albatross (Diomedea e.epomophora) with an estimated population of 4243 birds (Dilks and Grindell 1983). Light-mantled

sooty albatrosses (Phoebastria palpebrata) breed on coastal cliffs and offshore islets.

Campbell Island is also the main breeding ground for the endemic New Zealand black-browed mollymawk (Diomedea melanophris impavida) with numbers for the 1975-1976 summer estimated at 74 825 pairs (Robertson 1980). The estimated 11 530 breeding pairs of grey-headed mollymawk (Diomedea chrysostoma) on Campbell Island may represent up to 40% of the world population for this species.

An estimated 2-3 million rockhopper penguins (Eudyptes creatatus) breed on Campbell Island (Westerkov 1960), with smaller numbers of erect-crested penguins (Eudyptes sclateri) and yellow-eyed penguins (Megadyptes antipodes). There are 8 breeding prion and petrel species, and a total population of 8000 endemic Campbell Island shag (Phalacrocorax campbelli) (Van Tets 1980).

Other breeding species include 4 gulls, 8 terns, 8 passerines and 2 ducks. The rare Campbell Island teal (Anas aucklandica nesiotis) is confined to Dent Island.

For a comprehensive outline of the island's fauna see Bailey and Sorenson (1962).

There are three species of introduced mammals in addition to the sheep. Thirty cattle abandoned in 1931 are now in the process of being eradicated, and are believed to number only two or three individuals. Norway rats (Rattus norvegicus) are abundant, and were the target of an Ecology Division, DSIR study from April

1984 - April 1985. Feral cats are present but not often seen.

The stream fauna is of low diversity, with mayflies and snails absent, but with a high number of isopods. There is one galaxiid fish (Galaxis brevipinnis) (New Zealand Department of Lands and Survey 1983). Six Foot Lake and the tarns have predominantly chironomid midges and worms (Crosby 1980).

Gressitt (1964) described 300 species of terrestrial insects from the island, and more have been recorded since then (New Zealand Department of Lands and Survey 1983). Up to 200 of these may be endemic. Forster (1964) described 16 spiders and 1 harvestman. Climo (pers comm.) lists 7 species of land snail, and 1 endemic slug (Climo 1980). Other invertebrate groups have been poorly studied, if at all.

1.3.6 WEATHER

Campbell Island lies in a zone of strong prevailing westerly winds. The climate is dictated largely by the passage (at 6-7 day intervals) of a succession of anticyclones, each separated by a trough of relatively low pressure (New Zealand Department of Lands and Survey 1983). Each trough develops a number of cold fronts which are preceded by gale force winds and a period of rain.

The following statistics come from Meteorological Service data for the years 1941-1980. Readings are taken at the Meteorological Base at sea level, and thus

represent minimum windspeeds and maximum temperatures for the island. (see Appendix A for mean monthly weather recordings for 1941-1980, and for daily weather recordings and monthly summaries for the duration of this study).

Average annual rainfall is 1361 mm spread over 246 raindays (1.0 mm or more of precipitation) throughout the year. Maximum 2-day rainfall recorded was 104 mm. Snow falls on an average of 42 days per annum, but it is usually light and lies on the ground for only a few days. Mean number of sunshine hours per year is low at 659 hours. The lowest number of sunshine hours ever recorded in one month is 1.1 hours in June 1984.

Mean annual air temperature is 6.9°C, and mean annual grass temperature is 3.2°C. Temperature variations are small with an average daily range of 4.7°C. Relative humidity is high averaging 85%.

The dominant climatic element is the wind. The mean hourly windspeed per annum is 32 kilometres per hour. There are 280 days per year when wind gusts are above 63 kilometres per hour, and 106 days when gusts are above 96 kilometres per hour. There are 60 days a year classed as having gale force winds, that is, average wind speed is greater than 62 kilometres per hour.

1.3.7 HUMAN HISTORY

Campbell Island was discovered in January 1810. From then until about 1830 it was visited by sealers, but

these visits ceased once fur seal populations declined almost to extinction. From then until the 1890's it was visited by several scientific and exploratory expeditions (Redwood 1950, Kerr 1976). The first of the two major expeditions was the British James Clark Ross expedition of 1840-1842, during which Lyall and Hooker compiled the first plant and animal inventories for the island. In 1874 a French expedition visited Campbell Island to observe the transit of Venus, and work was carried out by Filhol on the geology. Many of the French placenames on the island date from this expedition.

The island was visited periodically between 1868 and 1923 by Government vessels servicing the castaway depots, but, unlike the Auckland Islands which lay on the main shipping routes and have a history of shipwrecks, no shipwrecks have been found on Campbell Island (Eden 1955).

Throughout this period whalers were also visiting the island, and the last of the shorebased whaling stations at North-west Bay operated from 1909-1916 (Kerr and Judd 1978).

In 1864 the island was leased as a Government Pastoral Run, and farming began the following year with the introduction of 300-400 sheep. Farming continued until 1931 when the project was abandoned due to difficulties inherent in the climate and isolation from markets.

Since 1941 the island has been continuously occupied, beginning with the coast watching station during World War II, and continuing since 1945 by Meteorological Service staff.

Kerr (1976) gives a detailed history of the island, and Judd (1980) a list of historic sites.

1.4 AIMS

1. To describe the status of the Campbell Island sheep population in the south-east of the island at June-July 1984.

2. To consider the possibility that sub-populations have become established.

3. To investigate home range, movements and social groupings.

4. To examine daily activities.

CHAPTER TWO

METHODS AND STUDY AREAS.

2.1 TIMING OF THE STUDY

Field work on Campbell Island was carried out from 10 April until 1 August 1984. Timing and duration of the study were dictated by transport and availability of support, hence there was a need to fit all aspects of the study into a four month period.

Until mid-June emphasis was on behavioural aspects, and data were collected with help from a field assistant.

From mid-June emphasis was changed to concentrate on the collection of data from the culled population in the south-east of the island, and during this stage I worked closely with the team of Wildlife Service shooters.

2.2 POPULATION STUDY

2.2.1 INTENT

This population study had three aims. First, to determine the reproductive status of the population by autopsying a representative sample of sheep. Second, to collect from the maximum possible number of sheep throughout the cull area information on sex, age, wool colour, presence/absence of horns, and location. Third, to use information collected for aims one and two in a comparison between localities.

2.2.2 CULL AREA

The area in which the cull took place lies between the 1970 and 1984 fencelines, and with an area of 4780 hectares comprises 42% of the total area for the island. It includes the peaks of Honey, Puiseux, Eboule, Filhol, Dumas, and the south Col ridge (figure 2.1).

2.2.3 DATA COLLECTION

To meet the first aim, 311 autopsies were carried out. Effort was concentrated on 284 ewes, with 27 rams sampled principally to provide information, and wool and skin samples, for a co-worker.

Information collected in the autopsies is detailed in Appendix B, and autopsy sites are shown in figure 2.1.

Data to meet the second aim were collected by the shooting team. Half of the lower mandible of each sheep sampled was removed, and a waterproof label attached containing information on sex, colour, presence of horns, date and locality. Each jawbone was later given a permanent numbered metal tag, and this number was recorded along with information from the label. After 1570 jawbones had been collected this procedure was modified so that sheep were aged in the field and jawbones not collected. This information was recorded in prepared notebooks, and brought the total sample size (including the autopsy sample) to 2529. Table I shows population and sample sizes for each locality.



FIGURE 2.1 - map of cull area, south-east Campbell Island, showing localities (dotted lines) and autopsy sites (numbers in circles, where number refers to the number of autopsies).

PLATE 1 - Garden Cove and the head of Perseverance
Harbour, and Filhol, with Homestead Ridge
in the foreground. Note the dark green of
the Dracophyllum and the lighter colour of
the tussock.

PLATE 2 - Shag Point and the southern side of Honey.



PLATE 3 - view east across Kirk Stream to Eboule and
Puisseux (half obscured).



TABLE I
NUMBER OF SHEEP SHOT AND AUTOPSIED,
AND POPULATION SIZE AND DENSITY OF EACH LOCALITY.

LOCALITY	NUMBER SHOT	SAMPLE SIZE (INCLUDES AUTOPSIES)	NUMBER AUTOPSIED	AREA (HA)	DENSITY (SHEEP PER HA)
COL	376	260	36	620	1/1.6
DUMAS	694	532	99	700	1/1.0
EBOULE	274	119	20	380	1/1.3
FILHOL	752	572	62	460	1/0.6
HONEY	1433	925	93	2160	1/1.5
PUISEUX	346	121	1	460	1/1.3
unspecified	125				
TOTAL	4000	2529	311	4780	1/1.2

2.2.4 AGE CLASSES AND TOOTH WEAR INDEX

From the sequence of incisor eruption each sheep was assigned to an age class (hogget, two-tooth, four-tooth, six-tooth, and fullmouth). In addition, each fullmouth jawbone was rated for tooth wear on the incisors. Since Campbell Island is a fairly uniform environment with little abrasive dust or grit to wear teeth (Suckling and Rudge 1977), the assumption was made that tooth wear is a consequence of age rather than the environment. Based on this assumption, very worn teeth were taken to belong to the oldest sheep.

Three categories of tooth wear could be distinguished :

- 'young' fullmouth (referred to as fullmouth 8) - incisors had no obvious wear, or slight wear on the first incisor only.

- 'middle aged' fullmouth (referred to as fullmouth 9) - incisors had slight to moderate wear on at least the first and second incisors.

- 'old' fullmouth (referred to as fullmouth 10) - all the incisors showed considerable wear.

2.2.5 OVARY ACTIVITY IN NON-PREGNANT EWES

Non-pregnant ewes were ranked into three categories of ovary activity, as determined by the number of follicles, and the number and state of active or retrogressing corpora lutea (Restall 1964). Category one comprised ewes with highly active ovaries, that is, the ovaries had a high number of active and clearly visible retrogressing corpora lutea. Category two comprised ewes with ovaries that were just becoming significantly active, that is, one or two active corpora lutea and a high number of ripe follicles. Category three comprised ewes with non-active ovaries, which showed some follicle activity but had no corpora lutea.

2.2.6 FOETAL AGE DETERMINATION

Foetal age was determined by foetal straight crown-rump length and foetal weight (Joubert 1956). As it was felt that the straight crown-rump length measurement

involved some degree of arbitrariness in the positioning of the foetus during measuring, and the amount of spinal curvature that each foetus was assumed to have, a curved crown-rump measurement was taken for comparison. A plot of straight crown-rump measurement against curved crown-rump measurement gives a strong positive correlation, with a high correlation value of 0.973. Thus, the margin of error associated with the straight crown-rump measurement is acceptable.

Foetal weight was also taken, although there is a higher degree of variation between foetuses of the same age, particularly in the later stages of gestation, and it is not such an effective indicator of age (Barcroft 1945, Joubert 1956).

Each foetus was assigned a birth date, by determining age at the time of sampling. Assuming an average gestation period of 144 days, date of birth and date of conception could be extrapolated from the sampling age.

Age was determined from both weight and straight crown-rump measurement, and a weighted average taken (Joubert 1956). The margin of error for this method of determining age is probably in the range of 5-10%, although it may in some cases be as high as 20%. To overcome some of this error, dates have been grouped rather than being retained as absolute dates.

2.2.7 COLOUR

For the purpose of the major data collection effort, a sheep was described as pigmented if it had any conspicuous areas of wool colouration, and the colour and pattern was noted. More detailed information was collected for the autopsy sample, with the following patterns recognised:

1. all white
2. white, with tan or light brown markings on the face and/or legs
3. white, with tan or light brown markings on the face and/or legs, and with black spots on the face, ears and/or legs
4. white, with black spots on the face, ears and/or legs
5. white, with dark brown on the face and/or legs
6. predominantly or totally brown or black.

2.2.8 FACE COVER

As an indication of openness of face, a face cover index was devised (based on Cockrem and Rae 1966). The index is illustrated in Appendix B.

2.2.9 CONDITION INDEX

Ewes were assigned a subjective ranking for condition based on the amount of mesenteric and intestinal fat. Rank one indicated zero fat, and increasing rank values indicate increasing amounts of fat. Rank five indicated copious fat, and rank three was an average amount of fat.

2.2.10 WEIGHT AND BODY SIZE

Sheep were weighed using a 100 kilogram clock-face balance, with 0.5 kilogram gradations. The sheep was suspended with its legs tied from an aluminium pole held between two people, and the weight was read by either one of the weighers or by a third person.

Body measurements were taken using a flexible tape measure, and the points between which measurements were taken are detailed in Appendix B. Foetal measurements were taken with Vernier calipers and with a tape measure. Foetal weight was measured with a 5 kilogram balance, with 100 gram divisions, or with a 500 gram Passola balance.

2.3 DEFINING THE LOCALITIES

To test the hypothesis that sub-populations might exist within the population, the cull area was divided into six localities (figure 2.1). For ease of recording each locality was based around one of the peaks. Because there are not always definite topographic boundaries the borders between localities should be viewed as a zone of overlap rather than a single line. Sheep undoubtedly moved between the peripheries, but due to the flexibility of the recording system these "edge" sheep would have been allocated fairly randomly to localities. Thus, rather than biasing any one area the effect would have been to homogenize the population.

The main areas where sheep would have overlapped two localities would have been the Filhol-Dumas saddle, the Honey-Filhol saddle and the Col-Dumas saddle. In other contiguous areas, for example between Col and Filhol, and between Puiseux and Filhol, observations of low numbers of sheep in the intermediate area, combined with a dense stretch of Dracophyllum, suggested that there was little movement of sheep between these localities.

Given the size of home range determined in this study (section 3.4.4), the fairly strict adherence shown by sheep to their range, and the area of the localities, each locality would probably have contained several independent mobs of sheep.

By comparing physical attributes of the sheep, and population attributes such as age structure and timing of lambing, the hypothesis that adherence to a home range has resulted in distinct sub-populations can be tested.

2.4 HOME RANGE STUDY

2.4.1 STUDY AREA

The behaviour study area lies immediately to the west of the 1984 fenceline (figure 1.1). It was chosen for three reasons. First, it contained sheep excluded from the cull which were therefore available for any ongoing research. Second, it was conveniently near the hut at North-west Bay which provided field accommodation, and was the most accessible and the nearest part of the

fenced-off south-west area to the Meteorological Base.

Third, the fence provided a barrier against which sheep could be rounded up during the tagging operation.

The study area (see figure 2.2) covers approximately 200 hectares. It is approximately 2 kilometres wide from east to west, and approximately 1.6 kilometres from north to south. Average elevation is about 125 metres above sea level, with the highest point at 300 metres ASL. The eastern boundary is the 1984 fence, and the southern boundary is the south coastline. The other boundaries were designated after several weeks of observations as the furthest points at which tagged sheep were ever recorded. Thus, the western boundary became the rise immediately to the west of Cave Stream between Menhir and Mt. Paris, and cut across from the top of Cave Stream to the top of the West Menhir slip in a north-westerly direction. The northern boundary became the line of tall Dracophyllum scrub running parallel to the northern coast from the fence to Menhir Stream, and across the northern slopes of Menhir where the tall Dracophyllum reached almost to the summit.

2.4.2 SHEEP TAGGING

To enable consistent and accurate identification of sheep, individuals were tagged with combinations of coloured and numbered Allflex eartags (see Appendix C for list of tag combinations). A holding pen and guide-in wing were constructed next to and incorporating the

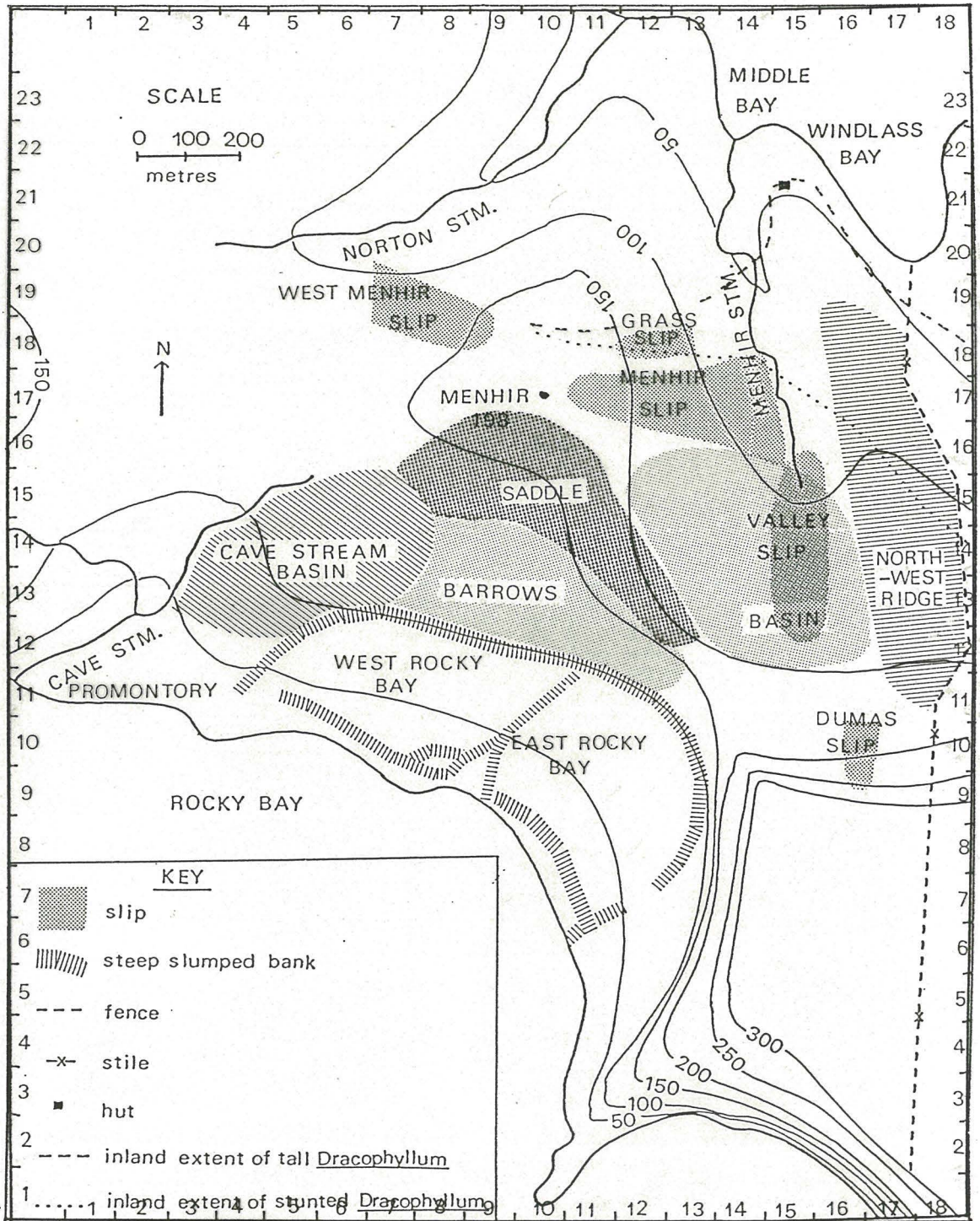


FIGURE 2.2 - map of home range study area. Location in relation to the rest of the island is shown in figure 1.1.

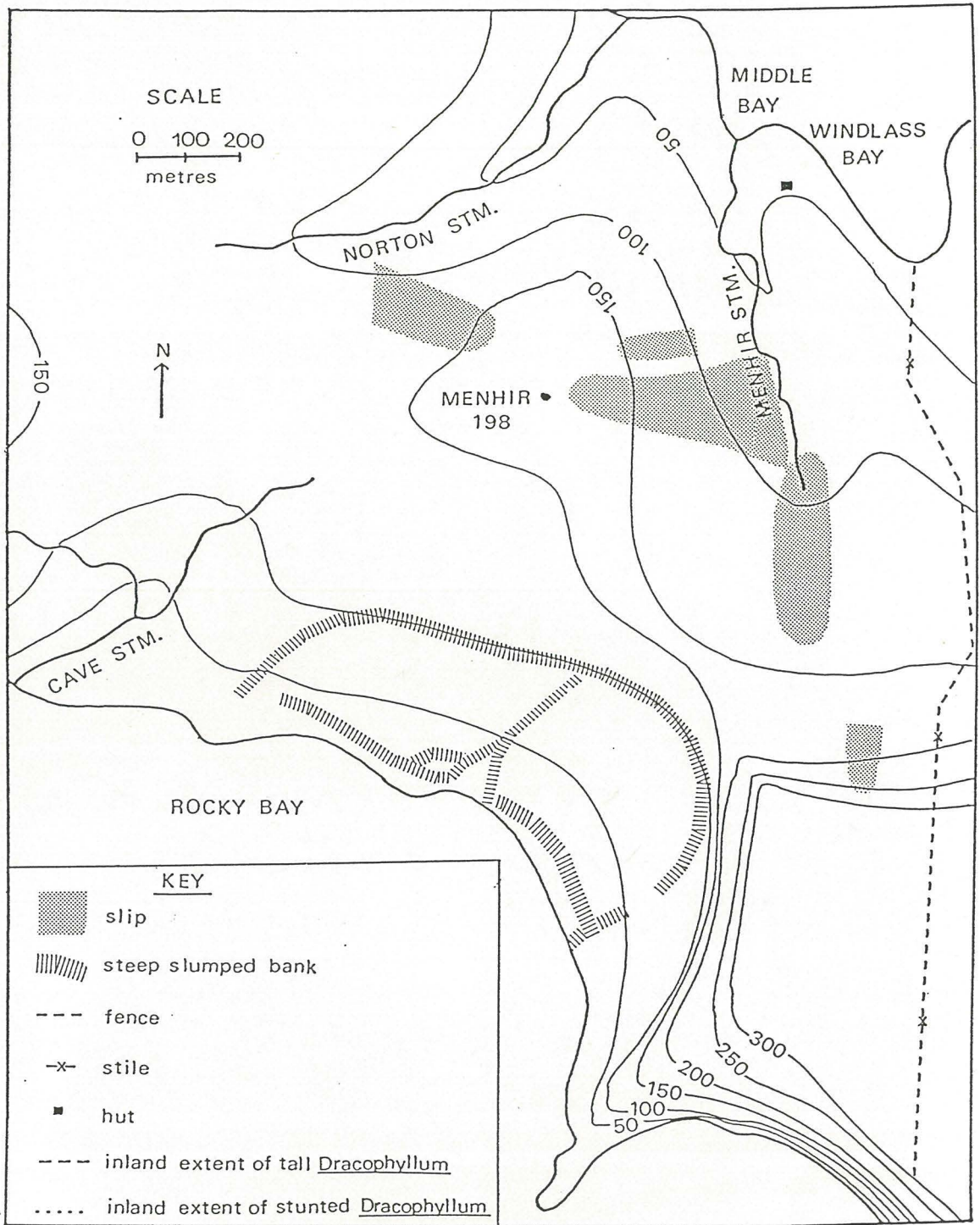


FIGURE 2.2 - map of home range study area. Location in relation to the rest of the island is shown in figure 1.1.

PLATE 4 - view south-east to Menhir, showing part of the home range study area. The prominent dark area is the Valley Slip (65 m wide and 340 m long), with Menhir Slip on the eastern side of Menhir at right angles to it. The beige area is the Basin, with North-west Ridge and the 1984 fence running down to the end of the cliffs.

PLATE 5 - Rocky Bay, in the home range study area. East Rocky Bay is to the left of the photo and West Rocky Bay to the right.



fence, approximately one third of the way down from the top of the fenceline. The muster involved six people and covered the area eastwards from the Dumas-Menhir ridge. I estimate that the 70 sheep penned and tagged represent 60 to 70% of the sheep present in the area on that day.

2.4.3 HOME RANGE DATA COLLECTION

Home range data and time activity budgets were collected concurrently, with the two observers alternating responsibilities.

Information was collected on the distribution and movement of individuals to determine whether they showed an adherence to a particular area, or home range, and to determine the extent of their association with other individuals, that is, whether they formed home range groups.

The study area was sampled completely on 16 days and incompletely on a further 12 days, between 25 April 1984 and 9 May 1984, and again on the 24, 26 and 27 July 1984. Information on home ranges was collected by moving around the study area recording the size of each group of sheep encountered, the time of the observation (to provide a check on suspected duplicate data), and the identity of any tagged sheep present. Each group or individual was given a location to within 100m using a map with a grid overlay (figure 2.2).

2.4.4 IDENTIFYING TAGS

Identifying tagged individuals usually involved reading

the numbers on one or both ear tags, a task which could generally be achieved with binoculars from up to 10m. At times when cloudy, drizzly weather made the use of binoculars impossible, or when the terrain was such that the sheep could not be approached without disturbing them, it was not always possible to record the identity of a tagged sheep with certainty. In these cases, as much information as could be elucidated was recorded, and if nothing else, this data allowed an accurate record of the total number of tagged sheep present.

2.4.5 SCATTER PLOTS OF HOME RANGE

Locality records for all the tagged sheep allowed scatter plots to be made for each sheep, showing their spatial and temporal distribution. Each point on the scatter plot represents one locality for that sheep. In some cases sheep were observed moving between grid squares. When this happened, sheep were recorded in both squares, and this has been shown by linking the data points with a dotted line.

2.4.6 MOVEMENT AROUND THE HOME RANGE

To illustrate the direction of movement around the home range, data points were linked in a temporal sequence. For each scatter plot the movement arrow begins on the first day the sheep was observed, and links points which are successive but not necessarily on consecutive days.

2.4.7 AREA OF HOME RANGE

Area (hectares) was obtained for each scatter plot by linking the outside data points so as to enclose the maximum area ("minimum area method" (Mohr 1947)). This shape was cut out and weighed, and the weight measurement converted to area. Although this method of analysing home range data has recognized inadequacies (Sanderson 1966), it is nevertheless a useful descriptor of size. These minimum area boundaries were not included on the plots as they are an artificial device whose presence implies a rigid circumscribing of an area which is in reality much more loosely defined.

2.4.8 DAILY DISTANCES MOVED

To attempt to show the distances moved daily by sheep, and to see how this distance related to size and usage of the home range, three distance-moved values were extracted from the data. First, a minimum value was taken from the scatter plots by linking data points on any two consecutive days, and measuring the distance between them. Since this method assumes that the sheep moved in a straight line directly from point A to point B, it is a gross under-estimation of the actual distance travelled, but it is nonetheless useful as an absolute minimum value. Second, a similar conservative straight line measurement was taken between any two observations taken on one day. Third, distance moved each five minutes was recorded during time activity observations.

These values were summed for each day and divided by the total time of observations to give a mean distance moved per five minutes. This can then be approximated to a full day, assuming 10 hours of daylight which was the average day length for that time of year, and is the most realistic of the values.

2.4.9 DEFINITION OF A 'GROUP'

A 'group' was defined as animals standing, grazing or moving together. Members of groups observed during time activity budgets were generally spaced less than 10m apart from any other group member, and thus a group had a cohesive appearance. Single sheep were recorded if they were greater than 20m from a group, and not interacting with it.

2.5 TIME ACTIVITY BUDGETS

Time activity budgets were carried out in the Menhir-Dumas basin as this was the only area in which sheep could readily be watched without the presence of the observer interfering with activities. Observations were made at 5 minute intervals for 30 seconds on the most clearly visible group or groups. Each identifiable sheep was scored for its activity from a list of 12 activity types, distance to the nearest sheep, and distance moved since the last observation.

The following types of activity were recognized :

grazing, still) = feeding

grazing, moving)

browsing, still)

browsing, moving)

ruminating, standing * = ruminating

ruminating, lying *

standing

standing, looking fixedly

lying

lying, head down

moving purposefully

miscellaneous

PLATE 6 - view south-west from Menhir across part of the home range study area, showing the basin, Valley Slip (centre), and the Dumas Slip (extreme left). Note sheep to centre right of photo.

PLATE 7 - sheep penned prior to tagging, showing long woolly tails, varying amounts of fleece loss, and variations in horn size in the rams.



PLATE 8 - view north-east across the basin, to the south slopes of Menhir, with the top of the Valley slip in the foreground. The sheep second to the left has a big yellow tag in its left ear. The centre group of sheep includes a royal albatross chick, and the bright white object in the background is another albatross chick.

PLATE 9 - view looking east from Cave Stream across the barrows, with the slopes of Menhir (top left) and the Dumas cliffs (top right). Note group of sheep at centre right.



CHAPTER THREE

RESULTS

3.1 POPULATION CHARACTERISTICS

3.1.1 INTRODUCTION

The size and structure of a population is a result of gains (births and immigrations) and losses (deaths and emigrations) (Krebs 1978; Begon and Mortimer 1981; Hedrick 1984). In a closed system such as an island where there is no migration, births and deaths are the important causal factors in population change. The situation on Campbell Island is further simplified by the virtual absence of predation and competition as regulatory processes.

In this section, the productivity and mortality of the population in 1984 will be described. Then the consequence of these, the age structure of the population, will be described. Long term changes in the population will be illustrated by showing changes in population size and lambing rates since the population was established.

3.1.2 PRODUCTION

Campbell Island sheep have a high potential

NOTE : full workings for all chi-square calculations are detailed in Appendix D.

productivity, with 232 (82%) of the 284 ewes sampled pregnant. Five pregnancies (1.76%) were twins.

Prenatal mortality does not appear to be an important source of loss - only one foetus in the sample was found dead, and none of the non-pregnant ewes showed any evidence of having recently aborted or resorbed the foetus.

Ewes can become pregnant in their first year. Hoggets would have been between five and twelve months old at the time of sampling, and 20 out of the 48 sampled (46%) were pregnant. Of the remaining 28, five had highly active ovaries (category one), and fifteen had ovaries which were just becoming active (category two). Eight hoggets with small body size and low weights had inactive ovaries (category three), and were probably the last of that years lambs to have been born. Given the time of the sampling, from June until the end of July, and the length of gestation period of approximately 144 days, it is possible that hoggets could have conceived after July, and still have carried a pregnancy to full term within the observed period of lambing.

Lambing is spread over six months of the year, and generations are not overlapping. The earliest foetal lamb recorded had an estimated date of birth on the 19 June, and the latest on the 17 December. The first live lamb was seen on the 24 June when it was already at least two or three days old.

Of the 22 ewes lambing after 9 October, eight (36%) were hoggets, seven (32%) were two-tooths, two (9%) were four-tooths, and five (23%) were fullmouths.

