GENETIC IMPROVEMENT OF LAMB SURVIVAL IN THE AUSTRALIAN MERINO: BEHAVIOURAL AND PHYSIOLOGICAL INDICATORS OF MATERNAL ABILITY

A thesis submitted to the Faculty of Rural Science, University of New England, Australia, for the degree of Master of Rural Science.

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DECLARATION

I certify that the substance of this thesis has not already been submitted for any degrees and is not being currently submitted for any other degree.

I certify that to the best of my knowledge, any help received in preparing this thesis and all sources used, have been acknowledged in this thesis.

Signed: [redacted]
M.R. Szantar-Coddington

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SUMMARY

Poor lamb survival in the Australian Merino has been recognised as a problem since the late 1950's. From the numerous studies cited in the literature, starvation is ultimately the cause of most lamb deaths but there may also be many intermediate effects involved. These may include dystocia, ewe/lamb interactions, climate and nutrition. While dystocia and starvation appear to be distinct causes of lamb deaths, sub-lethal birth trauma may result in the animal dying of starvation through low vigour or simply an incapacity to follow its mother.

Two methods of overcoming the problem of lamb mortality are management and genetic selection. Management has met with limited success and incurs an annual cost. Improvements obtained through breeding however are permanent. The major thrust of the study reported here deals with identifying behavioural and physiological indicators of maternal ability using two flocks that have been shown to differ genetically in their capacity to rear lambs. The first of these flocks was the Trangie Fertility Flock, the ewes of which have a superior capacity to rear their lambs than those of the second flock, the Trangie Random Flock. The differences between these two flocks were arrived at by genetic selection.

As part of this thrust towards the genetic improvement of lamb survival, the principal aim of this study comprised two components. These were (a) to understand the reasons for the superior rearing performance of ewes from the Fertility Flock and (b) to look for other differences between the two flocks that have potential as indirect selection criteria.

Chapter 4 describes a study, the aim of which was to understand the reasons for the superior rearing ability of the Fertility Flock ewes. In this study the behaviour of ewes and lambs during and for a short period after birth, was studied for three consecutive years. In the first year, observations were carried out during daylight hours only, while in the other two years, 24-hour observations were made. During the observation period, the duration of events of parturition and the events involved in the establishment of the ewe/lamb bond, were recorded. These observations included such measurements as the length of the birth process, time spent on the birth site, time taken for the lamb to stand and drink as well as the ewe's grooming behaviour and their reaction to the lamb suckling. Data were collected for both single and multiple lambs. From the data collected there were no significant flock differences recorded for any of the parameters measured. The large variation observed in the observations measured suggests that more subtle behaviours of changes should have been recorded particularly those involved with the establishment of the ewe/lamb bond.

Chapter 5 describes a study aimed at unearthing potential criteria for the genetic improvement of lamb survival. In this study, the behaviour of ewes in two short-duration behavioural tests, potentially correlated with maternal behaviour traits, was measured. The tests performed were the open-field test of Putu (1988) and the arena test of Fell and Shutt (1989). The open-field test was performed on ewes pre-joining in 1990 and involved placing the ewe singly in an outside arena for 5 minutes and recording behaviours such as the number of squares crossed, bleats, grazing bouts, urinations and defaecations. There were no significant flock effects on any of the parameters measured. In the absence of any significant results and the fact that the validity of the open-field test as a true measure of temperament has been of considerable concern, ewes were not subjected to the open-field test in the following year.

The arena test was performed on ewes from the two flocks for two years pre-joining (1990-1991) and one year pre-lambing (1991). The test involved placing the ewe singly in an indoor arena for 10 minutes and recording behavioural traits such as the minimum, mean and maximum approach distance as well as the total distance travelled during the test. The number of bleats, urinations and defaecations were also recorded. There were significant effects of flock on travel and number of bleats on all three occasions and a significant flock effect on minimum approach, maximum approach and the proportion of ewes that bleated on two occasions. The Fertility ewes consistently travelled and bleated less during the tests than the Random ewes. It would appear that these two behavioural traits, total distance travelled and number of bleats, could be used as a possible indicator of the degree of stress being experienced by the animal whilst in the arena and could therefore suggest that the Fertility ewes appeared less stressed or agitated than the Random ewes. The high repeatability of these two traits and the presence of constant flock differences in both pregnant and dry ewes, even though the test periods were separated by lengthy time periods, suggests that the arena test is identifying consistent differences between the two flocks involved but exactly what it is measuring remains unsolved. Further work would need to be performed before the behavioural differences identified in the arena test could be used as a possible predictor of maternal ability and as a possible selection criterion for improved lamb survival.

One criticism of the arena test is that it is time consuming. If ewe behaviour is to be used as a selection criterion, then its measurement must be greatly simplified. One means of doing this is to measure arena behaviour in groups of ewes rather than singly. In fact, previous workers have generally tested animals in groups of three or four when attempting to identify behavioural differences in the arena test. Therefore, Chapter 6 was designed to study whether differences in the behaviour of sheep when they are tested singly in the arena are maintained when they are tested in a group of four. This study conclusively showed that the differences in behaviour between the two flocks which were recorded when the ewes were tested singly, completely disappeared when the ewes were tested in groups. While the direction and magnitude of the differences seen in the single ewe test were similar to the findings of the previous experiment, the lack of behavioural differences when the ewes are tested in groups suggests that the behavioural traits exhibited by the ewe when in a group are very different from those expressed when the ewe is alone. This could be a possible explanation for the absence of any significant flock effects in the previous experiment when ewes were observed during lambing in the paddock as a group. More conclusive results may have been obtained if ewes were observed with their lambs in isolation from other ewes.

The final experiment (Chapter 7) was designed to assess whether differences in behaviour and response to stress between the two flocks could be identified by examining the hormonal responses in blood cortisol levels to an ACTH challenge. Two doses of ACTH were used, as well as an external stress stimulus, a dog. The use of an external stimulus provided a form of stress that avoided interference with the hypothalamo pituitary adrenal

axis. Exposure to the dog had very little effect on the cortisol response of the ewes and, overall, there were no significant flock effects recorded in response to a challenge with ACTH, at either dose. There was a definite response to ACTH with levels rising sharply shortly after the treatment and the lower dose resulted in significantly higher response levels than the higher dose or the dog treatment. The lack of any significant differences between the two flocks in their response to the challenge with ACTH may highlight that the behavioural differences previously recorded in the arena test were not associated with stress but some other aspect of behaviour.

In conclusion, the arena test behaviour showed considerable promise as an indirect selection criterion for the genetic improvement of maternal ability. This is shown by the highly consistent differences between two flocks known to differ in lamb rearing capacity and the fact that these differences appeared regardless of the ewe's physiological state. While flock differences were not reflected in paddock behaviour, the paddock behaviours that were measured were perhaps not as subtle as those measured in individual sheep in the arena while the lack of any flock differences in their cortisol response to a challenge with ACTH may demonstrate that the arena behaviour recorded was not a measure of stress or that more animals were needed in the final experiment to overcome the large degree of variation recorded between individuals.

PART A. REVIEW OF LITERATURE

CHAPTER 1. INCIDENCE OF LAMB MORTALITY IN AUSTRALIA

1.1 INTRODUCTION

The Australian sheep flock continues to be dominated by the Merino breed. At 30 June 1990 merinos accounted for 88% of the total sheep flock (Australian Bureau of Agricultural and Resource Economics, 1990). However, despite the Merino's prominence, their average reproductive rate remains low. For example, lamb marking percentages in New South Wales in 1986, 1987 and 1988 were 80.9, 78.2 and 83.7 respectively (Wilson, 1990). Using a figure of 1.36 as the mean ovulation rate of Merino ewes aged 18 to 54 months (Purvis *et al*, 1988), these marking percentage figures amount to only about 60% of the Merino's potential. More recently, Kilgour (1992) using ultrasonograghy, showed that in New South Wales the potential number of foetuses per 100 ewes was 131 for adult ewes and 112 for maiden ewes. Kleeman *et al* (1991) similarly showed that the potential number of foetuses per 100 ewes was 133 in adult South Australian Merino ewes.

There are three sources of reproductive wastage: loss from failure to mate, loss from failure to lamb following mating and loss of lambs from birth to marking. The relative importance of the source of the loss varies in different areas but a number of studies (for example, Jordan et. al. ,1989) found the major cause of low lamb marking percentages to be the loss of lambs from birth to marking. Kleeman *et al* (1991) found that overall, 54% of the total reproductive loss in South Australian Merino flocks was attributed to lamb losses from birth to lamb marking.

One of the reasons for the failure of Merino ewes to attain their potential is high lamb mortality. This review examines the information available on the extent of lamb mortality, on the causes of death and on the potential to improve lamb survival by genetic selection. The review is restricted almost exclusively to the Merino breed because of its relative importance in Australia and due to the fact that mortality in other breeds such as the Dorset Horn and Border Leicester are largely attributed to breed-specific causes. Many

Dorset Horn ewes experience high dystocia problems (George, 1976) and McGuirk (1967) suggested that pneumonia might be implicated in the poor reproductive performance of Border Leicester flocks.

1.2 INCIDENCE

While there are many estimates of the extent of lamb mortality in Australia, many of these are not supported by reliable data. In the section which follows, the only estimates of lamb loss that are considered are those based on the numbers of lambs born or on the numbers of ewes that were known to have given birth but failed to rear a lamb to marking.

The studies reviewed have been considered under three headings:
(i) Those large field studies where results are presented for a number of commercial flocks, (ii) single flock studies where only one commercial flock was studied and
(iii) experimental studies where information has mainly been obtained from the comparison of experimental flocks/treatments.

1.2.1 Large field studies

Two large field studies have been reported, one in Western Australia (Knight *et al*, 1975) and the other in New South Wales (Luff, 1980). Knight *et al*, (1975) monitored over 25 000 ewes from 55 flocks. They showed that, in ewes joined from October to March (Spring - Summer), the mean percentage of ewes which failed to rear a lamb was 11.4. However they gave no indication of the range of losses between flocks.

In the New South Wales study based on almost 46 000 ewes, Luff (1980) reported that 22.1% of ewes which gave birth failed to rear a lamb. This figure ranged from 3.9% to 61.4% for individual flocks.

These estimates of lamb loss probably reveal the scale of lamb loss in Australia because they are based on such large numbers of ewes. However, they both underestimate the loss in terms of lambs dying since they are based on ewes which lost all their lambs. They take no account of the partial losses of lambs which were born as multiples nor of the fact that ewes which failed to rear a lamb may have lost more than one.

Two more recent studies overcome these problems by measuring foetal number in utero by ultrasonagraphy. Kilgour (1992) reports data representing diagnosis of over 30 000 ewes from 21 properties in New South Wales. On two of these properties, ewes diagnosed as twin-bearers were run separately from the single-bearers and survival of the lambs to marking was recorded. Assuming minimal fetal loss between scanning and birth, an overall mortality rate of 33%, with a range of 27 to 44% for single and twin-bearers respectively, was recorded for maiden ewes on one of the properties. Adult ewes on properties 1 and 2 recorded mortality rates of 18% and 26%, respectively. Mortality ranged from 12 - 24% on property 1 for single and twin-bearers, respectively and 17 - 35% on property 2.

Kleeman *et al* (1991) conducted a study involving a total of 26 flocks of mature age Merino ewes to determine sources of reproductive wastage in the South Australian Merino. In the first and second year of the study, lamb losses from birth to marking were of 24.5% (10 flocks) and 33.5% (16 flocks), respectively. Overall, 54% of the total reproductive loss was attributed to lamb losses from birth to lamb marking.

1.2.2 Single flock studies

Data from central Queensland reveal mortality rates as high as 72.3% in lambs born during November and 21.1% in lambs born between mid-August and mid-October (Smith, 1962). The level of mortality was probably accentuated in the November period due to a low plane of maternal nutrition and to high ambient temperatures. Small experimental numbers on a single property may also exaggerate the problem particularly for the November period when only 47 lambs were born.

Watson and Elder (1961) observed Corriedale ewes lambing during daylight hours in Western Victoria. Of the lambs born in August 28% died while of those born in October, 15% died. At least 90% of deaths occurred within 3 days of birth. Lower lamb losses in October were attributed to less severe weather conditions than those experienced by the

August born lambs.

As well as observing ewes lambing in pens, Jordan and Le Feuvre (1989) carried out daily observations on Merino ewes lambing in paddocks in south-west Queensland. In the first study, of the 576 lambs born, 20% died with the majority of deaths occurring in the first few days of life. In the second study however, large paddock sizes and spread of ewes and lambs made complete lamb recovery difficult. Therefore the 9% figure recorded for lamb deaths was thought to be an underestimate.

1.2.3 Experimental conditions

Publications reporting levels of lamb mortality in experimental flocks in Australia and other countries are numerous and only the studies, whose data have been strongly supported by the methods involved in their collection, are tabulated (Table 1.1). Most of the studies tabulated were carried out in Australia.

It can be concluded that Merino lamb losses in a wide variety of environments and management systems ranged from 6.0 - 91.1% with an average of around 28.0%. Corriedale lamb losses range from 10.3 - 53.7% with an average of around 29% while mortality rates amongst Polwarth lambs ranged from 15% (Mullaney and Hyland, 1967) to 36.7% (McDonald, 1966).

The levels of mortality listed in Table 1.1 vary from lamb losses recorded over the neonatal period, to lamb losses up to lamb marking and some up to weaning. For most studies, no specific period is reported and it is simply described as perinatal lamb mortality. Some of the studies listed in Table 1.1 could be categorized into more specific experimental conditions which include:

(i) Length of observation

When studying the incidence of lamb mortality, direct observation of the lambing flock is one of the most accurate ways of assessment. Through this method not only is the extent of lamb loss determined but also the apparent cause of mortality. A large proportion of the studies listed in Table 1 used continuous observations of the lambing flock, although a

TABLE 1.1: Incidence of lamb mortality in Australia according to breed, experimental conditions, locality and lambing season

Author	Year	Breed of Sheep	Method of Measuring Mortality	Number of Ewes Lambing	Number of Lambs Born	Mortality Rate %	Range of Mortality %	Locality	Lambing Season
Alexander *et al*	1955	M	Once or twice daily observations	>248	421	12.1	-	Victoria	-
Alexander *et al*	1959	C	Continuous observations	48	62	40.3	-	South East Victoria	Winter
Alexander & Peterson	1961	M	Continuous observations	50 (maidens)	52	40.4	-	New England, NSW	-
Alexander *et al*	1980	M	Hourly observations	-	567	26.5	16.2 - 56.3	Armidale, NSW	Winter
Arnold & Morgan	1975	M	Daylight observations	105 (joined)	77	6	-	Western Australia	Winter
		M	Daylight observations	105 (joined)	87	29	-	Western Australia	Summer
		M	Daylight observations	43 (joined)	43	26	-	Western Australia	Summer
Dalton *et al*	1980	M	Observations at tagging and autopsies	-	337	39.6	-	New Zealand	Winter
Egan *et al*	1972	M	Twice daily observations	180	175	25.7	-	Hamilton, VIC	Spring/ Winter
Haughey, K	1983	M	High efficiency line	-	484	20.2	12.8 - 32.2	Camden, NSW	-
		M	Low efficiency line	-	354	33.6	24.6 - 42.2	Camden, NSW	-
Hight & Jury	1970	BL x R & R	Daylight observations	7091	7727	17.8 (To weaning)	14.5 - 21.5	New Zealand	-
Jordan & Le Feuvre	1989	M	Once daily observations	433	576	20.0	-	Bollon, Qld	Winter
		M	Once daily observations	566	-	9.0	-	Charleville, QLD	Spring
		M	Outdoor pens	340	297	20.0	-	Charleville, QLD	-
McDonald	1966	P	Frequency of observations not specified	~1600	1064	36.7	26.6 - 57.0	South West Victoria	Autumn Winter
McHugh & Edwards	1958	BL x M & C X M; DH rams	Once or twice daily obsevations	6448	7307	8.0	-	Rutherglen, Victoria	Winter

TABLE 1.1: Continued

McLaughlin *et al*	1970	C	Four hourly observations Four hourly observations	- -	148 148	29.7 20.3	17.0 - 43.3	Hamilton, VIC Hamilton, VIC	Spring Winter
Moore *et al*	1966	M	Twice daily observations - set stocked - drifted	} 545	313 320	27.0 21.0	- -	Minnipa, SA Minnipa, SA	Autumn Autumn
Moule	1954	M	Close surveillance or under paddock conditions	Sound udders Unsound udders	1664 11 obser- 466 } vations	10.34 neonatal 23.61 period (excluding stillbirths)	- -	QLD QLD	Spring & Autumn
				Sound udders Unsound udders	1333 } 7 obser- 475 } vations	30.45 (up to 53.05 lamb marking)	- -	QLD QLD	Spring & Autumn
Mullaney & Hyland	1967	M C P	All births & deaths recorded as far as possible	- - -	- - -	16.3 18.4 15.0	6.7 - 27.7 10.3 - 42.1 9.7 - 18.4	Western Victoria Western Victoria Western Victoria	} Autumn } /Winter
Obst & Day	1968	M C	Twice daily observations Twice daily observations	200 - 300 200 - 300	1684 1393	28.6 24.9	15.1 - 91.1 16.4 - 53.7	Kangaroo Island Kangaroo Island	Winter Winter
Obst & Ellis	1977	M C	Hourly observations at the sheltered site & continuous observation at exposed site	230 230	750 Total M&C	pooled 18.8 } over two 25.5 } sites	- -	Kangaroo Island Kangaroo Island	Winter Winter
Shelley	1970	M	Continuous observations	235	257	39	-	Hamilton, VIC	Winter
Watson *et al*	1968	C	Continuous observations	134	173	38.2	-	Western Victoria	Winter
Winfield	1970	C	Continuous observations	232	278	32.1	-	Southern Victoria	Winter

LEGEND: M = Merino; C = Corriedale; P Polwarth; BL = Border Leicester, R = Romney; DH = Dorset Horn.

number inspected the flock only once or sometimes twice daily. The minimal observations for these latter studies suggest the possibility that not all lamb births and deaths were accounted for.

(ii) Extreme lamb mortality rates

In the study of Obst and Day (1968), mortality amongst Merino lambs (1984) ranged from 15.1 to 91.1%. The very high figure of 91.1% occurred under conditions of high winds (>24 - 56 kph) and a rainfall of 5.3 - 26.0 mm/day. At the other extreme, Jordan and Le Feuvre (1989) reported a mortality rate of only 9% amongst Merino lambs but suggested that the figure was an underestimate for several reasons. Firstly, total carcass recovery in large paddocks was very difficult and some scavenging or killing of lambs by feral pigs did occur. Secondly, this figure assumed no twins were born.

(iii) Conclusion

From the figures presented on lamb mortality (Table 1.1), it is obvious that the death of lambs from birth to marking plays a large role in reducing the reproductive performance of the Merino. For example, if we assume 49% of the national flock are breeding ewes which have a lamb marking percentage of around 75%, then 55 million lambs would have been marked in 1988. If we assume only a 20% mortality occurred, then the 55 million represents only 80% of what was born. Therefore, approximately 14 million lambs would have died in that year. Having established the importance of lamb mortality on the potential of the national flock, something needs to be done to reduce its occurrence. As a first step, we need to know why lambs die and this is discussed in the following chapter.

CHAPTER 2. CAUSES OF LAMB MORTALITY IN AUSTRALIA

2.1 INTRODUCTION

There are two approaches used in assessing the cause of lamb deaths in Australia and elsewhere.

1. Autopsy approach. The autopsy approach adopted by most workers is based on that of McFarlane (1961 & 1965). The procedure involves carcass examination to estimate the time of death of the lamb in relation to birth and is divided into the following classes:

    - ante-parturient deaths (APD)
    - parturient deaths (PD)
    - post-parturient deaths (immediate-IPPD, delayed-DPPD and late-LPPD)

From this procedure it can be established whether or not the lamb breathed, walked, starved or experienced dystocia or some form of birth trauma before its death. Two large studies have adopted the time of death classification of McFarlane. Dennis (1974) investigated causes of lamb mortality in Western Australia receiving 4417 lamb carcasses from 695 farms and Hughes *et al* (1964) examined 8016 lambs from the Oberon, Orange and Monaro districts of New South Wales. The time-of-death classification of lambs autopsied in the above two studies are summarised in Table 2.1.

More recently, Haughey (1973a) modified the autopsy procedure described by McFarlane (1965) to include an examination of the central nervous system (CNS) for haemorrhages indicative of birth injury.

The autopsy approach used by McFarlane (1965) and Haughey (1973a) has allowed partitioning into apparent causes of death but not necessarily the predisposing circumstances.

2. Direct observation. The other approach used when assessing the cause of lamb deaths is direct observation and recording of behavioural patterns of the lambing flock. This approach is very labour intensive and is suitable mainly for research of parent-offspring behaviour in individual flocks (Haughey, 1991).The actual causes of lamb

Table 2.1. Time-of-death classification of lambs autopsied (%) in two large studies

Class	Dennis (1974)	Hughes *et al* (1964)
APD	5.0	1.6
PD	20.5	36.1
IPPD	19.8	21.1
DPPD	4.7	24.5
LPPD	47.5	15.4
Unclassified	2.5	1.1

deaths involve the action and interaction of many factors, including weather conditions, genetic factors, deficiency of nutrients during pregnancy, predation, infections, maternal and neonatal behaviour, adequacy of milk supply, management and the effects of birth asphyxia and/or trauma on the foetal CNS (Haughey, 1991). In most cases more than one cause is responsible for the death of the lamb and this makes it very difficult to pinpoint the primary cause of death. In Table 2.2 a summary of the literature on the probable causes of lamb deaths is presented for both Australian and overseas studies and it is these causes which will now be examined in more detail.

Another factor that should be taken into account when reporting the studies concerned with the causes of lamb deaths is the actual number of animals involved. The relative importance of the cause of death of the lamb is really only seen when large numbers are involved preferably collected over a number of years.

2.2 STILLBIRTH AND DYSTOCIA

In most reports, lambs are classified as having been born dead, stillborn or born alive. Lung aeration is the main criterion used to differentiate between these categories (McFarlane,1965). Ante parturient deaths or stillbirths are characterised by the absence of a thrombus in the umbilical arteries and by any signs of viability during the birth process. Mummification of the lamb has also been used to characterise stillbirths (Hight and Jury, 1970; McDonald, 1966; McFarlane, 1961) and Watson (1972) described stillborn lambs as being those which died immediately before, during or immediately after birth without breathing.

From the figures presented in Table 2.2, the proportion of deaths resulting from stillbirths ranges from 0.6 to 40.0% of lamb deaths. Watson (1972) quoted stillbirths as having varied from about 2 to 15% but most frequently at about 2 to 4 percent. There are several high figures quoted for stillbirths in Table 2.2. McHugh andEdwards (1958) associated 18.9% of deaths with stillbirths of which 13.3% were anatomically perfect when examined and therefore no apparent cause could be found for these lambs being born dead.

TABLE 2.2: Causes of Lamb Mortality in Australia (and the percentage of total lamb deaths attributed to each cause)

Author	Method of determining cause of death	Breed of sheep	Number of lambs born	Number of lambs examined	Stillbirth	Dystocia	Starvation Mismothering	Exposure	Primary predation
Alexander *et al*, 1990b	Autopsy & observation	M	-	634	-	-	-	-	-
Arnold & Morgan, 1975	Autopsy & observation	7 Breeds	-	147	24.5	-	30.6	-	-
		7 Breeds	43	11	-	-	36.4	63.6	-
		M	87	25	4.0	-	4.0	92.0	-
		M	77	5	40.0	-	-	-	-
Dennis, 1974	Autopsy	M	-	4417	-	18.5	46.4	2.1	2.7
Haughey, 1973b	Autopsy	M	-	199	1.5	34.2	47.2	*	5.0
Haughey, 1989	Autopsy	M	-	173	0.6	31.8	24.3	*	1.2
Hight & Jury, 1970	Autopsy & some observation	R & BL x R	7727	814	10.3	32.3	26.5	*	-
Hinch *et al*, 1986	Autopsy	R	160	70	1.4	38.6	12.9	-	-
Hughes *et al*, 1964	Autopsy		-	3503	-	53.6	6.8	8.6	7.4
Jordon & LeFeuvre, 1989	Autopsy	M	576	115	-	16.5	67.0	-	8.7**
			-	56	-	19.5	53.6	-	25.0**
			297	58	3.5	10.3	69.0	8.6	-
Luff, 1980	Autopsy	M	-	2534	-	17.8	58.2	*	7.8
McDonald, 1966	Autopsy & observation	P	1064	390	2.8	19.5	31.5	4.9	33.3
McFarlane, 1964	Autopsy	-	-	3039	-	-	-	-	2.9
McHugh & Edwards, 1958	Autopsy	BL x M & C x M	7307	512	18.9	17.2	30.5	1.2	11.0**
Moore *et al*, 1966	Autopsy	M	633	157	3.2	8.9	35.0	-	12.1
Moule, 1954	Autopsy	M	2130	453	-	4.9	29.8	11.0	34.2**
Shelley, 1970	Observation	M	257	100	2.0	-	37.0	17.0	-
Smith, 1962	Autopsy & observation	M	128	27	11.0	26.0	48.0	-	
		M	47	34	-	3.0	82	-	
Smith, 1964	Autopsy & some observation	M	-	981	1.43	12.03	66.9	-	14.68
Watson & Elder, 1961	Autopsy & observation	C	385	41	-	29.3***	70.7	-	-

LEGEND: M = Merino; C = Corriedale; P = Polwarth; R = Romney; BL = Border Leicester; DH = Dorset Horn; * = Exposure combined with starvation/mismothering; ** = Refer to text; *** = Includes stillbirths.

TABLE 2:2 Continued

Author	Method of determining cause of death	Breed of sheep	Infection	Congenital defects	Nutritional disorders	Unknown	Comments
Alexander *et al*, 1990b	Autopsy & observation	M	-	-	22.4	-	
Arnold & Morgan, 1975	Autopsy & observation	7 Breeds 7 Breeds M M	- - - -	27 - - -	- - - -	- - - -	Winter lambing Summer lambing Summer lambing Winter lambing
Dennis, 1974	Autopsy	M	13.9	9.1	0.5	2.5	
Haughey, 1973b	Autopsy	M	5.0	3.5	-	1.5	
Haughey, 1989	Autopsy	M	4.0	4.0	-	-	
Hight & Jury, 1970	Autopsy & some observation	R & BL x R	11.6	1.4	-	19.6	
Hinch *et al*, 1986	Autopsy	R	-	-	-	-	
Hughes *et al*, 1964	Autopsy		4.9	5.5	7.7	2.8	BL x M ewes; DH rams
Jordon & Lefeuvre, 1989	Autopsy	M	- - -	- - -	- - -	4.3 - -	Outdoor study Outdoor study Outdoor pen study
Luff, 1980	Autopsy	M	4.4	-	-	16.2	-
McDonald, 1966	Autopsy & observation	P	3.3	4.6	-	-	
McFarlane, 1964	Autopsy	-	-	-	-	-	
McHugh & Edwards, 1958	Autopsy	BL x M & C x M	3.9	3.3	-	2.7	DH & Southdown rams
Moore *et al*, 1966	Autopsy	M	-	-	-	21.7	
Moule, 1954	Autopsy	M	1.8	-	-	13.0	
Shelley, 1970	Observation	M	-	-	-	-	
Smith, 1962	Autopsy & observation	M M	- -	7.5 -	- -	- -	
Smith, 1964	Autopsy & some observation	M	0.84	-	-	-	
Watson & Elder, 1961	Autopsy & observation	C	-	-	-	-	Stillbirths pooled with dystocia

LEGEND: M = Merino; C = Corriedale; P = Polwarth; R = Romney; BL = Border Leicester; DH = Dorset Horn; * = Exposure combinedwithstarvation/mismothering; ** = Refer to text; *** = Includes stillbirths.

occurs when birthweights were high, usually being associated with single lambs. Hight and Jury (1970) classified deaths from dystocia as those which died from asphyxiation or inhalation of foetal fluids and those with oedema, excess cavity fluids, or trauma. Of the studies reported in Table 2.2, the proportion of deaths associated with dystocia ranged from 3.0 to 53.6% and averaged 21.4%.

More recently, another aspect of difficult births has been implicated in lamb deaths. Haughey (1973a&b) implicated birth injury in 56 - 80% of all lamb deaths based on his autopsy findings that dead lambs showed haemorrhage in the CNS. Injury to the CNS, sustained during the birth process, has not only been implicated as a major cause of dystocia but has also been implicated in the starvation/mismothering/exposure (SME) complex (Haughey, 1973a&b). When the CNS injury is severe, death results during or immediately after birth and is classified as dystocia. The controversial issue is when less severe CNS injury occurs which may prejudice lamb survival by impairing suckling drive, reducing locomotor activity and impairing thermoregulatory activity.

Duff et.al. (1982) supported the view that a high incidence of CNS injury was present in Romney lambs dying from dystocia (87%) but argued that CNS injury contributed little to S/E mortalities with only 32% of the S/E lambs exhibiting CNS lesions.

Haughey (1989) implicated birth injury in 56.7% of the Merino lambs that were classified as dying from the SME complex and concluded that overall birth injured SME lambs were a mean 10% heavier than uninjured SME lambs.

The cause of death categories used in the study of Hinch *et al* (1986) differed to those used normally in that they identified the lambs which had CNS damage using the methods of Haughey (1973 a&b). Lambs that would normally have been classified as ‘unknown’ or included in the SME category were placed into more specific categories, namely ‘prolonged birth’ or ‘starvation/CNS’. The deaths included in these two categories are not presented in Table 2.2 but will be discussed briefly.

The lambs included in the ‘prolonged birth’ category exhibited spinal lesions, epidural, blood-stained CSF and leptomeningeal haemorrhages usually associated with hypoxia and/or anoxia but without signs of difficult birth (Haughey, 1973b). They accounted for 11.4% of the total deaths. The spinal lesions observed in the 'starvation/CNS' category of death were most often typical 'hypoxia' lesions, particularly epidural lesions, but may have included some cranial lesions which could be associated with 'dystocia'. This category accounted for 20% of the total lamb deaths. Since the above deaths were not included in the SM category, a relatively smaller proportion of lamb losses are linked with starvation (Table 2.2) than has been the case in other studies. Regardless of the controversy, deaths associated with birth problems contribute substantially to the overall mortality rate of lambs.

Several studies include an "unknown/other" category in their classification of lamb deaths often including lambs that breathed but failed to stand and lambs that suckled but still died (Arnold and Morgan, 1975; Jordan and Le Feuvre, 1989; McHugh and Edwards, 1958; Shelley, 1970; Smith, 1964; Winfield, 1970). No cause is identified for these lamb deaths but birth injury may be the underlying cause for the lamb failing to stand and that a delayed response to birth injury may also be responsible for the lamb dying after suckling.

Jordan and Le Feuvre (1989) conducted two outdoor studies and one pen study on lamb survival in Queensland. Overall, 8.7% of deaths were attributed to lambs that breathed but failed to stand and lambs that died after suckling. McHugh and Edwards (1958) recorded 11.3% of lamb deaths attributable to injury received during parturition and to desertion because of lamb weakness. However Shelley (1970) attributed 19.7% of lamb deaths to lambs who failed to stand and 24.6% to lambs who died after suckling. The flock was in fair to poor condition and this could have contributed to mortality, due to any cause associated with lamb vigour, higher than the former studies.

In a study conducted in Western Queensland, Smith (1964) recorded that the incidence of lambs which had breathed but failed to stand was low (1.6%). Similarly the percentage of lambs which had sucked but when autopsied had undigested milk in the abomasum was low (3.1%). Birth injury could be implicated in these deaths particularly in the latter group because clearly the lambs did not die from starvation because of the presence of undigested milk in the abomasum. Heat prostration of the newborn lamb due to the high air temperatures during lambing in the Merino flocks could also have contributed to these deaths.

Over a two year period, seven breeds of sheep (including Merino) were used to assess levels and causes of lamb mortality in Western Australia (Arnold and Morgan, 1975). When the data were pooled over the years and different breeds, approximately 35% of lamb deaths were classified as lambs which failed to stand and lambs which died after suckling. In the summer months, the majority of lambs that died after drinking were classified as dying from heat stress and were therefore entered under the exposure category. Their deaths were attributed to hyperpyrexia and/or heart failure. In the winter months, 5.9% of all lamb deaths were attributed to lambs dying without standing and were recorded as having lower birth weights than lambs which survived. Of the lambs that died after drinking (28.7% of all lamb deaths), they had a longer than average length of labour and therefore could be included in a "prolonged birth" category.

2.3 STARVATION/MISMOTHERING (SM)

The reasons for the failure of the lamb to suck successfully can be assessed from direct observation of the lambing ewe (Alexander 1984; Alexander 1985), provided there are no underlying causes such as congenital abnormalities or severe birth injury, both only detectable at autopsy.

The majority of lamb deaths are normally included in this category together with exposure in some cases (Haughey, 1973b; Haughey, 1989; Hight and Jury, 1970). Some of the reasons contributing to the SM of lambs include:

- failure of the ewe to bond with her lamb/s (Alexander, 1980; Arnold & Morgan, 1975)
- udder defects such as shearing injury or mastitis (Hayman *et al*, 1955)
- delayed lactogenesis (McCance & Alexander, 1959)
- competition with litter mates (Purser and Young, 1964)
- difficult birth interfering with normal maternal behaviour (Alexander, 1984)

The range of mortality associated with SM (Table 2.2) varied from 4.0 to 82.0% of lamb deaths. The low figure of 4.0% of deaths resulting from SM was reported for a study conducted in Western Australia (Arnold and Morgan, 1975). At one site seven breeds of sheep were involved and 36.4% of lamb deaths were associated with SM while at the other site where Merinos were lambing in the summer months, only one of 25 lamb deaths (4.0%) resulted from the lamb not being allowed to suck. One possible explanation for such a low percentage of deaths being associated with SM could be that 92% of deaths were associated with suspected heat stress and therefore if the cause of death was combined as the SME complex, the percentage would be much higher overall.

In contrast, there are several studies that have reported a high proportion of mortalities associated with SM. Watson and Elder (1961) studied lamb mortality in a Corriedale flock in Western Victoria. An overall mortality rate of 24.4% was recorded and deaths were associated with various combinations of factors including poor lamb vigour, maternal factors and poor weather conditions. The data listed in Table 2.2 includes only deaths associated with the maternal factors (41 of 94 deaths) as the author clearly indicates that only these deaths can be classified with certainty.

Several experiments compared the effect which the condition of the ewe's udder, sound or unsound, had on the level of lamb mortality (Jordan and Le Feuvre, 1989; Moule, 1954). As can be seen from Table 1.1, Moule (1954) reported that during both the neo-natal period and the post neo-natal period mortality amongst lambs born to ewes with unsound udders was significantly greater than mortality amongst lambs born to ewes with sound udders.

In studies carried out in south-west Queensland, Jordan & LeFeuvre (1989) reported a high proportion of mortality due to SM in two outdoor and one pen study: 67.0%, 53.6% and 69.0% respectively. The pen study involved ewes with sound and unsound udders fed on 110%, 90% and 70% of maintenance requirements and it was suggested that udder damage and poor maternal nutrition contributed substantially to the losses which were predominantly due to lamb starvation. They found that significantly fewer lambs (10.1%) died in the group fed 110% of maintenance than in the groups fed 90% (24.7%) and 70%

(26.5%) of maintenance requirements. Significantly fewer lambs died in the 'sound' than in the unsound udder groups (13.8% and 27.1%, respectively). These two factors contributed considerably to the 69% of total lamb deaths that were attributed to starvation in this pen study. Although no explanation was provided for such high levels of deaths from starvation in the outdoor studies, one possible cause could have been a lower than average birthweight of the lambs that starved. Birthweights were not measured in the outdoor studies but from birthweights recorded in the pen study, lambs which died from starvation had significantly lower mean birthweights than those that survived, 3.0kg and 3.8kg, respectively. Maternal factors may also have been involved but were not measured.

The highest reported proportion of lamb mortality attributed to SM was in a study conducted in Central Western Queensland (Smith, 1962) where 82% of deaths were attributed to SM. The lambing took place in November and deaths were accentuated by a low plane of nutrition for the ewes and the high ambient temperatures. Ewes often rejected attempts by the newborn lamb to suckle, possibly due to the low plane of maternal nutrition which resulted in little mammary development at the time of parturition, and as a result of the rejected attempts to suckle, the lamb was quickly weakened by a combination of heat and starvation. In this state the lamb was abandoned and therefore, although categorized as SM, exposure played a major part in these deaths as well.

2.4 EXPOSURE

During periods of low temperatures, with wind and rain or periods of very high temperatures deaths from exposure become apparent. The primary cause of death in these circumstances is rarely classified as exposure because normally the lambs have been debilitated for other reasons (Alexander, 1984). These reasons include starvation, low birth weight and 'birth' injury, all of which make the lamb highly susceptible to hypothermia.

There is no reliable autopsy criterion to determine death due to exposure although Haughey (1989) states that catabolism of brown fat, subcutaneous ("peripheral") oedema of the distal limbs, tail, face, muzzle and ears and the characteristic damages in the adrenal cortex associated with systemic stress are the main gross pathological evidence of cold exposure in new born lambs. McFarlane (1961) states that a lamb dying from **uncomplicated** exposure will show a complete absence of pathological lesions which reduces its survivability and no body fat reserves or tissue fluids can be utilised because this is defined as starvation. He states that the only cold exposure lesion known to him is a complete flaccidity of the ileum on the left hand side where the ventral abdominal wall is in contact with the ground. When a lamb has fed and is subjected to sufficient cold exposure to cause flaccidity of this part of the gut, no milk absorption occurs from this area but occurs from all other parts and therefore the exposure is uncomplicated.