Excluding hoggets, productivity seems to be similar throughout age classes, with no significant decline as age increases ($\chi^2 = 3.42$, df.5). Of the twelve non-pregnant fullmouth ewes, all had apparently functional ovaries with high numbers of active and retrogressing corpora lutea. Of these, seven had notably long and/or daggy wool over their rumps which would have impeded copulation. Four had missing teeth, or were otherwise in poor condition, and one had mastitis.

Four of the five sets of twins sampled were from fullmouth ewes, while the fifth was a six-tooth.

There was no significant relationship between ewe colour and the number of pregnancies in each colour class ($\chi^2 = 22.31$, df. 10), although it is interesting to note that all five ewes classified as being heavily pigmented were pregnant, and one had twins.

There was no significant difference between the timing of lambing in each colour class when tested with an ANOVA, although the mean lambing dates for classes three and four were earlier than those for the other classes. That is, heavily pigmented sheep and very lightly pigmented sheep seemed to lamb slightly later.

3.1.3 SURVIVORSHIP

Mortality is illustrated as a survivorship curve (figure 3.1), because data on the exact number of sheep dying each year was unobtainable. Similarly derived survivorship curves are plotted for the Campbell Island population in 1970, New Zealand domestic sheep, Santa Cruz sheep and Soay Island sheep.

The mortality rate was highest for hoggets, as shown by the large decrease between the hogget and two-tooth class. Neonatal mortality was probably in the range of 50%, given a foetal lambing rate of 82% (number of ewes with foetuses), and a hogget:ewe ratio of <40:100.

3.1.4 AGE STRUCTURE

Figure 3.2 shows the age:sex structure of the population in 1984.

Life expectancy of Campbell Island sheep in 1970 was eleven years (Rudge pers comm.), and a similar life expectancy has been assumed for 1984. The class of 'fullmouth' covers six or seven years. For the purposes of the figure, the fullmouth 9 and fullmouth 10 categories have been taken to be the oldest classes, approximately equal to years nine and ten, and eleven and above respectively. The bulk of the fullmouths have been divided into four equal parts to cover the approximate spread of ages, but as this does not take into account any decline through time, it is represented by a dotted line. It is most likely that the year classes five and

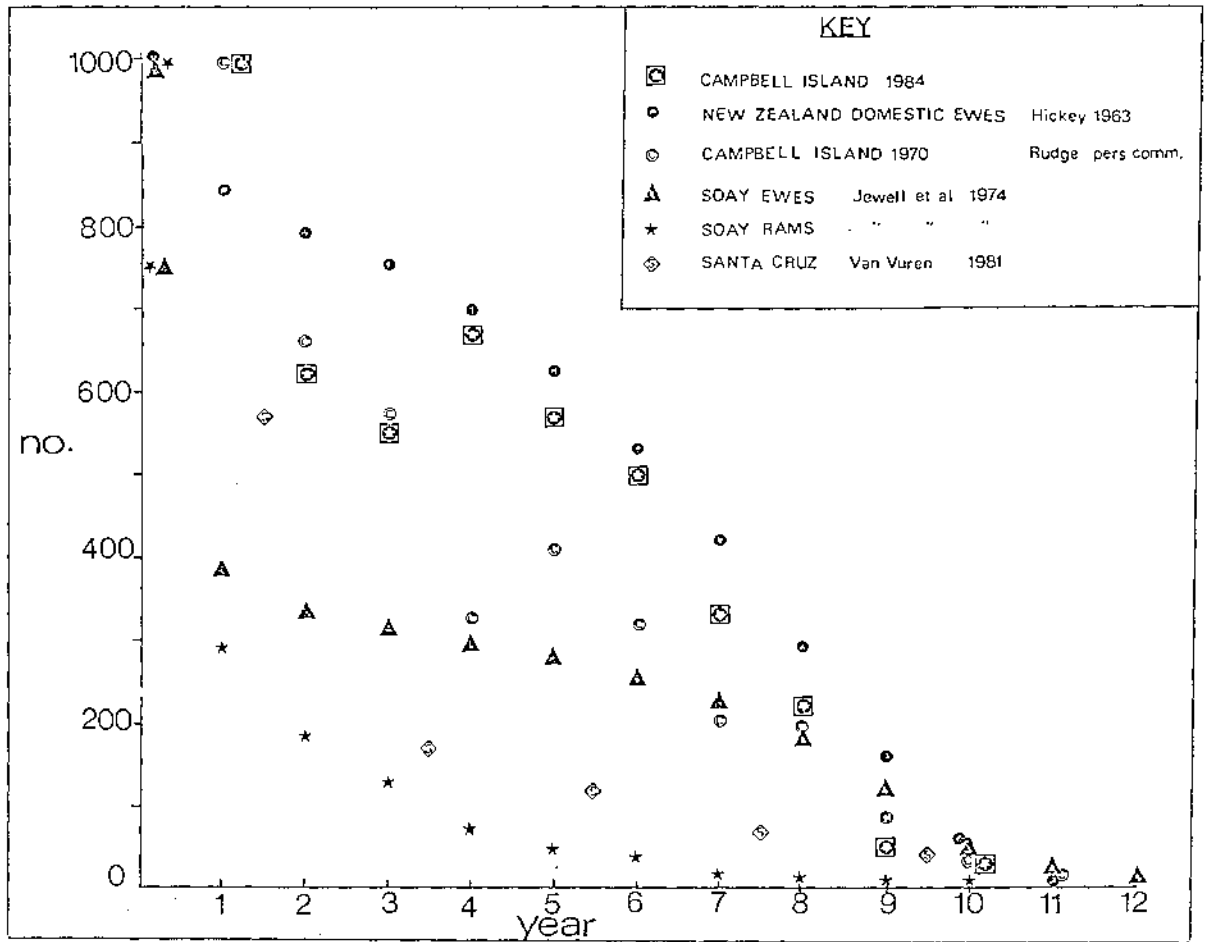
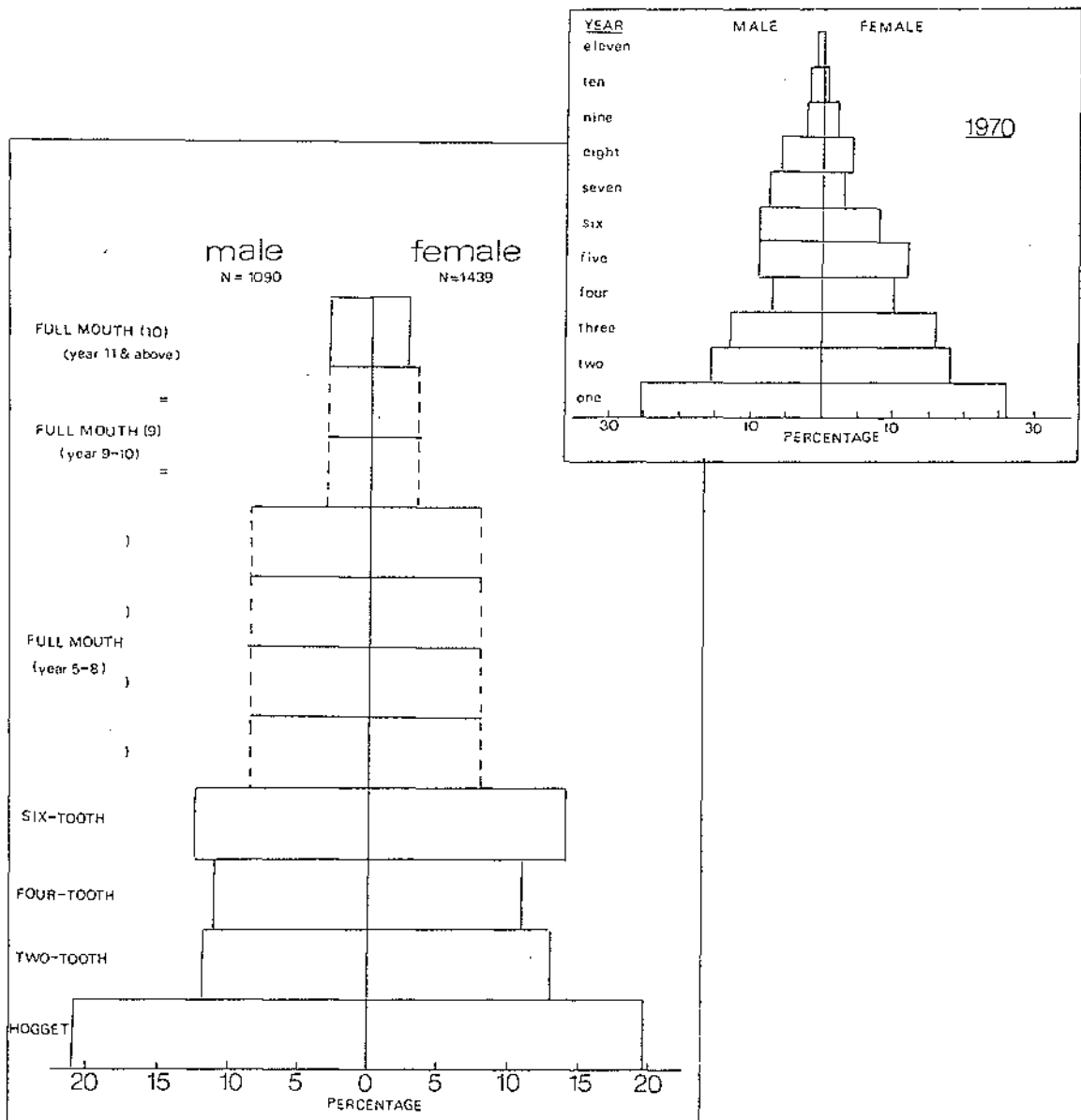


FIGURE 3.1 - survivorship curves for 1984 Campbell Island population, 1970 Campbell Island population, Soay population, Santa Cruz population and a domestic population.



dotted lines represent approximations.
 SEE section 4.2.3 for further explanation.

FIGURE 3.2 - age:sex structure of Campbell Island sheep
 in 1984. (inset: age:sex structure in 1970).

six have a higher than expected representation, as information on lambing percentages and numbers of lambs (table II) shows a bulge in the population between 1976 and 1979. This bulge is still evident for the six-tooth class (1980) cohort.

TABLE II

POPULATION SIZE, LAMBING RATES AND ESTIMATED SIZE
OF COHORTS FOR SOUTHERN CAMPBELL ISLAND SINCE 1968.

<u>YEAR</u>	<u>TOTAL POPULATION</u>	<u>LAMBING PERCENTAGE</u>	<u>EST. SIZE OF COHORT</u>
1968-1969	2088	26.5%	553
1969-1970	(2250)	(26%)	(585)
1970-1971	2521	25.4%	640
1971-1972	(2500)	(24%)	(600)
1972-1973	(2450)	(23%)	(563)
1973-1974	(2450)	(22%)	(539)
1974-1975	(2450)	(22%)	(539)
1975-1976	2400	21.9%	526
1976-1977	2861	29.7%	850
1977-1978	3175	29.3%	930
1978-1979	(3370)	(31%)	(1044)
1979-1980	3561	33%	1175
1980-1981	3341	24.1%	805
1981-1982	(3441)	(22%)	757
1982-1983	3540	20%	708

() INDICATES ESTIMATE MADE FROM DATA IN SURROUNDING YEARS.

NUMBERS ARE FROM ECOLOGY DIVISION COUNTS, AND ARE SIMILARLY ACCURATE (SEE APPENDIX E FOR ESTIMATION OF ACCURACY).

3.1.5 POPULATION SIZE 1895-1984

Figure 3.3 illustrates changes in population size and lambing rates since the population was first established. Where known, sizeable imports or exports/losses of sheep have been specified in section 1.2.1. All other changes are functions of the population itself.

3.2 PHYSICAL ATTRIBUTES OF THE SHEEP

3.2.1 SEX RATIO

The ratio of ewes to rams was 57 to 43.

There was no significant difference in the sex ratio between age classes ($\chi^2 = 4.86$, df. 6).

The sex ratio at birth was 53:47, and this is not significantly different to the adult population ($\chi^2 = 1.0$, df. 1).

3.2.2 HORNS

9.9% of ewes, and 81% of rams had horns.

3.2.3 WOOL COLOUR

1.8% of the population was pigmented. The following patterns were noted : all black; all dark brown; brown legs and head with a white body; and dark head (similar to badger face markings). One ram with dark brown wool had a white blaze down his nose, a white line across the back of his neck, and a white tail. One ewe had dense spots of black, dark brown, light brown and grey, although the overall wool colour appeared brown, and

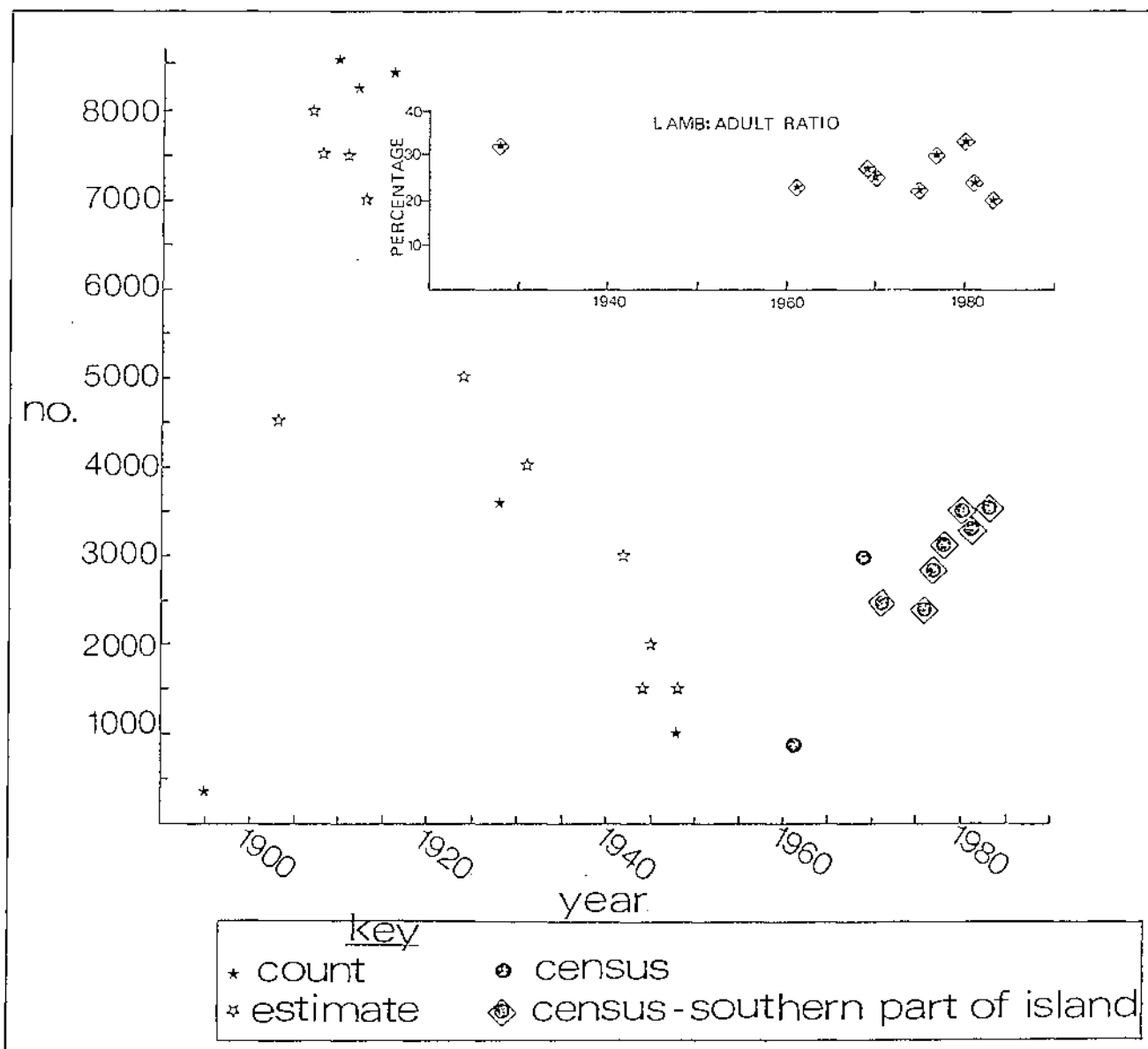


FIGURE 3.3 - changes in population size and lambing rates in the Campbell Island sheep population since 1895.

was carrying a foetus bearing the same dense spotting.

There is no significant difference between age:sex classes in the number of pigmented sheep ($\chi^2 = 4.9$, df. 5).

Table III shows colouration patterns noted in the autopsied sheep, and foetal colour patterns.

TABLE III
COLOUR PATTERNS IN ADULT AND FOETAL SHEEP.

COLOUR PATTERNS	ADULT SHEEP (sample size 311)	FOETAL SHEEP (sample size 230)
	number (%)	
1. WHITE	124 (40%)	177 (77%)
2. WHITE & LIGHT BROWN	71 (23%)	33 (14%)
3. WHITE, LIGHT BROWN AND BLACK SPOTS	52 (17%)	2 (1%)
4. WHITE, BLACK SPOTS	37 (11%)	4 (2%)
5. WHITE, DARK BROWN AND BLACK SPOTS	21 (7%)	11 (5%)
6. BROWN OR BLACK	6 (2%)	3 (1%)

3.2.4 HOOF COLOUR

27% of the autopsied sheep had white hooves, 59% had black and white hooves, and 14% had totally black hooves.

3.2.5 NOSE COLOUR

15% of sheep had totally pink noses, and 12% had totally black noses. The remaining 73% had varying proportions of brown and/or black with pink.

3.2.6 FACE COVER

All sheep would be classified as open faced. 84% had cheek wool covering up to one third of the cheek. 13% had one to two thirds cheek wool, and one individual had a full cover of cheek wool. 3% had no cheek wool, and less wool than expected on the poll.

3.2.7 LACTATION

211 of the 284 ewes sampled were pregnant and not lactating. A further 51 were neither pregnant nor lactating.

Seven ewes were lactating, and 12 were producing a yellow fluid from one or both teats. These 19 ewes were all pregnant, and all except one had foetuses with a straight crown-rump length of greater than 260mm. Since these foetuses are all close to a feasible birth size, it is assumed that lactation was in response to imminent parturition, and that the yellow fluid was colostrum. There was one exception which does not conform to this assumption, and this was a ewe producing a yellow fluid, but with a very small foetus, only 20mm long.

No hoggets were seen still associating with their dams, and none were seen suckling, so it is unlikely, although not impossible, that suckling was a cause of lactation.

Three ewes had mastitis. Two were serious, and had foetuses greater than 280mm long, and the third was not pregnant and was a milder case.

3.2.8 CONDITION INDEX

154 ewes (54%) had an average amount of fat, and were assigned a condition ranking of three. 76 (27%) were placed in rank four, and 46 (16%) in rank two. Three sheep had no fat at all (rank one), and five had copious amounts of fat (rank 5).

There was no significant difference in fat rankings between age classes ($X^2 = 22.6$, df. 24).

3.2.9 WEIGHT AND BODY SIZE

Table IV shows mean weight, leg length, shoulder height, and body length for ewes and rams.

TABLE IV

<u>MEAN WEIGHT AND BODY SIZE.</u>		
	<u>EWES</u>	<u>RAMS</u>
	<u>WEIGHT (KG)</u>	
MEAN	40.7	46.4
STD. DEV.	9.5	12.6
MAX.	60.0	66.0
MIN.	17.0	22.5
	<u>LEG LENGTH (MM)</u>	
MEAN	312.5	332.2
STD. DEV.	20.0	32.9
MAX.	360.0	420.0
MIN.	235.0	270.0
	<u>SHOULDER HEIGHT (MM)</u>	
MEAN	640.6	679.6
STD. DEV.	20.0	59.5
MAX.	770.0	780.0
MIN.	440.0	540.0
	<u>BODY LENGTH (MM)</u>	
MEAN	651.2	685.6
STD. DEV.	50.8	63.5
MAX.	780.0	820.0
MIN.	500.0	570.0

Table V gives the mean weights in each age class for ewes and rams, and the spread of weights is illustrated in figure 3.4.

Mean weight of pregnant ewes was 42.6 kg (std. dev. 7.9, max. 60.0, min. 24.5), while non-pregnant ewes had a mean weight of 31.2 kg (std. dev. 10.3, max. 55, min. 17). These means are very skewed due to the high number of non-pregnant hoggets, whose low weights lower the

TABLE V

MEAN WEIGHT IN EACH AGE CLASS FOR EWES AND RAMS.

	EWES		RAMS
		<u>HOGGET</u>	
MEAN	26.9		25.9
STD. DEV.	5.3		2.9
MAX.	40.0		28.5
MIN.	17.0		22.5
NO.	48		4
		<u>TWO-TOOTH</u>	
MEAN	35.1		39.2
STD. DEV.	5.4		7.7
MAX.	44.5		47.0
MIN.	23.0		25.0
NO.	43		7
		<u>FOUR-TOOTH</u>	
MEAN	39.4		51.5
STD. DEV.	6.2		7.8
MAX.	51.0		57.0
MIN.	28.5		46.0
NO.	25		2
		<u>SIX-TOOTH</u>	
MEAN	46.7		52.9
STD. DEV.	5.9		6.8
MAX.	55.0		66.0
MIN.	33.0		48.0
NO.	35		6
		<u>FULLMOUTH 8</u>	
MEAN	47.3		53.8
STD. DEV.	5.4		4.5
MAX.	60.0		61.5
MIN.	33.0		52.5
NO.	88		3
		<u>FULLMOUTH 9</u>	
MEAN	44.0		
STD. DEV.	7.0		
MAX.	59.0		
MIN.	33.5		
NO.	20		
		<u>FULLMOUTH 10</u>	
MEAN	45.6		
STD. DEV.	6.1		
MAX.	56.0		
MIN.	35.0		
NO.	16		

mean. Presenting the data with hoggets excluded from the calculations achieved the following results : pregnant ewes had a mean weight of 43.8 kg (std. dev. 7.1, max. 60, min. 26), and non-pregnant ewes a mean weight of 39.1 kg (std. dev. 9.44, max. 55, min. 23). The mean weight for ewes carrying twins was 51.5 kg (std. dev. 3.6, max. 55, min. 46).

3.3 LOCALITY DIFFERENCES

3.3.1 PRODUCTIVITY

There was no significant difference between localities in the proportions of pregnant and non-pregnant sheep ($\chi^2 = 5.78$, df. 4).

3.3.2 LAMBING DATES

Lambing times differed significantly between localities ($\chi^2 = 94.894$, df. 27, prob. < 0.005). This value is for data pooled to minimize the number of zeroes in the calculation, and excludes Eboule with a small sample size of only 15.

Lambing in Col started three weeks earlier than in any other locality. Lambing in Dumas extended for five weeks beyond any other area. In all areas except Dumas, the peak of lambing occurred in weeks seven, eight and nine, whereas in Dumas it peaked in weeks twelve, thirteen and fourteen (figure 3.5).

3.3.3 OCCURRENCE OF TWINS

Although the occurrence of twins differed visually

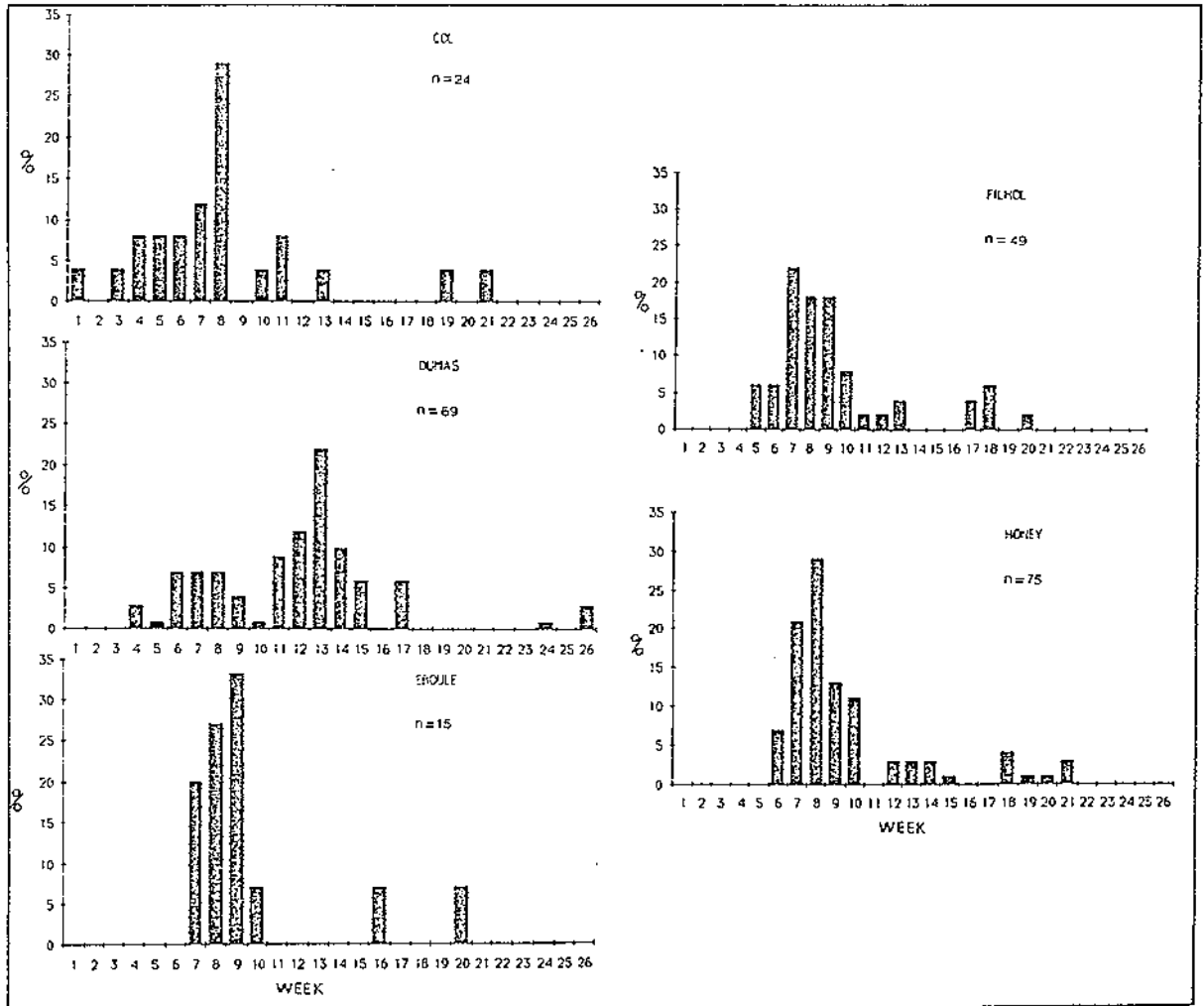


FIGURE 3.5 - lambing times in each locality. Week one begins on 19 June.

between localities, with one set of twins recorded from each of Col and Dumas, three sets from Filhol, and none from Honey or Eboule, there was no significant difference between localities ($X^2= 7.24$, df. 4).

3.3.4 AGE CLASSES

The proportion of sheep in each age class differed significantly between localities ($X^2= 77.185$, df. 30, prob. <0.001). Most of this difference is due to the localities of Eboule ($X^2= 26.14$) and Puiseux ($X^2= 25.14$), both of which had smaller sample sizes than other areas.

If the fullmouth tooth wear index is excluded, and all fullmouths are grouped together, there is a lesser, but still significant, difference between localities ($X^2= 32.919$, degrees of freedom 20, prob. <0.01). Eboule and Puiseux still account for a major part of this chi-square value.

When the data are further separated into ewes and rams, both sexes show roughly equal significant differences between the representation of age classes in localities (ewes - $X^2= 53.76$, df. 30, prob. <0.005 ; rams - $X^2= 60.78$, df. 30, prob. <0.005).

3.3.5 SEX RATIO

Sex ratio was not significantly different between localities ($X^2 = 4.544$, df. 5).

3.3.6 HORNS

The number of rams with and without horns differed significantly between localities ($X^2= 12.655$, df. 5,

prob. < 0.05). The major factor contributing to this was the greater than expected number of rams without horns in Dumas. Honey and Puiseux also had fewer rams with horns than expected.

The number of ewes with and without horns also differed significantly between localities ($X^2 = 41.88$, df. 5, prob. < 0.001). More than half of this chi-square value came from Col, where significantly more ewes than expected had horns. In the Honey sample fewer ewes than expected had horns.

3.3.7 WOOL COLOUR

A chi-square test on the number of pigmented sheep recorded in each locality shows a significant difference between localities ($X^2 = 22.474$, df. 5, prob. < 0.001). Half of this value is accountable from one area, Col, which had nearly three times as many pigmented sheep as expected. Dumas also had more pigmented sheep than expected, whilst Eboule and Filhol had fewer than expected.

There was no significant difference between localities in the colour ranks assigned to the autopsy sheep ($X^2 = 37.36$, df. 20).

There was no significant difference between localities for foetal colour patterns ($X^2 = 20.75$, df. 20).

3.3.8 FACE COVER

There was no significant difference between localities for face cover rank ($X^2 = 23.86$, df. 12).

3.3.9 CONDITION INDEX

There was no significant difference between localities in condition rankings ($\chi^2 = 18.52$, df. 16).

3.4 HOME RANGE

3.4.1 NUMBER OF OBSERVATIONS

Table VI shows the number of observations made, and the number of sheep in each observation category. An observation is not always equivalent to a day, as on some occasions a sheep was observed at sufficiently different localities at different times of the day as to warrant two observations. The mean number of observations was 10.5 (standard deviation = 4.81), with a mode of 13. Only one tagged sheep was not observed at all, and the maximum number of observations for an individual was 21.

TABLE VI
NUMBER OF SHEEP IN EACH OBSERVATION FREQUENCY CATEGORY.

NUMBER OF OBSERVATIONS	NUMBER OF SHEEP
0	1
1	1
2	2
3	2
4	3
5	4
6	4
7	4
8	2
9	5
10	4
11	3
12	6
13	8
14	6
15	4
16	5
17	2
18	3
21	1

3.4.2 NUMBER OF SHEEP RECORDED IN STUDY AREA

Figure 3.6 shows the number of sheep recorded on each complete day of observations. The mean total number of sheep present was 227, with a range from 181 to 307.