McFarlane, (1961) also suggested that uncomplicated exposure is not an important cause of death but when coupled with other factors such as starvation and birth injury, might be of extreme importance. Alexander *et al* (1980) showed that lambs coming to autopsy with oedema and with milk in the stomach were almost certain to have died from exposure. From Table 2.2, the proportion of deaths caused by exposure ranged from 1.2 - 92.0%.

The two highest proportions of lamb mortality attributed to exposure were reported from studies conducted in Western Australia (Arnold and Morgan, 1975). On both occasions the lambing occurred during the summer months and all lambs were severely stressed. The majority of lamb deaths (23/25 and 7/11) occurred after the lamb had obtained a drink and and the deaths were attributed to hyperpyrexia and/or heart failure.

2.5 OTHER CAUSES

2.5.1 Predation

The extent of lamb losses associated with primary predation is highly variable. Predation can involve foxes, dingoes, feral pigs, feral dogs, eagles or ravens who are often blamed for a high proportion of lamb deaths simply because these potential predators have been sighted amongst the lambing flocks or because a large proportion of carcasses show mutilation. It seems that the majority of these lambs are already dead when mutilated or would have died had they not been mutilated (Watson, 1972). These deaths should more correctly be categorized as secondary predation.

Moore *et al* (1966) defined predation as lambs showing injury with haemorrhage indicating that the lamb was alive when injured. Primary predation was defined as an apparently normal lamb showing signs of fatal injury as the only abnormality. Primary predation levels reported in Table 2.2 ranged from 1.2 to 33.3%. Those studies where no descriptions were given of the type of predation were excluded from the tabulated data.

In a study conducted in Victoria, McHugh and Edwards (1958) attributed 11% of deaths to predation. Predation was identified as lambs either being deserted and attacked by predators or taken by predators, possibly after desertion. The predators involved were crows and foxes and in the majority of cases the lambs were considerably weakened from lack of food and the predators simply hastened their death.

Several studies conducted in Queensland have associated lamb deaths with predation but have failed to report what type of predation was involved. Moule (1954) attributed 34.2% of lamb deaths to predation of which 72% of these deaths occurred in the one observation period. A possible explanation provided by the author was the occurrence of a rat plague which subsided at the time lambing commenced in this observation period. With the rat plague came an increase in lamb predators and this could explain the heavy losses attributed to predators. Irrespective of the increase in lamb predators, the author failed to provide evidence as to the type of predation involved. Likewise Jordan and Le Feuvre (1989) who reported predatory losses responsible for 8.7 and 25% of lamb deaths also failed to identify the predators involved. In both studies primary predation cannot be cited as the cause of these lamb deaths because of the lack of conclusive evidence.

The effects of feral pigs on the lambing performance of Merinos was studied at Nyngan, New South Wales (Pavlov *et al*, 1981). The ewes were lambed in two paddocks: one with feral pigs and the other with feral pigs excluded. In one year, feral pigs were implicated in lowering the numbers of lambs surviving to marking per 100 ewes by 37.9 and 31.9 in autumn and spring, respectively. The difference in the number of lambs between paddocks was assumed to be due to feral pigs, the other causes of mortality assumed to be similar between paddocks. It was suggested that an underestimate of the effect of feral pigs on the number of lambs surviving may have occurred because one of

Arnold and Morgan (1975) found that amongst seven breeds of sheep lambing in Western Australia, 24.5% of the dead lambs examined were stillbirths. Stillbirths were associated with longer than average length of labour, but it was unclear whether the deaths were in fact a consequence of a long labour. Lambs that were stillborn did not have an above average birthweight. The ewe may have experienced uterine inertia or the lamb may have suffered some form of brain damage if the cord was damaged or broken during labour. A second study undertaken by Arnold and Morgan (1975) at another location attributed 40% of lamb deaths to stillbirths. Lamb mortality was low with only 5 out of 77 lambs dying, therefore with such small experimental numbers, the proportion of deaths attributed to stillbirths may not represent a 'normal' situation.

Dystocia or difficult birth has long been known as a cause of lamb deaths and is usually attributed to foeto-pelvic disproportion or to malpresentation (Alexander, 1984). Foeto-pelvic disproportion arises from foetal oversize (Haughey, 1989), small maternal pelvic size (Haughey et.al., 1985) or both and these traits predispose the ewe to prolonged parturition (Haughey, 1981). In a study conducted on Scottish Blackface sheep (Purser and Young, 1964), approximately 5% of the single lambs born died as a result of difficult births but this cause of mortality was rare in twins. They reported that difficult birth only became a cause of death for birthweights above a critical value which depended on the age of the dam. For example, mortality rose sharply for lambs born to 2 year old ewes for birthweights over 8lb while for lambs born to older ewes mortality did not rise until birthweights were over 10lb. The birthweight of the twin lambs in this study did not exceed these values and their mortality due to difficult birth was low.

Hughes *et al*, (1964) attributed 53.6% of lamb deaths to dystocia and found that dystocia was a cause of lamb deaths when birthweights exceeded 9lb (4kg). The only explanation provided for such a high figure was that in 79% of the dystocia cases, the lambs were progeny from Border Leicester x Merino ewes and Dorset Horn rams. With a history of birth difficulties amongst purebred Dorset lambs (George, 1976), this may partly explain the reason for such a large percentage of dystocic deaths amongst these lambs and this is further supported by the fact that lambs which were nearly all of Merino origin did not experience such high dystocia problems. The authors concluded that dystocia mainly the indicators used to assess lamb survival was the percentage of ewes lactating and this does not take into account the presence of twins. For example, in the case where only one of a set of twins was killed, the percentage of ewes lactating would not change. Few lamb carcasses were found in either of the paddocks because of the large areas involved and the height of the pasture. Therefore no autopsies were performed. This raises the question as to what proportion of the losses described were due to primary or secondary predation.

In conclusion it appears that isolated cases of primary predation may cause high levels of lamb mortality (McDonald 1966). However losses from primary predation are generally small and the majority of deaths are a result of secondary predation.

2.5.2 Infection

Reports of infection as a major cause of lamb mortality are rare in Australia. The extent of lamb mortality associated with infection is summarized in Table 2.2 and ranges from 0.84% to 13.9% of lamb deaths. The highest percentage of 13.9 was reported in an investigation into the causes of perinatal lamb mortality in the agricultural areas of Western Australia. Infectious abortion was diagnosed on 14.6% of the farms investigated and individual neonatal infections were considered to be responsible for the death of 7.6% of the lambs examined.

Lamb deaths resulting from infection are often due to disease outbreaks and its sporadic nature results in large year to year variation. Most of the reports on lamb deaths from infection rely on the submission of dead lambs for autopsy and they are prone to bias because generally only a representative sample of the dead lambs are submitted (Dennis, 1974).

The most frequent infective agents associated with the deaths during and after parturition included *Escherichia coli,* clostridia, staphylococci, corynebacteria, *Fusobacterium necrophorum*, pasteurellae, streptococci and a pleomorphic gram negative bacillus. Overall, on most properties where losses have been studied in detail, infection has not been recognised as a significant cause of loss, despite careful examination of all dead lambs (Watson, 1972).

2.5.3 Congenital defects

In various studies, the proportion of lamb deaths associated with congenital abnormalities ranged from 1.4 to 9.1% (Table 2.2). Dennis (1974) examined 401 malformed lambs (9.1% of lamb deaths) and the defects involved the musculo-skeletal system, digestive system, cardiovascular system, urogenital system and CNS. This survey was reliant on submission of lamb carcasses and therefore may have been prone to bias associated with submission of the "unusual".

2.5.4 Nutritional disorders

While implicated as a cause of lamb deaths in only a few studies (for example, Dennis, 1974; Hughes *et al*, 1964), the percentage of deaths attributed to nutritional disorders ranged from 0.5 to 22.4%. These disorders included goitre and white muscle disease and in the study of Hughes *et al* (1964), 7.5% of deaths resulted from goitre in one of the districts studied with 152 of the 170 lambs which died from goitre coming from one property.

In a five year study on behavioural traits concerned with lamb survival (Alexander *et al*, 1990b), an outbreak of goitre was reported in the final year. It was after a week of lambing that large thyroid glands were found in a lamb at autopsy and thereafter, the thyroid glands of all lambs were routinely examined and scored. Of the lambs scored, 53% had palpable enlarged thyroids and approximately 22.4% of these lambs died between birth and weaning. Although goitre was clearly the cause of most of the deaths in this study, it was suggested that slight to moderate thyroid enlargement might not be detected in a farming situation and when overshadowed by other causes of death such as cold exposure, starvation or prolonged and difficult birth, this 'subclinical' goitre could have contributed to the deaths of lambs more often than was recorded. It seems that lamb losses from nutritional disorders can be substantial in some cases but this is likely to vary considerably from year to year, from district to district and even between properties.

2.5.5 Unknown

The number of deaths attributed to miscellaneous causes varied considerably, 1.5 to 21.7% and largely depends on the ability of the workers or the facilities available to identify the underlying causes of death. Even in intensive production systems, including pen lambing, the actual cause of some deaths remains unidentified.

2.6 CONCLUSION

Infection, accident, congenital defects and nutritional disorders are usually minor causes of lamb mortality. Predation problems are also localised, but may become a major cause of lamb loss in some areas. The majority of lamb deaths are associated with the starvation/mismothering/exposure complex and these are widespread throughout Australia. However, the factors which predispose lambs to these causes of death are still unclear. Why does a lamb die from starvation...? The following factors have been implicated in the lamb deaths: birth injury, pelvic size, weak ewe/lamb bond formation, stress, temperament, behaviour at birth, nutrition of the ewe, age and parity of the ewe. In the following chapter the predisposing factors to lamb survival will be examined in greater detail and ways of improving lamb survival, both managerially and genetically will be evaluated.

CHAPTER 3. PREDISPOSING FACTORS TO LAMB MORTALITY AND METHODS OF IMPROVING LAMB SURVIVAL

3.1 INTRODUCTION

The previous chapter indicates that although the SME complex is associated with a large percentage of lamb deaths, there are many underlying causes involved. The factors which predispose lambs to die from these causes will be examined. Management and genetic selection techniques used to prevent lamb deaths will also be examined.

In the absence of factors such as disease and predation, the major requirements for a high lamb survival rate are clearly a birth weight near the optimum for the breed, easy birth, protection from cold, and maximum contact between ewe and her lamb during the first 12 hours post partum (Alexander, 1984). Factors such as nutritional manipulation, supervision at lambing, stocking intensity, shearing and crutching before lambing or provision of shelter at lambing, have all been suggested as means of decreasing lamb mortality. The adoption of most of these techniques becomes a question of economics and depends largely on the farmers' attitude towards improving lamb survival.

Genetic improvement by selection for improved survival is permanent and may be cheaper than some of the management options (Slee, 1985) already listed. Selection for higher fertility is of particular importance in Australian Merinos because of their comparatively low reproductive rate (Young *et al*, 1963). Lamb survival is a major determinant of weaning percentage and although increased twinning may increase weaning percentage overall, the number of lamb deaths is not overcome because of the higher perinatal mortality among twin lambs. Haughey *et al* (1985) suggest that in the harsh Australian environment, unless we recognize the importance of repeatable and heritable maternal and fetal characteristics to rearing success, our lamb-marking percentages will continue to be low. Therefore the use of sheep with a genetic propensity for high lamb survival would be an attractive option (Alexander, 1984). The most common predisposing factors of lamb mortality and some of the management and genetic options available for reducing the occurrence of these factors will now be discussed.

3.2 DEATHS ASSOCIATED WITH PARTURITION

3.2.1 Common Predisposing factors

There are two factors that predispose lambs to death associated with parturition and these include the type of birth and lamb birthweight.

(i) Type of birth

Irrespective of breed and environment, mortality of twins is usually about twice that of singles (Watson, 1972). Davies (1964) reported that losses amongst twins were higher than amongst singles (39% and 21%, respectively) and also among the lighter of the single lambs suggesting low birthweight as a possible cause of these deaths. An average of 42.1% (range 18-75%) of twin Merino lambs born had died before weaning compared with an average of 17.6% (range 7.6-49.1%) of single lambs over a period of four years in a study conducted in western Victoria (Mullaney and Hyland, 1967). A study conducted in south-western Queensland (Smith, 1964), found mortality amongst twins was consistently greater than amongst single lambs.

Mc Hugh and Edwards (1958) studied lamb losses in cross-breds over seven years in northern Victoria and found that 11% of twin lambs and 6% of single lambs died from birth to lamb marking. They suggested a number of reasons for the heavier losses among twin lambs including desertion of one of the lambs, weaker lambs and insufficient milk to adequately feed these lambs. Similar findings were reported for Corriedales (Watson and Elder, 1961) with overall mortality rates of 25-43% and 5-16% for multiple and single births respectively, over two different lambing seasons in western Victoria. They found there was a tendency for mortality to be more common in the heavier singles and the lighter twins.

In a study involving British hill breeds in Britain, it was found that twin lambs generally had a higher mortality rate and a lower average birth weight than did single-born lambs in the same flock (Purser and Young, 1964). However, they suggested that weight for weight, mortality was similar for singles and twins. This similarity arose from a number of factors including ewes which produced twins being in better condition at conception than single bearers and secondly, twins were reared on better grazing therefore enabling the ewe to manage the twins as effectively as singles provided they were of equal birthweight.

The higher mortality rates recorded for twin lambs compared to single lambs are generally correlated with lower than average birthweights although desertion of one of a pair of twins has also been implicated.

Stevens *et al* (1982) observed fine-woolled Merino ewes lambing at Armidale, N.S.W. They recorded a total mortality of 37.4% for twins, much higher than the 9.6% for single lambs. Of the ewes who gave birth to twins, 56% became permanently separated from one or both lambs and although approximately 42% of these lambs were classified as "weak" at tagging, the remaining abandoned lambs were "strong" and the ewes inability to care for the twins was obvious. Many ewes appeared completely unconcerned if accompanied by only one of a twin pair. Similarly, Alexander *et al* (1983) reported that 46% of Merino ewes that produced live twins became permanently separated from at least one lamb. Therefore, the inability of the ewe to keep the twins together and maintain contact with both may result in higher mortality rates compared to that of singles.

(ii) Lamb birthweight

Birthweight mortality curves indicate that the highly susceptible groups for most breeds are below 3.0 and above 5.0 kilograms (Alexander, 1984; Alexander *et al*, 1985). The curve is generally U-shaped relating mortality percentage to birthweight (Smith, 1977). The high mortality of lambs with low birthweights is probably largely due to deaths at birth or from starvation (Hight and Jury, 1970; McHugh and Edwards, 1958). Stillbirth mortality rates are normally very high for very small birthweights and decline with increasing weight of lamb (Purser and Young, 1964) whereas deaths from dystocia or difficult birth generally increase with increasing birthweight.

The birthweight of lambs can be sensitive to such influences as prenatal nutrition, placental size and litter size but there is little direct evidence to explain why small lambs die in such high proportions in the field (Alexander, 1984). Small lambs have been reported to be disadvantaged in thermoregulation, in the relative magnitude of their energy reserves (Robinson, 1981) and in the proportional size, and presumably function, of various tissues and organs (Alexander, 1984).

Alexander *et al* (1959) concluded that mortality rate for both singles and twins tended to be highest at the extremes of the birthweight range and Mullaney (1969) studied the effect of birthweight on lamb survival for three sheep breeds: Merino, Corriedale and Polwarth, lambing in western Victoria. He concluded that few lambs of birthweight less than 3lb survived and maximum survival occurred at a birthweight of about 10lb (Merino), 11lb (Corriedale) and 8lb (Polwarth). At higher birthweights, survival started to decline. Hinch *et al* (1985) found birthweight to be the dominant factor influencing survival for both single and multiple born lambs.

Generally the highest mortality rates occur in the extreme birthweight areas but we need to recognize that within the optimum birthweight range, the number of lambs lost is greater than within the extreme range, despite the overall percentage being low. For example, Alexander *et al* (1955) found that among the 421 Merino lambs born on a field station in Victoria, the level of mortality was high among the very light and the very heavy lambs. Six of the eleven lambs (55%) that weighed less than 4lb at birth died and eight of the thirteen lambs (62%) which weighed more than 11lb died. Although a much lower level of mortality occurred among the remaining lambs, 37 of the 397 died (9%), the greatest number of deaths occurred in this group. Although the size of the optimal birthweight group may vary from study to study, depending on the definition of 'extreme' birthweights, generally the optimal group contains the majority of lambs born.

A similar result was obtained in a study on mortality among Blackface and Welsh lambs (Purser and Young, 1964). Over 12 000 Blackface lambs were born with a mortality rate of 13% in the high weight range and 76% in the low weight range (10.0lb and over, and under 4.0lb, respectively) while approximately 17% of lambs died in the remaining weight group. Among the Welsh lambs, over 5000 lambs were born of which 14% died in the high weight group and 48% died in the low weight group (8.0lb and over, and under 4.0lb, respectively) and 11% of lambs died from the medium weight range. Despite the very high mortality rates recorded in the low birthweight group, the total number of losses recorded in the optimum weight group were 2026/11692 Blackface lambs and 530/4762 Welsh Mountain lambs which were of similar magnitude to the losses recorded in the high weight group (58/431 and 68/489, respectively).

Traditionally studies have not expressed concern for losses in the intermediate birthweight area of the curve because this is the 'optimum' birthweight group. However it should be noted that the number of lambs that die in this group is generally greater than the number of lambs that die in the extreme weight groups. At the low birthweight extreme, starvation can be suggested as the major contributor to lamb deaths whereas at the high birthweight extreme, dystocia is suggested as the major contributor to lamb deaths (Smith, 1977). Where the optimum birthweight group is concerned, the major causes of death may not be as clear cut and could involve a combination of factors including starvation, birth injury and exposure. It is for this reason that we should evaluate techniques for reducing lamb deaths not only for the extreme birthweights but for all birthweights including the optimum birthweights.

3.2.2 Methods for reducing parturient lamb deaths

(i) Management options

Good nutrition of the ewe during the last third of pregnancy is most important in enhancing the likelihood of lamb survival. Severe undernutrition at all stages of pregnancy should be avoided (Alexander, 1984) whereas at the other extreme, it has been suggested that abundant nutrition can result in large single lambs and difficult births (Alexander, 1980; Ferguson, 1982).

Alexander (1960) studied aspects of maternal behaviour in the Merino ewe and found a significant correlation between birthweight and length of labour and suggested that nutrition during late pregnancy was the underlying factor. Ewes which gained weight when fed *ad lib* up to a month before lambing produced larger lambs and experienced longer than average length of labour. Therefore, he suggested that there may be some advantage in 'underfeeding' 2 year old ewes in late pregnancy to produce smaller lambs and therefore reduce the shock of parturition and length of labour.