The total number of all tagged sheep ranged between 30 and 60, with a mean of 45.

Definite tag identifications had a mean of 33, ranging from 13 to 47.

For the first two observation periods (days 1-5) fewer than 63% of tags could be positively identified. After this efficiency increased to greater than 80%, as the observers became better acquainted with the study area and its topography, and with the behaviour of the sheep and their reactions to humans. That is, there was a trend in the relationship between definite tag records only and all tag records, which was a consequence of observer efficiency.

3.4.3 SCATTER PLOTS AND MOVEMENT ARROWS

Figure 3.7 a-e illustrate home range data collected for some sheep. The sheep illustrated were each observed 11 or more times, which places them in the most frequently observed 50% of the population. The purpose of the movement arrows depicted on the overlays is to attempt to elucidate whether there were any temporal trends in the way the home range was occupied, or whether sheep moved continuously throughout the home range.

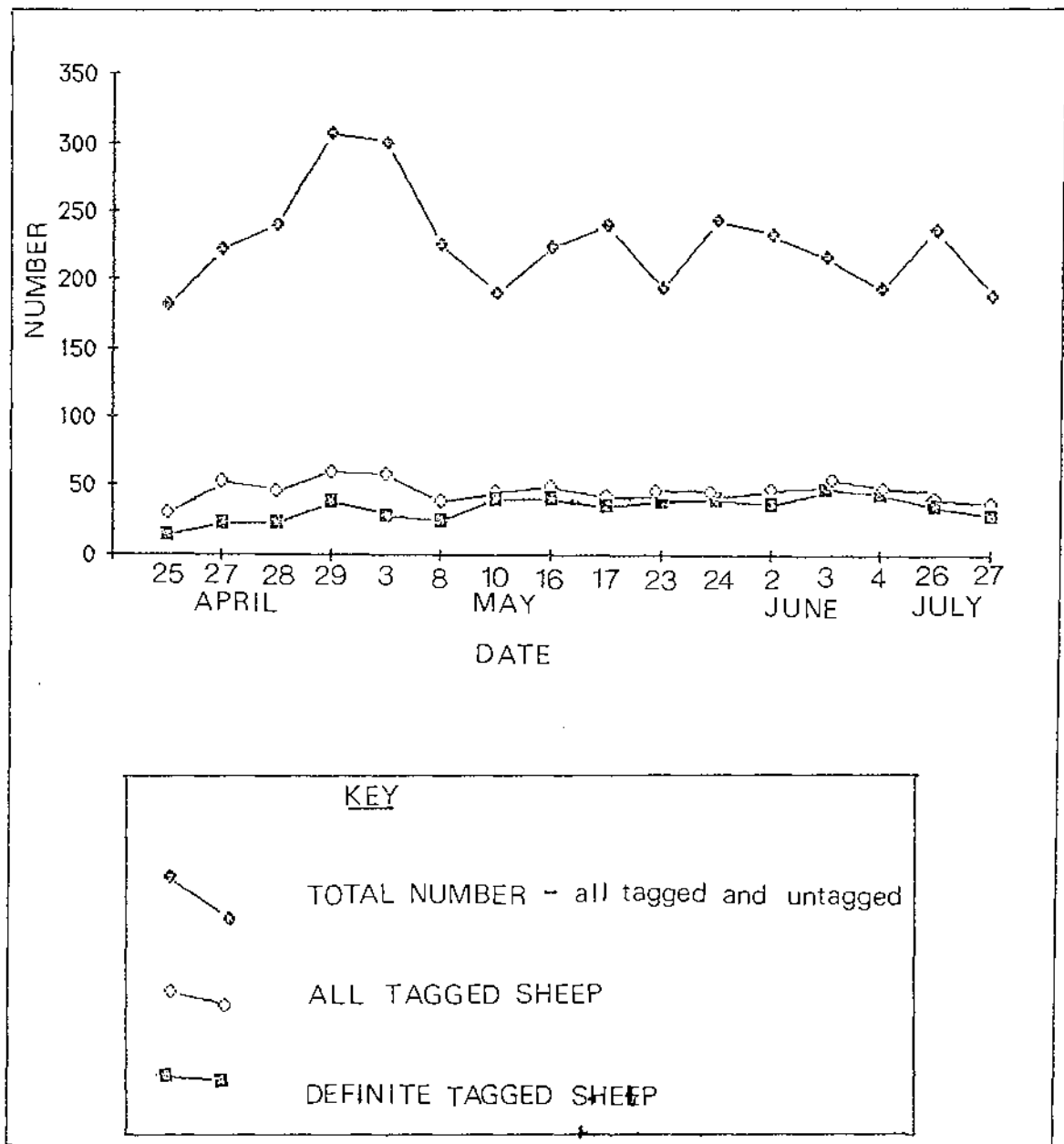
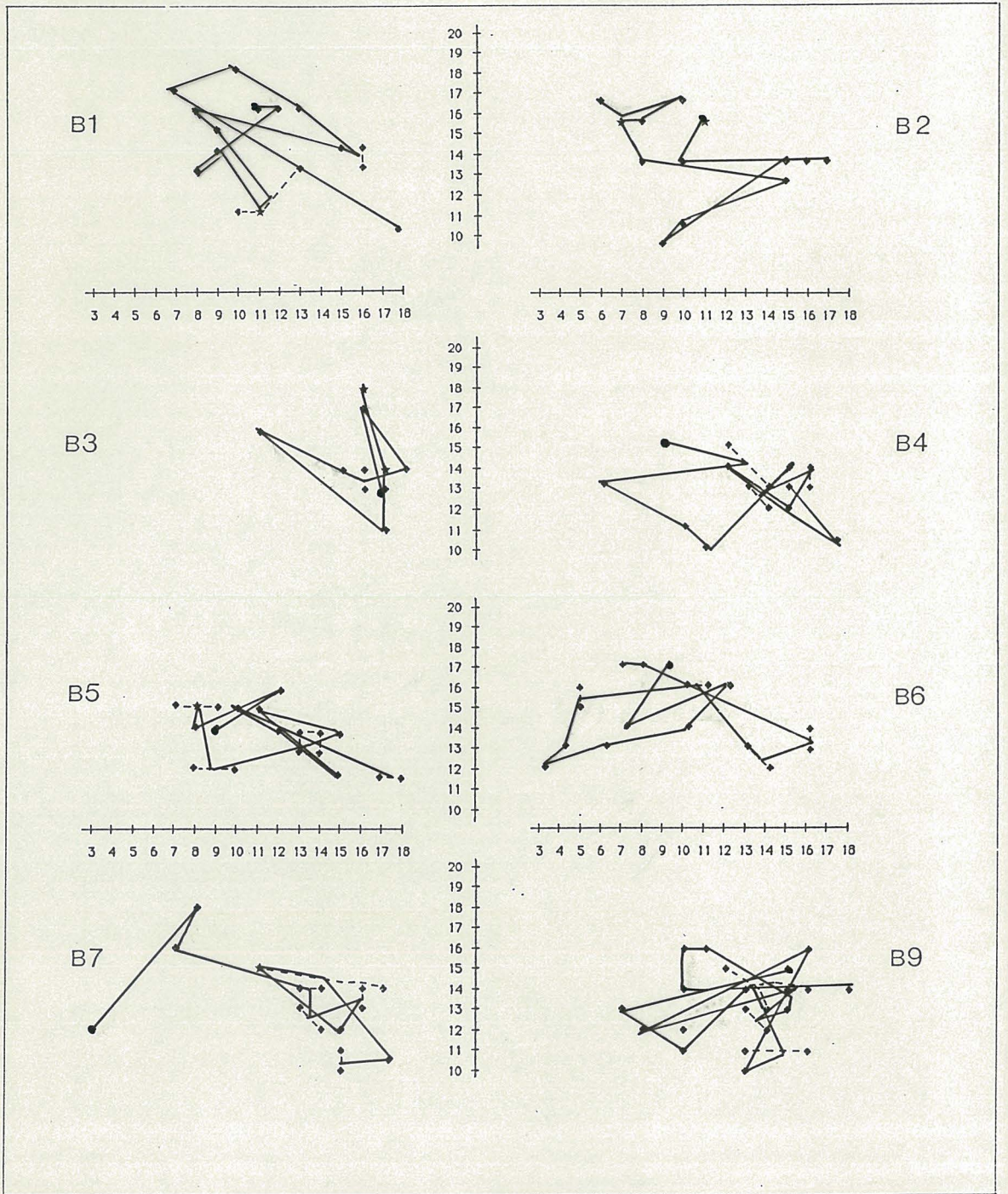


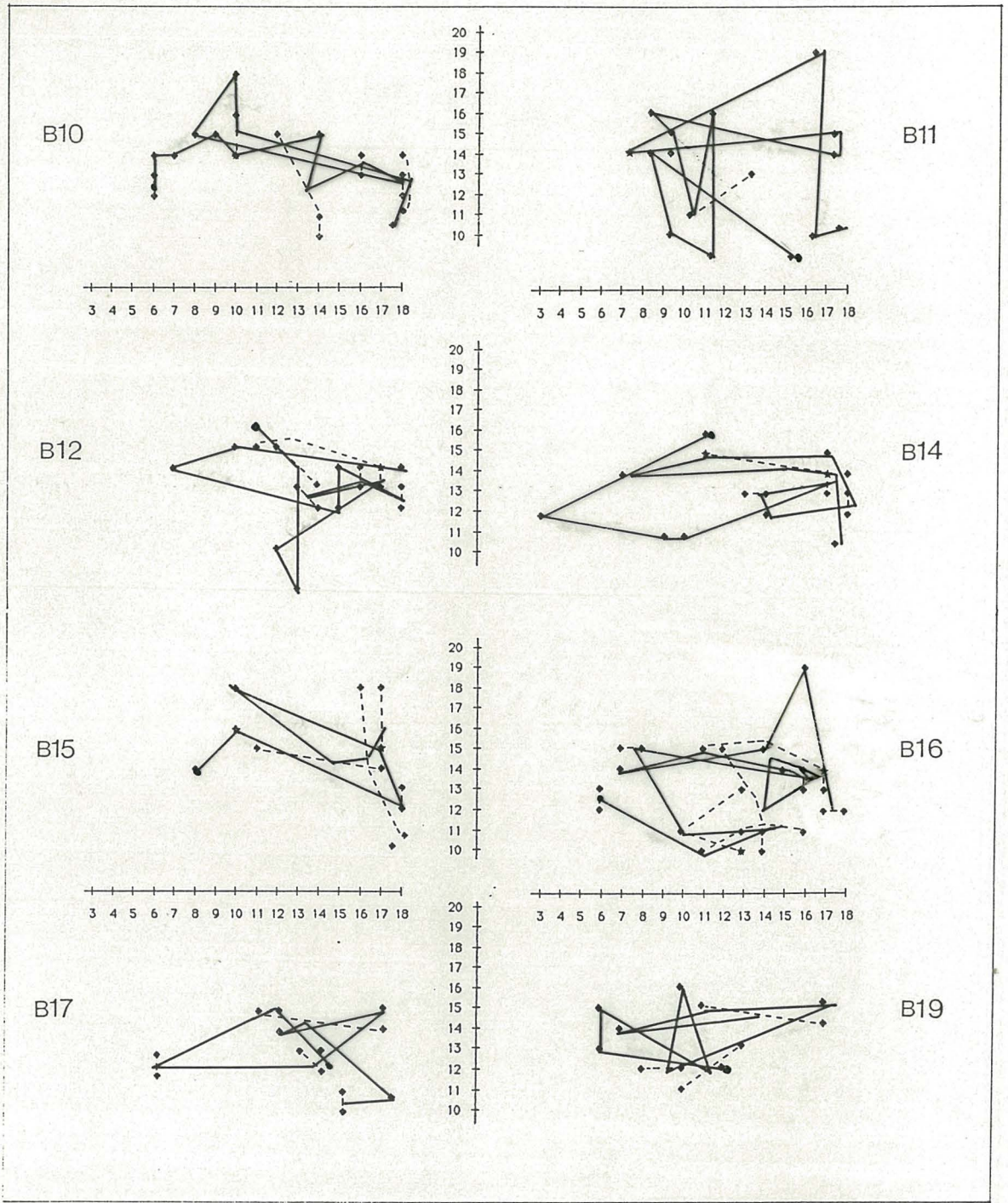
FIGURE 3.6 - number of sheep recorded in the home range study area for each complete day of observations.

FIGURE 3.7 a,b,c,d,e - home range scatter plots. Dotted lines represent two or more points belonging to the same observation.

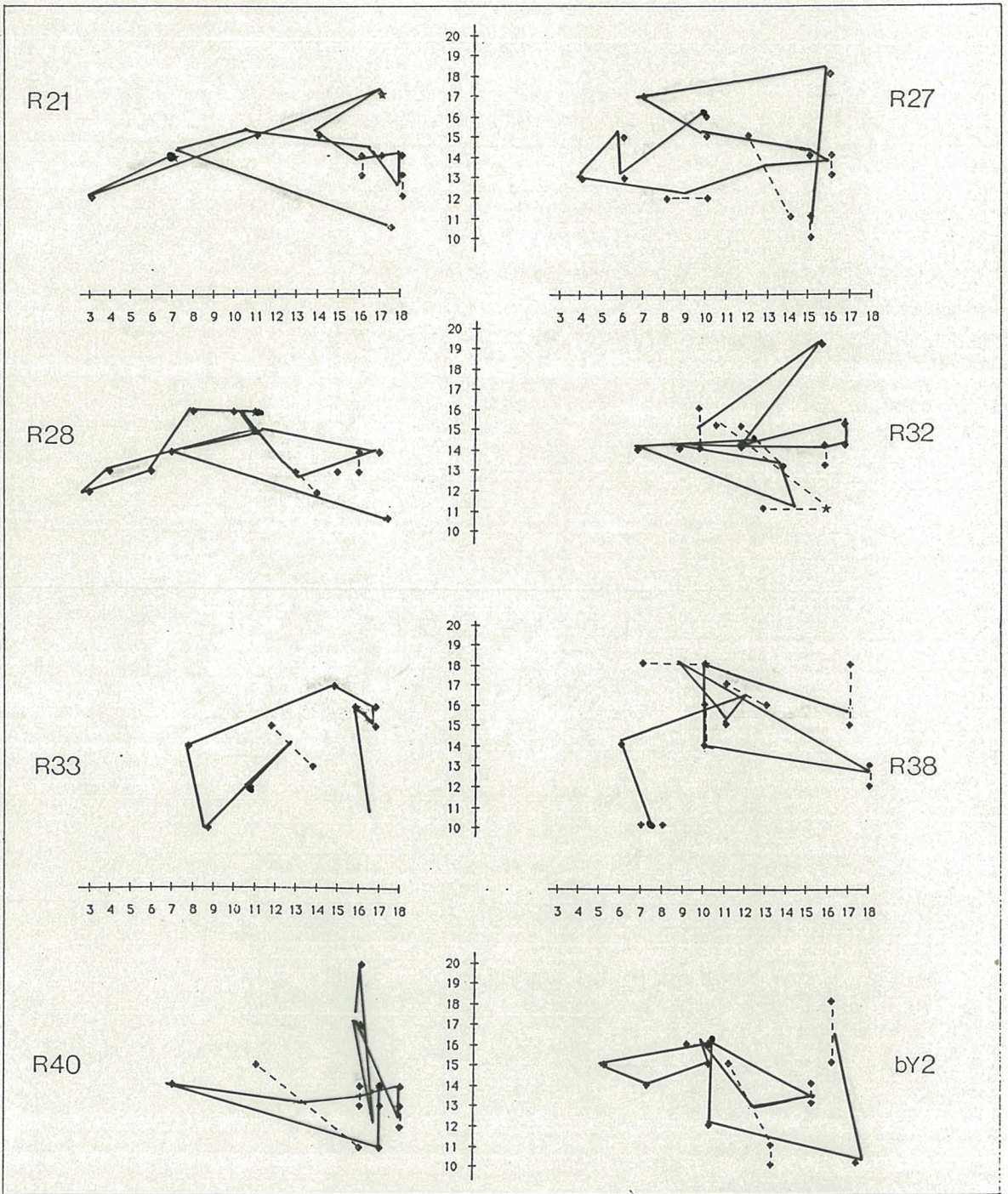
OVERLAYS - movement lines drawn between successive observations. When there are two or more points on one day, the line is drawn to a point roughly equidistant between them. The beginning of the line is marked with a dot.



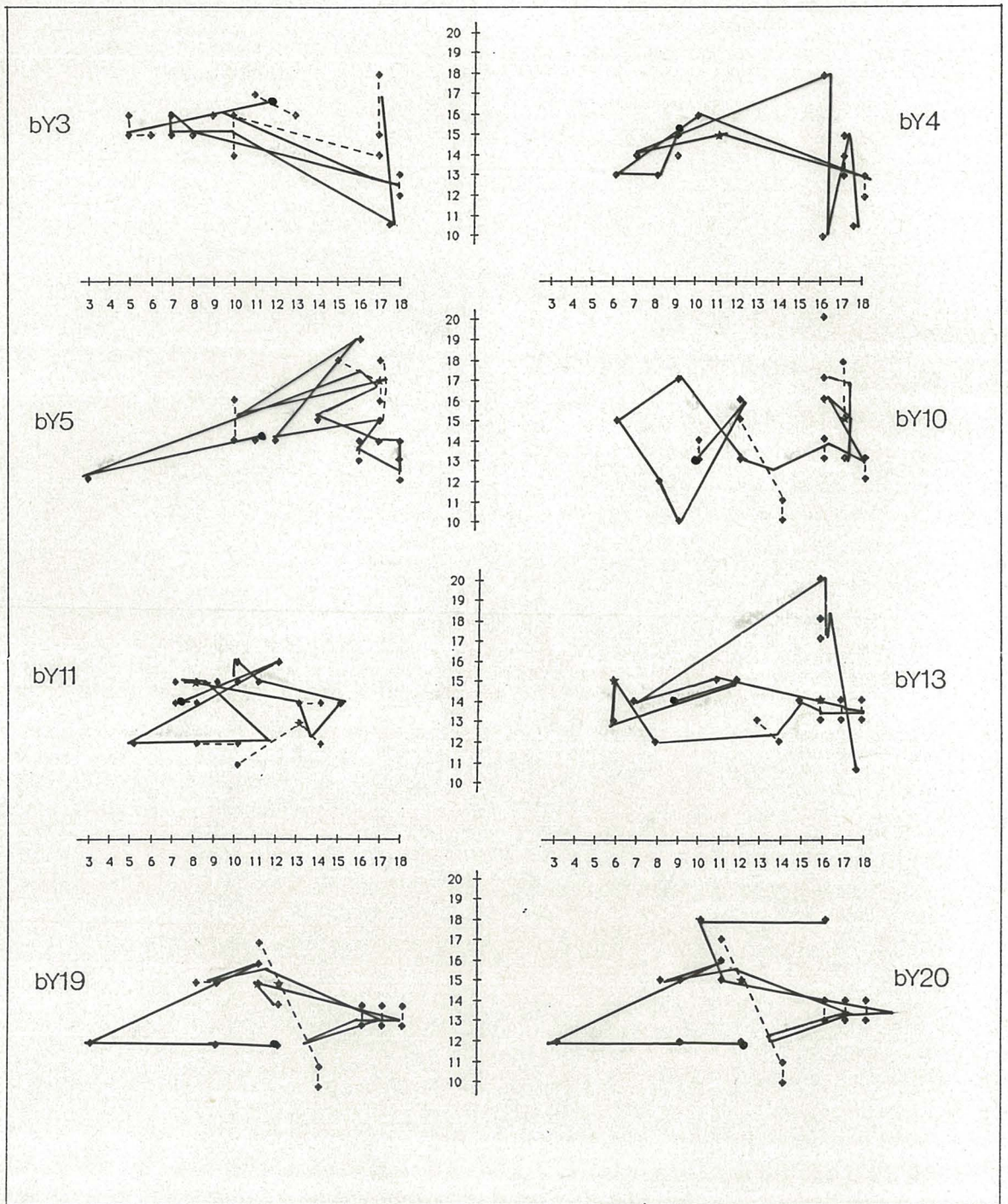
A



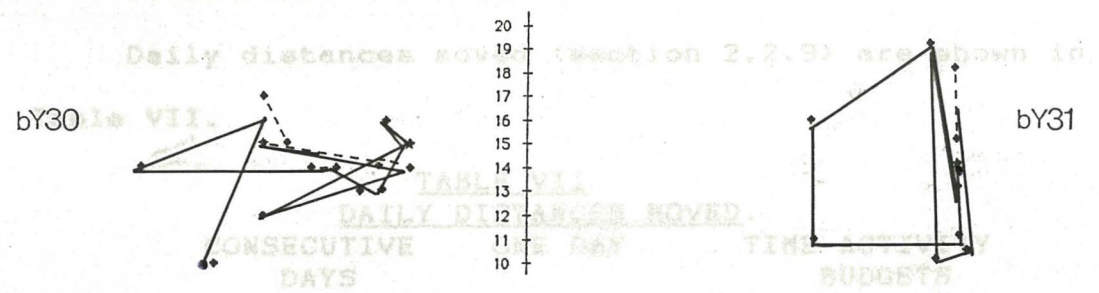
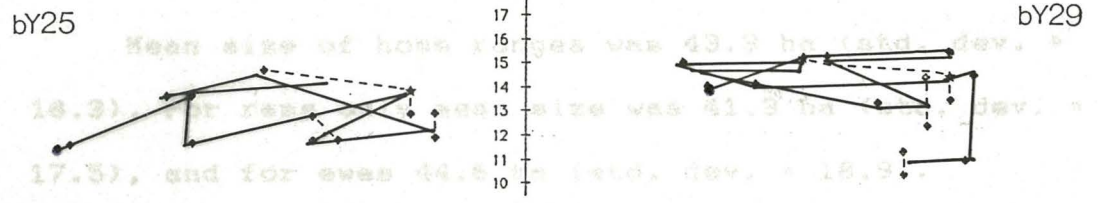
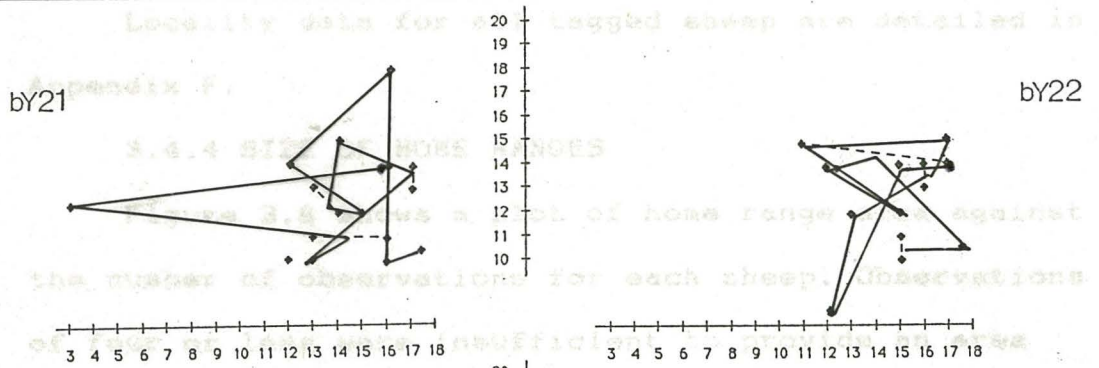
B



C



D



MEAN DISTANCE PER DAY (METRES)	STANDARD DEVIATION	NUMBER	MEAN DISTANCE PER DAY (METRES)	STANDARD DEVIATION	NUMBER
270.5	254	254	472	56	56
			(6.6 m/3 minutes)	(4.8)	17 Days

3.4.6 INTENSITY OF USE OF STUDY AREA

Figure 3.9's and b illustrate distribution of density of observations in the behaviour study area.

Density is taken as the number of sheep recorded in each grid square for each complete day of observations throughout the study period. The intervals are not numerically equal, but are scaled so as to represent approximately equal proportions of each sample size.

E

Locality data for all tagged sheep are detailed in Appendix F.

3.4.4 SIZE OF HOME RANGES

Figure 3.8 shows a plot of home range area against the number of observations for each sheep. Observations of four or less were insufficient to provide an area measurement, and are not included.

Mean size of home ranges was 43.3 ha (std. dev. = 18.3). For rams only mean size was 41.3 ha (std. dev. = 17.5), and for ewes 44.6 ha (std. dev. = 18.9).

3.4.5 DAILY DISTANCES MOVED

Daily distances moved (section 2.2.9) are shown in Table VII.

	<u>TABLE VII</u> <u>DAILY DISTANCES MOVED.</u>		
	CONSECUTIVE DAYS	ONE DAY	TIME ACTIVITY BUDGETS
MEAN DISTANCE PER DAY (METRES)	400	472	792 (6.6 m/5 minutes)
STANDARD DEVIATION	270.5	219	(4.8)
NUMBER	254	56	17 Days

3.4.6 INTENSITY OF USE OF STUDY AREA

Figure 3.9 a and b illustrate distribution of density of observations in the behaviour study area. Density is taken as the number of sheep recorded in each grid square for each complete day of observations throughout the study period. The intervals are not numerically equal, but are scaled so as to represent approximately equal proportions of each sample size.

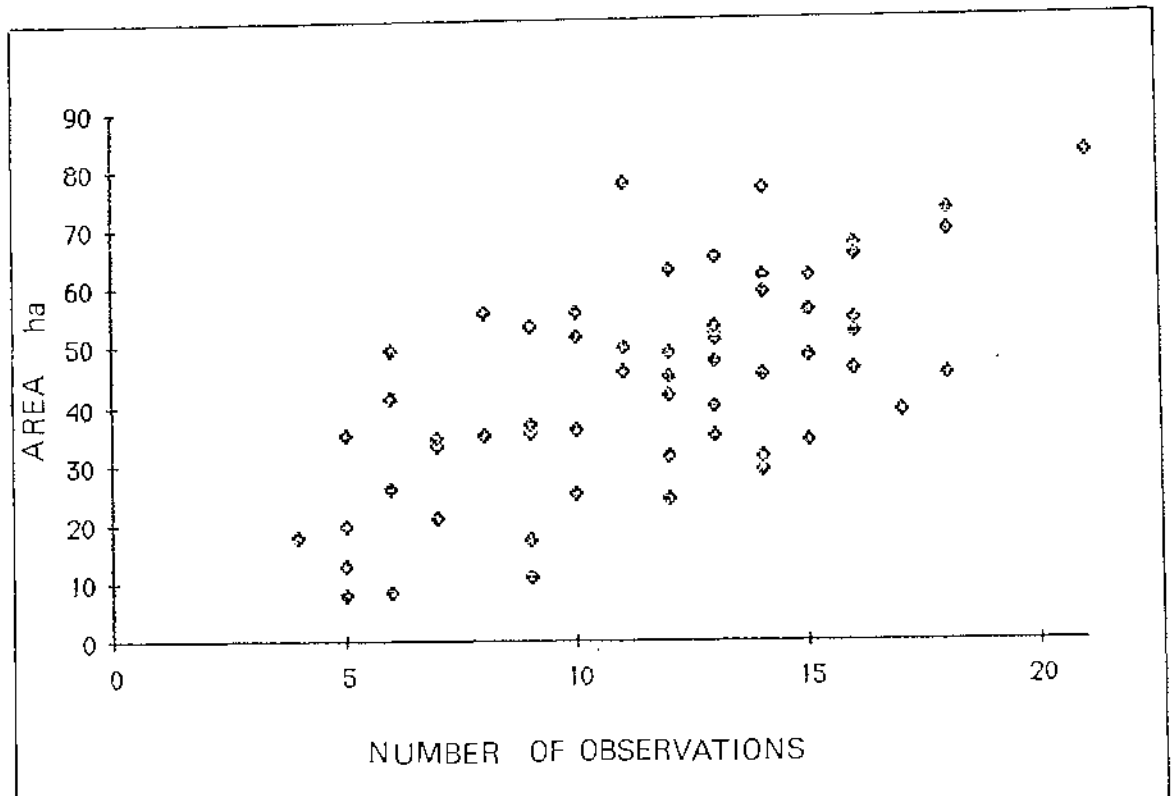


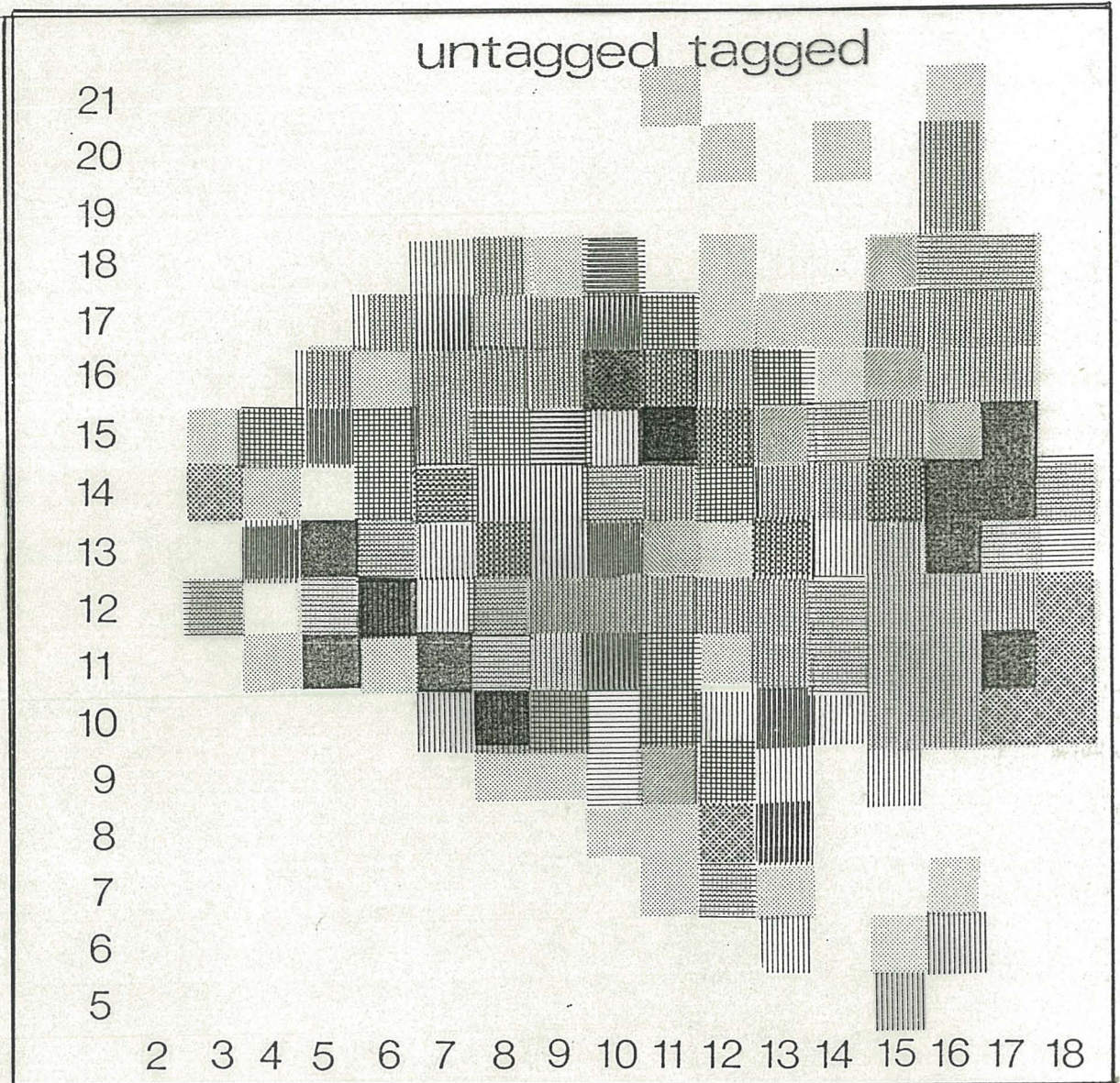
FIGURE 3.8 - home range area (ha) versus number of observations. Correlation coefficient = 0.639.

FIGURE 3.9 a and b plus overlays - density distribution
of sheep in the home range study area.






a - tagged and non-tagged sheep.

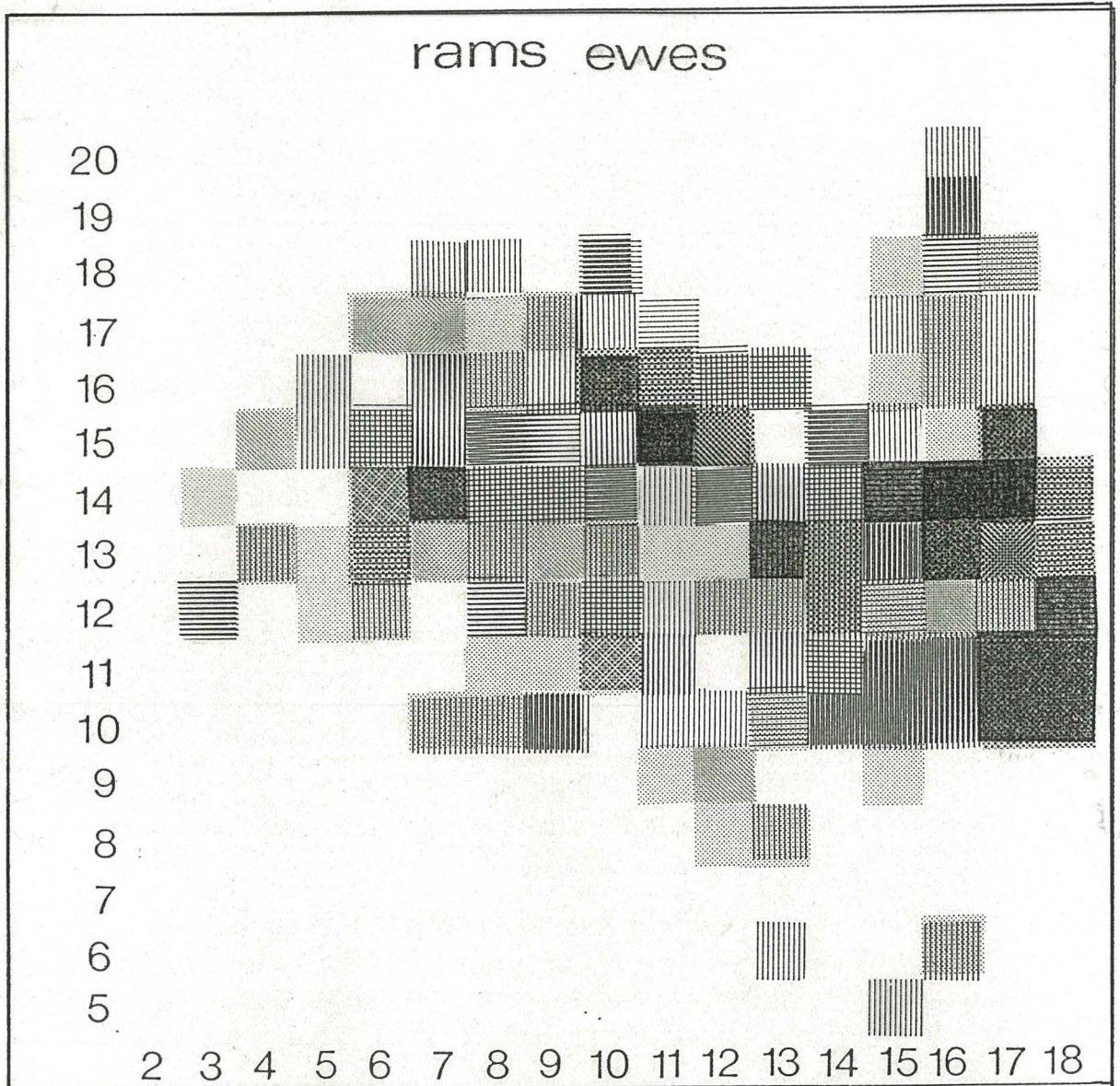
b - ewes and rams (all tagged).

SEE section 3.4.6 for further explanation.








key

untagged		tagged
1-15		1
16-30		2-9
31-45		10-16
46-60		17-23
>60		>23



key

rams		ewes
1		1
2-3		2-5
4-5		6-10
6-9		11-15
>9		>15

A comparison is made in figure 3.9a between the distribution of tagged and non-tagged sheep. This shows that there were two main concentrations of sheep. One in the area to the east of Menhir and the saddle, where most were tagged, and another in the Rocky Bay/Cave Stream area where the sheep were predominantly untagged.

3.4.7 GROUP SIZE

Information was collected on the size of the groups in which sheep were associating. The size frequency for the 708 groups encountered are plotted in figure 3.10. Mean group size was 6.31, with a range from one to 65.

3.4.8 ASSOCIATION DATA

Information collected on the occurrence of tagged sheep was plotted on an interaction matrix to record the number of times each individual occurred with each other individual. Figure 3.11 shows the frequency of each interaction category plotted against the expected Poisson distribution. Values from five to 11 are lumped.

A goodness of fit test on the observed versus expected frequency values has a chi-square value of 284.31. Thus, the observed values are significantly different from random (df. 4, prob. <0.001).

3.5 TIME ACTIVITY BUDGETS

3.5.1 TIME SPENT IN EACH ACTIVITY

A total of 5829 time activity observations were made, representing 48.58 hours, or 2914.5 minutes. The overall percentage of time spent in each of the 12

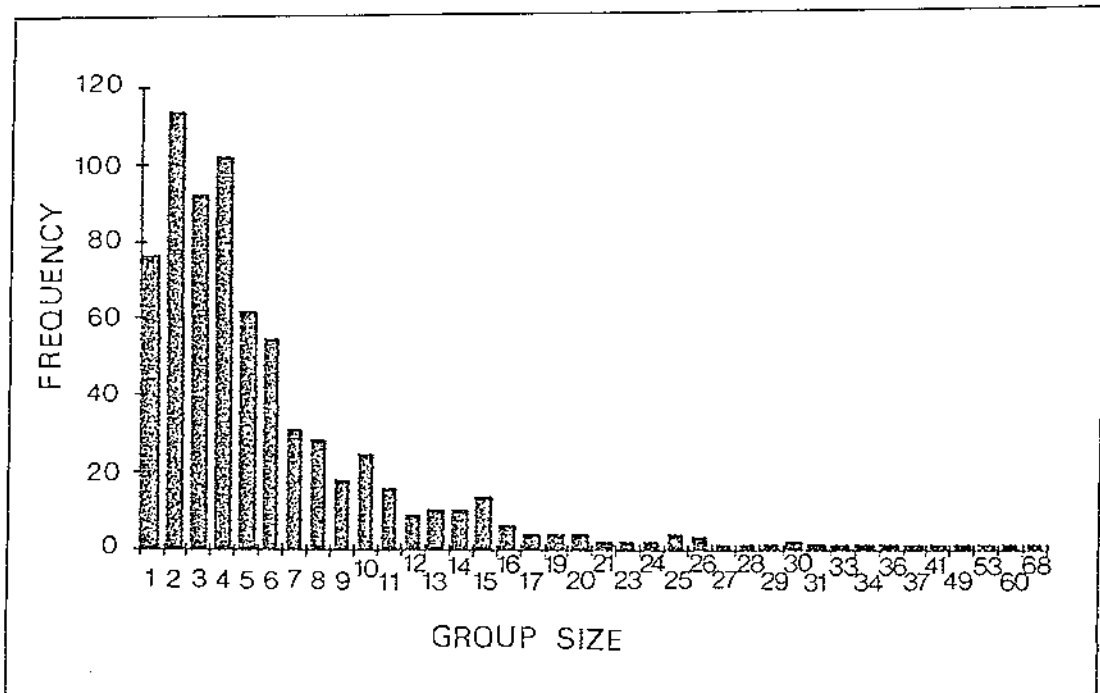


FIGURE 3.10 - group size frequency.

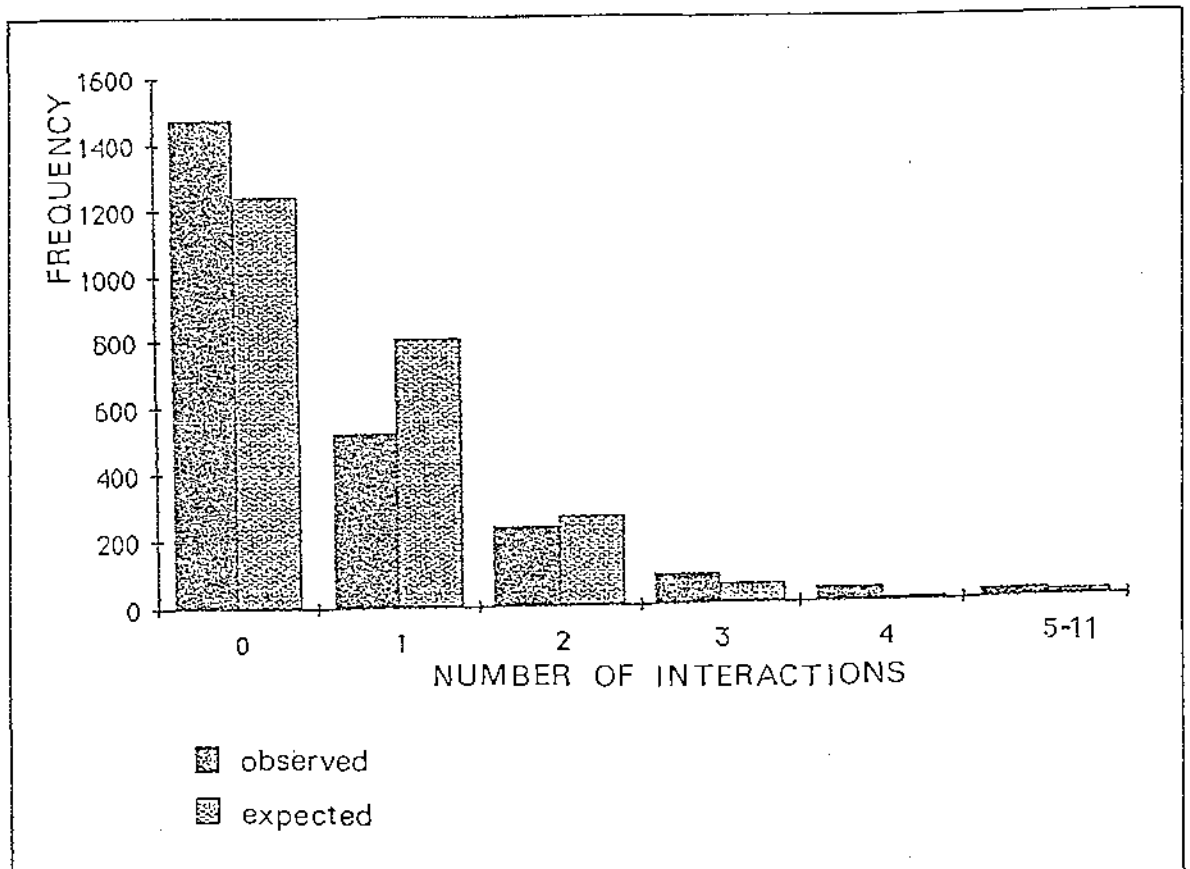


FIGURE 3.11 - observed and expected frequency of interaction categories.

NO.OF INTERACTIONS	CHI-SQUARE VALUE
0	43.96
1	97.5
2	2.84
3	15.79
4	108.79
>5	15.43
TOTAL	284.31

degrees of freedom = 4

activity categories is given in table VIII.

3.5.2 TIME SPENT FEEDING OR RUMINATING THROUGHOUT THE DAY

Observations were divided into hourly intervals, from 0830 hours onwards. The percentage of time spent each hour in feeding, ruminating or other activities, for the whole period observations were made are plotted in figure 3.12.

Time activity lines for individual sheep on different days are illustrated in figure 3.13.

TABLE VIII
NUMBER OF 30-SECOND OBSERVATIONS AND PERCENTAGE
OF OVERALL TIME SPENT IN EACH ACTIVITY CATEGORY.

FEEDING	- still, grazing	2016 (34.5%)
	- still, browsing	256 (4.4%)
	- moving, grazing	1767 (30.3%)
	- moving, browsing	59 (1.0%)
RUMINATING-	standing	201 (3.5%)
	- lying	761 (13.1%)
OTHER	- moving purposefully	140 (2.4%)
	- standing	161 (2.8%)
	- looking fixedly	191 (3.2%)
	- lying	133 (2.3%)
	- lying, head down	96 (1.7%)
	- miscellaneous	48 (0.8%)

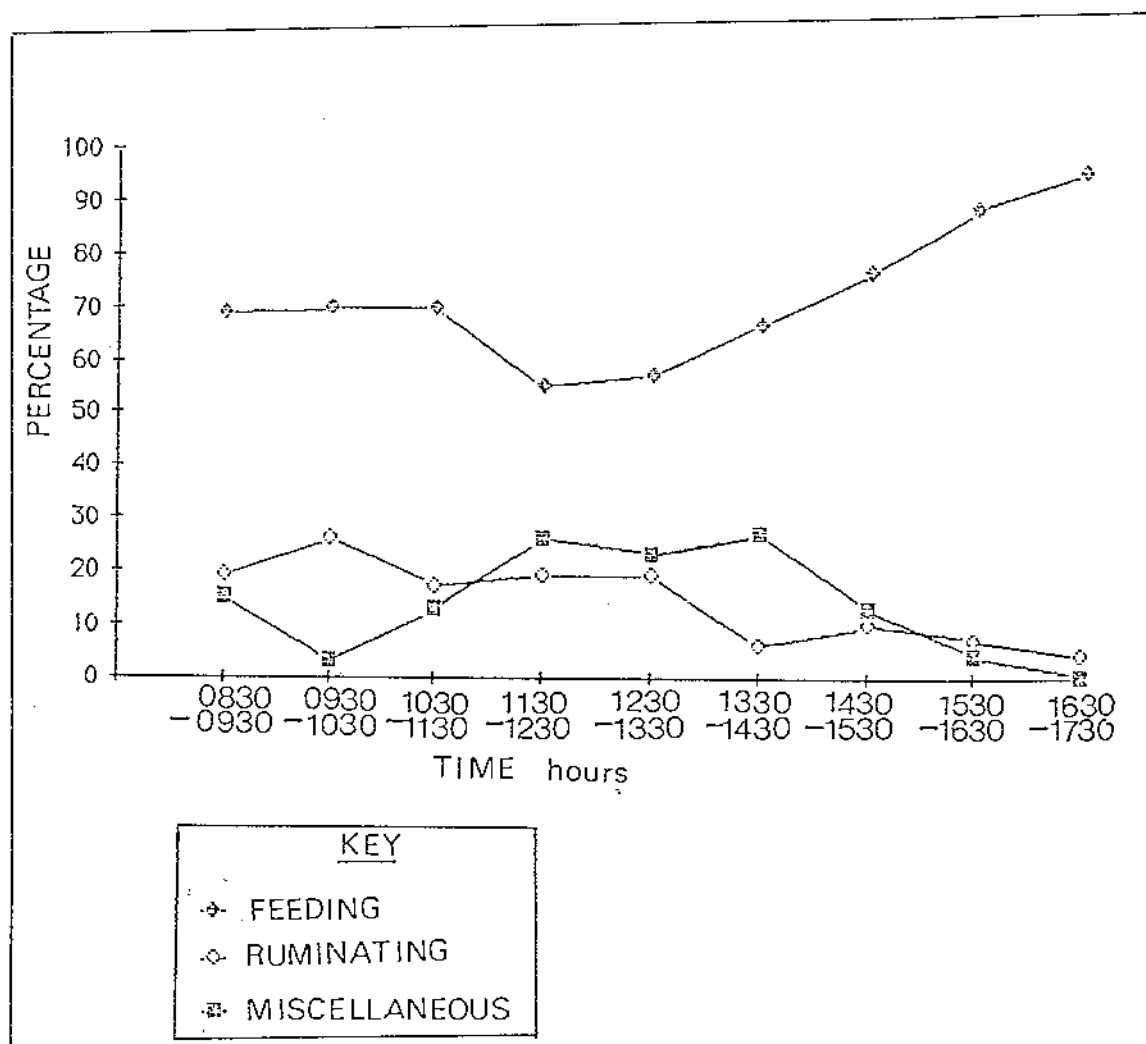


FIGURE 3.12 - percentage of time spent feeding, ruminating or in miscellaneous activities at hourly intervals throughout the day.

bY5

bY15

8 MAY
unid.

bY5

bY15

9 MAY
unid.

17 MAY
R40

R32

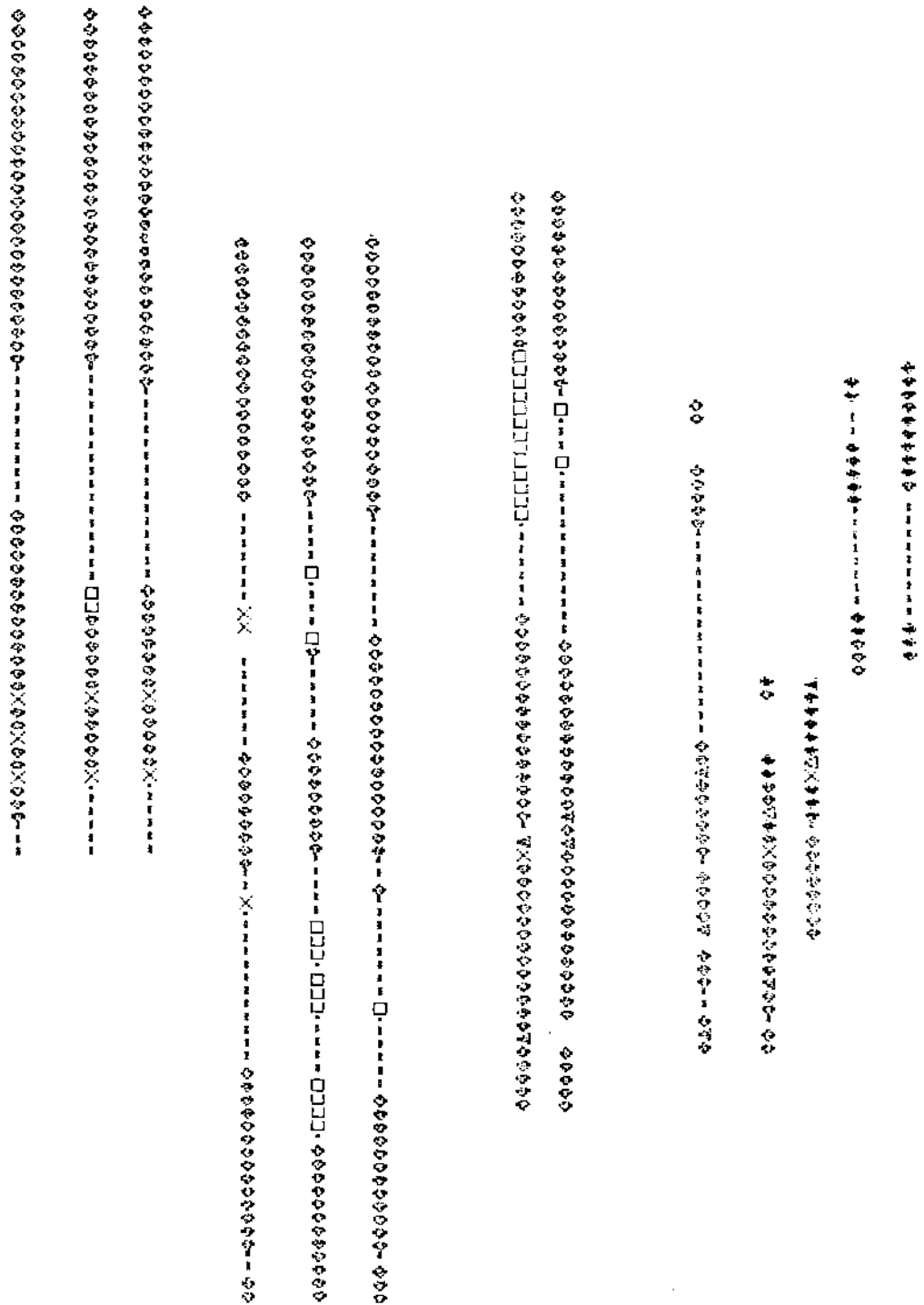
bY5

bY10

B11

bY30

R28



TIME (hours)

CHAPTER FOUR

DISCUSSION

4.1 INTRODUCTION

Comparisons are made with the Soay population, the Mauna Kea population, and the Santa Cruz population, and, where the appropriate data are available, with feral populations in New Zealand, including Arapawa Island sheep and Pitt Island sheep (table IX).

Unless otherwise specified, all references to the Soay sheep come from Jewell et al (1974). All those to the sheep of Mauna Kea are from Giffin (1976), Santa Cruz from Van Vuren (1981), Arapawa Island from Orwin and Whitaker (1984), and Pitt Island from Rudge (1983).

The Soay sheep of St. Kilda exist at an equivalent northern latitude to Campbell Island, and the two islands experience a similar climate. Both populations are free from predators, and there is no human interference. However, the Soay sheep is the most primitive domestic form of sheep in Europe. The population has existed in isolation for many hundreds of years, and thus the sheep are very different from the modern Campbell Island population.

The Mauna Kea sheep have been in a feral state since at least 1822, and are probably derived from Merino /Rambouillet /Suffolk /Hampshire stock. They exist in

TABLE IX

A COMPARISON OF SIX FERAL SHEEP POPULATIONS AND ONE
DOMESTIC SHEEP POPULATION.

SOAY ISLAND SHEEP, ST. KILDA, NEW HEBRIDES (Grubb and Jewell 1964, Jewell et al 1974).

ISLAND SIZE - 630 HA
POPULATION SIZE - 1835 IN 1966, AND 1400 IN 1973.
DENSITY - 1 SHEEP/0.34 HA
HOME RANGE SIZE - 7.8 HA
GROUP SIZE - MEAN 27-37, RANGE 2-69
EWE:RAM RATIO - 3.6:1 - 4.6:1
LAMBING PERCENTAGE (LAMBS:EWES) - 92%

MAUNA KEA, HAWAII (Giffin 1976)

HABITAT SIZE - 32 417 HA
POPULATION SIZE - 1735 IN 1975
DENSITY - 1 SHEEP/18.6 HA
HOME RANGE SIZE - 558 HA
GROUP SIZE - MEAN 28, RANGE 5-400
EWE:RAM RATIO - 1:0.56 (1971), 1:0.38 (1975)
LAMBING SURVIVAL - 38%

SANTA CRUZ ISLAND, CALIFORNIA (Van Vuren 1981)

HABITAT SIZE - 25 000 HA
POPULATION SIZE - 20 000 (MINIMUM EST. 11 000, MAXIMUM EST. 43 000)
DENSITY - 1 SHEEP/0.5 HA - 1 SHEEP/5 HA
HOME RANGE SIZE - MEAN 129 HA (RANGE 20 HA - 306 HA)
GROUP SIZE - 7 (RANGE 1-41)
EWE:RAM RATIO - 2:1
LAMBING PERCENTAGE - 77-90%

PITT ISLAND, CHATHAM GROUP, NZ (Rudge 1983)

HABITAT SIZE - 200 HA
POPULATION SIZE - 300 (1982)
DENSITY - 1 SHEEP/0.67 HA
HOME RANGE SIZE - UNKNOWN
GROUP SIZE - UNKNOWN
EWE:RAM RATIO - 1.44:1
LAMBING PERCENTAGE - 68%

ARAPAWA ISLAND, MARLBOROUGH SOUNDS, NZ (Orwin and Whitaker 1984)

HABITAT SIZE - 700 HA
POPULATION SIZE - 120
DENSITY - 1 SHEEP/6 HA
HOME RANGE SIZE - NOT KNOWN
GROUP SIZE - MEAN 2.88, RANGE 1-14
EWE:RAM RATIO - 3.76:1
LAMBING SURVIVAL - 40%

TABLE IX continued

CAMPBELL ISLAND, NZ (THIS STUDY)

HABITAT SIZE (remaining fenced off SW corner) - 1140 HA
 POPULATION SIZE - 1014 (G. TAYLOR PERS COMM)
 DENSITY - 1 SHEEP/1.12 HA
 HOME RANGE SIZE - MEAN 43.3 HA
 GROUP SIZE - MEAN 6.3, RANGE 1-65
 EWE:RAM RATIO - 1.33:1
 LAMBING SURVIVAL - 35%

HILL COUNTRY SHEEP, UK (Hunter 1964)

HABITAT SIZE - 142 HA
 POPULATION SIZE - 160
 DENSITY - 1 SHEEP/0.89 HA
 HOME RANGE SIZE - 32-40 HA
 GROUP SIZE - MEAN 37.5

 an extensive dry, high altitude environment, and are subject to pressure from trophy hunters.

The feral sheep of Santa Cruz are probably Merino, Rambouillet and other breeds, and have been feral for over a hundred years. They exist on a large, steep island, up to 730m in height, with a low annual rainfall, and are subject to hunting.

4.2 POPULATION CHARACTERISTICS

4.2.1 PRODUCTION

4.2.1.1 LAMBING RATES

Soay sheep had a lambing rate of 92 lambs:100 ewes, between 1961 and 1964. The proportion of lambs dropped to between 52% and 80% after neonatal mortality in the first three months, between 1965 and 1967.

No strictly comparable data are available for the Mauna Kea population, although a rough proportion of lambs of between 32% and 46% was observed. Annual lambing rates were estimated to be up to 91%. The Santa Cruz

sheep were highly productive, with a lambing rate of 77-90% in 1980. Lamb survival was high, approaching 100%. In Arapawa Island sheep approximately 40% of ewes had a lamb in 1979, and in Pitt Island sheep the lambing rate was approximately 68% in 1982, with a reported previous average in the range of 80%.

Campbell Island sheep in 1984 had a lambing rate of 82%, and a lamb:ewe ratio of 35:100 after neonatal mortality, as evidenced by the number of first year sheep in the population.

The variety of data does not easily lend itself to direct comparison, although it seems that the New Zealand populations have a lower productivity than the other feral populations. In all populations except Santa Cruz, neonatal mortality accounted for up to 50% of lambing losses.

Hoggets comprised about 20% of the total Campbell Island population, and this level of replacement over two years was apparently sufficient to maintain the population as there was no apparent decline in overall numbers.

4.2.1.2 TWINS

Twins are common in the Soay population, with a 113% lambing rate for ewes older than two-tooth. That is, at least 13% of births were twins. Twins were apparently quite common in the Mauna Kea population, with four of the eleven ewes tagged at the beginning of Giffin's study "leading twins". Santa Cruz sheep twin rarely, with only 10 sets of twins observed throughout Van Vuren's study.

Pitt Island sheep apparently produced twins quite commonly, but none were reported in the feral Arapawa Island population.

Twins were present but uncommon on Campbell Island, comprising 1.76% of pregnancies in 1984. All of the ewes carrying twins were physically mature. In a situation where vegetation productivity during winter is virtually nil (G.Taylor pers comm.), and where, at high population density food supply becomes potentially limiting, a ewe might not be able to cope with the added demands of carrying twins to full term unless she had attained full body size and weight, and had reasonable supplies of body fat. This situation is probably true for other feral populations, and high twinning rates in domestic flocks are only possible under a comparatively high feed regime.

Since twins tend to be smaller in size at birth, and since feeding two lambs could be expected to place additional stress on the ewe, twins are probably at a disadvantage in comparison with single lambs, and probably experience higher mortality. If this were the case, there would be no reproductive advantage in producing twins, and this is suggested as an explanation for the low occurrence of twins in the New Zealand feral populations. The higher number of twins recorded in the Kirk Stream-Six Foot Lake locality might reflect lower selection pressures against twins due perhaps to a greater than average abundance of feed, and a possibly higher survival of sheep carrying genes for twins.

4.2.1.3 AGE AND PRODUCTIVITY

Soay sheep were potentially productive in their first year, with a lambing rate of 39% for yearlings. Productivity increased until physical maturity, with two-tooth ewes having a lambing rate of 83%, and all older ewes a lambing rate of 113%. There was no marked decline in fecundity due to senility.

Little is known on the age of sexual maturity in the Mauna Kea population, although one ewe was reported to have mated at nine months old, and lambed successfully.

In Arapawa sheep, sexual maturity could be reached at six months old, and 12 month old Arapawa sheep in the captive flock have lambed successfully.