Smith (1962) found that ewes that lambed under adequate nutritional conditions gained significantly more weight during the last three weeks of pregnancy than ewes which lambed under deteriorating levels of nutrition and lost weight in the last three weeks of pregnancy. As a result, the lambs of the adequately fed ewes had significantly heavier mean birthweights than those of the poorly fed ewes which lead to dystocia being responsible for 26% of total mortalities in the adequately fed group compared to only 3% of total mortalities in the underfed group. The ewes which produced the heavier lambs were adequately fed for most of their pregnancy and therefore one possible solution could be to provide adequate nutrition during late pregnancy only and provide maintenance feed for the remainder of pregnancy therefore reducing the risk of producing heavier lambs.

However if differential feeding is to be incorporated in the management programme, littersize would need to be identified because the optimum feeding requirements for twin and single bearing ewes are different, with ewes carrying multiples requiring a higher nutritional regime than ewes with singles.

In a study conducted on Scottish hill flocks, Gunn & Robinson (1963) reported a negative effect of overfeeding ewes during pregnancy on lamb survival. Although the incidence of loss from difficult birth was abnormally high in this particular year, they recorded that the pregnant ewes in this year lost very little weight during the winter months compared to other years when weight losses were quite substantial. As a result, the ewes were 'over-conditioned' and their lambs 'over-developed' which resulted in a loss of 29% of lambs through difficult birth compared to less than 1% in a 'normal' year. One possible solution would have been to check the ewes during these winter months and ensure adequate nutrition during the latter part of their pregnancy.

(ii) Genetic improvement

A large percentage of lamb mortality has been associated with birth stress resulting from foeto-pelvic disproportion (Haughey, 1973 a&b; Haughey, 1989) and the two elements of this stress, namely birth mass and pelvic size, have a genetic basis. Haughey (1991) suggests that effective selection for optimal birth mass would be difficult because of the wide variation in the factors affecting it. On the other hand, Haughey *et al* (1985) demonstrated that in Merino and Dorset Horn ewes, the mature pelvic conjugate diameter was highly correlated with lifetime rearing ability. They classified ewes as good (reared lambs on three or all occasions) or poor (failed to rear a lamb on two, three or all occasions) mothers and found that the mean conjugate diameter and pelvic area of the good mothers were significantly larger than those of the poor mothers.

Further studies need to be undertaken before pelvic dimensions can be widely used as a possible selection criteria for improving lamb survival because of the time and cost involved in measuring these dimensions. One possible solution would be to find another part of the sheeps' anatomy, which was not only easier to measure but could be strongly correlated with pelvic area. It has been suggested (Kilgour, personal communication) that any 'long' bone in the sheep's anatomy could be a starting point, for example, cannon bone, femur etc.

3.3 DEATHS ASSOCIATED WITH STARVATION

3.3.1 Predisposing factors

(i) Bond formation

(a) Isolation seeking

The essential feature of maternal - offspring behaviour is the rapid development by the mother of a bond with her young and the exclusion of other young. Alexander (1980) suggested that birth in isolation should facilitate the formation of this exclusive bond. Isolation to facilitate exclusive bonding between mother and newborn has been observed in domestic sheep (Arnold and Morgan, 1975; Sharafeldin *et al*, 1971). Arnold and Morgan (1975) found that 46% of ewes lambed in isolation from the flock, 34% lambed in the flock and only 20% were left behind as the flock moved off. Daytime observations have shown that the majority of Merino ewes lamb where the flock happens to be, and are left behind with their lambs as the flock continues grazing (Stevens *et al*, 1981).

The large differences reported in the number of ewes which seek isolation may be due to differences in the definition of 'isolation seeking' and Arnold and Dudzinski (1978) suggested that it was difficult to assess objectively whether or not an animal was deliberately seeking to isolate itself from a flock. Alexander *et al* (1990a) recorded the distance from the nearest group of sheep as an indication of isolation when the first signs of impending birth were observed. They found that 37-47% of ewes were more than 20m from the nearest group of sheep when they showed first signs of labour.

Alexander *et al* (1979) found that there was a trend for ewes in both large and small paddocks to lamb away from other sheep. This tendency was indicated by the relatively high concentration of lambing sites near the fences. More unshorn ewes tended to isolate themselves than recently shorn ewes in both sized paddocks. This may have been due to the fact that more shelter was provided in the middle of the paddocks hence encouraging shorn ewes to lamb there. Overall, approximately half of the ewes were said to have isolated themselves for lambing from high concentrations of other sheep but this proportion may have been higher than 'normal' situation because of the definition used for isolation. That is, ewes were classified as being isolated if there was no other ewe within 10m, regardless of paddock size. In the larger paddocks, 10m may not be a reasonable indication of isolation.

(b) Selection of a birth site

The selection of a birth site to minimise environmental hazards has also been suggested for domestic sheep (Smith, 1965). However, support for this suggestion is limited despite the perceived advantages of selecting a birth site that provided protection from weather and safety from misadventure (Alexander, 1988). Numerous studies have been conducted on the use of shelter by Merino ewes during lambing in the cooler parts of Australia (Alexander *et al*, 1980; Lynch & Alexander, 1980a; Egan *et al*, 1972; McLaughlin *et al*, 1970; Stevens *et al*, 1981). Most workers have concluded that lamb survival was increased when shelter was provided in the paddock but, unless the ewes were confined to these sheltered areas, the provision of the shelter had little effect on improving lamb survival (Alexander *et al*, 1980; Egan *et al*, 1972; McLaughlin *et al*, 1970; Winfield *et al*, 1969).

For example, observations were made over 3 years on a flock of Welsh Mountain sheep (Winfield *et al*, 1969) and it was concluded that at wind speeds >8km/hr, the chosen lambing sites were progressively more sheltered. It was evident however that there was considerable variability between the amounts of shelter sought and it was suggested that only imposed compulsory shelter would be fully effective in reducing the amount of exposure suffered by all newborn lambs.

Shearing of ewes just prior to lambing to encourage sheltering behaviour during lambing has also been examined (Alexander *et al*, 1979; Lynch & Alexander, 1980b; Lynch *et al*, 1980; Stevens *et al*, 1981). It was found that more use was made by lambing ewes of closely spaced shelter (20m) compared to widely spaced shelter (240m) in a study conducted in the Armidale district of N.S.W. (Alexander *et al*, 1979). Reasons for this trend included more shelter being provided on the lee side of closely spaced shelter and fewer ewes with their lambs tended to move deliberately to shelter when it was widely spaced. More shorn ewes, with or without lambs, made use of the shelter as opposed to unshorn ewes but with strategic placement of shelters, at preferred lambing sites, unshorn ewes could be encouraged to lamb in these areas.

Lynch and Alexander (1980b) found that shearing of ewes up to 4 weeks before lambing was due to commence appeared to encourage them to seek shelter voluntarily during inclement weather, whereas ewes shorn 8 weeks before lambing made little use of the shelter. Ewes were shorn 2 days prior to the commencement of lambing and placed in a sheltered or exposed paddock (Lynch *et al*, 1980). Lamb mortality in the sheltered paddock was half that in the unsheltered paddock and it was observed that ewes made extensive use of the shelter both at night and during the day. This use of shelter continued for seven weeks after shearing and it was suggested that shearing of ewes several weeks before lambing could result in them using the shelter during lambing. However such continued use of the shelter may have been because the sheep had become accustomed to using it as camp-area rather than as a shelter.

Stevens *et al* (1981) concluded that ewes, whether shorn or unshorn, showed no evidence of seeking shelter in which to lamb, although it appeared that many lambs were born in the sheltered areas, this resulted from the extensive use of shelter made by the flock as a whole and ewes on the point of parturition remained at these sites as the flock moved away.

(c) Attraction towards foetal fluids

The onset of maternal behaviour in the form of attraction towards newborn young usually occurs quite suddenly shortly before parturition (Alexander, 1980). The attraction of the ewe to the newborn is initiated by the presence of foetal fluids, either her own or those of other parturient females (Alexander, 1960). The attraction of the ewe to foetal fluids other than their own may lead to confusion over the ownership of some lambs and rejection by the ewe of either the alien lamb or her own, or of both (Arnold and Dudzinski, 1978). The attraction to foetal fluids probably represents an essential first stage in the bonding process.

Maternal behaviour around parturition was studied in multiparous and primiparous ewes whose lambs had been washed to remove amniotic fluids from their coats (Levy and Poindron, 1987). Overall they confirmed that the attraction towards amniotic fluids plays an important role in the establishment of the ewe/lamb bond particularly in inexperienced ewes. They found that primiparous ewes showed a greater delay in the onset of licking of the washed neonate, were more aggressive towards their washed neonate and almost always rejected their lamb when it attempted to suckle. In contrast experienced ewes were able to compensate for the loss of olfactory cues from amniotic fluids and would still suckle their lambs.

(d) Sensory cues involved in mutual recognition

The importance of the senses and sensory cues used for mutual recognition have been widely studied. Visual and auditory cues probably serve to bring mother and young together, but olfaction clearly provides the most specific and final information for recognition of offspring by mothers (Alexander, 1988).

Removal of the olfactory bulbs was performed on 8 pregnant Soay ewes and its effect on maternal behaviour was observed (Baldwin and Shillito, 1974). In 50% of cases, the lambs were not properly licked after birth and in 75% of cases, ewes did not respond specifically to their own lambs so that often lambs other than their own were allowed to feed. Consequently it was suggested that the sense of smell has a particular role in maternal care and when it is absent, the other senses of hearing and sight assist in the successful rearing of the lambs.

Morgan *et al* (1975) studied the roles palyed by the senses of the ewe in location and recognition of her lamb using Border Leicester x Merino ewes. They showed that recognition at close quarters relied on olfaction whereas sight and hearing was mainly used to help locate the lamb. The ewe relies so heavily on smell to discrimate between her own and alien lambs that without the use of this sense, she would accept any lamb.

The ability of multiparous Merino ewes to recognize their own single lambs after they were washed in a 0.05% solution of a neutral non-ionic detergent was studied by Alexander and Stevens (1981). They found that ewes, with lambs that were anaesthetized to remove auditory cues and reduce visual cues to recognition, mostly chose their own lamb except after it had been scrubbed in a detergent solution. On the other hand, tests with washed, conscious lambs showed that ewes could identity their own lambs on the basis of cues other than scent but some of these ewes refused to let their lambs suckle even after correct identification, therefore suggesting the odour of the lamb was the final criterion used by the ewes in rejecting or permitting suckling.

Several studies have found that vision is used to some extent for mutual recognition between the ewe and her lamb. Shillito and Alexander (1975) used a simple test to assess the ability of ewes and lambs to recognize each other, by using four breeds of sheep which had varying degrees of colouration in their coats. They showed that the ability of both the lamb and ewe to discriminate between their natural partner and an alien starts to develop within 24 hours after birth. The results in the study of Shillito and Alexander (1975) suggest that discrimation was associated with the appearance of a partner.

Alexander and Shillito (1978) then studied the maternal response of Merino ewes to artificially coloured lambs and found that ewes hesitantly approached the coloured lambs with black having the greatest effect and yellow the least effect. Ewes rapidly became habituated to the change in appearance and when confronted with the choice of several anaesthesized coloured lambs in a second test, the ewe tended to initially choose lambs on the same colour as her own but their final choice in over 50% of cases, was no lamb at all. A possible explanation is the fact that the lambs were anaesthesized and could not assist in the recognition process. Overall, it was concluded that ewes are able to distinguish, to a certain degree, between a range of colours which may assist in the mutual recognition between the ewe and her lamb.

(e) The 'critical period'

During parturition the ewe usually lies down but may stand during the final stages of expulsion. Labour is generally short, most lambs being born within an hour or two of the first sign of the lamb protruding at the vulva (Alexander, 1960; Alexander, 1988) and is even shorter for second born lambs (Arnold and Morgan, 1975).

The 'critical period' after parturition during which a mother will form a bond with her offspring is short (Arnold and Morgan, 1975). Grooming of the newborn is essential for the formation of a firm exclusive maternal bond (Alexander, 1984). This grooming process appears to be an extension of the attraction to the spilt foetal fluids and usually begins by consumption of the remnants of the foetal fluids by the ewe (Alexander, 1988). The ewe usually commences cleaning her lamb within a few minutes of birth and the intensity of grooming remains high for the first half an hour or so (Alexander, 1960; Arnold and Morgan, 1975; Bareham, 1976).

The period of maternal responsiveness appears to be up to 8 hours in sheep and may be extended to 12 hours if the ewe has had some contact with the newborn after birth (Smith *et al*, 1966). If there has been no contact since birth with any young, there is a rapid decline in maternal interest in the new born with increasing aggressive acts against the young when it approaches the dam (Arnold and Morgan, 1975).

(f) Early post partum separation

Several studies have been conducted on the effect of early post-partum separation on maternal responsiveness and bonding (Alexander *et al*, 1986; Levy *et al*, 1991). Multiparous Merino ewes were separated from their lambs immediately after birth and presented with their lamb in a cage 0 or 1 hour post-partum (Alexander *et al*, 1986). It was concluded that ewes were able to establish an exclusive bond with their lamb when contact began at parturition. When the lamb was absent for the first hour after birth, ewes displayed non-selectivity rather than failure to accept any lamb. Levy *et al* (1991) showed that 4 hours of immediate post-partum contact using Ile-de-France ewes, was sufficient to maintain maternal behaviour when followed by a separation period of up to 24 hours. They suggested that the ewe needs to experience a limited amount of contact immediately after parturition in order to maintain maternal behaviour for a long period.

(g) Suckling behaviour

It is essential that the newborn shows behaviour adapted to suckling very rapidly after birth. After birth, the time taken for the lamb to suckle varies but 60 - 80% suck within an hour of birth (Arnold and Morgan, 1975). On average, lambs appeared to suck for the first time about 40 minutes after birth (Alexander *et al*, 1990a) and amongst Merino lambs, singles were significantly faster than twins to suckle ($P<0.05$).

The teat seeking drive in the newborn is strong and it will try to suckle any part of the dam's body, therefore the teat seems to be found by trial and error (Smith, 1965). Several studies have been conducted on the underlying factors involved in teat-seeking behaviour of newly-born lambs (Vince, 1984; Vince *et al*, 1984; Billing and Vince, 1987). From the work of Vince (1984) it was shown that the external surfaces of the ewe vary in temperature and the inguinal cavity at the base of the udder showed the highest readings. This combined with evidence that the lambs become more active when their muzzles are placed in contact with a warm rather than a cold surface suggests that the response to warmth may be one possible means by which the lamb locates the teat.

In addition to this work, Vince *et al* (1984) showed that teat-seeking behaviours such as vigourous forward and upward head movements could be encouraged in newborn unsuckled lambs by tactile stimulation of the head and face. Once again, this activity was more dominant when a warm, smooth bag was used to stimulate the face as opposed to a cold, smooth bag. This type of stimulation attempted to mimmick the natural situation where tactile stimulation arises from maternal licking and encourages the lamb to seek the teats.

More recently, Billing and Vince (1987) found that newborn, unsuckled lambs showed the most oral activity when exposed to a warm, smooth surface as opposed to a warm, woolly surface. This suggests that lambs may show preference for the areas of bare skin on the ewe than to woolly areas. When the degree of surface 'yield' was included, that is the extent to which the smooth surface could be moved horizontally, lambs favoured the intermediate-yielding surface which was designed to resemble the udder and its degree of yield.

From the above studies, it could be suggested that finding the ewe's teat may not be all trial and error as suggested by Smith (1965) and may be induced by the warmer, smooth surfaces of the udder and the tactile stimulation provided by the ewe.

During the initial approaches of the lamb, the ewe may keep circling the lamb and is intent on grooming it. This can last for hours in the primiparous ewe but is shortlived for the experienced ewe (Alexander, 1960). The lamb's teat seeking attempts decline rapidly with time if the attempts are unsuccessful and continued suckling failure diminishes the chances of successful sucking (Alexander, 1980).

An attempt was made to determine the effect of denying the lamb access to the udder for differing periods of time on the overall teat-seeking activity of the lamb (Alexander and Williams, 1966). They found the teat-seeking activity declined progressively for up to 12 hours for newly born lambs and the chances of never suckling became more frequent as the period of prevention increased. However many lambs did suck successfully after being denied access to the udder for as long as 24 hours post-partum but this period may be greatly reduced under unfavourable conditions such as adverse weather, prolonged parturition or poor milk supply.

(h) Time spent on the birth site

The time spent by the ewe on the birth site after parturition has been related to the incidence of lamb separations and hence lamb survival. Putu *et al* (1988) found that by either forcing the ewes and lambs to remain on the birth site for the first 6 hours after birth or by lambing the ewes undisturbed, increased the survival of twin born Merino lambs (97.4 and 88.5%, respectively) compared to those ewes that were either forced away from their birth site permanently or returned after a short period (82.4 and 77.3%, respectively). The decrease in lamb mortality was attributed to a reduction in the number of permanant desertions brought about by allowing the ewes to remain on their birth site.

Alexander *et al* (1990a) found that ewes with triplets remained on the birth site for an average of 7 hours, significantly longer than single or twin bearing ewes. Among twin bearing Merino ewes, there was a non-significant trend for ewes moving from the birth site within 4 hours of birth to experience more separations than ewes moving after 4 hours.

(i) 'Follower' species

The gregarious nature of the sheep presents a conflicting situation with the development of the mother/young bond. Generally, except in inexperienced ewes, the attraction of the newborn overides the gregarious nature of the ewe and she stays with her young until several hours after birth. Once the bond has been established and the lamb has suckled, another challenge arises for the newborn. The lamb not only has to suckle the ewe when she is stationary, but must follow her when she moves off the birth site to graze or travel to water.

Alexander *et al* (1990a) found that the proportion of lambs that followed the ewe when she moved off the birth site clearly depended on litter size. The proportion of triplets that followed (100%) was significantly higher than for twins (91%) and singles (78%). Significantly fewer Merino lambs followed the ewe than Border Leicester and Border Leicester x Merino crosses.

Young lambs are more precocious than young calves and follow their dam on the day of birth (Arnold and Morgan, 1975). Maternal care involves not only suckling the lamb and staying close to it to ensure that the lamb doesn't wander too far away, but also ensures that if the flock moves off, the lamb maintains contact with its dam (Arnold and Morgan, 1975). Once the lamb has learned to follow its mother for the first time, as it gets older, this behaviour becomes an automatic response.