Campbell Island sheep appear to be similar to the other populations, becoming potentially productive between five and twelve months old. There was no decline due to old age. Dagginess or poor condition can explain the few non-pregnant fullmouth ewes.

4.2.1.4 TIMING OF LAMBING

Soay sheep follow a general trend amongst sheep in temperate zones of being seasonally polyoestrus, mating in the autumn, and exhibiting a marked summer anoestrus, a cycle which is stimulated by changing day length. The Soay sheep display a high level of co-ordination in the onset of oestrus, and the mean day of oestrus is particularly highly co-ordinated within ewe groups. Fifty percent of lambing occurred over a seven day period, with a range of 60 days. Over three years between 1965-1967, the mean lambing date differed by only six days,

although before 1965 lambing times were observed to differ between years.

Mauna Kea sheep usually mated in the late summer and autumn. However, lambing was spread throughout the whole year, with a bi-modal peak in winter and in autumn. The onset and duration of lambing differed significantly for each of the three years of the study, with the onset varying by one month each year, and the ending date varying by three months. Winter lambing usually extended over three months. There were noticeable differences in the timing of lambing between ewes from different home ranges.

Most lambs in the Santa Cruz population were observed in early winter (December and January), although lambs were born throughout the year. Lambing peaked at different times in some areas, with an observed peak in October for several areas.

Lambing in the Arapawa sheep was extended approximately from June until December with a peak in June and July (winter).

Campbell Island sheep have a much more protracted period of lambing than the Soay sheep, with it occurring in a six month period between June and December, although the bulk of lambing in 1984 would have taken place in a three week period in August. In one area (Dumas), this peak began six weeks later than in the other areas. The onset and end of lambing differed significantly between areas, beginning early in Col, and ending late in Dumas.

Only one ewe was ever observed in oestrus during the study, and this was a tagged sheep (R21) on the 23 and 24 May.

Sadleir (1969) and Jewell and Grubb (in Jewell et al. 1974) have discussed reasons for variations in the timing of oestrus, and hence of lambing. Dates of onset of oestrus differ significantly between breeds. The importance of day length has already been alluded to. Environmental conditions may have an effect: for example, good summer feeding may advance oestrus, and low summer temperatures may also advance oestrus. Social environment may influence oestrus, especially rutting activity in rams, and there may be facilitation amongst ewes especially those in the same home range group. Lamb survival from the time of births and the age of weaning determine the time of the next mating season.

There are a variety of reasons which could explain the long lambing season in Campbell Island sheep. Locality differences may be due to differences in environmental quality between areas, differences in micro-climate, and differences in the availability of feed, especially during periods of snow. The apparent lack of co-ordination in lambing between ewes in the same locality supports the absence of closely associating home range groups, and the relative lack of a defined period of rutting might lessen the influence of rutting behaviour over the initiation of oestrus.

4.2.2 SURVIVORSHIP

Survivorship in the Soay population was density

dependent, that is, there was a low survival in a winter following a large summer population. Survivorship was also age and sex dependent.

Neonatal mortality was closely correlated with the mortality of older sheep and with population density. Yearling mortality was high, and also sensitive to population density. High yearling and ram mortality may have been partially due to their higher weight loss over winter. After the yearling stage, ewe survival was fairly constant to age nine, and then it dropped sharply. Survival rate in rams was lower, although the survivorship curve was of similar shape. There was no senile phase in mortality.

While survivorship trends on Mauna Kea were masked due to the hunting of rams, and predation pressure from wild dogs, in the absence of these mechanisms mortality was probably density dependent, and would follow the boom-bust fluctuations which characterize the Soay population.

Natural mortality in the Santa Cruz population was low, and rifle and archery shooting were the major sources of death. No differential mortality was noted for rams, or for lambs. The high survival rate of lambs was reflected in their high representation (approx. 30%) in the total population.

The Boreray sheep of St. Kilda (Morton Boyd 1981) showed a differential mortality operating on rams and lambs, similar to that of the Soay sheep, and this was reflected in the very low numbers of adult rams in the

population.

Campbell Island sheep suffered a high differential mortality immediately after birth (neonatal) and between the hogget and two-tooth stage during their first winter. Mortality does not seem to affect ewes and rams differentially, and there are insufficient data available on absolute mortality figures to postulate any relationship to density.

In figure 3.1, survivorship in the Campbell Island population approximated that of domestic ewes more closely than that of any of the other feral populations. A relatively high proportion of sheep survived beyond the first two years. Mortality and productivity appear to be fairly constant, and the population has not been subject to the great oscillations in numbers that occur in the Soay population. This situation may change in the remnant population in the south-west of the island if density continues to increase, and food supply becomes limiting, but only continued monitoring of the population will show how it adjusts and regulates itself.

4.2.3 AGE STRUCTURE

The age:sex structure for all feral populations except the Soay sheep have not been intensively studied, and since information for the Soay population has been collected by following the survival of cohorts rather than studying a large sample of sheep at one point in time, no comparison has been made.

The age:sex histogram (figure 3.2) for Campbell Island sheep in 1984 illustrates an aging population.

Productivity peaked between 1976 and 1979, and this is evidenced as a bulge in the population. The slightly lower representation of four-tooth sheep may just be a smaller initial cohort, or that cohort may have been subject to greater than usual neonatal and first year mortality.

Although the graphical representation of the fullmouth age class is largely conjecture, there is definitely a larger proportion of sheep in the fullmouth class in 1984 than there was in 1970. The 1984 value for fullmouth rams was 43.9%, compared to 37% in 1970, and for ewes was 42.2% in 1984, compared to 29.5% in 1970. Thus there has been a greater survivorship, which combined with lessening productivity and the smaller contribution from first and second year cohorts, means the population has become increasingly top heavy.

In both years, a slightly greater proportion of males survived to the fullmouth category than in females, although numerically there were more fullmouth ewes than rams. This similarity between ewes and rams would appear to confirm the lack of any sex specific mortality.

4.2.4 POPULATION SIZE SINCE 1895

Rudge (1984, pers comm.) has investigated reasons for the gradual decline of the Campbell Island population to 1961, and its subsequent recovery. Since 1970, the trend in population size has been one of a gradual increase, although there was a slight dip in numbers in 1975.

The Campbell Island population shows none of the

fluctuations which characterize the Soay population, and possibly the Mauna Kea population. This may be because food has not been a limiting factor, due to a different environment and a lower density of sheep. Thus, the island has been able to support the increasing population, particularly as sheep have moved into and opened up previously ungrazed areas.

Productivity also declined up to 1961, and is possibly the reason for the decrease in population size. It increased to 1980, although it dropped in 1975-1976, coincident with the slight decrease in overall population size. As the population has continued to increase, productivity has dropped to 20% (number of hoggets in the population). There may be a density dependent factor operating, and the lowered productivity may be a reflection of an increased population, and a lessening availability of food.

4.3 PHYSICAL CHARACTERISTICS

4.3.1 SEX RATIO

The sex ratio of the Campbell Island population seems to have stabilised over the last 15 years, there being no change in the ewe:ram ratio of 57:43 between 1970 and 1984. During the farming era, males comprised about 35% of the adult population. 30% were wethers, making no reproductive contribution to the population. Since then the ratio has changed in favour of rams, with 1.3 ewes to every ram, compared to the earlier 2.9:1. Rudge (pers comm.) found that a ratio of 57:43 was

significantly different from equality.

Campbell Island sheep do not seem to have the intense period of rutting such as is found in the Soay population, and this may account for the higher ram survival.

The Soay rams are subject to a high differential mortality, and the ewe:ram ratio in the 1960's was between 3.6:1 and 4.6:1. The Santa Cruz population had a ewe:ram ratio of 2:1, and it is not thought that there was any selection by hunters for the age or sex of the sheep that they shot. The Mauna Kea population had a ewe:ram ratio between 1.78:1 and 2.6:1, although this was partially due to the selective hunting of rams.

Arapawa sheep had a ewe:ram ratio of 1.61:1 until August 1979, when it changed suddenly and unaccountably to 3.76:1. Pitt Island sheep approach the Campbell Island situation with a ratio of 1.44:1.

In all feral populations there are more ewes than rams, although Campbell Island would appear to have proportionally more rams than any other. Pitt Island is the most similar to Campbell Island. Despite the expectation that a high number of rams might increase rutting intensity, rutting does not appear to be as intense as in the Soay population.

4.3.2 HORNS

Commercial Merino rams, and up to 50% of ewes have horns (Ryder and Stephenson 1968), but the occurrence of horns in feral populations of predominantly Merino origin varies. In the Mauna Kea population, most adult rams

are horned, but only one ewe was observed with horns. On Arapawa Island, 88% of rams were horned, and no ewes were horned. On Pitt Island, 96.8% of rams, and 13% of ewes had horns.

Since the occurrence of horns is genetically determined, variability between populations reflects differences in the founder populations as well as genetic change through time.

The proportion of sheep on Campbell Island with horns has changed significantly since 1961. In 1961, 50% of the ewes sampled were horned, and 71% of rams (cf. 60% for both ewes and rams, quoted in Orwin and Whitaker 1984). In 1970, 20% of females, and 67% of males were horned, and this is significantly different to the values for 1984 ($X^2 = 44.11$, df. 1, prob < 0.005). In the sample taken in 1975-1976, 79% of the rams were horned, and 30% of the ewes had horns or scurs. In 1984, 9.9% of ewes, and 81% of rams were horned. Thus, there has been a trend for the proportion of rams with horns to increase, and for the proportion of ewes with horns to decrease.

The size of horns on the Campbell Island rams varied from a tight half spiral close to the head, to open double spirals. Ewes' horns were much smaller, both in length and circumference, and often appeared only loosely attached to the skull. In some rams, the horns had grown into the skull around the eyes, causing infection, and in several rams the horns were totally covering the eyes.

Geist (1971) found that dominance among rams was determined by horn size. The increase in the number of

horned rams may reflect the greater breeding success of horned rams as opposed to unhorned rams, and it would be of interest to investigate the relationship between horn size and dominance in Campbell Island rams.

The differing proportions of rams with horns between localities may reflect the varying breeding success of horned and unhorned rams within localities. The different proportions of ewes and rams with horns between localities is probably a reflection of genetic changes within sub-populations.

4.3.3 PIGMENTATION

A marked increase in the number of pigmented sheep in feral populations seems to be a regular phenomenon.

In the Mauna Kea population, which has been feral since 1822, 80% of the sheep are a reddish brown or solid brown, 16% are white with black face and legs, and 3.5% are all white. Reports from the 1930's suggest that white sheep predominated, and the subsequent trend to pigmented sheep may have been hastened by the greater susceptibility of white sheep to shooting.

The Arapawa population, feral since the 1860's, now comprises 89.6% black, or black and white, sheep. The Pitt Island population has been feral for at least 70 years, and comprises 90.2% pigmented sheep - 67-71% are black, and 17% are black and white. Moorit (brown) sheep are present.

Mainland New Zealand feral flocks were also observed to change from white to predominantly pigmented within "fifty or so years" (Orwin and Whitaker 1984).

The Campbell Island population has demonstrated only a small, insignificant increase in the number of pigmented sheep in fifty years. A comparison of the 1.3% pigmented sheep in 1970 to the 1984 value of 1.8% shows no significant increase ($X^2 = 1.24$, $df = 1$).

The founder populations of all the feral merino flocks are presumed to have been all white, with perhaps 0.2% pigmented lambs as in current commercial flocks (Regnault 1976).

Adalsteinsson (1984) has related increased fertility to pigmentation in Icelandic sheep, and greater production may lead to the observed increase in the number of pigmented sheep.

Orwin and Whitaker (1984) found that pigmented sheep in the Arapawa population had lower fleece weights, weaker wool fibres, and more shed fibres than white feral sheep. Lower fleece weight, and a tendency to self-shedding would probably enhance survival in a wet, muddy environment where a heavy fleece would be disadvantageous (Regnault 1976), and would thus differentially select in favour of pigmented sheep.

However, the Campbell Island population seems not to conform to these hypotheses. Since many of the genes for pigmentation may be present in the population, but hidden as recessive heterozygotes, an increase in the number of pigmented sheep is still a possibility. Only one pigmented ewe was observed to carry a pigmented foetus. All other pigmented foetuses had white dams. Productivity does not seem to be related in any way to coat colour,

although it is worth noting that all five heavily pigmented ewes in the autopsy sample were pregnant, whereas all other colour classes included non-pregnant ewes.

The Campbell Island population seems to include sheep with badger face, or badger face-type, patterns, which the Arapawa population does not.

4.3.4 HOOF AND NOSE COLOUR

Pink noses and white hooves are typical Merino characteristics, while noses and hooves with some degree of black are more characteristic of Corriedale sheep. The purpose of these rankings was to quantify the proportions of sheep with various degrees of colouration in the Campbell Island population, and it is of interest that only a few sheep conform to the Merino trait.

4.3.5 FACE COVER

Face cover was graded to confirm previous observations (Orwin pers comm.; Renault pers comm.; Rudge pers comm.) that Campbell Island sheep were very open faced. Although there was no difference between the localities in the proportion of sheep in each face cover class, in that each locality included areas of Dracophyllum as well as tussock, it was notable that sheep on the high eastern slopes of Honey, which comprised very short vegetation, seemed to have more face wool than sheep from places with thick vegetation.

4.3.6 LACTATION

Weaning appeared to have totally finished, as no hoggets were seen suckling, and six of the seven ewes observed lactating were probably doing so in response to imminent parturition.

Two pregnant ewes had mastitis, and it is probable that the lambs would have died shortly after birth due to an inadequate milk supply.

4.3.7 CONDITION INDEX

Ewes varied in the condition they were judged to be in, but on average seemed to have reasonable supplies of fat, especially considering the added demands of pregnancy and the colder, windier weather. Although plant growth appeared to have stopped during winter, the effects of a limited food supply on the condition of the ewe may have only become apparent later, when the lambs were suckling.

4.3.8 WEIGHT AND BODY SIZE

Campbell Island ewes appear to have increased very slightly in mean weight since 1961 from 38 kg to 40.7 kg, and rams have decreased from 51.2 kg to 46.4 kg. There were big differences in mean weights recorded in the summer and winter of 1984, although the summer weights were taken from a small sample size (Orwin unpub.). Rams weighed 55.8 kg in summer compared to 46.4 kg in winter. Lactating ewes in summer weighed 35.8 kg, while

non-lactating ewes weighed 48 kg. Pregnant ewes in winter (excluding hoggets) weighed 43.8 kg, and non-pregnant ewes (excluding hoggets) weighed 39.1 kg.

Summer weights in the 1975-1976 expedition gave a range from 20 kg to 58.5 kg (including hoggets) with a mean of 35 kg for ewes. Rams ranged from 38 kg to 80+ kg, with a mean of 65 kg.

Santa Cruz rams weighed 50 kg, and ewes 37 kg. Mauna Kea rams weighed 45 kg, and ewes 34 kg. Shorn Arapawa rams weighed 51.2 kg, and non-pregnant ewes 37.8 kg.

Physical maturity of Campbell Island sheep, judging by mean weight, is attained by ewes after their third year (six-tooth or older), and by rams after their second year (four-tooth or older). However, there is a wide variation in weight in each age class, and some of the heaviest hoggets weighed more than some of the lightest fullmouths.

The weights recorded from both Campbell Island ewes and rams covers the range of weights found in other Merino feral populations.

Orwin (unpub.) suggested that non-pregnant ewes would weigh more since they were not subject to the stress of pregnancy. However, data from the winter of 1984 suggested the contrary, that pregnant ewes weigh more. This may have been because heavier ewes with greater reserves of fat may have a greater chance of a successful pregnancy. However, added to the weight of

the ewe was also the weight of the foetus and placental fluid, which may have added several kilograms to overall weight especially if the ewe was in the later stages of gestation.

4.4 SUB-POPULATIONS

The evidence seems to suggest that adherence to a home range is having an affect on the genetic make-up of portions of the population, and that distinct sub-populations are appearing. These sub-populations are distinguishable by physical trait such as pigmentation and the occurrence of horns, and by features such as the timing and duration of lambing. Differences in pigmentation were only significant for the number of sheep classed as pigmented in the large sample, and there was no significant difference between localities in spotting on the face and legs from the autopsy sample.

Significant differences in age classes between localities exist, and these may be explainable in terms of the past history of the area. For example, both Puiseux and Eboule were unfavoured grazing areas which have been increasingly opened up in the last 10-20 years as population density increased. The lack of very old sheep (fullmouth 9 and 10) may reflect the previously low density, with the larger numbers of younger sheep due to migration and increasing productivity. Alternatively, the wear index may not be applicable to these areas, and all fullmouths regardless of age fit into wear category fullmouth 8, as suggested by the low chi-square values for lumped fullmouth categories.

Rudge (pers comm.) found differences in lambing times, presence or absence of horns, and sex ratio between areas.

I suspect that the presence of twins was in fact another locality effect, and that the chi-square analysis was insignificant because of the low numbers. The three sets of twins from Filhol were all recorded in a very small area at the head of Six Foot Lake. The set of twins recorded from Dumas came from the head of Kirk Stream, which is geographically close to Six Foot Lake, and this recording from two localities may reflect the splitting up of localities, with a home range area in fact overlapping both localities.

4.5 HOME RANGE

4.5.1 RELIABILITY OF TAG IDENTIFICATIONS

Although the study was conducted with the assumption that all sheep had an equal chance of being observed and recorded, the assumption was not entirely valid.. The tags were coloured and numbered systematically, but unfortunately there was some confusion in identifying individuals. For example, there were seven ewes with red-white tag combinations, and in the absence of any conspicuous physical characteristics there was sometimes difficulty in ascertaining which individual was being observed if the numbers could not be read with certainty. Two sheep whose tags were accidentally 'reversed' to the usual order (R28 and B8), were instantly recognizable from tag colour alone, even at a distance.

An attempt was made to paint large numbers on the side of the sheep to aid identification, and this met with varying degrees of success. The red numbers painted on about six ewes were never readable, and almost immediately wore off. However, about twelve rams painted with blue numbers retained at least some vestige of a number or recognizable pattern throughout the four month period I was on the island, and thus had a greater chance of being observed from a distance.

Due to the dense nature of the Dracophyllum, the ear tags had a tendency to be pulled out, and by the end of the behaviour study, eight sheep were known to have lost one tag. Sheep with one tag remaining were still identifiable, and one ram (bY29) with distinctively broken horns was identifiable without a tag. Since the sheep still retained the small metal WRONZ tag which was noticeable through binoculars, and since they had obviously torn ears, they could still be ascertained as having been tagged. Several ewes with only WRONZ tags were caught and their identity established, but although they were sufficiently distinct to be recognizable for a while, once they moved away from where they were recaptured they could no longer be assigned a definite identification. Unfortunately, recapture of sheep was very difficult and involved serious disturbance so this was not a successful method of re-identifying sheep with lost tags.

It is probable that some of the sheep that were not observed towards the end of the study had lost their

tags, and were in fact present but unrecognized.

4.5.2 NUMBER OF SHEEP IN THE STUDY AREA

Perhaps the most obvious point in figure 3.6 is that the number of sheep present in the study area fluctuated. This may have been partially due to the terrain, as sheep were easily obscured by the large tussock bushes present to the west of the barrows, or by the Dracophyllum scrub on Northwest ridge and the northern slopes of Menhir. This was especially so if the sheep were lying down or standing still.

However, it was probably due also to the movement of sheep in and out of the census area, for although the study area was designed to encompass the entire range of the tagged sheep, it also included portions of the ranges of untagged sheep. The high density of untagged sheep in Rocky Bay and the Cave Stream area has been noted already in section 3.4.6, and it is probable that the range of these sheep extended westwards to Mt. Paris. A further smaller number of untagged sheep were recorded north from the Menhir slip, and in the area around the hut at Northwest Bay in the Dracophyllum and clearings. These sheep were observed moving through the Dracophyllum (Meteorological Station staff, pers comm.), and have been steadily moving back into the Windlass Bay area below the present northern end of the fence.

The reason for the initial low number of tag identifications has been discussed in section 3.4.2. Tag losses and the difficulty in finding sheep probably accounted for the variability in the number of

observations per sheep (section 3.4.1), and for why the total number of tagged sheep seen on any one day never reached the total tagged sample size.

4.5.3 HOME RANGE

The concept of home range was first formally defined by Burt (1943), and has been restated by Jewell (1966) as "the area over which an animal normally travels in pursuit of its routine activities." Jewell (1966) elaborated further by stating that "it (home range) is a restricted area within which individuals or groups live, and the manner in which they use this area.... and is an area with a certain productivity that meets the energy requirements of the individual or group that occupies it."

All animals seem to show an adherence to a particular area or areas, and this adherence suggests a "self-implied restriction to movement" (Grubb and Jewell, in Jewell et al. 1974). The formation and maintenance of a home range is the result of a number of effects, such as topography, both natural and man made, vegetation type and distribution, and the preferred social environment of the animal. There are obvious advantages to be accrued for an individual familiar with its physical and social environment, and as well, home ranges may function ecologically to disperse members of a population (Jewell 1966).

Sanderson (1966) has reviewed home range, mammal movements and techniques for obtaining data. Various methods for illustrating home range have been used

(for example, Hayne 1949; Davis 1953; Don and Rennolls 1983), but many of these are more relevant to studies where trapping or indirect methods were the source of data. In the present study, direct observations alleviated many of the problems associated with other methods of data collection.

Although many ungulates display territorial behaviour, the Bovinae and Caprinae do not (Owen-Smith 1977). In the Caprinae, home range has been studied in the Soay sheep of St. Kilda (Grubb and Jewell 1966; Jewell 1966; Jewell et al. 1974), the feral sheep of Mauna Kea (Giffin 1976), and the feral sheep of Santa Cruz Island (Van Vuren 1981). Geist (1971) studied the wild bighorn sheep of Canada, and found that they adhered to seasonal home ranges, and Schaller (1977) noted an adherence to specific areas in most of the Himalayan Caprinae. Domestic sheep (Hunter and Milner 1963; Hunter 1964) showed adherence to a home range, as did feral goats in New Zealand (Riney and Caughley 1959).

Campbell Island sheep seemed to adhere to home ranges. Those of most of the tagged sheep seemed largely to overlap, and extended westwards from the fence across North-west ridge, the basin and the saddle into the barrows. Some individuals included Rocky Bay in their range, while others extended as far as the top of the West Menhir slip. One ewe (bY14) was observed on three occasions in a small enclosed valley under the Dumas cliffs at the east end of Rocky Bay, and another ewe (R26) was always sighted on the west side of Cave Stream.

4.5.4 HOME RANGE SIZE

Home range size is the consequence of a variety of factors including lifestyle (carnivore or herbivore), population density (Jewell 1966), body size and energy demands (McNab 1963).

There was a large variation in the size of home range of Campbell Island sheep. Much of this was due to the different number of times individuals were observed, with a significant correlation between the number of observations and area. It was unfortunately not possible to collect any more data due to the time constraints on the study, so it was impossible to reach the situation discussed by Odum and Kuenzler (1955, cited in Lehner 1979) who considered only those areas above the point where an increasing number of observations did not lead to a significant increase in area.

Table IX compares the varying sizes, densities and home range sizes for six feral and one domestic population.

Because of the constraints of living on an island, migration and long distance seasonal movements are not important factors in the movement patterns of Campbell Island sheep. Since data collection was confined to only a two month period, with three further days of observations a month later, it was not possible to determine any seasonal trends in movement. The overlays on figure 3.7 do not appear to show any obvious trends in the direction of movement during the study. However, there seemed to be a tendency for sheep to move to

lower, more sheltered slopes in winter, and to higher ground in summer. As the study progressed, there seemed to be an increasing number of sheep recorded from the scattered Dracophyllum scrub on North-west ridge. This was coincident with a general deterioration in the weather as winter proceeded. The highest area above the western cliffs of Dumas was probably the most exposed part of the study area. It was closely cropped, but only occasional sheep were recorded from there during the study. However, large numbers of sheep were seen there during the summer of 1984-1985 (G. Taylor, pers comm.).

Unlike other feral populations, there appears to be no daily routine movements in Campbell Island sheep. Soay sheep moved daily to higher feeding grounds, returning at night to lower bedding grounds. The sheep of Mauna Kea also followed a daily vertical movement pattern, moving down to feeding sites in the morning, and returning to higher bedding grounds at night.

Daily movement patterns were evident in the Santa Cruz sheep, but varied according to location and season. In one locality, sheep were observed to move downslope in the morning, and return upslope in the evening, but elsewhere the pattern was the reverse.

The Soay sheep followed particular routes and paths in their daily movements, which were consequently well defined. In high density areas on Santa Cruz Island, sheep trails were worn to bare ground, and at all densities sheep trails were obvious. There are only a few well used paths on Campbell Island, and these

tend to be around geographical obstacles. For example, the most noticeable tracks in the study area ran around the top of Rocky Bay. This was a very exposed area, with very short vegetation cover. The tracks were bounded by the steep slumped banks which delineate Rocky Bay, with access to the bay afforded at only a few points along the banks. The tracks became less clearly defined, and increased in number to the western end of Rocky Bay as the vegetation changed to large tussocks. Elsewhere in the study area, there was a criss-crossing of numerous ill-defined and faint tracks.

Another feature of the Soay and Mauna Kea populations was the presence of camping or bedding areas, which were used every night. The Campbell Island sheep did not, however, seem to move in this way, and were often recorded at the same location on consecutive days, which lends support to the idea that perhaps they simply bedded down wherever they were grazing. Tussock provides a good source of cover from the wind, and there may be little advantage in moving further down into the Dracophyllum.

4.5.5 DISTANCE MOVED PER DAY

The approximate distances moved by the sheep were worked out to demonstrate first, that whilst having the potential to move long distances, they move in such a way so as not to extend beyond the boundaries of their range. That is, they do restrict their movements. Second, the difference between the two straight line measurements of 400m and 472m, and the distance moved during time

activity budgets of 792m, shows what is perhaps intuitively obvious, that sheep do not graze in a straight line.

Net daily movement in Santa Cruz sheep, as measured by the difference between pairs of locations on consecutive days, was strikingly identical to the similar measurement for Campbell Island, with a mean of 399m.

4.5.6 INTENSITY OF USE

Intensity of use and extent of home range usage has been illustrated in Soay sheep by Grubb and Jewell (in Jewell et al. 1974), and in hill country sheep by Hunter (1964). Although similar plots for the Campbell Island sheep do not show the distinct delineation of home range groups which was more the purpose of the other studies, they do illustrate the combined effects of spatial and temporal variations in density, which supports the contention of Taylor et al. (1978) that spatial distribution is not random, either in regard to other individuals (discussed further in section 4.4.7) or to the environment.

There are evidently more favoured areas, which are those with the greatest density of sheep. The existence of more favoured areas has been noted in other studies, and Don and Rennolls (1983) have drawn attention to "biological attraction points" or nuclei. Such areas may be the best feeding grounds, the most sheltered areas, or a combination of these and other factors. A high density of sheep was always noted on the slips throughout the southern part of the island, which had a cover of young,

rapidly growing introduced grasses.

The tagged sheep occurred in greatest numbers on the east side of the basin and onto Northwest ridge, and also on the saddle. Untagged sheep had an overlapping peak density on the saddle, but were more concentrated in the Rocky Bay and Cave Stream basin area. A comparison was made between the density distribution of ewes and rams to illustrate the complete intermingling of the sexes (figure 3.9b). If there had been differences in their social groupings, there would have been observable differences in their geographic distributions. However, both ewes and rams appeared to use all of the home range with the same variations in the degree of intensity. This situation may change at different times of the year.

The intensity of use figures could be interpreted as suggesting that a particular point was being avoided, although there is no real reason why this should be so. Intuitively I believe that rather, they were simply points at which sheep happened not to be recorded.

It should be noted that this observed density pattern need not reflect the 'usual' state of affairs for this population, but that "on an ecological time scale, spatial dispersion is a transient condition, an instantaneous aspect of a dynamic system" (Taylor et al 1978). That is, these figures reflect a population at a given density at one particular point in time.

Taylor and Taylor (1977) see spatial disposition as the result of movements of individuals acting under opposing ecological pressures: on one hand, they

maximise living space by moving further apart, whilst at the same time attempting to maximise environmental quality by moving closer together.

4.5.7 GROUP SIZE

Sheep exhibit congregatory behaviour, both as a result of their social tendency to associate with other sheep, and because more favoured feeding grounds attract and can sustain greater numbers of sheep. This high population density in a limited area favours the formation of groups.

Figure 3.10 illustrates how Campbell Island sheep associate in groups. The high number of single animals is more likely to have been because they were transient animals moving between groups, rather than they being lone animals. Only one ram was ever consistently observed on his own, even when other sheep were in the same vicinity. This ram appeared one day by the middle stile, and over the next month was observed continually in an area covering less than one hectare. He was observed on several occasions walking along next to the fence, or standing looking through the fence.

The most favoured group size appeared to be between two and nine, with a mean of six. The slightly larger groups of between 15 and 30 animals, occurred more commonly in Rocky Bay on the flat, closely cropped grassy areas. The few very large groups were observed in the basin, and although there may well have been sub-groups within them, the sheep were too closely interspersed to be able to distinguish such groups and the overall

impression was of a large loosely associating flock. When disturbed, neighbouring groups of sheep would join and move off together. Whilst being rounded up for tagging, the sheep formed readily into a large mob.

Group composition and size was in a continuous state of flux, with sheep moving readily between groups.

Soay sheep existed in distinct long lived groups of a constant size. Ewe groups varied in size from 2 to 69, with a mean between 1964 and 1967 of 27 to 37. Ram groups had a mean size of 1-5.9. The sheep of Mauna Kea had a strong herding instinct, and formed large herds with greatly fluctuating numbers. Average herd size was 28, and the largest herd observed comprised 400+ individuals.

Mean group size in the Santa Cruz population was seven or less, and group size changed frequently. Arapawa Island sheep associate in small groups of 1-14, and although this may be in part a consequence of the small population size, a similar sized domestic population formed groups with a mean size of 37.5 (Hunter 1964).

Although the upper range of herd size is a function of total population size, it is of note that the Soay ewes and Mauna Kea sheep, which existed at the highest and lowest densities respectively of the feral populations cited, had very similar values for mean group size. Soay rams, on the other hand, formed very small groups. Perhaps hunting and predation pressures on the Mauna Kea population caused the high degree of clumping noted.

The Santa Cruz, Arapsawa and Campbell Island populations all had a smaller, and similar, mean group size, although the range of sizes recorded from the Campbell Island population included much larger groups than any found in the other two populations.

4.5.8 HOME RANGE GROUPS

Soay Island sheep formed two distinct social units sharing a home range. Ewe home range groups comprised ewes, their lambs and some of the younger adult males, and ram home range groups contained adult males. Home range groups were identified by observing that particular individuals kept together, were confined to limited ranges within the area occupied by the whole sub-population, and did not mix indiscriminately with other sheep. The home range groups had continuity in time, and ewe groups appeared to be self perpetuating. Within each ewe group family units could be distinguished consisting of a ewe, her surviving offspring and their offspring.

Hill country sheep studied by Hunter and Milner (1963) and Hunter (1964) formed home range groups, and other studies (cited in Arnold and Dudzinski 1978) demonstrated the presence of home range groupings in other large flocks of sheep within the same paddock.

Giffin (1976) studied the feral sheep on Mauna Kea, and found that although the sheep adhere to a home range, herd composition varied greatly. A herd generally comprised rams, ewes and lambs, with occasional small ram groups. Family units were not maintained, with lambs and their dams separating shortly after weaning.

Groups on Santa Cruz Island showed no evidence of long term stability in composition. Membership of groups was fluid and highly variable, and no cohesion was noted between ewes and previous offspring.

Although the existence of home range groups has been assumed in the Campbell Island population (Regnault 1980, M. Crompton pers comm.) no evidence was found to support this. The study population was a large grazing mob sharing a common area or home range. There was no constancy in the composition of groups.

The number of associations between individuals was tested to see if any individuals consistently occurred together. Although a chi-square goodness of fit test suggested that the observed associations were significantly different from what would have been expected had they been purely random, this was probably due to the length of the sampling period and the frequency of sampling. Sampling was confined to a two month period, with observations made on up to four consecutive days. If the data had been collected at weekly intervals for a year, it may well have tended to randomness, although as has already been mentioned, Taylor et al. (1978) state that randomness is generally not a feature of biological populations.

Since the expected length of time that any group of individuals would stay together was three or four days, it is probable that there was an over representation of the occasions when members of such groups were recorded associating together. This is supported by the greater

than expected number of three and four associations. Similarly, there is a greater than expected number of zeroes, as the duration of the study was insufficient to have allowed a sheep to interact with the number of sheep it might have done over a longer period.

There is a greater than expected number of observations of five or more, which was due to the presence of several closely associating pairs of animals. These associations are explicable, and violate the assumptions of randomness. BY19 and bY20 were a ewe:hogget pair who were recorded together 11 times. However, this bond was in fact observed to break up in the last week of the study, with the two sheep recorded from very different localities. BY7 and bY3, and R28 and B6 were other ewe:hogget pairs that were still associating closely. BY11 was often seen associating with two hoggets - B5 and an untagged but distinctively marked hogget.

A ram group of five to eight individuals was observed over several weeks, although at times it intermingled with other groups of ewes and lambs. Several members of this group were recorded together five or six times.

It is possible that the rams split into separate ram groups at other times of the year, since previous expeditions have noted a predominance of rams in particular areas, for example between Menhir and Paris (Regnault 1980). Such observations have been made in January to February, which would have been after lambing

and before mating, whereas the present study was in winter after mating had finished.

4.6 TIME ACTIVITY BUDGETS

The daily activities of all animals are concerned with maintenance and survival (Arnold and Dudzinski 1978), and animals adopt different life strategies to optimize the allocation of resources such as energy and time between maintenance, growth and reproduction (Duncan 1985). Daily activities include grazing, browsing, walking, ruminating, resting, defaecating and urinating. For species such as sheep where rumination is an important part of the digestive process, a sizeable proportion of the day is spent ruminating, with most of it taking place during the hours of darkness (Arnold and Dudzinski 1978). Grazing is the major daylight activity, with major grazing periods beginning around sunrise and before sunset (Arnold and Dudzinski 1978). Grubb and Jewell (in Jewell et al. 1974) found that most of the day for Soay sheep was occupied by grazing or lying, with time spent lying taken as being synonymous with cudding time.

Santa Cruz sheep exhibited a peak in feeding activity in the early morning and late afternoon, with a midday period of inactivity, usually lying down in the shade.

Campbell Island sheep spent on average 70.2% of the day in feeding activities, and 16.6% ruminating. The percentage of time spent in ruminating peaked around

midday. Data in figure 3.12 were pooled for the whole study period. The onset of rumination varied on any particular day between 1100 and 1300 hours, so although grazing appears on the graph to continue right throughout the day, on any one day there would generally be a complete cessation of grazing activity when the major rumination period began. All group members stood or lay in close proximity to each other while ruminating.

The tendency for group members to co-ordinate activities is termed allelomimetic behaviour by Scott 1965 and Arnold and Dudzinski (1978). In both sheep and cattle, groups act as a unit, with all sheep in a group either grazing or not grazing except for short periods at the beginning and end of grazing periods. Horses, on the other hand, exhibit varying percentages grazing at any one time (Arnold and Dudzinski 1978). This conformity is illustrated for Campbell Island sheep in figure 3.13.

It was not possible in this study to determine how sheep occupied the hours of darkness due to the difficulties in locating sheep. Grubb and Jewell (1974) assumed that ruminating was the major night time activity in Soay sheep, and Arnold and Dudzinski (1978) stated that ruminating was generally the major activity for sheep at night.

Grubb and Jewell (1974) found in the Soay sheep that the proportion of the day spent ruminating varied with day length, and on the shortest days little or no ruminating took place. Arnold and Dudzinski (1978) stated that "generally, in latitudes greater than 35⁰, the

breaks between grazing decrease as the days get shorter, until in mid winter some animals will always be found grazing during daylight". Although the Campbell Island study took place in the two months preceeding the shortest day, no sheep was ever observed not to ruminate. Unfortunately no data are available for longer day lengths, as it would be of interest to compare the proportion of time spent ruminating at different day lengths.

The relatively important contribution of ruminating to time activity budgets is contrary to an observation made by Renault (1980) that "grazing appears to occupy all the daylight hours", particularly as this was made during summer.

Campbell Island sheep seemed to make few changes in behaviour in spite of the frequent adverse weather conditions, although on several occasions during heavy hail sheep were observed to stop grazing and face away from the prevailing wind.

Very few sheep were observed during or after periods of snow, and when the ground was snow covered. This may have been because they had moved into the Dracophyllum for shelter, or as was observed on several occasions, that they were sheltering by lying in the lee side of tussock bushes, or perhaps just that they were not being seen against a background of white.

The relative time spent grazing is the consequence of a variety of factors, including day length, season, social environment, climate and physical condition of

the sheep, and in the absence of a complete year's data from Campbell Island it is difficult to make a full comparison with other studies.

4.7 FUTURE RESEARCH

There are several aspects of the behavioural side of this study which would lend themselves to further research. In particular, an extension of the present study to include at least one full years study would enable home ranges to be more completely defined. Any extensions/contractions of home range size at different seasons, and any changes in the location of home ranges could be then determined. If the population was monitored over a longer time span, any trends in movement could be more accurately elucidated.

Similarly, any changes in group characteristics could be determined. For example, does group size change with seasons? Do rams associate with ewes all year round?

It would be of interest to observe rutting and mating, and to establish if dominance hierarchies were present, and how they related to features such as horn size in rams. The behaviour of ewes with lambs, and how this may change interactions with other sheep would also merit study.

An extension of the time activity studies to include other seasons would allow changes at different day lengths and under more varied weather conditions to be noted.

I believe it is important to continue monitoring the size and lambing rates of the population, and document changes with respect to density and food availability. It would be sensible to include a method for ranking vegetation quality so that future effects on the vegetation could be quantified. An analysis of stomach contents would provide information on the impact of sheep grazing on the vegetation. This information would be invaluable in helping make decisions on the future of the population.

REFERENCES

- ADALSTEINSSON, S. (1984) Relation of Colour Genes to
 Reproduction. p.237-241 In Proceedings of the World
 Congress on Coloured Sheep and Their Products, 20-31
 January 1984. Edited by H.T. Blair. New Zealand
 Black and Coloured Sheep Breeders Association.
- ADAMS, C.J. (1981) Migration of Late Cenozoic volcanism
 in the South Island of New Zealand and the Campbell
 Plateau. Nature 294 : 153-155.
- ARNOLD, G.W. and DUDZINSKI, M.L. (1978) Ethology of free-
 ranging mammals. Elsevier Scientific Publishing
 Company, Amsterdam.
- BAILEY, A.M. and SORENSON, J.H. (1962) Subantarctic
 Campbell Island. Proceedings 10 Denver Museum of
 Natural History.
- BARCROFT, J. (1945) The range of weights of foetal sheep
 at various ages. Journal of Physiology 104 : 32
- BEGON, M. and MORTIMER, M. (1981) Population Ecology : a
 unified study of plants and animals. Blackwell
 Scientific Publications, Oxford and London.
- BELL, R.D. AND TAYLOR, R.H. (1970) The wild sheep of
 Campbell Island. Forest and Bird 178 : 6-10.
- BIGHAM, M.L. and COCKREM, F.R.M. (1982) Feral sheep: have
 they any value? New Zealand Journal of Agriculture
144 : 3-4.

- BIGHAM, M.L. and COCKREM, F.R.M. (1984) Observations on wool growth and other characteristics of feral sheep. p.302-305 In Proceedings of the World Congress on Coloured Sheep and Their Products, 20-31 January 1984. Edited by H.T. Blair. New Zealand Black and Coloured Sheep Breeders Association.
- BLAIR, H.T. editor (1984) Proceedings of the World Congress on Coloured Sheep and Their Products, 20-31 January 1984. New Zealand Black and Coloured Sheep Breeders Association.
- BOWMAN, J.C. (1981) Conservation of farm animals. Biologist 28(4) : 186-193.
- BOYD, J.M.; DONEY, J.M.; GUNN, R.G. and JEWELL, P.A. (1964) The Soay sheep of the island of Hirta: a study of a feral population. Proceedings of the Zoological Society of London 142 : 129-163.
- BURT, W.H. (1943) Territoriality and home range as applied to mammals. Journal of Mammalogy 24(3) : 346-352.
- CAMPBELL, I.B. (1980) Soils of Campbell Island. p. 56-58. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- CAUGHLEY, G. (1966) Mortality patterns in mammals. Ecology 47 : 906-918

- CLIMO, F.M. (1980) Contributions to mollusc and algae collections from Campbell Island. p.98. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- COCKREM, F.R.M. (1980) Campbell Island sheep at Whatawhata Hill Station. p.128-129. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no.7.
- COCKREM, F.R.M. and CLARKE, J.N. (1976) Physiological adaptation. p.39-43. In The Value of Feral Farm Mammals in New Zealand. Edited by A.H. Whitaker and M.R. Rudge. New Zealand Department of Lands and Survey, Information Series volume 1.
- COCKREM, F.R.M. and RAE, A.L. (1966) Studies of face cover in the New Zealand Romney Marsh sheep. I. The relationships between face cover, wool blindness and productive characters. Australian Journal of Agricultural Research 17 : 967-974.

- CROSBY, T.K. (1980) Invertebrate animal studies from Campbell Island. p.99-100. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- DAVIS, D.E. (1953) Analysis of home range from recapture data. Journal of Mammalogy 34(3) : 352-358.
- DILKS, P.J. and DUNN, E. (1978) Report on a visit to Campbell Island 1977-1978. with recommendations on bird banding. Unpublished file report, Ecology Division, DSIR, May 1978.
- DILKS, P.J. and GRINDELL, J.M. (1983) Visit to Campbell Island by P.J. Dilks and J.M. Grindell, 11 January-23 February 1983. Unpublished file report, Ecology Division DSIR.
- DILKS, P.J. and WILSON, P.R. (1979) Feral sheep and cattle and Royal Albatrosses on Campbell Island : population trends and habitat changes. New Zealand Journal of Zoology 6 : 127-139.
- DON, B.A.C. and RENNOLLS, K. (1983) A Home Range Model incorporating biological attraction points. Journal of Animal Ecology 52 : 69-81.
- DUNCAN, P. (1985) Time Budgets of Camargue Horses: environmental influences. Behaviour 92(1-2) : 185-200.
- EDEN, A.W. (1955) Islands of Despair. Andrew Melrose Ltd.

- FLEMING, C.A. (1980) Campbell Island Geology. p.44-46. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- FORSTER, R.R. (1964) The Aranae and Opilcones of the subantarctic islands of New Zealand. Pacific Insects Monograph 7 : 58-115.
- GEIST, V. (1971) Mountain sheep - a study in behaviour and evolution. University of Chicago.
- GIFFIN, J.G. (1976) Ecology of the Feral Sheep on Mauna Kea. Pittman Robertson Project W-15-5 study no. 11. Final report. State of Hawaii Department of Lands and Resources, Division of Fish and Game.
- GIVEN, D.R. (1980) Botanical investigation on Campbell Island. p.60-82. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- GIVEN, D.R. and MEURK, C.D. (1980) Checklist of the vascular flora. p.83-89. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- GRESSIT, J.L. ed. (1964) Insects of Campbell Island. Pacific Island Monograph 7 : 1-633.

- GRUBB, P. (1974) Mating activity and the social significance of rams in a feral sheep community. Paper no. 23, p.457-476. In The Behaviour of Ungulates and its relation to Management. Edited by V. Geist and F. Walther. IUCN New Series no. 24 volume 1.
- GRUBB, P. and JEWELL, P.A. (1966) Social grouping and home range in feral Soay sheep. Symposium of the Zoological Society of London no.18 : 179-270.
- GRUBB, P. and JEWELL, P.A. (1974) Movement, daily activity and home range of the Soay sheep. p. 160-194. In Island Survivors. edited by Jewell et al. 1974.
- HAYNE, D.W. (1949) Calculation of size of home range. Journal of Mammalogy 30(1) : 1-17.
- HEATH, A.C.G. (1976) The parasitology of some feral Artiodactyla in New Zealand. p.44-50. In The value of Feral Farm Mammals in New Zealand. Edited by A.H. Whitaker and M.R. Rudge. New Zealand Department of Lands and Survey, Information Series volume 1.
- HEATH, A.G.C. (1979) Ectoparasites of feral sheep on Campbell Island. New Zealand Journal of Zoology 6 : 141-144.
- HEDRICK, P.W. (1984) Population Biology : the evolution and ecology of populations. Jones and Bartlett Publishers Inc., Boston.
- HICKEY, F. (1963) Sheep mortality in New Zealand. New Zealand Agriculturalist 15(4) : 1-3.

- HOLMES, R.J. (1976) Behaviour. p. 59-64. In The Value of Feral Farm Mammals in New Zealand. Edited by A.H. Whitaker and M.R. Rudge. New Zealand Department of Lands and Survey, Information Series volume 1.
- HUNTER, R.F. (1964) Home range behaviour in hill sheep. p.155-171. In Grazing in Terrestrial and Marine Environments. Edited by D.J. Crisp. British Ecological Society Symposium no. 4.
- HUNTER, R.F. and MILNER, C. (1963) The behaviour of individual, related and groups of South Country Cheviot Hill sheep. Animal Behaviour 11 : 507-513.
- HUTTON, J.B. (1976) Animal health. p. 51-54. In The Value of Feral Farm Mammals in New Zealand. Edited by A.H. Whitaker and M.R. Rudge. New Zealand Department of Lands and Survey, Information Series volume 1.
- HUTTON, J.B. (1980) The disease status of the sheep population of Campbell Island in 1975. p. 130-143. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- JEWELL, P.A. (1966) The concept of home range in mammals. Symposium of the Zoological Society of London 18 : 85-109.
- JEWELL, P.A. and GRUBB, P. (1974) The breeding cycle, onset of oestrus and conception in Soay sheep. p. 224-241. In Island Survivors. edited by Jewell et al 1974.

- JEWELL, P.A.; MILNER, C. and MORTON BOYD, J. ed.s (1974) Island Survivors- the ecology of the Soay sheep of St. Kilda. Athlone Press.
- JOUBERT, D.M. (1956) A study of pre-natal growth and development in the sheep. Journal of Agricultural Science 47 : 382-427.
- JUDD, N. (1980) Leader's report on historical sites. p.28-42. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- KENWORTHY, L.M. (1980) Background to the expedition. p.8-10. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- KERR, I.S. (1976) Campbell Island : a history. A.H. and A.W. Reed Ltd., New Zealand.
- KERR, I.S. and JUDD, N. (1978) Marlborough Whalers at Campbell Island 1909-1916 : a narrative based on the recollection of J. Timms. New Zealand Department of Lands and Survey.
- KREBS, C.J. (1978) Ecology : the experimental analysis of distribution and abundance. Second edition. Harper and Row, New York.
- LEHNER, P.N. (1979) Handbook of Ethological Methods. Garland STPM.
- McNAB, B.K. (1963) Bioenergetics and the determination of Home Range Size. American Naturalist 97(894) : 133-140.

- MEURK, C.D. (1975) Contributions to the flora and plant ecology of Campbell Island. New Zealand Journal of Botany 13(4) : 721-742.
- MEURK, C.D. (1977) Alien plants in Campbell Island's changing vegetation. Mauri Ora 5 : 93-118.
- MEURK, C.D. (1980) Plant ecology of Campbell Island. p.90-96. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- MEURK, C.D. (1982) Regeneration of subantarctic plants on Campbell Island following exclusion of sheep. New Zealand Journal of Ecology 5 : 51-58.
- MOHR, C.O. (1947) Table of equivalent populations of North American small mammals. American Midland Naturalist 37 : 223-249.
- MORRIS, P.A. (1980) Studies of igneous rocks on Campbell Island. p.49-53. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- MORTON BOYD, J. (1981) The Borersey sheep of St. Kilda, Outer Hebrides, Scotland : the natural history of a feral population. Biological Conservation 20 : 215-227.
- NEW ZEALAND DEPARTMENT OF LANDS AND SURVEY (1980) Preliminary Reports of the Campbell Island Expedition 1975-1976. Reserves Series no. 7.

NEW ZEALAND DEPARTMENT OF LANDS AND SURVEY (1983)

Management plan for the Campbell Islands Nature Reserve. Management Plan Series NR no. 13.

OLIVER, R.L. (1950) Preliminary report on the geology of Campbell Island. In The Geology of Campbell Island, Cape Expedition Series Bulletin 3 : 7-44.

OLIVER, R.L. and SORENSON, J.H. (1951) The Vegetation. In Botanical Investigations on Campbell Island, Cape Expedition Series Bulletin 7 : 5-24.

ORWIN, D.F.G. and WHITAKER, A.H. (1984) Feral sheep (Ovis aries) of Arapawa Island, Marlborough Sounds, and a comparison of their wool characteristics with those of four other feral flocks in New Zealand. New Zealand Journal of Zoology 11 : 201-224.

ORWIN, D.F.G. (1984) Report on sheep and wool studies, 1984 Campbell Island expedition, 29 January-17 February 1984. Unpublished report to the New Zealand Department of Lands and Survey.

OWEN-SMITH, N. (1977) On territoriality in ungulates and an evolutionary model. Quaternary Review of Biology 52 : 1-38.

PARSONS, S.R. (1980) The feral sheep (Ovis aries L.) of Woodstock Station, Canterbury, New Zealand. unpublished BSc(hons) project, University of Canterbury, New Zealand.

REDWOOD, R. (1950) Forgotten Islands of the South Pacific. A.H. and A.W. Reed, New Zealand.

- REGNAULT, W.R. (1976) Feral sheep : skin, wool and fleece characters. p. 33-38. In The Value of Feral Farm Mammals in New Zealand. Edited by A.H. Whitaker and M.R. Rudge. New Zealand Department of Lands and Survey, Information Series volume 1.
- REGNAULT, W.R. (1980) Report on wool and sheep observations. p. 144-148. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- RESTALL, B.J. (1964) The growth and retrogression of the corpus luteum in the ewe. Australian Journal of Experimental Agriculture and Animal Husbandry 4 : 274-276.
- RICKETTS, W. (1977) The behaviour of wild and feral sheep. Unpublished Dip. Ag. Sci. project, Massey University, New Zealand.
- RINEY, T. and CAUGHLEY, G. (1959) A study of home range in a feral goat herd. New Zealand Journal of Science 2 : 158-170.
- ROBERTSON, C.J.R. (1980) Birds on Campbell Island. p.106-119. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no. 7.
- RUDGE, M.R. (1976) Ageing domestic sheep (Ovis aries L.) from growth lines in the cementum of the first incisor. New Zealand Journal of Zoology 3 : 421-424

- RUDGE, M.R. (1982) Conserving feral farm mammals in New Zealand. New Zealand Agricultural Science 16 : 157-160.
- RUDGE, M.R. (1983) A reserve for feral sheep on Pitt Island, Chatham Group, New Zealand. New Zealand Journal of Zoology 10 : 349-364.
- RUDGE, M.R. (1984a) Distribution, status and preservation of feral sheep in New Zealand. p.295-302. In Proceedings of the World Conference on Coloured Sheep and their Products, 20-31 January 1984. Edited by H.T. Blair. New Zealand Black and Coloured Sheep Breeders Association.
- RUDGE, M.R. (1984b) The influence of climate, habitat and natural selection on the numbers of feral sheep (Ovis aries L.) on Campbell Island (subantarctic). Manuscript submitted for Proceedings of the First International Conference on Wild Sheep and Goats, Whitehorse, Yukon April-May 1984. In press.
- RUDGE, M.R. (1984c) The occurrence and status of populations of feral goats and sheep throughout the world. p. 57-84. In Caprinae Specialist subgroup of SSC/IUCN workshop on feral mammals. Background Papers, International Theriological Congress, Helsinki 1982.
- RUDGE, M.R. (pers comm.) Feral sheep of Campbell Island. Unpublished manuscript.
- RYDER, M.L. (1976) Why should rare breeds of livestock be saved? International Zoo Yearbook 16 : 244-249.

- RYDER, M.L. and STEPHENSON, S.K. (1968) Wool Growth. Academic Press, London and New York.
- SADLEIR, R.M.F.S. (1969) The Ecology of Reproduction in Wild and Domestic Mammals. Methuen, London.
- SANDERSON, G.C. (1966) The study of mammal movements : a review. Journal of Wildlife Management 30 : 215-235.
- SCHALLER, G.B. (1977) Mountain Monarchs : wild sheep and goats of the Himalayas. University of Chicago Press, Chicago.
- SORENSEN, J.H. (1959) Botanical factors. In Ecology of the Subantarctic Islands. Proceedings New Zealand Ecological Society 2 : 17-18.
- SPENCE, A. (1969) A story of the Campbell Islands. Tussock Grasslands and Mountain Lands Institute Review 15 : 63-75.
- SUCKLING, G.W. and RUDGE, M.R. (1977) Changes with age in the length of central incisor teeth and their clinical crowns in sheep. New Zealand Journal Agricultural Research 20 : 145-149.
- TAYLOR, L.R. and TAYLOR, R.A.J. (1977) Aggregation, migration and population mechanics. Nature 265 : 415-421.
- TAYLOR, L.R.; WOIWOD, I.P. and PERRY, J.N. (1978) The density-dependence of spatial behaviour and the rarity of randomness. Journal of Animal Ecology 47 : 383-406.

- TAYLOR, R.H. (1968) Introduced mammals and islands :
priorities for research and conservation.
Proceedings New Zealand Ecological Society 15 : 61-
67.
- TAYLOR, R.H. (1980) Feral sheep on Campbell Island :
review of research and management programme and the
recommendations of the 1975-1976 expedition. p.149-
152. In Preliminary Reports of the Campbell Island
Expedition 1975-1976. New Zealand Department of
Lands and Survey, Reserves Series no. 7.
- TAYLOR, R.H.; BELL, B.D. and WILSON, P.R. (1970) Royal
albatrosses, feral sheep and cattle on Campbell
Island. New Zealand Journal of Science 13 : 78-88.
- VAN TETS, G.F. (1980) The Campbell Island shag. p.117-
119. In Preliminary Reports of the Campbell Island
Expedition 1975-1976. New Zealand Department of
Lands and Survey, Reserves Series no. 7.
- VAN VUREN, D. (1981) The feral sheep on Santa Cruz
Island- status and impacts. Nature Conservancy,
Arlington, Virginia, USA.
- WHITAKER, A.H. (1976) Feral sheep in New Zealand. p. 27-
32. In The Value of Feral Farm Mammals in New
Zealand. Edited by A.H. Whitaker and M.R. Rudge. New
Zealand Department of Lands and Survey, Information
Series volume 1.

- WHITAKER, A.H. and RUDGE, M.R. eds (1976) The Value of Feral Farm Mammals in New Zealand. New Zealand Department of Lands and Survey, Information Series volume 1.
- WILSON, P.R. (1979) Inter-relationships of feral stock, seabirds and vegetation on Campbell Island. New Zealand Journal of Ecology 2 : 92-93.
- WILSON, P.R. (1980) Report on short-term visit to Campbell Island. p.153. In Preliminary Reports of the Campbell Island Expedition 1975-1976. New Zealand Department of Lands and Survey, Reserves Series no.7.
- WILSON, P.R. and ELLIOT, G.P. (1981) Report on sheep, cattle and Royal Albatross counts at Campbell Island during 1979-1980 and 1980-1981 : with other biological notes recorded during the 1979-1980 visit. Unpublished file report, Ecology Division DSIR.
- WILSON, P.R. and GAZE, P.D. (1983) Report to Lands and Survey Dept. on short visit by P.R. Wilson and P.D. Gaze to Campbell Island, 1-10 April 1983. Unpublished file report, Ecology Division DSIR.
- WILSON, P.R. and ORWIN, D.F.G. (1964) The sheep population of Campbell Island. New Zealand Journal of Science 7 : 460-490.
- WILSON, P.R. and RUDGE, M.R. (1982) The future of the sheep population of Campbell Island. Unpublished file report, Ecology Division DSIR.

WODZICKI, K. and WRIGHT, S. (1984) Introduced birds and mammals in New Zealand and their effect on the environment. Tuatara 27(2) : 77-104.

APPENDIX A :
 WEATHER SUMMARIES FOR CAMPBELL ISLAND.

A - MEAN MONTHLY AND MEAN ANNUAL RECORDINGS.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
RAINFALL (mm)													
mean	118	107	128	118	134	120	107	105	106	109	107	102	1361
highest monthly	183	165	198	213	253	218	198	184	174	187	171	239	1755
average no. of rain days (>1.0)	19	18	20	21	22	23	22	22	20	21	20	18	246
AIR TEMPERATURE (°C)													
mean	9.3	9.3	8.6	7.2	6.0	4.7	4.7	5.0	5.5	6.1	7.1	8.7	6.9
mean daily max	11.9	11.7	10.9	9.4	8.1	6.8	6.7	7.1	7.9	8.6	9.8	11.4	9.2
mean daily min	6.7	6.8	6.2	5.0	3.8	2.6	2.6	2.9	3.1	3.6	4.4	5.9	4.5
GROUND TEMPERATURE (°C)													
mean grass min.	5.5	5.6	5.0	3.7	2.4	1.0	1.1	1.5	1.8	2.4	3.3	4.8	3.2
FROST (days):													
ground	0.8	0.4	0.8	1.6	4.5	7.8	7.9	6.3	6.4	3.8	2.2	1.4	42.9
air	0.1	0.0	0.2	1.0	2.5	5.5	5.2	4.0	3.8	2.2	1.3	0.6	26.4
RELATIVE HUMIDITY (%)													
mean hourly	85	86	85	85	86	85	86	86	85	81	84	86	85
VAPOR PRESSURE (millibars)													
average at 9AM	10.2	10.1	9.7	9.0	8.4	7.7	7.6	7.8	7.9	8.1	8.6	9.6	8.7
SUNSHINE (total hours)													
mean	99	81	61	37	18	9	13	27	55	71	92	96	659
WIND (km/hr)													
mean hourly	31	34	34	34	33	32	29	27	33	35	33	28	32
mean no. of days -													
gusts >63 km/hr	21.4	22.3	24.8	25.4	24.3	23.4	21.9	22.7	23.7	26.5	22.2	21.6	280
gusts >96 km/hr	6.5	9.1	9.9	10.8	9.8	10.2	7.4	8.2	9.5	11.8	8.5	4.6	106
SPECIAL PHENOMENA (days)													
snow	0.2	0.3	0.7	2.1	4.4	7.6	5.9	5.3	5.9	5.3	3.3	0.8	42
hail	2.6	3.3	4.8	5.7	6.7	8.6	6.1	8.4	7.3	8.0	6.1	3.1	69
gale	4.1	4.9	5.5	5.2	6.0	5.9	4.8	5.0	5.8	6.3	4.4	2.5	60

B - MONTHLY SUMMARIES FOR APRIL-JULY 1984.