(ii) Abnormal behaviour

(a) Difficult labour

A difficult birth may also affect the behaviour of both the ewe and lamb during the 'critical period' of bond formation. After a difficult birth, the ewe may remain lying for a prolonged period or may show no interest in the lamb after birth and desert it (Alexander, 1960; Shelley, 1970). Alexander (1960) suggested that several environmental and nutritional factors may inhibit the formation of the mother-young bond and include extremely high or low temperatures; inadequate prenatal nutrition and overfeeding of ewes in late pregnancy, resulting in large single lambs and dystocic problems.

(b) Litter size

Where multiples are involved, the bonding procedure becomes more complex. Usually a bond is formed between the ewe and each of her lambs but occasionally one lamb is born a few metres from the other and the ewe fails to form a bond with both of the lambs (Alexander, 1980). Inadequate grooming and poor bond formation are common with multiple births in Merinos. The 'following' response is especially important for survival of twins. The Merino ewe, when she moves from the birth site, appears satisfied by the presence of one lamb and makes no attempt to recover the other twin, who for various reasons, may not follow (Alexander, 1980).

As previously discussed (Section 3.2.1.i.), Stevens *et al* (1982) recorded 56% of twin bearing ewes became permanently separated from one or both of their lambs and in the following year Alexander *et al* (1983) reported 46% of ewes that produced live twins became permanently separated from at least one lamb. This inability of the Merino ewe to attend to both lambs and ensure they both follow her, would reduce the chances of developing a strong bond between mother and young.

A study conducted in South Australia on the ability of 48 hour old Merino lambs to follow their mothers (Oppong-Anane *et al*, 1990) found that single-born lambs tended to be superior to twin-born lambs in their ability to maintain contact with their mothers and follow them over long distances. Failure of the ewe to recognise their litter size readily when the lamb is learning to follow, can lead to separation and death of twin lambs (Alexander, 1984).

(c) Pre-lambing maternal interest

Interference by other ewes around parturition can also cause problems in the bonding process. Attraction to birth fluids by other pre-parturient females may lead to confusion over the ownership of some lambs and rejection by the ewe of either the alien lamb or her own, or of both. However most ewes lost interest in the lambs of other ewes immediately prior to the birth of their own lamb (Arnold and Dudzinski, 1978).

Arnold and Morgan (1975) recorded that although 21% of all ewes displayed some form of pre-lambing maternal interest, this resulted in the deaths of only 7 lambs and accounted for approximately 4% of the total mortality. Shelley (1970) attributed only 3% of lamb deaths to pre-lambing maternal interest displayed by interfering parturient Merino ewes.

On the other hand, Watson *et al* (1968) recorded that amongst Corriedale ewes, of a total of 29 lambs that experienced some form of interference by ewes other than their own dam, more than half of these lambs died, which accounted for approximately 23% of the overall mortality. One possible reason for such a high figure was the adverse weather conditions under which this study was conducted. The combination of adverse weather and pre-lambing interest from other ewes could reduce the chances of survival of the lamb after it becomes separated from a ewe as a result of interference.

Winfield (1970) attributed approximately 27% of lamb losses amongst multiparous Corriedale ewes to pre-lambing maternal interest and adverse weather conditions cannot be held responsible for this high level of interference because lambing occurred under fine weather conditions.

Generally, deaths associated with pre-lambing maternal interest are not a major contributor to lamb mortality but can become a problem under conditions such as adverse weather or high stocking densities.

(d) Primiparous versus multiparous ewes

The behaviour of the ewe around parturition depends partly on her previous experience. In a study conducted by Alexander (1960), it was reported that two year old Merino ewes did not start cleaning their lamb immediately on standing and 29% of the maiden ewes failed to stand still as the lamb started to search for the udder. In contrast, this behaviour was rare in the multiparous ewes. Another aspect reported was the degree of desertion of the lamb by the ewe. No older ewe was observed deserting her lamb but in one year, as many as 32% of the younger ewes deserted their lamb soon after birth. The ewes were in good condition during this year and heavy lambs may have resulted in longer than average length of labour.

Poindron and Le Neindre (1980) observed Ile-de-France and Prealpes-de-Sud ewes for 30 minutes after parturition. A high proportion of primiparous ewes showed disturbances of maternal behaviour which included the ewe's failure to stand for the lamb during its attempts to reach the udder (61%) and some primiparous ewes (21%) took as long as 30 minutes to commence grooming of the neonate. Aggressive behaviour was observed in 17% of primiparous ewes compared to 1.4% in multiparous ewes.

In an attempt to determine whether hormonal status varied according to parity and therefore explained differences between experienced and non-experienced ewes, Poindron and Le Neindre (1980) carried out two further studies. They found primiparous ewes failed to show any maternal inclinations 10 days before delivery compared to 35% of multiparous ewes being maternal at this time. When injected with exogenous hormones (progesterone and estradiol), to induce maternal behaviour, only 8% of primiparous ewes responded compared with 60% of multiparous ewes.

(iii) Hormonal control

The large hormonal changes associated with the initiation of the birth process could be involved in the onset of maternal behaviour (Poindron and Le Neindre, 1980). The initiation of parturition has been closely related to the increased foetal glucocorticoid secretion by the foetal adrenal cortex (Liggins *et al*, 1972; Nathanielsz, 1978). The increased foetal glucocorticoid secretion stimulates placental production of oestrogen and the levels of free plasma oestrogen increase sharply during the last few days of pregnancy (Thorburn *et al*, 1972). Concentrations were about 20pg/ml on the second day before parturition and increased to as high as 880pg/ml within a few hours of birth. This increase in oestrogen provides stimulus to prostaglandin (PG) production in late pregnancy. Progesterone levels in the ewe reach a peak at approximately 125 to 130 days of gestation with single pregnancies approaching 9.5ng/ml and twin pregnancies approaching 15.5ng/ml (Stabenfeldt *et al*, 1972). They showed that the decline in progesterone concentration began about 2 weeks prior to parturition and levels as low as 2ng/ml were recorded at parturition. Chamley *et al* (1973) showed the mean progesterone level was 1ng/ml on the day of parturition. The decline in progesterone levels in the final 24 hours is rather rapid and could be associated with the initiation of labor but should be viewed as only one of a number of factors involved (Stabenfeldt *et al*, 1972).

It was suggested by Nathanielsz (1978) that interrelationships between oestrogen, progesterone, oxytocin and PG results in a cascade phenomenon with several interconnected positive feedback loops that ensure rapid and controlled delivery (Nathanielsz, 1978).

Poindron *et al* (1984) suggested that oestrogens rather than progesterone are responsible for the onset of maternal receptivity because maternal interest has been shown to be present at oestrous and during the last ten days of pregnancy when oestrogen levels are enhanced but during mid-pregnancy when progesterone concentrations are high, no maternal behaviour is observed.

Induction of maternal behaviour with exogenous hormones showed that oestradiol is slightly more effective in eliciting maternal behaviour than progesterone in a single injection given to ovariectomized females (Poindron and Le Neindre, 1980). They reported that it was unknown as to whether oestrogen was the direct initiator that acts on the brain or whether it was merely an indirect component interacting with other hormones. It has also been suggested that oestrogen may not only be involved in the onset of maternal behaviour but may also control the fading of maternal responsiveness to the neonate after parturition.

More recently it was shown that hormones are not the only factors facilitating maternal behaviour. Keverne *et al* (1983) found that in non-pregnant ewes primed with oestrogen and progesterone, the full complement of maternal behaviour could be induced after 5 minutes of vaginal-cervical stimulation. Therefore, after the birth of the first lamb there is a resurgence of maternal interest following vaginal stimulation associated with successive births.

Alexander *et al* (1988) argued that in the absence of vaginal stimulation, the normal endogenous hormonal preparation of the ewe, together with previous experience, are sufficient to allow ewes to become maternal. They found that 88% of the multiparous ewes showed maternal behaviour and accepted their lambs within 6 hours of delivery by caesarian section whereas none of the primiparous ewes showed any signs of maternal behaviour. This suggests that previous maternal experience does play a role in the induction of maternal behaviour. Vaginal stimulation may also play a vital role in the induction of maternal behaviour in primiparous ewes and without this stimulation, which was the case with the caesarian delivery, the primiparous ewes did not exhibit maternal behaviour.

3.3.2 Methods to reduce the number of starving lambs

(i) Management options

(a) Pre- and post-lambing nutrition

Both inadequate and abundant nutrition in late pregnancy can adversely affect the behaviour of the ewe and lamb (Alexander, 1980). Poor nutrition in late pregnancy can cause pregnancy toxaemia and poor maternal behaviour (Ferguson, 1982) and result in the birth of slow, weak twins (Alexander, 1980). Several studies have reported the effect of different nutritional regimes on lamb survival via its effect on the onset of lactation (McCance and Alexander, 1959) and lamb birthweight (Holst *et al*, 1986; Lynch *et al*, 1990).

The effect of different nutritional regimes on the onset of lactation in Merino ewes was studied by McCance and Alexander (1959). They found that ewes fed to maintain or gain weight during pregnancy showed more rapid changes in secretions than ewes fed to lose weight. Copious lactation occurred during the day prior to lambing in most high-plane ewes compared with after lambing in most low-plane ewes. The low-plane ewes tended to be slower than the other ewes in exhibiting secretions of the type similar to normal ewes' milk. After the onset of lactation, the rate of secretion by poorly fed ewes was about half that of ewes fed to gain or maintain weight during pregnancy. It was concluded that ewes on low-planes of nutrition during pregnancy experienced a delayed onset of lactation and a reduced rate of production of milk which would reduce the chances of survival of their lambs.

Holst *et al* (1986) studied the effects of different feeding regimes during early and late pregnancy on lamb birthweight and survival in a Border Leicester x Merino flock. They found that birthweight of lambs was most affected by the level of nutrition in late pregnancy as opposed to early pregnancy and this was particularly so for twin lambs. They reported no significant difference in the survival of single lambs across the feeding regimes but found the survival of twin lambs was lowest from ewes receiving a low level of nutrition throughout pregnancy. They concluded that regardless of nutrition during early pregnancy (whether high or low), management strategies should aim to provide adequate levels of nutrition during the last trimester of pregnancy in order to achieve optimal birthweight and enhance lamb survival.

A study was conducted on 300 mixed aged Border Leicester x Merino ewes to examine the effects of a cottonseed supplement on lamb birthweight and survival (Lynch *et al*, 1990). Ewes were fed according to litter size and it was shown that supplementation significantly increased the birthweight and survival of litter sizes of 1-3 lambs.

Nutrition at lambing is also important and it has been suggested that ewes are more likely to remain longer at the birth site in the presence of plentiful pasture (Haughey, 1991). This would assist in the development of the ewe/lamb bond and subsequently lamb survival. Putu (1988) showed the importance of nutrition around lambing with twin-bearing ewes quickly leaving the birth site in order to graze. If sufficient pasture were available around the birth site, ewes may have remained there longer and this could possibly have reduced the chances of separations between the ewe and her lambs and enhanced lamb survival.

(b) Provision of shelter

There are numerous studies that involve recording lamb survival under sheltered or exposed conditions (Alexander et.al.,1959; Alexander et.al.,1980; Alexander and Peterson, 1961; McLaughlin *et al*, 1970; Obst and Ellis, 1977; Watson *et al*, 1968). These two conditions can be defined as:

1. 'exposed' - lambing ewes remain outdoors
2. 'sheltered' - lambing ewes are housed in pens and/or paddocks with some degree of shelter provided from trees and hedges

Only levels of lamb mortality from the 'exposed' groups have been included in Table 1.1 because they relate more closely to the experiments reported in this thesis. However it has been reported (Alexander *et al,* 1959; Alexander and Peterson, 1961) that levels of mortality can be drastically reduced from over 40% to near nil mortality by providing shelter and assistance. Alexander and Peterson (1961) described their adverse weather conditions as cold, wet and windy with the sky being mainly overcast and rain falling on 9 of the 13 days involved.

Watson *et al* (1968) reported levels of mortality were reduced for both single and twin born lambs when lambing ewes were placed in sheltered pens (8% and 24%, respectively) compared to ewes lambing outdoors (21% and 58%, respectively). Although only one of the seven periods of observation experienced severe weather, it accounted for two thirds of lamb deaths after birth in the exposed group. The maximum and minimum temperatures experienced during this period were 9 and 6 degrees celsius, respectively while 2.59 centimetres of rainfall and wind speeds of up to 8 m/sec were recorded.

Although lambing indoors in not widely practiced in Australia, McLaughlin *et al* (1970) showed that by providing shelter outdoors, mortality rates can be reduced to levels similar to those obtained in shed lambing. For single lambs, mortality rates were reduced from 14% in exposed conditions to under 5% in sheltered conditions and for twin lambs the mortality levels were reduced from 28% to 9%, respectively. In both years of the study, rain fell on more than half of the observation days and the exposed site recorded mean minimum temperatures <8 degrees celsius for both years and mean maximum temperatures <15 degrees celsius for both years. The average wind velocity at various sites in the sheltered area varied from 28 to 40% and from 21 to 44% of the average velocity in the exposed area for 1967 and 1969 respectively.

Alexander *et al* (1980) reported that provision of shelter by means of grass wind-breaks increased survival by up to 10% in single lambs and as much as 32% in multiples. They found that wind (>15km/hr) combined with rain and/or with low air temperatures (<5 degrees celsius) increased mortality by increasing the proportion of lambs that died of hypothermia immediately after birth.

Lamb mortality in sheltered paddocks was reported to be half that in the unsheltered paddocks in a study conducted in Armidale, New South Wales on shorn Merino ewes (Lynch *et al*, 1980). In this study, two distinct weather patterns were recorded, ‘calm’ and ‘windy’ weather. During the ‘windy’ weather, maximum temperatures varied from 6 to 8 degrees celsius and minimum temperatures from 1.5 to -1.5 degrees celsius with winds continuously >15km/hr and ranged up to 35km/hr.

Therefore it has been shown that with the provision of some degree of shelter, lamb mortality can be reduced to much lower levels than if no shelter is provided particularly under the adverse weather conditions described in the above studies.

(c) Shearing ewes before lambing

Shearing ewes prior to lambing has been claimed to reduce lamb loss (Ferguson, 1982). The rationale is that recently shorn ewes seek out shelter and lamb there (Alexander, 1984). The advantages of this practice may be reduced under more favourable weather conditions. In addition to the practical problems associated with shearing ewes close to lambing is the problem that ewes in poor condition are at risk if exposed to cold, wet conditions off-shears (Alexander, 1984; Ferguson, 1982). More detailed studies of the effect of shearing ewes prior to lambing have been discussed previously in Section 3.3.1(i)(b).

(d) Supervision at lambing

The degree of supervision of lambing ewes varies from zero supervision to lambing in individual pens (Alexander, 1980; Alexander, 1984; Ferguson, 1982). The concept of zero supervision stems from producers believing that any interference by humans, vehicles or dogs is likely to cause mismothering and separation of lambs from their mothers (Alexander, 1980; Alexander, 1984). Under this system, some ewes and lambs will die through lack of obstetrical assistance but under Australia's extensive pastoral systems, where nutrition of the ewe is generally not excessive, these losses are likely to be small because of the absence of high birth weights (Alexander, 1980).

Most producers in Australia inspect lambing ewes once or twice daily and provide assistance to ewes having difficulty around parturition (Ferguson, 1982). More intensive shepherding both outdoors and indoors is rarely practised in Australia because of our extensive pastoral systems and indoor lambing is both capital and labour intensive. Blackburn and Rizzoli (1968) conducted an experiment on Corriedale and Merino ewes lambing in Victoria to show the advantages of pen lambing in comparison to outdoor lambing on lamb survival. They found that among both breeds, pen lambing greatly increased the number of lambs surviving compared to lambing outdoors but suggested that pen lambing should only be considered if lamb losses are more than 20% and if the costs involved are economically feasible. In the southern areas of Australia, pen lambing may be an option if the enterprise involved is of a small size, otherwise the costs involved would be too great.

Drift lambing is another system that has been practised in Australia but is generally confined to research establishments (Alexander, 1984). It involves separating (or 'drifting') unlambed ewes from the lambing and lambed ewes with minimum interference to the lambing camp (Haughey,1991). Moore *et al* (1966) compared the effectiveness of two management systems during lambing in Merino ewes in terms of lamb survival. They found no significant differences in lamb mortality between the drifted and set-stocked groups but recorded a high level of lamb losses from predation in the set-stocked group. This may have been due to the creation of small groups of ewes with lambs of similar age in the small drift lambing paddocks which may have enhanced the formation of strong bonds between the ewes and their lambs. However, in the set-stocked group, lambs of all ages were present and this may have increased the chances of separation of the lamb from the ewe.

Three lambing systems were compared at Trangie, N.S.W. by Tyrrell and Giles (1974) which included a drift lambing system (supervised), an unsupervised set-stocked system (A) and an unsupervised set-stocked system where flocks were sub-divided according to their expected date of lambing (B). Although there were no significant differences in lamb survival between the three systems, it was shown that lamb losses before marking were lowest in the supervised group but these losses fell to be significantly lower in the unsupervised group (B) post-marking than in the supervised group.

It is not known how each management system compares with the other with regards to improving lamb survival because there have been few if any comparisons performed on the different husbandry options. Alexander (1980) argued that frequent inspections are advantageous for flocks with few multiple births, however these advantages may diminish when a higher incidence of twins are present and separation of the ewe and her lamb/s becomes more likely due to the disturbance.

(e) Environmental control

The main aim of environmental manipulation is to protect lambs from cold, wet and windy conditions in the southern parts of Australia and from excessive heat in the more tropical regions (Ferguson, 1982). While lambing can be timed to avoid extremes of temperature, there are many other management issues such as pasture availability and livestock prices that need to be considered before a decision can be made on the time of lambing (Ferguson, 1982; Watson and Elder, 1961).

Studies have shown that shelter which reduces wind velocity can reduce heat loss from lambs sufficiently to increase survival (Alexander *et al* 1980; Egan *et al*, 1972; McLaughlin *et al*, 1970). Haughey (1991) stated that sheltered lambing camps reduced evaporative heat loss from newborn lambs therefore minimising losses from exposure. The cost and type of shelter that needs to be established in lambing paddocks in order to enhance lamb survival, needs to be assessed before it is included in the farm management system.

The influence of other factors such as paddock size, stocking rate, fences, location and number of watering points, positioning of shelter and topography on the survival of both ewes and lambs remain to be studied in detail (Alexander, 1980; Alexander, 1984; Alexander, 1988; Ferguson, 1982; Haughey, 1991). Haughey (1989) found a significant correlation between perinatal mortality and stocking density at lambing and Alexander *et al* (1983) showed that mismothering increased disproportionably at stocking densities exceeding 18 lambing ewes/ha. Twin-bearing ewes require low stocking densities at lambing (not more than 15 ewes/ha) to prevent mismothering (Haughey, 1991). Although overstocking of lambing paddocks may increase lamb stealing, mismothering and separation of ewes and lambs, it has been suggested that ewes producing multiples may be best lambed in small paddocks to minimise the chances of permanent separation of lambs from ewes (Alexander, 1984).

(f) Ewe characteristics

Several studies have been conducted to assess the effect of udder damage on lamb survival (Hayman *et al*, 1955; Jordan *et al*, 1984; Moule, 1954). The studies concluded that a reduction in lamb growth and survival was due to the lower milk yield of ewes with defective udders. The proportion of ewes with unsound udders in the flocks studied were 6.3, 10.8 and 22.1% for two New South Wales and one Queensland study respectively (Hayman *et al*, 1955; Jordon *et al*, 1984; Moule, 1954). From the view point of general management, Hayman *et al* (1955) suggested that culling of ewes with defective udders would obviously improve both the percentage of lambs raised by a ewe flock and the type of lamb weaned.

Jordon *et al*, (1984) suggested that culling of ewes with damaged udders would be a useful management practice in many Queensland flocks. Most damage in the flocks studied occurred at shearing and in one study involving 2 flocks as many as 20% of the ewes 7-8 years old, exhibited udder damage. The increase with age in the incidence of udder damage was observed as 2.2% per year (Jordan *et al*, 1984) and Hayman *et al*, (1955) also concluded that there was an association between age and incidence of defective udders, the incidence being highest among the older ewes.

Culling of older ewes is practiced not only because they have a higher incidence of udder defects but often because of a lowered reproductive capacity (Rose, 1972). McDonald, (1966) found that perinatal lamb mortality was highest among the lambs of young and aged ewes, being associated with a higher incidence of lambs dying from dystocia and starvation respectively. Culling of older ewes in a flock depends largely on the management policies.

(ii) Genetic Improvement

Lamb survival can be manipulated genetically in several ways either selecting for specific components of lamb survival such as cold resistance or selecting for more comprehensive components of lamb survival such as maternal rearing ability.

(a) Selection for cold resistance

Cold resistance, defined as the ability to resist hypothermia during a standard cold exposure, was tested in several British sheep breeds and Merinos, and it was estimated to have a heritability of about 0.3 (Slee, 1985; Slee and Stott, 1986). Although heritabilities of this magnitude offer considerable scope for improving lamb survival, the selection technique involved is impractical on a large scale (Haughey, 1991) and unless a more simple technique is developed, its use as a selection criteria will remain limited.

Direct selection for cold resistance is unlikely to find widespread application in the industry because of the costly labour-intensive selection techniques involved. Haughey

(1991) suggested that selection for rearing ability may be a more practical technique for widespread use. In contrast Alexander (1984) suggests that selection for specific components of survival (for example, lamb components) shows more potential because of the low heritable nature of maternal components of lamb survival.

(b) Selection for maternal rearing ability

Rearing ability is most commonly defined as the ratio of the number of lambs weaned to the number of lambs born (LW/LB). Other definitions treat it as an all-or-none character; for example, wean at least one lamb versus wean no lambs and wean all lambs born versus wean none (Piper *et al*, 1982). Haughey *et al* (1985) concluded that given the repeatable and heritable nature of rearing ability, that there are real prospects for improving lamb survival by 'aggressive' selection for better rearing performance of ewes. Piper *et al* (1982) estimated the heritability of rearing ability in two randomly bred Merino flocks to be 10%.

Selection programmes with Merinos appeared to have increased lamb survival at Trangie (Atkins, 1980). The reproductive performance in the Fertility flock was compared with that in an unselected Random control flock and after 15 years of selection, the Fertility flock showed a 7% increase in the survival to weaning of both singles and twins. Not all of this difference was necessarily genetic with some degree of current generation improvement occurring because all dry ewes and those lambing but failing to rear a lamb to weaning culled (Atkins, 1980).

Another selection experiment was conducted at Trundle in central western New South Wales which involved a Nucleus flock in which ewes and succeeding replacement ewes which had successfully reared a lamb each year were compared with a control Stud flock (Donnelly, 1982). Once again, the ewes which were selected for rearing ability, showed a 9% improvement in lamb survival over a 5 year period for both single and twin-born lambs. As reported in the previous study, differences in lamb rearing percentages were a combination of both permanent genetic and current generation gains. Alexander (1984) commented that it was not clear how much of the improvement was due to culling, selection for increased litter size or to improved lamb survival.

Two line-bred Merino selection flocks were established by Haughey (1984) based on their rearing efficiency over four lambings. The high efficiency (HE) ewes had reared at least one lamb on three or all occasions and the low efficiency (LE) ewes had failed to rear their progeny on 2, 3 or all occasions. The mean survival to weaning of single and twin lambs of ewes with a high lifetime rearing ability, was 9% and 15% higher respectively, than those from ewes with a low rearing ability.

In a study conducted in Cunnamulla, Queensland on selection for higher fertility in Australian medium Peppin Merino sheep (Young *et al*, 1963), it was concluded that selection for fertility on a ewes early performance would not raise lifetime production. They found that the lifetime gains through selection of ewes for the number of lambs born or the number of lambs weaned are likely to be small, though selection on the 3 year old performance is likely to be more effective than on 2 year old performance. The estimate of heritability at 2 years of age was negligible for each fertility trait, but the estimates for the 3 year old record were higher, the heritability for lambs born being over 0.3 and for lambs weaned, over 0.1. Therefore selection for the number of lambs born at 3 years of age would be expected to lead to some degree of genetic progress, accompanied by some progression in the number of lambs weaned (Young *et al*, 1963).

In a more recent study, data collected from one Dorset Horn and three Merino flocks were used to examine the ability of the ewes to successfully rear their lambs on four occasions (Haughey *et al*, 1985). It was shown that ewes who reared successfully in their maiden year reared more lambs at the next three lambings, by amounts ranging from 2.8 to 14.7%, than ewes that failed to rear at 2 years of age. This finding suggests that performance at maiden lambing may be a useful indicator of subsequent rearing performance (Haughey, 1991).

(c) Selection for ewe temperament

More recently another characteristic, ewe temperament, has been considered as an indicator of maternal ability. Temperament can be defined as the behavioural characteristics resulting from the individuals's physical, hormonal and nervous organisation, which contributes to the unique disposition of one animal in contrast to other species members (Kilgour, 1975). Selection criteria for mothering ability could include birth site selection in respect to isolation and shelter, duration and intensity of grooming, period that the ewe remains at the birth site, ability to recognize litter size and to keep multiples together, bond strength, and temperament that might reflect ease of disturbance during bond formation (Alexander, 1984).

Most lamb losses occur within the first three days of life. It has been suggested that this may be due to a breakdown in the bond between the ewe and the neonate, since ewes are susceptible to bond formation for only a short period following birth (Poindron *et al*, 1984). If lamb losses are due to poor bond formation, a predictive measure of the strength of the bond in individual ewes may mean that we can select for it. This led several workers to develop tests in which the behaviour of the ewe could be monitored and include the open-field test (Putu, 1988) and the arena test of Fell and Shutt (1989).

1. Open-field test

The test developed by Putu (1988) was used to measure the temperament of ewes after having previously observed parturition behaviour. He stated that maternal behaviour in sheep is an activity that is likely to be highly dependant on the emotivity and temperament of the animals concerned. If this is so, then it should be possible to predict maternal behaviour by measuring temperament. The open-field test involved releasing a ewe into the open field (16 metres square) for a period of 5 minutes and recording the number of squares crossed, and the number of vocalizations emitted during the test. Significant correlations were found between temperament of the ewes (number of squares crossed) and maternal behaviour at lambing (r=0.65). He did not describe how 'maternal behaviour' was measured and as the temperament test was carried out after the ewes first parturition, the test may have been influenced by previous experience of lambing.

Significant correlations, calculated on a flock basis, were also found between temperament and the time spent on the birth site (r=0.60) and the incidence of ewe/lamb seperation (r=0.30). However there was no significant relationship between the temperament scores of the ewes and the level of lamb mortality. Only 19 lambs died of which 10 were attributed to the disturbance of maternal behaviour.

Several workers have been cautious about the use of the open-field test as a 'true' measure of temperament and Kilgour (1975) discussed some problems associated with the open-field test. Firstly, the entry and exit points caused some biased movement in the arena with animals 'hanging around' these points and not moving freely around the arena. Another problem area was that the arena was not strange enough for the animal to show marked behaviour differences. The choice of the behaviours measured such as ambulation or vocalisation may not be discrete enough to detect differences between the groups involved and Kilgour (1975) suggested measuring behaviours such as ear-pricking, sniffing or head-turning.

Many other workers have used the open-field test in an attempt to measure behavioural differences in ewe groups but none of them, apart from Putu (1988), attempt to correlate the ewe's behaviour in the test with her behaviour around parturition.

2. Arena test

Another test has been developed (Fell and Shutt, 1989) in which behavioural differences have been noted between animals under a wide range of treatments; whether or not they were mulesed (Fell and Shutt, 1989), challenged with parasite burdens (Fell *et al*, 1990), treated pharmacologically (Barnett *et al*, 1989) or immunized against ACTH (Behrendt *et al*, 1991).

The arena test developed by Fell and Shutt (1989) was performed on 20 Merino wethers of which half had been mulesed and the other half acted as the controls. It was found that when the human handler, who had held the sheep during the operation, was present in the arena, the mean distance from him was greater for the mulesed group throughout the test period and this difference did not disappear until 114 days after the operation. The mulesed animals minimum approach and mean distance remained significantly greater ($P<0.05$) than the control animals until day 37. When there was no human in the arena or when the regular handler was present, the difference between the 2 groups was not significantly different.

Prior to the arena test reported above the animals were bled 5, 15 and 60 minutes and 24 and 48 hours after the operation. Significantly ($P<0.01$) elevated concentrations of β-endorphin and cortisol were observed in the treated sheep 5-15 minutes after the operation. Previously, it was suggested that surgery increased the plasma levels of β-endorphin as a response to stress and its release further stimulated the adrenocortical release of cortisol (Shutt *et al*, 1987). From the above arena test it was suggested that hormones were released in response to stress and this was indicated by different behavioural patterns in the mulesed and control groups.

Barnett *et al* (1989) studied the arena behaviour response resulting from various pharmacological treatments on ewes infected with internal parasites. It was concluded that both opiates and histamine may be involved in the mediation of effects on sheep behaviour of a protective immune response to the presence of internal parasites.

Mature Merino ewes were actively immunized against ACTH(1-24) and their behaviour was studied in an arena test (Behrendt *et al*, 1991). Half the group were exposed to psychosocial stress and the other half were handled minimally. It was shown that different handling regimes did not influence the behavioural response of the ewes but the immunized sheep had extremely low cortisol concentrations compared to the non-immunized sheep ($P<0.001$). The immunized sheep exhibited a marked increase in avoidance behaviour and locomotor activity during the test ($P<0.001$) which did not appear to be associated with increased fearfulness in that their temperament was characterized by reduced attention to the human, a more docile response to handling and increased grazing behaviour. Therefore it was suggested that the immunized animals had a lack of feedback of either ACTH or cortisol on their central behavioural control mechanisms.

As well as measuring differences between animals in their temperament, some workers have gone a step further in an attempt to discover the underlying reasons for these differences. One possible explanation has been that animals behave differently according to their hormonal response to the stress incurred in these temperament tests. Hennessey *et al* (1984) studied the adrenal responsiveness to ACTH stimulation in female pigs of Large White x Landrace origin. The aim of this experiment was to devise a test that would assist in the identification of pigs that were superior, both genetically and physiologically, in their response to the many stressors encountered in commercial piggeries. The pigs were challenged with ACTH and their response measured by the levels of cortisol present in the blood samples collected post challenge. They concluded that 50 i.u. of synthetic ACTH at 60 minutes post challenge was the optimum dose and time which would allow detection of the high and low reactors from a normal population of pigs.

3. Other temperament tests

The following studies have used different temperament test regimes than the two already described and have attempted to correlate certain behavioural differences to a particular production trait. Although the studies do not deal directly with ewe temperament and its effect on lamb survival they are included in an attempt to evaluate methodology which may be useful in assessing ewe temperament and consequently maternal behaviour.

Assessment of temperament of individual cattle was performed on 72 cattle from 3 different breeds under standardised handling conditions (Tulloh, 1961). Animals were scored on their behaviour as they entered the scales, crush, bail and while they were in the bail. Significant breed differences were recorded for all behavioural parameters except entering the scales. When the mean temperament score for each animal was compared with its live weight, animals with high temperament scores (restless, nervous, wild or aggressive) had significantly lower body weights ($P<0.05$) than those with low temperament scores (docile).

Hemsworth *et al* (1981) measured the behavioural response of pregnant sows to the presence of human beings using two tests: one involved the human touching the head of the sow as she ate at the feed trough and the other involved the human entering an arena containing the sow. When correlated with the reproductive performance of the farms studied, they found that sows which displayed a greater withdrawal response to the approaching experimenter's hand and a corresponding reduction in the amount of approach towards the stationary experimenter in the arena were from farms in which the average total number of piglets born per sow per year was low. They concluded that these results suggest that the amount and type of handling that these animals received could greatly influence their overall reproductive performance.

An arena test described by Hemsworth *et al* (1990) involved 425 gilts measuring the time taken for each gilt to enter an area within 0.5m of a human, the time spent within this area and the number of physical interactions that occurred during the test. The time taken for the gilt to physically interact with the human was found to be moderately heritable (0.376 +/- 0.19). When the level of fear of humans was associated with subsequent reproductive performance, it was discovered that fewer gilts mated which displayed a high level of fear than those which displayed a low level of fear. This trend closely approached significance but there was no association between level of fear and pregnancy rate or litter size and more research needs to be performed on a within farm basis to evaluate these associations which are often not evident on a between farm basis.

3.4 GENERAL CONCLUSIONS

From the literature cited, the incidence of lamb mortality is high in the Australian Merino. One of the major causes (accounting for approximately 60%) is starvation which has resulted from poor maternal ability and/or poor lamb vigour (birth injury) and these are exacebated by adverse weather conditions. Management options aimed at reducing lamb mortality include nutrition of the ewe, pre-lambing shearing, supervision and provision of shelter, however, these give variable results and incur an annual cost. Selection is another means of reducing lamb mortality and poor maternal behaviour which predisposes lambs to starvation, may be a possible selection criteria. One problem is the apparent low heritability of survival traits, but this is true for ovulation rate and steady progress can still be made. What is needed are selection criteria based on ewe characteristics independant of pregnancy.

PART B. EXPERIMENTAL

This thesis reports a study of two flocks that are known to differ genetically in the ability of their ewes to rear lambs to weaning. The aim of the study is twofold: the first was to understand the mechanisms underlying this difference, while the second was to attempt to identify other characters that are related to this difference in lamb rearing ability.

In 1989, 1990 and 1991, the behaviour of the ewes and lambs of the two flocks during the time of birth and bond formation was quantified in order to understand the reasons for the differences between the two flocks. In 1990, 1991 and 1992, a parallel study was carried out in order to look for other characters that may differ between the two flocks. These other characters were the measurement of behaviour in tests of short duration and the response in blood cortisol levels to a challenge with ACTH.

CHAPTER 4. LAMBING OBSERVATIONS

4.1 INTRODUCTION

There are a large number of reports indicating large lamb losses between birth and weaning. Many lambs appear to be born dead or die within 3 days of birth as a result of certain genetic and environmental factors (Hight and Jury, 1970). Lambs are initially completely dependant on their dam's milk supply and their own energy reserves. Therefore if separation from their dam occurs, the lamb/s will normally die when their energy reserves are depleted.

Under normal circumstances, there are two essential criteria that must be met in order for a lamb to survive: the ewe must provide sufficient milk for the lamb and a strong ewe lamb bond must be established. Since ewes generally have enough milk for the survival of their young, there must be some cause of breakdown of the mother-young bond. Autopsy of dead lambs has shown that the majority of deaths result from the starvation mismothering-exposure (SME) complex (Alexander *et al*, 1980; Haughey, 1980; Luff, 1980).

In an attempt to identify the underlying causes of these lamb deaths, direct observation of two flocks was undertaken during the lambing period. Maternal traits of ewes which were thought to enhance the survival of the lamb and corresponding desirable traits of the lamb were recorded.

The two flocks under study differ in their reproductive rate with the "Fertility" ewes showing significantly greater numbers of multiple births, a greater number of lambs born and better survival of both single and twin lambs than the "Random" ewe flock (Atkins, 1980). The Fertility Flock ewes were also shown to have a high lamb rearing ability when they were compared to 14 other Merino bloodlines at Trangie between 1971 and 1985; they had the highest survival to weaning of single-born lambs and the second highest survival to weaning of multiple-born lambs (Atkins, personal communication). By recording as many behavioural traits of both the ewe and lamb, both during and after birth, as possible, the main aim of this experiment was to identify characteristics exhibited by ewes with a better capacity to rear their lambs to weaning.

4.2 MATERIALS AND METHODS

4.2.1 Animals

The sheep involved in this experiment were from the Trangie Fertility flock and an unselected Random control flock. The Fertility flock was established in 1959 with the aim of increasing reproductive performance by improving twinning and lamb survival (Atkins and Robards, 1976). The Random flock, as previously described by Pattie (1965), had undergone no selection for any characteristics. The reproductive performance of the Fertility ewes was compared with that of the Random ewes for the final three years of selection (Atkins, 1980). It was shown that following 15 years of selection, the Fertility ewes were superior in their capacity to rear lambs with a mean increase of 8% and 11% for twins and singles, respectively, in the number of lambs weaned/number of lambs born. Between 1974 and 1988 the two flocks were run separately. In late 1988 they were again run together. During this period, selection was relaxed in the Fertility ewes while selection of sires continued, with only those born as twins or triplets and reared at least as twins, being considered for selection.

In 1989, the flock under study consisted of approximately 100 ewes from each of the two flocks with five age groups in each (Table 4.1). These age groups comprised ewes born in the spring of the years 1983 to 1987 inclusive. There was approximately equal representation of ewes from each of the years, except 1985, where numbers were low due to sheep being used for other experimental reasons. In 1990 and 1991, all ewes were retained and approximately 20 ewes from each line that were born in the spring of 1988 and 1989 respectively were added to the study flock (Table 4.1).

The Fertility flock rams were selected on several factors including off-shears body weight, greasy fleece weight and their dam's previous reproductive performance while the Random Flock rams underwent no selection (S.I. Mortimer - personal communication). All rams used, in both flocks, were 18 months of age with no previous mating experience.

Table 4.1. Ewe numbers and age groups of the Fertility (F) and Random (R) flocks involved in the lambing observations.

Year of trial	Flock	1983	1984	1985	1986	1987	1988	1989
1989	F	23	20	12	22	20	-	-
	R	18	19	20	19	20	-	-
1990	F	12	14	6	17	20	20	-
	R	11	12	9	13	18	26	-
1991	F	9	13	7	15	12	20	13
	R	7	9	8	11	10	23	16

4.2.2 Management

Joining occurred in April/May each year for a period of 5 weeks. Single sire matings were used with one harnessed ram being joined to approximately 33 ewes. The joining paddocks were 5 hectares in area. The ewes were checked for the presence of crayon marks at the end of each week of joining and the colour of the crayons was changed at the end of the second and fourth weeks.