	APRIL	MAY	JUNE	JULY
NUMBER OF DAYS	22	31	30	31
MEAN TEMPERATURE (°C)	7.4	6.0	6.0	5.0
HIGHEST MAXIMUM (°C)	14.5 (18th)	10.5 (4th)	10.0 (17th)	9.1 (19th)
LOWEST MINIMUM (°C)	-0.4 (29th)	-2.0 (30th)	-2.5 (23rd)	-4.0 (8th)
LOWEST MAXIMUM (°C)	5.9 (8th)	4.0 (1st)	3.5 (22nd)	3.3 (14th)
HIGHEST MINIMUM (°C)	9.5 (19th)	7.5 (17th)	8.0 (3rd)	6.7 (11th)
RAINFALL (mm)	149.0	102.2	93.0	81.2
HIGHEST DAILY RAIN (mm)	15.9 (19th)	14.1 (14th)	14.2 (14th)	17.2 (30th)
NO. OF RAINDAYS (>0.1mm)	21	30	30	26
NO. OF WETDAYS (>1.0mm)	18	20	22	22
TOTAL SUNSHINE HOURS	11.7	11.9	1.1	16.2
MEAN WINDSPEED (knots)				
- at base	19.1	18.5	23	16.6
- at top of Seeman	30	28.7	34	23
MEAN MONTHLY CHILL FACTOR (°C)	-4.0	-6.2	-8.0	-6.0

C - DAILY INFORMATION FROM 9 APRIL TO 6 AUGUST 1984

DATE	WIND DIRECTION	RAIN(mm)	TEMPERATURE		SUNSHINE (hours)	MEAN WIND SPEED	CHILL FACTOR	OCCURENCES
			MAX.	MIN.		-BASE -BEEMAN		
<u>APRIL</u>								
9	SW	9.6	8.6	0.0	0.0	19	26	-8.0 G,S
10	SW	6.1	9.1	1.6	0.25	27	39	-9.0 G,H
11	W	8.7	10.0	3.5	0.0	26	34	-8.0 G
12	SW	4.8	9.0	6.4	0.36	26	35	-6.0 G
13	W	2.7	10.5	4.3	0.0	32	44	-7.0 G
14	WSW	4.7	6.8	5.7	0.0	15	22	-5.0 G
15	W	7.5	9.4	3.6	4.4	12	18	-3.0
16	WSW	0.7	9.5	4.6	4.6	23	27	-7.0
17	W	trace	10.2	6.3	0.9	14	21	-1.0
18	NNW	2.4	14.5	7.5	0.0	20	46	0.0
19	N	15.9	12.4	9.5	0.0	22	52	0.0
20	W	0.6	9.5	4.9	0.6	24	30	-8.0 H
21	W	1.2	9.6	7.4	0.0	13	17	1.0 F
22	NW	15.4	12.0	7.1	0.0	12	26	2.0
23	W	3.1	11.0	7.6	0.0	19	30	-2.0
24	NW	7.7	11.7	9.1	0.0	14	32	2.0 F
25	W	7.0	9.4	8.6	0.0	25	39	-4.0 G,H
26	WSW	1.3	8.2	2.4	0.02	17	22	-6.0 H
27	N	6.5	10.2	1.6	0.23	13	28	-4.0
28	N	0.3	9.2	6.8	0.0	15	23	-2.0
29	N	9.4	9.3	-0.4	0.17	10	15	-3.0 G
30	WSW	3.7	6.5	3.1	0.18	30	38	-11.0 G,H,S
<u>MAY</u>								
1	SW	10.4	4.0	1.1	0.0	24	32	-13.0 S,SL
2	SSW	2.7	6.1	-1.5	0.24	19	26	-13.5 S,SL
3	W	1.3	9.3	-0.4	0.01	18	22	-9.0 SL
4	WNW	1.9	10.5	5.7	0.0	17	28	-3.0
5	W	9.3	8.2	6.9	0.17	22	28	-8.0
6	SW	0.8	8.1	4.5	0.04	28	36	-8.0 G
7	SW	1.5	8.4	5.5	0.0	27	34	-8.0
8	SW	9.3	6.6	4.4	0.08	22	30	-8.0 H
9	SW	0.5	6.6	3.0	0.35	17	24	-8.0 H
10	W	0.5	8.2	3.0	0.03	14	22	-6.0
11	S	0.2	7.0	5.5	0.0	6	14	1.0
12	E	2.3	9.0	4.9	0.0	10	15	0.0
13	E	5.9	10.3	6.4	0.0	12	26	0.0 F
14	NW	14.1	7.4	5.5	0.0	22	34	-8.0 G
15	W	1.2	9.5	4.4	0.07	22	32	-6.0
16	W	0.9	9.7	4.6	0.01	26	37	-8.0 G
17	NW	5.3	9.8	7.5	0.0	24	37	-4.0 G
18	NNW	6.8	7.3	6.9	0.02	19	35	-5.0 G,H
19	SW	trace	5.3	2.6	0.03	23	40	-11.0 G,S
20	W	1.3	7.9	2.3	0.03	14	23	-6.0
21	W	0.1	9.3	4.0	0.0	15	24	-4.0
22	NW	0.2	9.4	4.9	0.0	23	34	-7.0
23	WNW	0.2	9.5	6.5	0.0	18	27	-3.0
24	N	2.4	9.3	7.4	0.0	9	20	2.0
25	S	0.4	9.1	7.0	0.0	2	9	8.0 F
26	SW	3.8	7.5	2.5	0.01	11	22	-4.0
27	W	9.8	6.3	3.0	0.04	11	23	-4.0
28	W	5.0	4.2	1.2	0.01	20	32	-12.0 H,S,SL
29	SW	1.8	4.3	-0.1	0.05	27	40	-15.0 G,H,S,SL
30	S	0.1	8.7	-2.0	0.0	25	37	-13.0 G,H,S,SL
31	WSW	2.0	9.2	1.7	0.0	26	42	-10.0 G

DATE	WIND DIRECTION	RAIN(mm)	TEMPERATURE		SUNSHINE (hours)	MEAN WIND SPEED		CHILL FACTOR	OCCURENCES
			MAX.	MIN.		-BASE	-BEEMAN		
<u>JUNE</u>									
1	WSW	1.9	9.2	6.8	0.0	26	31	-6.0	
2	NW	0.8	9.7	7.7	0.0	21	32	-5.0	
3	NW	5.1	9.2	8.0	0.0	19	33	-3.0	
4	W	1.5	7.9	3.9	0.0	21	28	-8.0	H
5	W	7.3	8.6	3.2	0.1	18	33	-7.0	
6	E	5.2	8.9	3.6	0.0	27	37	-9.0	G
7	SW	0.4	6.0	4.9	0.8	19	26	-8.0	
8	NW	3.4	9.7	1.4	0.0	13	28	-5.0	
9	W	2.9	8.4	5.6	0.0	32	48	-8.0	G,H
10	W	6.5	5.6	1.3	0.0	29	42	-13.0	G,H,S
11	W	14.2	6.7	0.4	0.0	28	35	-12.0	G,H
12	W	2.5	8.0	3.0	0.0	21	31	-8.0	G
13	SW	0.2	9.2	-1.1	0.0	32	45	-13.0	G,H,S,SL
14	E	4.2	9.0	-0.4	0.0	32	42	-13.0	G
15	EE	2.8	8.7	6.7	0.0	32	45	-7.0	G
16	EE	0.4	9.2	6.1	0.0	26	37	-8.0	G
17	W	5.3	10.0	6.0	0.0	23	35	-4.0	G
18	EE	2.7	8.1	6.0	0.0	24	34	-7.0	G
19	EE	2.8	7.6	3.4	0.0	27	35	-10.0	G,H
20	E	0.6	8.5	4.0	0.0	25	30	-9.0	
21	EE	5.8	8.2	6.9	0.0	23	38	-6.0	G
22	SW	1.2	3.5	1.2	0.01	25	35	-14.0	G,H,S,SL
23	SW	0.1	6.6	-2.5	0.0	26	38	-15.0	G,S,SL
24	EE	2.3	9.0	0.4	0.0	24	36	-11.0	G
25	EE	1.0	9.1	5.6	0.0	19	25	-5.0	
26	E	2.0	7.7	4.4	0.0	16	23	-5.0	
27	EE	0.2	7.5	4.8	0.0	23	29	-8.0	G
28	EE	0.3	7.1	4.6	0.0	22	24	-8.0	
29	-	1.6	7.3	4.1	0.0	7	?	0.0	
30	NE	7.8	8.4	4.0	0.0	15	?	-5.0	
<u>JULY</u>									
1	SE	0.0	4.5	3.8	1.1	25	?	-12.0	
2	E	1.6	5.1	-2.7	0.1	8	15	-5.0	
3	NE	5.1	6.2	-0.2	0.0	13	18	-8.0	
4	SE	3.4	6.0	4.2	0.0	14	19	-6.0	
5	-	1.5	7.2	5.1	0.2	4	8	4.0	
6	EE	1.8	7.4	3.0	0.0	14	19	-4.0	F
7	EE	2.2	6.9	5.5	0.1	4	8	-2.0	
8	-	2.7	7.1	-4.0	0.0	5	10	2.0	
9	EE	1.3	7.4	-3.9	0.0	11	15	-4.0	
10	EE	7.1	7.7	3.5	0.0	15	21	-5.0	
11	EE	0.9	9.0	6.7	1.2	9	15	2.0	F
12	NW	6.1	8.0	6.1	0.0	11	18	-1.0	
13	SE	0.2	4.8	3.3	1.3	18	25	-9.0	S
14	W	2.5	3.3	0.8	0.4	12	15	-8.0	S,SL
15	S	1.5	5.7	0.9	0.9	19	30	-10.0	S,SL
16	SW	0.8	6.3	0.3	0.1	22	30	-12.0	
17	SW	0.0	6.7	3.9	0.5	16	20	-6.0	
18	EE	0.7	8.0	4.6	0.0	19	28	-7.0	
19	EE	1.4	9.1	5.7	0.2	16	22	-4.0	
20	N	2.2	8.5	4.6	0.0	20	39	-7.0	
21	EE	1.9	7.5	6.6	2.5	20	27	-5.0	H
22	SW	3.5	7.6	1.3	2.5	20	26	-9.0	H,S
23	W	0.3	7.7	1.5	1.5	27	36	-12.0	G,H,T&L
24	EE	1.5	7.9	5.4	0.2	25	31	-7.0	
25	EE	2.8	7.3	2.0	0.0	22	30	-9.0	G
26	W	trace	8.9	3.0	1.0	21	30	-7.0	
27	W	5.5	9.0	3.7	0.0	29	40	-10.0	G
28	SE	trace	6.0	3.4	2.4	23	31	-9.0	G
29	E	trace	6.2	3.5	0.0	14	18	-6.0	
30	NE	17.2	7.9	3.8	0.0	20	27	-8.0	G
31	N	5.5	8.6	5.2	0.0	14	30	-3.0	
<u>AUGUST</u>									
1	W	5.1	8.6	6.5	0.0	15		-6.0	
2	W	5.4	7.2	2.1	0.0	33		-16.0	S,SL
3	W	6.4	4.8	0.2	0.0	22		-12.0	S,SL
4	S	32.6	5.0	0.0	0.0	13		-12.0	S,SL
5	E	11.5	1.5	-1.3	0.0	18		-11.0	S,SL
6	S	8.3	4.2	-1.5	0.0				S,SL

NOTE ON ABBREVIATIONS :

F - FOG; G - GALE; H - HAIL; S - SNOW; SL - SNOW LYING;
T&L - THUNDER AND LIGHTNING.

DATA SOURCE :

SUMMARY A - METEOROLOGICAL SERVICE, MINISTRY OF TRANSPORT. DATA FOR 1941-1980.
SUMMARY B & C - COMPILED FROM WEATHER RECORDS, CAMPBELL ISLAND METEOROLOGICAL
STATION.

APPENDIX C :TAG COMBINATIONS, AND INFORMATION
ON THE TAGGED SHEEP.

NAME	TAGS		WRONZ NO.	AGE	HORNS
	LEFT EAR	RIGHT EAR			
R21	red 21	yellow 41	1	4T/6T?	
R22	red 22	yellow 44	4	FM	
R23	red 23	yellow 45	5	FM	
R24	red 24	yellow 46	6	FM	
R25	red 25	(yellow 47)	7	FM	
R26	red 26	yellow 48	8	H	
R27	red 27	green 50	10	FM	
R28	green 51	red 28	11	4T	
R29	red 29	green 53	13	H	
R30	red 30	green 55	15	H	
R31	red 31	green 56	16	4T	
R32	red 32	purple 57	17	4T	one
R33	red 33	purple 59	19	H	
R34	red 34	(white 65)	25	2T	
R35	red 35	white 66	26	H	
R36	red 36	white 67	27	4T	
R37	red 37	white 68	28	H	
R38	red 38	(white 69)	29	6T	
R39	red 39	white 70	30	r6T	
R40	red 40	white 72	32	FM	yes
bY1	big yellow 1	orange 74	34	4T	
bY2	big yellow 2	orange 75	35	FM	
bY3	big yellow 3	orange 76	36	2T	
bY4	big yellow 4	orange 77	37	2T	
bY5	big yellow 5	orange 78	38	6T	
bY6	big yellow 6		41	FM	
bY7	big yellow 7		43	FM	
bY8	big yellow 8		46	FM	
bY10	big yellow 10		47	FM	
bY11	big yellow 11		48	FM	
bY12	big yellow 12		49	FM	
bY13	big yellow 13		50	rFM	
bY14	big yellow 14		51	FM	
bY15	big yellow 15		52	rFM	
bY16	(big yellow 16)		53	FM	
bY17	(big yellow 17)		54	rFM	
bY18	big yellow 18		55	rFM	
bY19	big yellow 19		58	H	
bY20	big yellow 20		59	FM	
bY22	big yellow 22		61	rFM	
bY24	big yellow 24		63	FM	
bY26	big yellow 26		65	6T	
bY28	big yellow 28		67	FM	
bY30	big yellow 30		69	FM	
bY31	big yellow 31		70	6T	

NAME	RAMS			AGE	HORNS
	LEFT EAR	RIGHT EAR	WRONZ NO.		
B1	blue 1	yellow 42	2	H	yes
B2	blue 2	yellow 43	3	H	
B3	blue 3	green 49	9	FM	yes
B4	blue 4	green 52	12	4T	yes
B5	blue 5	green 54	14	H	yes
B6	blue 6	purple 58	18	H	yes
B7	blue 7	purple 60	20	rFM	yes
B8	purple 61	blue 8	21	FM	yes
B9	blue 9	purple 62	22	rFM	yes
B10	blue 10	purple 63	23	FM	yes
B11	(blue 11)	purple 64	24	FM	yes
B12	blue 12	white 71	31	4T	yes
B13	blue 13	(orange 73)	33	FM	yes
B14	blue 14	orange 79	39	FM	yes
B15	blue 15	orange 80	40	FM	
B16	blue 16		42	4T	yes
B17	blue 17		44	FM	yes
B18	blue 18		45	FM	yes
B19	blue 19		56	FM	yes
B20	blue 20		57	4T	one
bY21	big yellow 21		60	FM	yes
bY23	big yellow 23		62	2T	yes
bY25	(big yellow 25)		64	FM	yes
bY27	big yellow 27		66	FM	
bY29	big yellow 29		68	FM	

EXPLANATION OF ABBREVIATIONS IN TABLE:

() tag known to be lost prior to August 1984.

H hogget, 2T two-tooth, 4T four-tooth, 6T six-tooth,

FM full-mouth

WRONZ NO. small metal tag in left ear. Numbers in this table refer to last two digits only.

Left and right ear tags were medium sized ALLFLEX sheep and cattle tags, except for big yellow tags which were large cattle tags.

APPENDIX DCHI-SQUARE ANALYSES1. AGE:PRODUCTIVITY (EXCLUDING HOGGETS)
section 3.1.2

	PREGNANT	NOT PREGNANT
TWO-TOOTH	36 (38.5)	7 (4.5)
FOUR-TOOTH	24 (24.2)	3 (2.8)
SIX-TOOTH	33 (31.3)	2 (3.7)
FULL MOUTH 8	78 (78.8)	10 (9.2)
FULL MOUTH 9	19 (17.9)	1 (2.1)
FULL MOUTH 10	15 (14.3)	1 (1.7)

CHI-SQUARE = 0.16 + 1.38
 0.0 + 0.01
 0.09 + 0.76
 0.01 + 0.07
 0.07 + 0.57
 0.03 + 0.27

TOTAL CHI-SQUARE = 3.42, DEGREES OF FREEDOM = 5

2. COLOUR : PRODUCTIVITY
section 3.1.2

	PREGNANT	NOT PREGNANT	TWINS
1	87 (83.1)	17 (19)	0 (1.8)
2	48 (54.4)	19 (12.5)	1 (1.2)
3	40 (40)	9 (9.2)	1 (0.9)
4	32 (29.6)	3 (6.8)	2 (0.7)
5	16 (16)	4 (3.7)	0 (0.4)
6	4 (4)	0 (0.9)	1 (0.1)

CHI-SQUARE = 0.18 + 0.22 + 1.83
 0.74 + 3.45 + 0.03
 0.0 + 0.0 + 0.02
 2.0 + 2.1 + 2.79
 0.0 + 0.03 + 0.35
 0.0 + 0.92 + 9.45

TOTAL CHI-SQUARE = 22.31, DEGREES OF FREEDOM = 10

3. SEX RATIO:AGE CLASSES
section 3.2.1

	FEMALE	MALE
HOGGET	276 (286.3)	227 (216.7)
2-TOOTH	184 (176.4)	126 (133.6)
4-TOOTH	157 (156.5)	118 (118.5)
6-TOOTH	202 (150.1)	132 (143.9)
FM 8	461 (474.7)	373 (359.3)
FM 9	101 (96.2)	68 (72.8)
FM 10	39 (39.8)	31 (30.2)

CHI-SQUARE = 0.37 + 0.49
 0.32 + 0.43
 0.0 + 0.0
 0.75 + 0.99
 0.39 + 0.52
 0.24 + 0.32
 0.02 + 0.02

TOTAL CHI-SQUARE = 4.86, DEGREES OF FREEDOM = 6

4. FOETAL SEX RATIO:ADULT SEX RATIO

section 3.2.1

	FEMALE	MALE
ADULT	1439 (1432.1)	1090 (1096.9)
FOETAL	112 (118.9)	98 (91.1)

CHI-SQUARE = 0.03 + 0.04
 0.40 + 0.53

TOTAL CHI-SQUARE = 1, DEGREES OF FREEDOM = 1

5. NUMBER OF SHEEP WITH HORNS 1970:1984

section 4.3.2

	1984	1970
FEMALE	142 (187.1)	126 (80.5)
MALE	883 (837.9)	317 (362.1)

CHI-SQUARE = 10.88 + 25.18
 2.43 + 5.62

TOTAL CHI-SQUARE = 44.11, DEGREES OF FREEDOM = 1, PROB
 <0.005

6. NUMBER OF PIGMENTED SHEEP:AGE CLASSES

section 3.2.3

	FEMALE	MALE
HOGGET	8 (7.8)	6 (6.2)
2-TOOTH	0 (0.6)	1 (0.4)
4-TOOTH	1 (2.8)	4 (2.2)
6-TOOTH	5 (3.9)	2 (3.1)
FM 8	8 (7.3)	5 (5.7)
FM 9 & 10	2 (1.7)	1 (1.3)

CHI-SQUARE = 0.0 + 0.01
 0.56 + 0.71
 1.15 + 1.45
 0.31 + 0.39
 0.08 + 0.10
 0.06 + 0.08

TOTAL CHI-SQUARE = 4.9, DEGREES OF FREEDOM = 5

7. NUMBER OF PIGMENTED SHEEP 1970:1984

section 4.3.3

	1984	1970
PIGMENTED	45 (41.1)	14 (17.9)
WHITE	2484 (2487.9)	1087 (1083.1)

CHI-SQUARE = 0.37 + 0.85
 0.01 + 0.01

TOTAL CHI-SQUARE = 1.24, DEGREES OF FREEDOM = 1

8. CONDITION INDEX (EWES):AGE CLASSES

section 3.2.8

	RANK 1	RANK 2	RANK 3	RANK 4	RANK 5
HOGGET	1 (0.5)	8 (7.5)	29 (25.9)	10 (13.3)	0 (0.9)
2-TOOTH	1 (0.5)	8 (6.7)	27 (23.2)	7 (11.9)	0 (0.8)
4-TOOTH	0 (0.3)	7 (4.2)	16 (14.6)	4 (7.5)	0 (0.5)
6-TOOTH	0 (0.4)	4 (5.6)	19 (19.4)	12 (10)	1 (0.6)
FM 8	1 (1.0)	14 (14.2)	41 (49.0)	32 (25.2)	3 (1.0)
FM 9	0 (0.2)	1 (3.3)	10 (11.3)	9 (5.8)	1 (0.4)
FM 10	0 (0.2)	2 (2.5)	10 (8.6)	4 (4.4)	0 (0.3)

CHI-SQUARE = 0.47 + 0.03 + 0.38 + 0.81 + 0.85
 0.64 + 0.25 + 0.63 + 2.01 + 0.76
 0.29 + 1.84 + 0.14 + 1.61 + 0.48
 0.38 + 0.47 + 0.01 + 0.42 + 0.2
 0.0 + 0.0 + 1.32 + 1.85 + 1.19
 0.22 + 1.58 + 0.15 + 1.75 + 1.06
 0.17 + 0.1 + 0.22 + 0.04 + 0.28

TOTAL CHI-SQUARE = 22.6, DEGREES OF FREEDOM = 24

9. NUMBER OF PREGNANT EWES:LOCALITY

section 3.3.1

	PREGNANT	NOT PREGNANT
COL	20 (23.8)	5 (5.2)
DUMAS	70 (73.8)	20 (16.2)
EBOULE	16 (14.8)	2 (3.2)
FILHOL	44 (47.5)	14 (10.5)
HONEY	78 (72.1)	10 (15.9)

CHI-SQUARE = 0.0 + 0.01
 0.19 + 0.88
 0.1 + 0.48
 0.26 + 1.2
 0.48 + 2.16

TOTAL CHI-SQUARE = 5.78, DEGREES OF FREEDOM = 4

10. LAMBING DATES:LOCALITY

section 3.3.2

NB. WEEKS HAVE BEEN POOLED TO MINIMIZE THE NUMBER OF ZEROES

WEEKS	COL	DUMAS	FILHOL	HONEY
1,2,3,4	4 (0.71)	2 (1.77)	0 (1.45)	0 (2.07)
5,6	4 (1.89)	6 (4.7)	6 (3.9)	5 (5.5)
7	3 (4.14)	5 (10)	11 (8.45)	16 (12)
8	7 (5.08)	5 (12.7)	9 (10)	22 (14.8)
9	0 (2.6)	3 (6.5)	9 (5.3)	10 (7.6)
10	1 (1.66)	1 (4.14)	4 (3.38)	8 (4.8)
11,12	2 (2.13)	12 (5.5)	2 (4.3)	2 (6.2)
13,14	1 (2.6)	15 (6.5)	2 (5.0)	4 (7.6)
15,16,17	0 (1.3)	8 (3.3)	2 (2.6)	1 (3.8)
18-26	2 (1.89)	3 (4.7)	4 (3.9)	7 (5.5)

CHI-SQUARE = 15.26 + 0.03 + 1.45 + 2.07
 2.35 + 0.34 + 1.18 + 5.52
 0.31 + 2.76 + 0.77 + 1.28
 0.72 + 4.68 + 0.18 + 3.47
 2.6 + 1.89 + 2.56 + 0.77
 0.26 + 2.38 + 0.11 + 2.08
 0.01 + 8.39 + 1.27 + 2.85
 0.99 + 11.1 + 2.06 + 1.7
 1.3 + 6.94 + 0.16 + 2.06
 0.01 + 0.63 + 0.0 + 0.4

TOTAL CHI-SQUARE = 94.894, DEGREES OF FREEDOM = 27

11. NUMBER OF TWINS:LOCALITY

section 3.3.3

	SINGLE	TWIN
COL	23 (23.5)	1 (0.5)
DUMAS	69 (68.5)	1 (1.5)
EBOULE	16 (15.7)	0 (0.3)
FILHOL	41 (43.1)	3 (0.9)
HONEY	78 (76.3)	0 (1.7)

CHI-SQUARE = 0.01 + 0.45
 0.0 + 0.17
 0.01 + 0.34
 0.10 + 4.44
 0.04 + 1.68

TOTAL CHI-SQUARE = 7.24, DEGREES OF FREEDOM = 4

12. AGE STRUCTURE:LOCALITY

section 3.3.4

	COL	DUMAS	EBOULE	FILHOL	HONEY	PUISEUX
HOGGET	54 (50)	106 (107)	17 (23.8)	114 (115)	180 (182)	32 (24.4)
2-TOOTH	32 (31)	72 (66)	7 (14.7)	76 (71)	115 (112)	8 (15)
4-TOOTH	30 (27)	51 (58)	8 (13)	60 (63)	105 (100)	21 (13.3)
6-TOOTH	28 (33)	70 (71)	26 (15.8)	83 (77)	116 (121)	11 (16.2)
FM 8	74 (83)	161 (177)	56 (40)	201 (191)	293 (303)	49 (40.5)
FM 9	19 (17)	52 (36)	3 (8)	26 (39)	69 (61)	0 (8.2)
FM 10	12 (7)	18 (15)	1 (3.3)	12 (16)	27 (25)	0 (3.4)

CHI-SQUARE = 0.29 + 0.01 + 1.94 + 0.02 + 0.03 + 2.37
 0.04 + 0.57 + 4.0 + 0.34 + 0.06 + 3.29
 2.24 + 0.94 + 1.93 + 0.15 + 0.28 + 4.4
 2.85 + 0.01 + 6.59 + 0.54 + 0.22 + 1.67
 1.02 + 1.47 + 6.95 + 0.5 + 0.3 + 1.81
 2.27 + 7.22 + 3.12 + 4.19 + 0.97 + 8.2
 3.6 + 0.66 + 1.61 + 1.02 + 0.1 + 3.4

TOTAL CHI-SQUARE = 77.185, DEGREES OF FREEDOM = 30, PROB <0.001

13. EWES : AGE STRUCTURE:LOCALITY

section 3.3.4

	COL	DUMAS	EBOULE	FILHOL	HONEY	PUISEUX
HOGGET	28 (28)	58(58.5)	10 (11)	64 (66)	95 (99)	21 (13)
2-TOOTH	18 (19)	36 (39)	4 (7.5)	47 (44)	75 (66)	4 (9)
4-TOOTH	14(19.9)	29 (33)	6 (6)	36 (37)	58 (56)	14 (7.6)
6-TOOTH	14 (20)	47 (43)	10 (8)	52 (48)	72 (73)	7 (9.8)
FM 8	47 (47)	96 (98)	26 (19)	117 (110)	152(166)	23 (22)
FM 9	13 (10)	29 (21)	2 (4)	14 (24)	43 (36)	0 (5)
FM 10	10 (4)	6 (8)	0 (1.5)	8 (9)	15 (14)	0 (2)

CHI-SQUARE = 0.0 + 0.0 + 0.14 + 0.04 + 0.17 + 4.29
 0.02 + 0.23 + 1.64 + 0.23 + 1.2 + 2.73
 0.23 + 0.55 + 0.03 + 0.05 + 0.05 + 5.32
 2.05 + 0.41 + 0.37 + 0.32 + 0.0 + 0.81
 0.0 + 0.03 + 2.73 + 0.48 + 1.11 + 0.02
 0.74 + 2.69 + 1.09 + 4.19 + 1.25 + 4.91
 9.24 + 0.62 + 1.59 + 0.18 + 0.07 + 1.9

TOTAL CHI-SQUARE = 53.76, DEGREES OF FREEDOM = 30, PROB <0.005

14. RAMS : AGE STRUCTURE:LOCALITY

section 3.3.4

	COL	DUMAS	EBOULE	FILHOL	HONEY	PUISEUX
HOGGET	26 (22)	48 (48)	7(13)	50 (49)	85 (83)	11 (11)
2-TOOTH	14 (12)	36 (27)	3 (7)	29 (27)	40 (40)	4 (6)
4-TOOTH	16(11.5)	22 (25)	2(6.6)	24 (20)	47 (43)	7 (6)
6-TOOTH	14 (13)	23 (28)	16 (7)	31 (29)	44(48.5)	4 (6)
FM 8	27 (36)	65(79.5)	30(21)	84 (81)	141(137)	26 (18)
FM 9	6(6.6)	23(14.5)	1 (4)	12 (15)	26 (25)	0 (3)
FM 10	2 (3)	12 (6.6)	1(1.7)	4 (7)	12 (11)	0 (1.5)

CHI-SQUARE = 0.66 + 0.0 + 2.54 + 0.01 + 0.03 + 0.0
 0.23 + 3.13 + 2.31 + 0.09 + 0.86 + 0.72
 1.74 + 0.39 + 3.19 + 0.11 + 0.31 + 0.29
 2.1 + 0.93 + 10.11 + 0.18 + 0.42 + 0.89
 2.44 + 2.63 + 4.05 + 0.10 + 0.11 + 3.51
 0.06 + 14.5 + 2.06 + 0.53 + 0.04 + 3.29
 0.35 + 4.41 + 0.31 + 1.12 + 0.03 + 1.5

TOTAL CHI-SQUARE = 60.78, DEGREES OF FREEDOM = 30, PROB <0.005

15. SEX RATIO : LOCALITY

section 3.3.5

	EWES	RAMS
COL	150 (148)	110 (112)
DUMAS	303 (303)	229 (229)
EBOULE	58 (68)	61 (51)
FILHOL	338 (325)	234 (246)
HONEY	521 (526)	404 (399)
PUISEUX	69 (69)	52 (52)

CHI-SQUARE = 0.03 + 0.04
 0.0 + 0.0
 1.39 + 1.84
 0.48 + 0.64
 0.05 + 0.07
 0.0 + 0.0

TOTAL CHI-SQUARE = 4.544, DEGREES OF FREEDOM = 5

16. RAMS - HORNS : LOCALITY
section 3.3.6

	HORNS	NO HORNS
COL	93 (90)	17 (20)
DUMAS	174 (188)	55 (41)
EBOULE	49 (50)	12 (11)
FILHOL	195 (192)	39 (42)
HONEY	337 (323)	57 (71)
PUISEUX	38 (43)	14 (9)

CHI-SQUARE = 0.08 + 0.39

1.02 + 4.67

0.02 + 0.10

0.05 + 0.22

0.59 + 2.68

0.51 + 2.32

TOTAL CHI-SQUARE = 12.655, DEGREES OF FREEDOM = 5, PROB <0.05

17. EWES - HORNS : LOCALITY
section 3.3.6

	HORNS	NO HORNS
COL	35 (14.8)	115 (135)
DUMAS	32 (29.9)	271 (273)
EBOULE	5 (5.7)	53 (52)
FILHOL	35 (33)	303 (305)
HONEY	29 (51)	492 (469)
PUISEUX	6 (7)	83 (62)

CHI-SQUARE = 27.56 + 3.02

0.15 + 0.02

0.09 + 0.01

0.08 + 0.01

9.77 + 1.07

0.1 + 0.01

TOTAL CHI-SQUARE = 41.88, DEGREES OF FREEDOM = 5, PROB <0.001

18. COLOUR : LOCALITY (LARGE SAMPLE)
section 3.3.7

	WHITE	PIGMENTED
COL	248 (255)	12 (4.6)
DUMAS	517 (522)	15 (9.4)
EBOULE	119 (117)	0 (2.0)
FILHOL	568 (562)	4 (10)
HONEY	913 (908)	12 (16)
PUISEUX	119 (119)	2 (2)