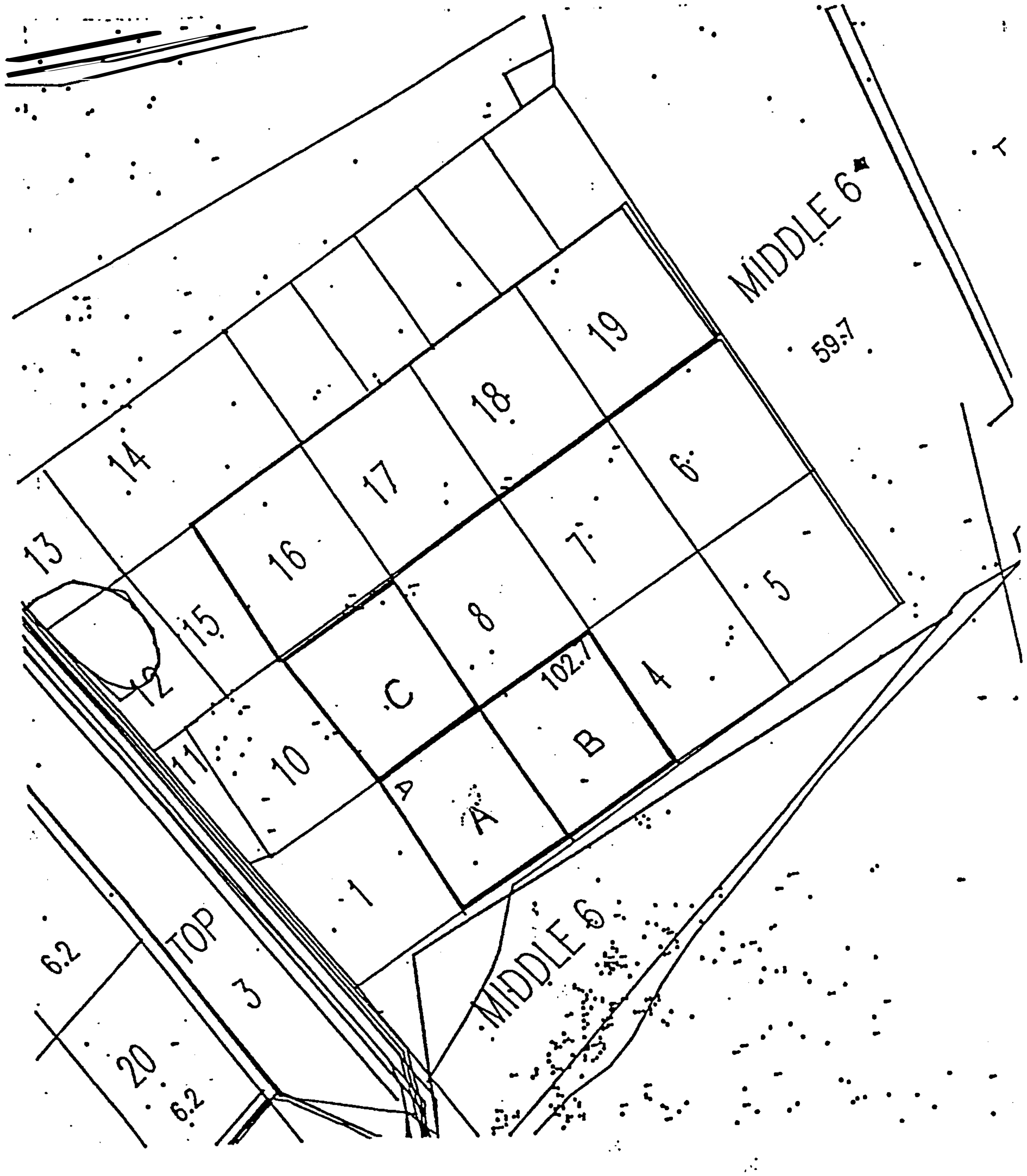
In 1989 ewes were endoscoped for ovulation rate pre-joining and in 1990/91 endoscopies were carried out the day after the end of joining. At the foetal age of 95-100 days (oldest), foetal number was determined by ultrasonography (Fowler and Wilkins, 1982). Each year, two weeks prior to the commencement of lambing, all ewes were side-branded with identification numbers on both sides to enable identification from a distance.

Ewes were introduced to the lambing paddocks a week before the commencement of lambing (calculated from raddle data) and during this week, the ewes were exposed to the presence of humans in these paddocks in an attempt to familiarize them with people who would be observing them during the lambing period. As a result of this process, the ewes could be approached within 5-10 metres during lambing without causing any visible disturbance to the ewes and newborn lambs.

4.2.3 Observation paddocks

(i) 1989 - Ewes were observed during the daylight hours only. The observations involved three paddocks of 4.6ha each (Figure 4.1). One paddock was used for the observations and, at the end of each day, the unlambed ewes were moved to an adjoining paddock (night paddock). Prior to the start of the next day's observations, lambs that had remained in the observation paddock overnight were tagged, marked on the side with their dam's side-brand number and moved to the third paddock (depot paddock).

The unlambed ewes were then moved from the night paddock back into the observation paddock and the observations for that day started. At the end of the day, the lambs that had been born overnight were tagged and moved from the night paddock to the depot



Legend: A = day paddock; B = night paddock; C = depot paddock; D = observation tower; . = location of trees (Source: Trangie Agricultural Research Centre).

Figure 4.1 Outline of the lambing observation paddocks used in 1989.

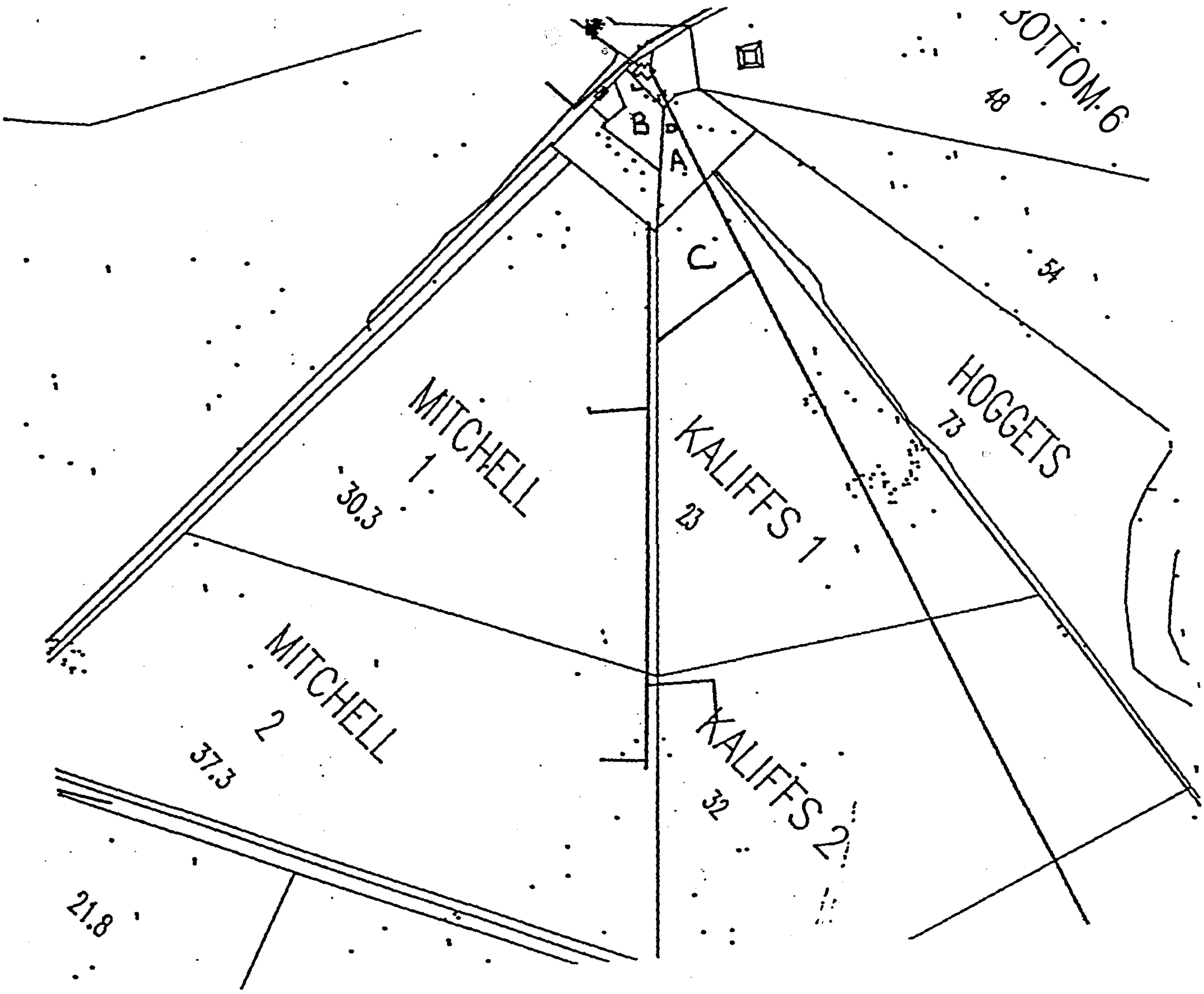
paddock and the unlambed ewes were moved from the observation paddock to the night paddock. This continued for the first three weeks of lambing - this period being estimated from the raddle data to cover the period when most ewes would lamb. Dry ewes were also left with the mob.

Ewes were observed from a tower in which one observer was always present to record data and three other observers were present either in the tower or on the ground, checking for ewes approaching labour. Information was relayed to the tower by 2-way radios and where necessary binoculars were used for viewing lambing ewes. The pasture availability in this year was sufficient to not require supplementary feeding.

(ii) 1990 - The observations once again involved three paddocks, but in this year there was a day paddock of 1.5ha for observations during the daylight hours, a night paddock of 1.0ha for night-time observations and a depot paddock of approximately 3.0ha (Figure 4.2).

At sunset each day, unlambed ewes were moved from the day paddock to the night paddock which was illuminated by floodlights. Ewes which had lambed during the day were left in the day paddock overnight. The following morning, ewes and lambs that were left in the day paddock were tagged, marked on the side with their dam's side-brand and moved to the depot paddock. The unlambed ewes were then moved from the night paddock to the day paddock, leaving behind ewes which had lambed overnight. When the unlambed ewes were being moved from one observation paddock to another, any lambs that were only recently born with recordings still being taken, were allowed to stay behind in the respective paddock until the following day. This allowed for minimal interference for both the ewe and the lamb and allowed the recordings to be completed. Ewes were observed for three weeks. Dry ewes were also left in the mob.

Data were recorded in the same manner as for 1989 with the exception that only 2 observers were used for most of the observation period, one recording in the tower at all times and the other either in the tower or on the ground relaying information. The pasture available to the ewes in this year was not ample for the three weeks of observation



Legend: A = day paddock; B = night paddock; C = depot paddock; D = observation tower; . = location of trees (Source: Trangie Agricultural Research Centre).

Figure 4.2 Outline of the lambing observation paddocks used in 1990.

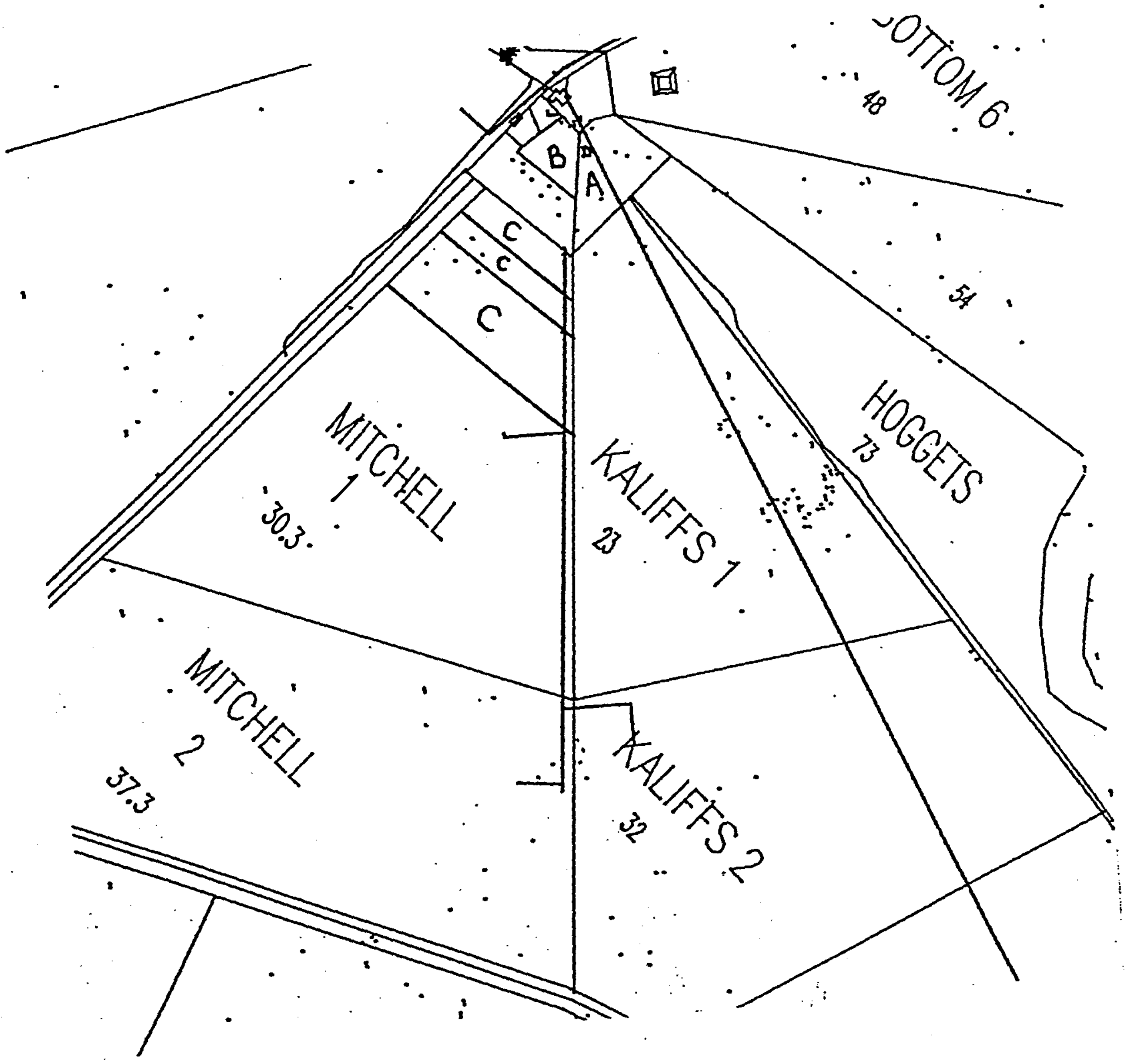
because of the limited size of the observation paddocks, therefore round baled were placed in the day paddock to provide *ad lib* supplementary feed. There was sufficient pasture available to the ewes and lambs once they were placed in the depot paddock.

(iii) 1991 - The observations were carried out in the same paddocks and in the same manner as for 1990 with the exception that a different depot area was used, this area being divided into three paddocks (Figure 4.3). The first two paddocks were 1.5ha each and the third paddock was 5ha. Ewes and their lambs were drifted into the first depot paddock after tagging and remained there for one to four days. They were then drifted into the next paddock for the following four days. Finally they were put out into the large depot paddock where they remained until the completion of the experiment. The amount of pasture available to the ewes in this year was similar to that in 1990 and therefore required the provision of round bales as previously explained in 1990.

4.2.4 Data collection

During the lambing period, the times of different events of parturition were recorded. These included:

1. appearance of mucus and/or waterbag at vulva
2. appearance of nose/feet at vulva
3. appearance of head at vulva
4. birth of lamb - the time when the lamb was completely expelled
5. commencement of grooming of lamb - the time when the ewe began licking the lamb
6. lamb first standing - the time when the lamb stood upright on all four legs for the first time
7. lamb's first drink - the time when the lamb suckled for the first time (indicated by the lamb's tail wagging, the lamb nudging the ewe's udder and/or the ewe hunching to assist suckling)
8. interval between birth of multiple lambs
9. expulsion of placenta - the time of commencement and completion of placental expulsion



Legend: A = day paddock; B = night paddock; C = depot paddock; D = observation tower; . = location of trees (Source: Trangie Agricultural Research Centre).

Figure 4.3 Outline of the lambing observation paddocks for 1991.

10. ewe leaving the birth site - the time when the ewe was >25m away from her birth site whether with or without her lamb/s.

The events above were recorded for each lamb born including multiple births. Lamb vigour was assessed according to the time taken to stand and suckle after birth.
Detailed data collection ended when the ewe left the birth site with or without her lamb/s. The ewes which had difficult births which required assistance in any way, were excluded from the experiments.

In an attempt to identify the birth order of multiples soon after birth, a paint gun was used to shoot a paint ball onto one of the lambs from a distance >10 metres. The gun consisted of a carbon dioxide chamber which when filled would shoot the paint ball onto the side of the lamb and cause minimal interference to the ewe and her lambs. When triplets were involved, different coloured paint balls would be shot onto two of the three lambs for easy identification.

Ewes with their lambs were routinely checked in the depot paddock until the lambs were 3-4 days old. This involved recording daily whether the lamb was still alive and which ewe it was with and whether the lambs appeared healthy or not.

4.2.5 Statistical analysis

Data were tested for their deviation from a normal distribution before any analysis was performed. In all cases the data were sufficiently normally distributed and therefore not transformed.

Values contained in the data set that were considered ‘extreme’ outliers were identified and excluded from the data for analysis if they were 11 - 12 standard deviations from the mean. The analysis reported incorporates the data set without these extreme outliers unless otherwise stated.

The following dependent variables were analysed:

- time (minutes) from appearance of the waterbag to birth of the first lamb, (length of labour)
- time (minutes) from birth to standing of the first, second and third lambs
- time (minutes) from birth to drinking of the first, second and third lambs
- time (minutes) from the birth of the first lamb to the birth of the second lamb
- time (minutes) from the birth of the second lamb to the birth of the third lamb
- time (minutes) from the birth of the first lamb to the ewe completely expelling the placenta
- time (minutes) from the birth of the first lamb to the ewe leaving the birth site

For least-square analysis of variance of each dependant variable, discrete fixed independent variables were: flock (fertility vs random), parity (maiden vs adult), year of observation (1989 - 1991) and all first order interactions. Littersize and the interaction of flock and littersize were only included in the model for the dependent variables which incorporated first-born lambs.

During several observation periods, insufficient data were collected for certain behavioural traits in order to allow the appropriate analyses to be performed. Therefore, no results are presented for these traits. The majority of these cases involved the birth of a third lamb which is certainly uncommon for Merino's.