CHI-SQUARE = 0.21 + 11.75

0.06 + 3.23

0.04 + 2.12

0.07 + 3.75

0.02 + 1.21

0.0 + 0.0

TOTAL CHI-SQUARE = 22.474, DEGREES OF FREEDOM = 5, PROB <0.001

19. COLOUR : LOCALITY (AUTOPSY SAMPLE ONLY)

section 3.3.7

	1	2	3	4	5	6
COL	11 (10.7)	5 (7)	4 (5.1)	5 (3.8)	2 (1.9)	2 (0.5)
DUMAS	25 (33.1)	25 (21)	17(15.9)	11(11.8)	10 (6)	2 (1.6)
EBOULE	10 (6.6)	6 (4.3)	2 (3.2)	0 (2.4)	0 (1.2)	0 (0.03)
FILHOL	12 (21.3)	16(13.9)	16(10.2)	10(7.6)	4 (3.9)	0 (1.0)
HONEY	46 (32.3)	16(21.1)	11(15.5)	11(11.5)	3 (5.9)	1 (1.6)

CHI-SQUARE = 0.01 + 0.56 + 0.25 + 0.39 + 0.0 + 4.32
 1.97 + 0.53 + 0.08 + 0.05 + 2.59 + 0.11
 1.73 + 0.65 + 0.44 + 2.35 + 1.21 + 0.32
 4.07 + 0.31 + 3.23 + 0.77 + 0.0 + 1.02
 5.79 + 1.25 + 1.33 + 0.02 + 1.43 + 0.2
 TOTAL CHI-SQUARE = 37.36, DEGREES OF FREEDOM = 20

20. FOETAL COLOUR :LOCALITY

section 3.3.7

	1	2	3	4	5	6
COL	20 (18.3)	2 (3.5)	0 (0.2)	1 (0.4)	1 (1.2)	0 (0.3)
DUMAS	48 (50.5)	10 (9.7)	0 (0.6)	2 (1.2)	5 (3.2)	1 (0.9)
EBOULE	11 (12.2)	5 (2.3)	0 (0.1)	0 (0.3)	0 (0.8)	0 (0.2)
FILHOL	36 (33.6)	3 (6.5)	0 (0.4)	0 (0.8)	3 (2.2)	2 (0.6)
HONEY	57 (57.3)	13 (11)	2 (0.7)	1 (1.3)	2 (3.7)	0 (1.0)

CHI-SQUARE = 0.15 + 0.66 + 0.21 + 0.77 + 0.03 + 0.32
 0.12 + 0.01 + 0.59 + 0.58 + 0.97 + 0.02
 0.12 + 3.0 + 0.14 + 0.28 + 0.78 + 0.21
 0.17 + 1.85 + 0.39 + 0.78 + 0.33 + 3.4
 0.0 + 0.36 + 2.67 + 0.08 + 0.76 + 1.0
 TOTAL CHI-SQUARE = 20.75, DEGREES OF FREEDOM = 20

21. FACE COVER :LOCALITY

section 3.3.8

	5	6	7	8
COL	0 (0.1)	1 (4.5)	32 (29.3)	2 (1)
DUMAS	0 (0.3)	10 (12.8)	88 (83)	1 (2.9)
EBOULE	0 (0.1)	7 (2.6)	13 (16.8)	0 (0.6)
FILHOL	0 (0.2)	5 (8.2)	54 (52.8)	4 (1.8)
HONEY	1 (0.3)	17(11.9)	72 (77.1)	0 (2.7)

CHI-SQUARE = 0.11 + 2.75 + 0.24 + 0.95
 0.32 + 0.6 + 0.3 + 1.23
 0.06 + 7.52 + 0.85 + 0.58
 0.2 + 1.22 + 0.03 + 2.55
 1.66 + 2.18 + 0.34 + 0.17
 TOTAL CHI-SQUARE = 23.86, DEGREES OF FREEDOM = 12

22. CONDITION INDEX : LOCALITY

section 3.3.9

	1	2	3	4	5
COL	0 (0.3)	3 (4.5)	16 (15.2)	9 (7.5)	0 (0.5)
DUMAS	0 (1.0)	17 (14.4)	46 (48.8)	25 (24.3)	2 (1.6)
EBOULE	0 (0.2)	4 (2.9)	14 (9.8)	0 (4.9)	0 (0.3)
FILHOL	0 (0.6)	10 (9.3)	31 (31.5)	15 (15.6)	2 (1.0)
HONEY	3 (0.9)	11 (14)	46 (47.7)	27 (23.7)	1 (1.6)

$$\begin{aligned}
 \text{CHI-SQUARE} &= 0.0 + 0.48 + 0.04 + 0.28 + 0.5 \\
 &\quad 0.96 + 0.48 + 0.16 + 0.02 + 0.1 \\
 &\quad 0.19 + 0.44 + 1.84 + 4.85 + 0.32 \\
 &\quad 0.62 + 0.06 + 0.01 + 0.03 + 0.92 \\
 &\quad 4.55 + 0.66 + 0.06 + 0.45 + 0.2
 \end{aligned}$$

TOTAL CHI-SQUARE = 18.52, DEGREES OF FREEDOM = 16

FIRST NUMBER = OBSERVED VALUE

NUMBER IN BRACKETS = EXPECTED VALUE

APPENDIX E

ACCURACY OF CENSUSES.

The censuses since 1961 by Ecology Division, DSIR have probably accounted for about 85% of the sheep present at each count. This percentage is based on information from the 1970 and 1984 culls as follows:

1. 1969 census = 895 sheep, for the northern part of the island.

Assuming that the lambing rate of 35% held for the following year, the estimated population for 1970 was 1208.

The actual number shot = 1386, therefore 87% accuracy.

2. 1983 census = 2763, for cull area.

Assuming that the lambing rate of 20% held for the following year, the estimated population for 1984 was 3316.

The actual number shot was 4030 (4000 to August 1984, plus a further 30 to April 1985 (G.Taylor, pers comm.)), therefore 82% accuracy.

APPENDIX F :RAW DATA FOR HOME RANGE SCATTER PLOTS :
DATES AND GRID REFERENCES, AREA AND NUMBER
OF OBSERVATIONS FOR EACH TAGGED SHEEP.

- B1** : area 46 ha., number of observations 16
25/04- ; 27/04- 11,16; 28/04- 12,16; 8/05- 8,13;
9/05- 9,14; 10/05- 11,11; 16/05- 11,11; 10,11 & 13,13;
17/05- 9,15; 18/05- 8,16; 22/05- 15,14; 24/05- 16,14 &
16,13; 2/06- 13,16; 3/06- 10,18; 4/06- 7,17; 26/07-
17.5,10.5;
- B2** : area 39.4 ha., number of observations 17
25/04- ; 27/04- 11,16; 28/04- 11,16; 29/04- 10,14;
2/05- 17,14; 3/05- 16,14; 4/05- 15,14; 8/05- 9,10;
9/05- 10,11; 10/05- 15,13; 16/05- 8,14; 18/05- 7,16;
24.05- 8,16; 2/06- 10,17; 3/06- 7,16; 4/06- 6,17;
27/07- 15,14;
- B3** : area 24.1 ha., number of observations 12
3/05- 17,14; 7/05- 17,14; 9/05- 17,11; 10/05-
11,16; 15/05- 15,14; 22/05- 16,14; 23/05- 16,13; 24/05-
18,14; 3/06- 16,17; 4/06- 17,13; 8/06- 16,18; 26/07-
16,18;
- B4** : area 40 ha., number of observations 13
29/04- 9,15; 7/05- 12,15 & 14,13; 8/05- 6,13;
9/05- 10,11; 10/05- 11,10; 16/05- ; 22/05- 15,14;
23/05- 14,12 & 13,13; 24/05- 16,14 & 16,13; 3/06-
15,12; 4/06- 12,14; 26/07- 17.5, 10.5; 27/07- 15,13
- B5** : area 29 ha., number of observations 14
27/04- ; 29/04- 9,14; 4/05- 12,16; 9/05- 8,14;
16/05- 9,15 & 8,15; 17/05- 8,15 & 7,15; 18/05- 10,12 &
8,12; 22/05- 14,13 & 13,13, & 14,14 & 13,14; 25.05-
15,14; 2/06- 11,15; 3/06- 15,12; 4/06- 12,14; 9/06-
10,15; 26/07- 18,12 & 17,12
- B6** : area 47.7 ha., number of observations 13
25/04- 9,17; 29/04- 7,14; 3/05- 10,14; 4/05-
12,16; 8/05- 6,13; 10/05- 3,12; 16/05- 4,13; 18/05-
5,16 & 5,15; 22/05- 11,16 & 10,16; 23/05- 14,12 &
13,13; 24/05- 16,14 & 16,13; 2/06- 8,17; 26/07- 7,17
- B7** : area 65.3 ha., number of observations 13
27/04- ; 18/04- ; 10/05- 3,12; 17/05- 8,18; 18/05-
7,16; 22/05- 14,14 & 13,14; 23/05- 14,12 & 13,13;
24/05- 16,14 & 16,13; 3/06- 15,12; 4/06- 11,15; 9/06-
17,14 & 11,15; 26/07- 17.5,10.5; 27.07- 15,11 & 15,10
- B8** : area 8.2 ha., number of observations 6
25/04- 9,12; 27/04- 12,16; 28/04- ; 3/05- 10,13;
23/05- 11,11; 3/06- 8,11
- B9** : area 45.4 ha., number of observations 18
28/04- 15,15; 29/04- ; 3/05- 7,13; 7/05- 12,15 &
14,13; 9/05- 10,11; 10/05- 15,13; 15/05- 16,11 & 13,11;
16/05- 13,10; 17/05- 16,16; 18/05- 10,12; 22/05- 15,14;
23/05- 14,12 & 13,13; 24/05- 16,14 & 13,14; 2/06-
15,14; 3/06- 11,16; 4/06- 10,16; 9/06- 10,14 & 10/16;
24/07- 18,14

EXPLANATION OF ABBREVIATIONS USED:

ha - hectare

& - denotes points that sheep were noted moving between
in one observation

+ - denotes two separate observations made on one day

- B10 : area 62 ha., number of observations 14
 8/05- 6,13 & 6,12; 10/05- 6,14; 16/05- 7,14; 17/05- 9,15; 18/05- 14,15; 22/05- 10,14; 23/05- 14,11 & 14,10 & 12,15; 24/05- 16,14 & 16,13; 25/05- 18,13 & 18,12; 2/06- 8,15; 3/06- 10,18; 9/06- 10,14 & 10,16; 24/07- 18,14 & 18,11; 26/07- 17.5,10.5
- B11 : area 73.3 ha., number of observations 18
 27/04- ; 28/04- ; 29/04- 15,9; 4/05- 8,14 + 12,16; 8/05- 9,10; 10/05- 11,9; 15/05- 11,16; 16/05- 9,14 + 10,11 & 13,13; 17/05- 9,15; 18/05- 8,16; 2/06- 17,14; 3/06- 17,15; 4/06- 7,14; 8/06- 16,19; 9/06- 16,10; 26/07- 17.5,10.5
- B12 : area 48.6 ha., number of observations 15
 27/04- 11,16; 29/04- 12,15 & 14,13; 16/05- 13,8; 17/05- 12,10; 18/05- 17,14 & 17,13; 23/05- 14,12 & 13,13; 24/05- 16,14 & 16,13; 25/05- 18,12 & 18,13; 2/06- 15,14; 3/06- 15,12; 4/06- 7,14; 9/06- 10,15 + 17,14 & 11,15; 24/07- 18,14
- B13 : area 34.9 ha., number of observations 5
 18/05- 10,12 & 8,12; 24/05- 16,14 & 16,13; 3/06- 4,15; 4/06- 10,16; 26/07- 18,12 & 17,12
- B14 : area 52.4 ha., number of observations 16
 27/04- 11,16; 28/04- ; 29/04- ; 10/05- 3,12; 16/05- 9,11; 17/05- 10,11; 18/05- 17,14 & 17,13; 22/05- 14,13 & 13,13; 25/05- 18,13 & 18,12; 2/06- 17,15; 3/06- 11,15; 4/06- 7,14; 9/06- 17,14 & 11,15; 24/07- 18,14; 26/07- 17.5,10.5
- B15 : area 49.8 ha., number of observations 11
 27/04- ; 16/05- 8,14; 23/05- 10,16; 24/05- 10,16; 25/05- 18,13 & 18,12; 2/06- 17,15; 3/06- 10,18; 9/06- 17,14 & 11,15; 24/07- 16,18 & 18,11; 26/07- 17.5,10.5; 27/07- 17,18 & 17,15
- B16 : area 67.4 ha., number of observations 16
 25/04- ; 8/05- 6,13 & 6,12; 10/05- 11,10; 15/05- 16,11 & 13,11; 16/05- 13,10 & 10,11 & 13,13; 17/05- 8,15 & 7,15; 18/05- 17,14 & 17,13; 22/05- 14,15; 23/05- 14,10 & 14,11 & 12,15; 24/05- 16,14 & 16,13; 2/06- 15,14; 3/06- 11,15; 4/06- 7,14; 8/06- 16,19; 9/06- 17,14 & 11,15; 26/07- 18,12 & 17,12
- B17 : area 41.8 ha., number of observations 12
 24/04- ; 25/04- ; 27/04- ; 8/05- 6,13 & 6,12; 15/05- 14,13; 17/05- 12,15; 23/05- 14,12 & 13,13; 3/06- 17,15; 4/06- 12,14; 9/06- 17,14 & 11,15; 26/07- 17.5,10.5; 27/07- 15,11 & 15,10
- B18 : area 20.8 ha., number of observations 7
 25/04- ; 29/04- ; 8/05- 6,13; 17/05- 8,18; 18/05- 10,18; 22/05- 14,15; 23/05- 13,16
- B19 : area 34.6 ha., number of observations 13
 25/04- ; 28/04- ; 29/04- ; 3/05- 12,12; 8/05- 6,13; 10/05- 6,15; 16/05- 10,11 & 13,13; 17/05- 10,16; 18/05- 10,12 & 8,12; 2/06- 17,15; 3/06- 11,15; 4/06- 7,14; 9/06- 17,14 & 11,15

- B20 : area 16.9 ha., number of observations 9
 27/04- ; 28/04- ; 29/04- ; 3/05- 9,13; 4/05- 10,16;
 2/06- 17,15; 4/06- 7,14; 26/07- 15,14 & 14,14; 27/07-
 15,14 & 12,14
- R21 : area 53.5 ha., number of observations 13
 25/04- 7,14; 29/04- 7,14; 10/05- 3,12; 17/05-
 17,17; 18/05- 17,17; 22/05- 14,15; 23/05- 16,14 & 16,13;
 24/05- 18,14; 25/05- 18,13 & 18,12; 2/06- 17,14; 3/06-
 11,15; 4/06- 7,14; 26/07- 17.5,10.5
- R22 : area 4.1 ha., number of observations 4
 28/04- ; 29/04- 12,9; 9/05- 15,5; 10/05- 16,6
- R23 : area 35.7 ha., number of observations 10
 10/05- ; 15/05- 16,11 & 15,11 & 14,11 & 13,11;
 16/05- 6,14; 17/05- 10,16; 18/05- 11,15; 22/05- 14,15;
 23/05- 14,11 & 12,15; 24/05- 16,14 & 16,13; 2/06- 8,17;
 27/07- 15,13
- R24 : area - , number of observations 1
 29/04- 6,13
- R25 : area 49.4 ha., number of observations 6
 25/04- 9,17; 3/05- 16,14; 16/05- 6,14; 23/05- 14,11
 & 12,15; 24/05- 16,14 & 16,13; 8/06- 16,19
- R26 : area 4.3 ha., number of observations 7
 29/04- 6,14; 8/05- 5,13; 16/05- 5,16; 2/06- 3,14;
 3/06- 4,15; 26/07- 6,14; 27/07- 6,14
- R27 : area 63 ha., number of observations 12
 3/05- 10,16; 8/05- 6,13; 10/05- 6,15; 16/05- 4,13;
 18/05- 10,12 & 8,12; 23/05- 14,11 & 12,15; 24/05- 16,14 &
 16,13; 2/06- 15,14; 3/06- 10,15; 4/06- 7,17; 8/06- 16,18;
 27/07- 15,11 & 15,10
- R28 : area 65.4 ha., number of observations 16
 27/04- 11,16; 28/04- ; 4/05- 8,16; 8/05- 6,13;
 10/05- 3,12; 16/05- 4,13; 18/05- 11,15; 22/05- 11,16 &
 10,16; 23/05- 14,12 & 13,13; 24/05- 16,14 & 16,13; 2/06-
 17,14; 3/06- 11,15; 4/06- 7,14; 24/07- 16,18; 26/07-
 17.5,10.5; 27/07- 15,13
- R29 : area 51.5 ha., number of observations 10
 16/05- 6,14; 18/05- 10,12 & 8,12; 23/05- 14,11 &
 12,15; 2/06- 17,14; 4/06- 12,14; 8/06- 16,18; 9/06-
 16,10; 24/07- 16,18; 26/07- 17.5,10.5; 27/07- 15,11 &
 15,10
- R30 : area 55.8 ha., number of observations 8
 16/05- 6,14; 24/05- 16,14 & 16,13; 2/06- 17,14;
 3/06- 17,15; 4/06- 12,14; 8/06- 16,20; 9/06- 16,17;
 27/07- 15,11 & 15,10
- R31 : area 41.1 ha., number of observations 6
 25/04- 13,16; 29/04- 11,12; 2/06- 15,14; 4/06-
 7,14; 26/07- 17.5,10.5; 27/07- 17,18 & 17,15
- R32 : area 44.7 ha., number of observations 12
 29/04- ; 7/05- 12,15 & 14,13; 10/05- 7,14; 15/5-
 16,11 & 13,11; 17/05- 11,15 & 16,11; 23/05- 9,14; 24/05-
 16,14 & 16,13; 2/06- 17,14; 3/06- 17,15; 4/06- 12,14;
 8/06- 16,19; 9/06- 10,14 & 10,16

R33 : area 48.9 ha., number of observations 12
 27/04- ; 29/04- 11,12; 7/05- 12,15 & 14,13; 8/05-
 9,10; 16/05- 8,14; 22/05- 15,17; 23/05- 15,17; 24/05-
 17,16; 25/05- 17,15; 2/06- 16,16; 9/06- 16,16; 26/07-
 17.5,10.5

R34 : area 35.4 ha., number of observations 9
 25/04- 13,16; 3/05- 10,16; 10/05- 6,15; 16/05-
 8,13; 17/05- 9,15; 3/06- 11,15; 4/06- 12,14; 8/06- 16,18;
 27/07- 16,12

R35 : area 33.2 ha., number of observations 7
 16/05- 8,10 & 7,10 + 6,14; 17/05- 11,17 & 13,16;
 18/05- 11,15; 24/05- 10,18 & 7,18; 2/06- 11,15; 9/06-
 10,14 & 10,16

R36 : area 53.6 ha., number of observations 9
 10/05- 3,12; 17/05- 17,17; 18/05- 17,17; 22/05-
 14,15; 23/05- 14,11 & 14,10 & 12,15; 24/05- 16,14 &
 16,13; 3/06- 11,15; 4/06- 7,14; 27/07- 17,18 & 17,15

R37 : area 34.8 ha., number of observations 8
 10/05- 3,12; 16/05- 8,13; 18/05- 7,16; 22/05-
 14,15; 23/05- 14,12 & 13,13 + 13,12; 24/05- 16,14 &
 16,13; 2/06- 11,15

R38 : area 77.8 ha., number of observations 11
 24/04- ; 16/05- 8,10 & 7,10 + 6,14; 17/05- 11,17 &
 13,16; 18/05- 11,15; 24/05- 10,18 & 7,18; 25/05- 18,13 &
 18,12; 2/06- 11,15; 3/06- 10,18; 9/06- 10,14 & 10,16;
 27/07- 17,18 & 17,15

R39 : area 17.4 ha., number of observations 4
 2/06- 15,14; 3/06- 10,18; 26/07- 16,18; 27/07-
 17,18 & 17,15

R40 : area 51.9 ha., number of observations 13
 3/05- 17,14; 7/05- 17,14; 9/05- 17,11; 10/05- 7,14;
 17/05- 11,15 & 16,11; 23/05- 16,14 & 16,13; 24/05- 18,14;
 25/05- 18,13 & 18,12; 3/06- 16,17; 4/06- 17,13; 8/06-
 16,20; 9/06- 16,17; 26/07- 17,14

bY1 : area - , number of observations 2
 24/04- ; 29/04-

bY2 : area 51.2 ha., number of observations 13
 24/04- ; 29/04- ; 4/05- 11,16; 10/05- 6,15; 16/05-
 8,14; 18/05- 11,15; 22/05- 11,16 & 10,16; 23/05- 14,11 &
 14,10 & 12,15; 24/05- 16,14 & 16,13; 3/06- 11,15; 4/06-
 11,12; 26/07- 17.5,10.5; 27/07- 17,18 & 17,15

bY3 : area 53.6 ha., number of observations 13
 28/04- ; 29/04- ; 17/05- 11,17 & 13,16; 18/05- 6,15
 & 5,15 & 5,16; 24/05- 9,16; 25/05- 18,13 & 18,12; 2/06-
 8,15; 3/06- 7,16; 4/06- 7,15; 9/06- 10,14 & 10,16 + 17,14
 & 10,16; 26/07- 17.5,10.5; 27/07- 17,18 & 17,15

bY4 : area 54.8 ha., number of observations 16
 29/04- ; 3/05- 10,16; 8/05- 6,13; 16/05- 8,13;
 17/05- 9,15; 18/05- 17,14 & 17,13; 23/05- 9,14; 24/05-
 10,18; 25/05- 18,13 & 18,12; 2/06- 11,15; 3/06- 11,15;
 4/06- 7,14; 8/06- 16,18; 9/06- 16,10; 24/07- 17,15;
 26/07- 17.5,10.5

bY5 : area 59.4 ha., number of observations 14
 8/05- 11,14; 10/05- 3,12; 17/05- 15,18 & 17,17 &
 17,16; 18/05- 17,17; 22/05- 14,15; 23/05- 16,14 & 16,13;
 24/05- 18,14; 25/05- 18,13 & 18,12; 2/06- 17,14; 3/06-
 17,15; 4/06- 12,14; 8/06- 16,19; 9/06- 10,14 & 10,16;
 27/07- 17,18 & 17,15
bY6 : area 55.7 ha., number of observations 10
 3/05- 7,13; 4/05- 12,16; 10/05- 6,14; 16/05- 6,14;
 17/05- 11,17 & 13,16; 18/05- 10,12 & 8,12; 2/06- 11,15;
 3/06- 10,18; 4/06- 6,17; 27/07- 16,6 & 13,8
bY7 : area 36.8 ha., number of observations 9
 24/04- ; 17/05- 11,17 & 13,16; 18/05- 6,15 & 5,16 &
 5,15; 24/05- 9,16; 25/05- 18,13 & 18,12; 2/06- 8,15;
 3/06- 17,16; 4/06- 7,15; 9/06- 10,14 & 10,16 + 17,14 &
 11,15
bY8 : area - , number of observations 3
 28/04- ; 9/05- 15,5; 10/05- 16,6
bY10 : area 82.7 ha., number of observations 21
 25/04- ; 27/04- ; 29/04- ; 3/05- 10,14 & 10,13;
 4/05- 12,16; 8/05- 9,10; 9/05- 8,12; 10/05- 6,15; 17/05-
 9,17; 22/05- 12,13; 23/05- 14,11 & 14,10 & 12,15; 24/05-
 16,14 & 16,13; 25/05- 18,13 & 18,12; 2/06- 16,16; 3/06-
 17,15; 4/06- 17,13; 8/06- 16,20; 9/06- 16,17; 26/07-
 17.5,10.5; 27/07- 17,18 & 17,15
bY11 : area 34.1 ha., number of observations 15
 27/04- ; 29/04- ; 3/05- 8,14 & 7,14; 4/05- 12,16;
 8/05- 5,12; 16/05- 9,15 & 8,15 + 10,11 & 13,13; 17/05-
 10,12 & 8,12; 18/05- 8,15 & 7,15; 22/05- 14,14 & 13,14;
 23/05- 14,12 & 13,13; 25/05- 15,14; 3/06- 11,15; 4/06-
 10,16; 9/06- 10,15
bY12 : area 19.3 ha., number of observations 5
 27/04- ; 3/05- 10,13; 17/05- 16,16; 18/05- 6,15 &
 5,15 & 5,16; 22/05- 14,15
bY13 : area 69.6 ha., number of observations 18
 3/05- 9,14; 4/05- 12,15; 8/05- 6,13; 9/05- 6,15;
 10/05- 6,15; 17/05- 8,12; 18/05- 17,14 & 17,13; 22/05-
 15,14; 23/05- 14,12 & 13,13; 24/05- 16,14 & 16,13; 25/05-
 18,14 & 18,13; 2/06- 16,14; 3/06- 11,15; 4/06- 7,14;
 8/06- 16,20; 9/06- 16,17; 24/07- 16,18; 26/07- 17.5,10.5
bY14 : area - , number of observations 3
 24/05- ; 4/06- 13,10; 9/06- 13,6
bY15 : area - , number of observations 4
 29/04- ; 4/05- 15,14; 8/05- 11,14; 10/05- 7,14
bY16 : area 7.8 ha., number of observations 5
 29/04- ; 3/05- 8,12; 9/05- 8,12; 10/05- 6,15;
 3/06- 11,15
bY17 : area 24.9 ha., number of observations 10
 29/04- ; 3/05- 17,14; 7/05- 17,14; 9/05- 17,11;
 10/05- 11,13; 15/05- 11,16; 23/05- 9,14; 24/05- 16,14 &
 16,13; 2/06- 17,14; 3/06- 17,15
bY18 : area 10.7 ha., number of observations 9
 27/04- ; 29/04- ; 2/05- 17,14; 3/05- 16,14; 4/05-
 15,14; 8/05- 9,10; 10/05- 11,11; 16/05- 8,10 & 7,10;
 24/05- 16,14 & 16,13

bY19 : area 56.2 ha., number of observations 15
 24/04- ; 29/04- ; 3/05- 12,12; 9/05- 9,12; 10/05- 3,12; 15/05- 11,16; 16/05- 9,15 & 8,15; 17/05- 11,17 & 12,15; 18/05- 17,14 & 17,13; 23/05- 14,10 & 14,11 & 12,15; 24/05- 16,14 & 16,13; 25/05- 18,14 & 18,13; 2/06- 11,15; 3/06- 11,15; 4/06- 12,14

bY20 : area 76.9 ha., number of observations 14
 24/04- ; 3/05- 12,12; 9/05- 9,12; 10/05- 3,12; 15/05- 11,16; 16/05- 9,15 & 8,15; 17/05- 11,17 & 12,15; 18/05- 17,14 & 17,13; 23/05- 14,10 & 14,11 & 12,15; 24/05- 16,14 & 16,13; 25/05- 18,14 & 18,13; 2/06- 11,15; 3/06- 10,18; 26/07- 16,18

bY21 : area 62.2 ha., number of observations 15
 27/04- ; 28/04- 15,15; 3/05- 16,14; 10/05- 3,12; 15/05- 16,11 & 13,11; 16/05- 13,10; 17/05- 12,10; 18/05- 17,14 & 17,13; 22/05- 14,15; 23/05- 14,12 & 13,13; 3/06- 15,12; 4/06- 12,14; 8/06- 16,18; 9/06- 16,10; 26/07- 17.5,10.5

bY22 : area 31.4 ha., number of observations 14
 29/04- ; 2/05- 17,14; 3/05- 17,14; 4/05- 15,14; 10/05- 12,18; 23/05- 13,12; 24/05- 16,14 & 16,13; 25/05- 17,15; 2/06- 11,15; 3/06- 15,12; 4/06- 12,14; 9/06- 17,14 & 11,15; 26/07- 17.5,10.5; 27/07- 15,11 & 15,10

bY23 : area 12.4 ha., number of observations 5
 28/04- ; 16/05- 8,10 & 7,10; 24/05- 12,9; 4/06- 13,10; 27/07- 16,6 & 13,8

bY24 : never seen

bY25 : area 31.2 ha., number of observations 12
 29/04- ; 10/05- 3,12; 16/05- 8,14; 17/05- 8,12; 18/05- 17,14 & 17,13; 23/05- 14,12 & 13,13 + 13,12; 25/05- 18,12 & 18,13; 3/06- 11,15; 4/06- 7,14; 9/06- 17,14 & 11,15

bY26 : area 25.9 ha., number of observations 6
 29/04- ; 16/05- 6,14; 17/05- 9,17; 22/05- 11,16 & 10,16; 25/05- 18,13 & 18,12; 26/07- 18,12 & 17,12

bY27 : area - , number of observations 2
 25/04- ; 27/04-

bY28 : area 34.4 ha., number of observations 7
 27/04- ; 29/04- ; 8/05- 6,13 & 6,12; 10/05- 15,13; 16/05- 9,15 & 8,15; 24/05- 15,16 + 10,18

bY29 : area 38.7 ha., number of observations 17
 28/04- ; 2/05- 9,14; 7/05- 12,15; 9/05- 6,15; 10/05- 6,15; 15/05- 14,13; 16/05- 16,12 & 16,14; 17/05- 12,15; 18/05- 17,14 & 17,13; 2/06- 17,15; 3/06- 11,15; 4/06- 7,14; 9/06- 17,14 & 11,15; 24/07- 18,14; 26/07- 17.5,10.5; 27/07- 15,11 & 15,10

bY30 : area 45.2 ha., number of observations 14
 28/04- ; 29/04- ; 8/05- 9,10; 16/05- 6,14; 17/05- 11,17 & 12,15; 22/05- 14,14 & 13,14; 24/05- 16,14 & 16,13; 25/05- 17,15; 2/06- 16,16; 3/06- 17,15; 4/06- 11,12; 9/06- 17,14 & 11,15; 26/07- 11,15; 27/07- 15,13

bY31 : area 45.9 ha., number of observations 11
 3/05- 17,14; 7/05- 17,14; 9/05- 17,11; 10/05- 11,11; 15/05- 11,16; 3/06- 16,19; 4/06- 17,13; 8/06- 16,19; 9/06- 16,10; 26/07- 17.5,10.5; 27/07- 17,18 & 17,15