The time of lambing was also analysed according to the time of day the lamb/s were born, be it day or night, for the 1990 and 1991 observation periods.

4.3 RESULTS

(a) Lambing

In all three years of the study, the Fertility ewes consistently produced more lambs per ewe joined than the Random ewes (Table 4.2). However, only in the final year of the study was the superior rearing ability of the Fertility ewes seen. The first year of the study was the first time that the two flocks had been run together for several years and

Table 4.2. The overall lambing performance of the Fertility and Random Flocks over the three observation periods.

Year of observation	1989		1990		1991	
Flock	Random	Fertility	Random	Fertility	Random	Fertility
Lambs born/ewes mated	1.41	1.8	1.57	2.52	1.48	1.73
Lambs marked/lambs born	0.81	0.68	0.79	0.49	0.88	0.94
Mean lamb birthweight (kg)	3.75	4.26	3.55	2.7	3.32	4.07

differences in survival may have been due to carry over effects on maternal ability. The second year of the study saw an unusually high lambing rate in the Fertility ewes (Table 4.2) due to a very high proportion of triplets and consequently low birthweight. The third year saw reproductive performance return to levels similar to those described by Atkins (1980).

(b) Time of lambing

In 1990 and 1991, the two years in which observations included the hours of darkness, lambs were observed to be born at all hours of the day and night. However, there was a trend for a greater proportion of lambs to be born over the period 7am to 1pm (Figure 4.4), with the net result that 60% of births occurred in the hours of daylight while 40% occurred during the hours of darkness. This was significantly different ($P<0.01$) from the distribution of 50% during the daylight hours and 50% during the night that would be expected around the spring equinox. For both years, there was no significant difference between the two flocks for the time of lambing.

(c) Length of labour

Length of labour varied from 2 minutes up to 89 minutes in the Fertility flock and from 2 minutes to more than 2 hours in the Random flock. There were no significant effects of flock, parity, littersize or year of observation on length of labour although the Fertility ewes tended to deliver their first lamb quicker than the Random ewes (31.0±3.0 vs 36.6±3.3, Fig.4.5). There were also no significant interactions.

(d) Interval from birth to standing of the first-born lamb

Although there were no significant effects of flock, parity or littersize on the time taken for the first-born lamb to stand, Random lambs stood slightly quicker after birth than the Fertility lambs (17.8±1.2 vs 19.3±1.7, Fig4.5). There was also no significant interactions. However, there was a highly significant effect of year of observation ($P<0.01$) lambs taking longer to stand in 1989 (22.8±2.6a) than in 1990 (19.5±1.6a) or 1991 (14.8±1.1b).

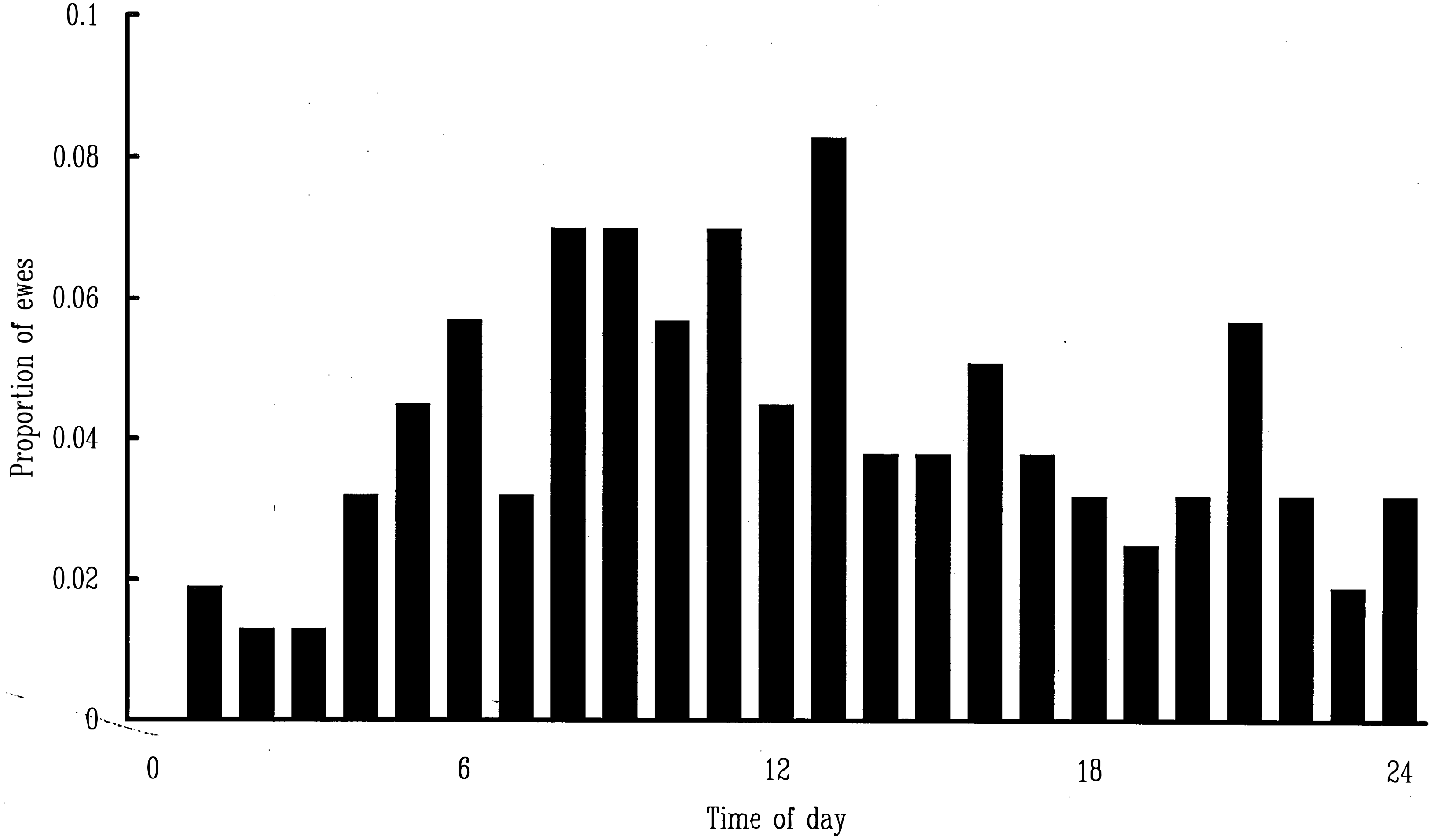
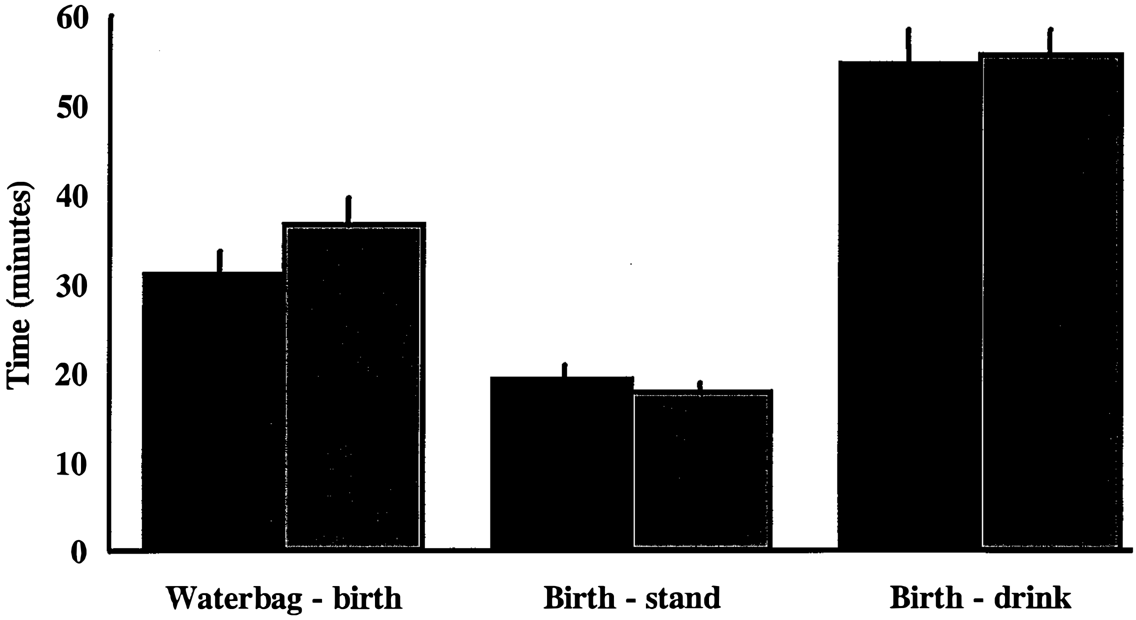


Figure 4.4 Distribution of births over 24 hours (12=midday;24=midnight) recorded for both the Fertility and Random flocks for the 1990-1991 observation periods.



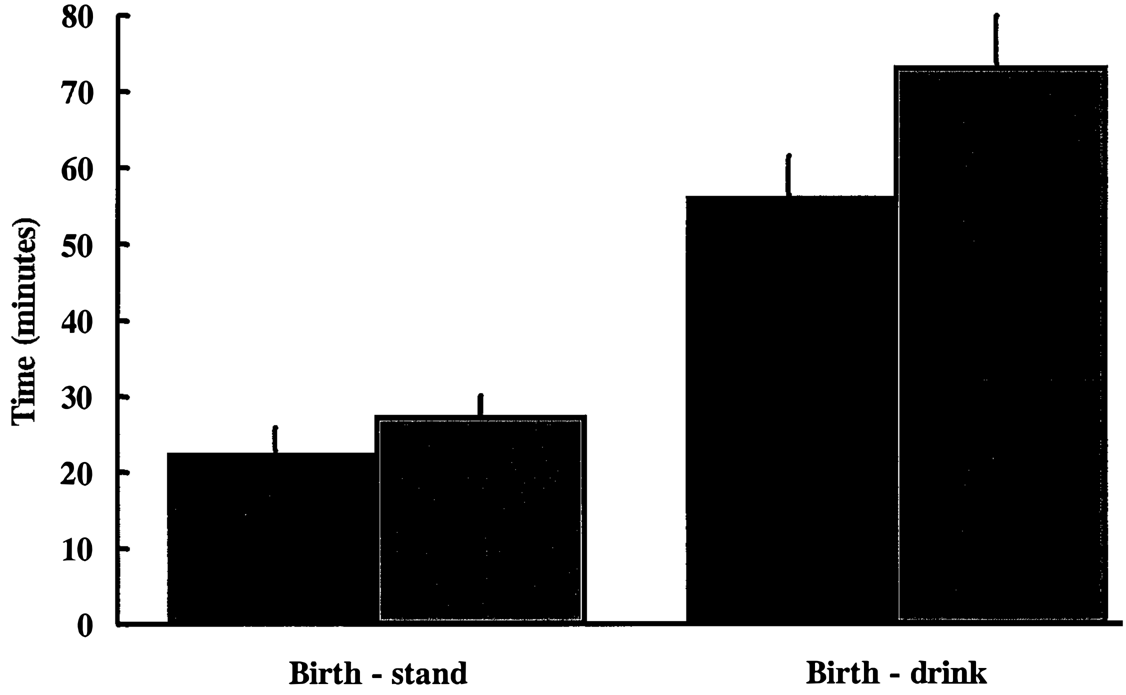


Figure 4.5 Mean (±sem) time intervals recorded during the 1989-1991 observation periods for the Fertility (black bars) and Random (grey bars) flocks for the time taken to give birth and the time taken for the first-born (upper) and second-born (lower) lambs to stand and obtain their first drink.

(e) Interval from birth to drinking of the first-born lamb

Again, there was no significant effect of flock, parity or littersize on the time taken for the lamb to obtain its first drink, nor were there any significant interactions. The Fertility lambs were slightly quicker than the Random lambs in obtaining their first drink (54.6±4.4 vs 55.6±3.0, Fig4.5). Year of observation was significant at the 1% probability level with first-born lambs taking significantly longer to obtain their first drink in 1990 (65.7±4.7) than in 1989 (50.8±4.8) and 1991 (48.6±3.6).

(f) Interval from birth to standing of the second-born lamb

There were no significant effects of flock or parity on the time taken for second-born lambs to stand nor was there any significant interaction between these variables. Overall the second-born Fertility lambs were quicker to get to their feet than the Random lambs (22.2±3.3 vs 27.2±3.7, Fig4.5). There was a significant year of observation effect ($P<0.05$) when the 'extreme' outliers were included in the analysis but this significance disappeared when the outliers were excluded. This can be explained by the presence of one outlyer in 1989 when one lamb took nearly five hours to stand after birth. However, the effect of year of observation was approaching significance at the 5% probability level even when the outlier was excluded from the analysis ($P=0.063$). Second-born lambs took much longer to stand in 1989 than in 1990 and 1991 (35.9±7.1, 20.6±2.7 and 22.7±3.9, respectively).

(g) Interval from birth to drinking of the second-born lambs

There were no significant effects of flock, parity or year of observation on the time taken for second-born lambs to obtain their first drink despite the Fertility lambs being much quicker than the Random lambs (55.9±6.0 vs 73.0±7.2, Fig4.5). There was no significant interactions between these variables.

(h) Interval between first and second births

There were no significant effects of flock or year of observation on this interval with Random ewes giving birth to their second lambs slightly quicker than the Fertility ewes (21.4±2.4 vs 23.7±2.3). Maiden ewes took significantly ($P<0.05$) longer to give birth to their second lambs than the adult ewes (32.2min±5.2 vs 21.3min±1.7,). There was a highly significant interaction between flock and year of observation for the interval between the first and second births (Figure 4.6).

(i) Interval from first birth to expulsion of the placenta

There was a significant effect of flock ($P<0.05$) on the time taken for the ewe to expel her placenta with Fertility ewes taking much longer than Random ewes (610.0±241.2 vs 451.0±198.2, Fig4.7). There was also a highly significant effect of year of observation ($P<0.01$) where ewes took much longer to expel their placentas in 1991 (239.8±10.6) than in 1990 (202.9±9.3) and 1989 (197.9±10.3). Littersize also had a highly significant effect on the time taken for placental expulsion ($P<0.01$) with twin-bearing ewes taking much longer (236.9±8.4) than single-bearing ewes (186.5±7.7).

(j) Interval from first birth to the ewe leaving the birth site

There were no significant effects of flock, parity or year of observation on the time taken for the ewe to leave the birth site with the Fertility ewes remaining on the birth site slightly longer than the Random ewes (266.1±19.6 vs 251.1±21.8, Fig4.7). However, there was a highly significant littersize effect ($P<0.01$) where the twin-bearing ewes remained on the birth site much longer than the single-bearing ewes (289.8±18.3 and 206.4±22.2, respectively).

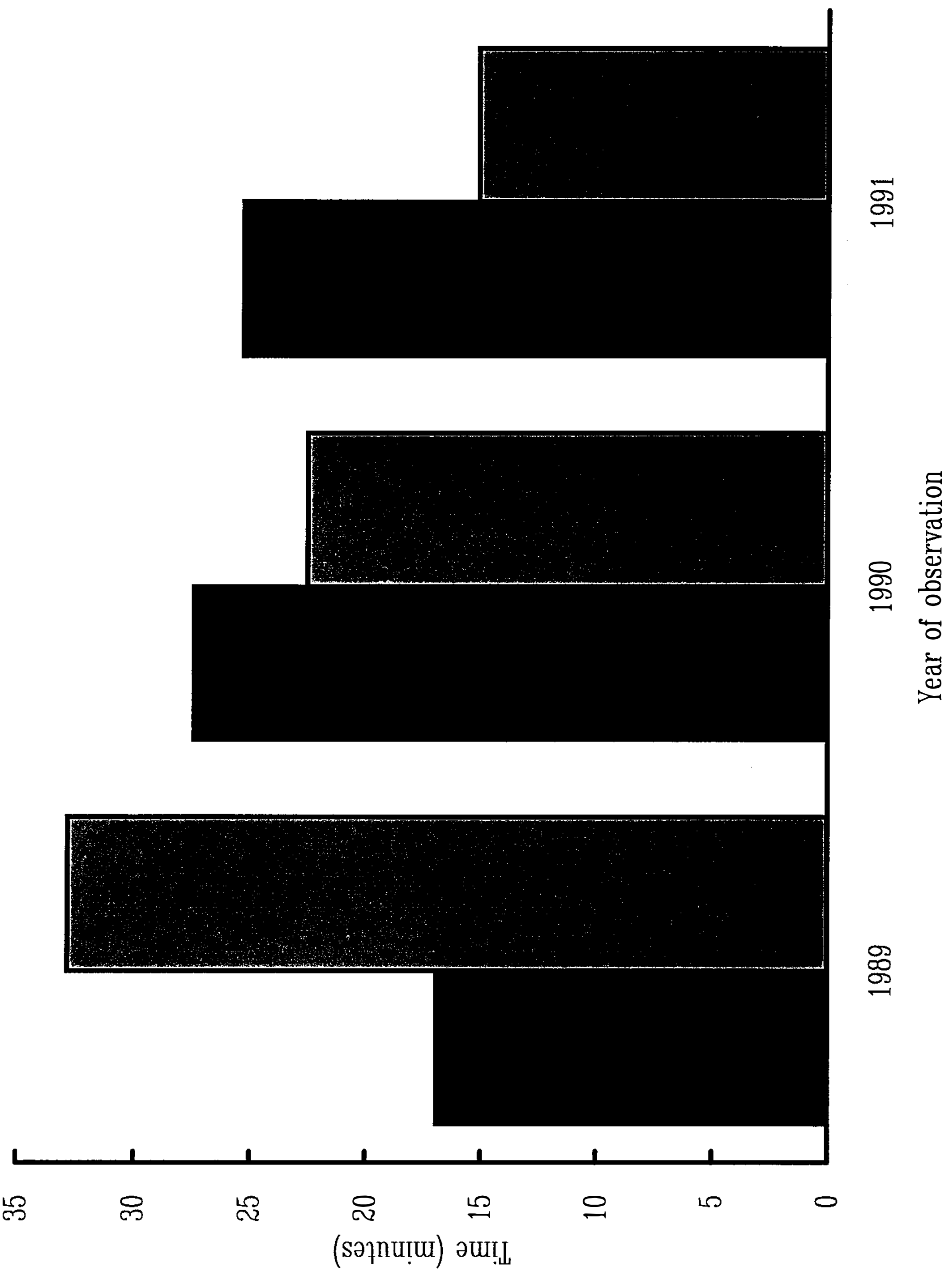


Figure 4.6 The unadjusted mean time interval between the birth of the first and second-born lambs recorded for the flock x year of observation interaction for the Fertility (black bars) and Random (grey bars) flocks.

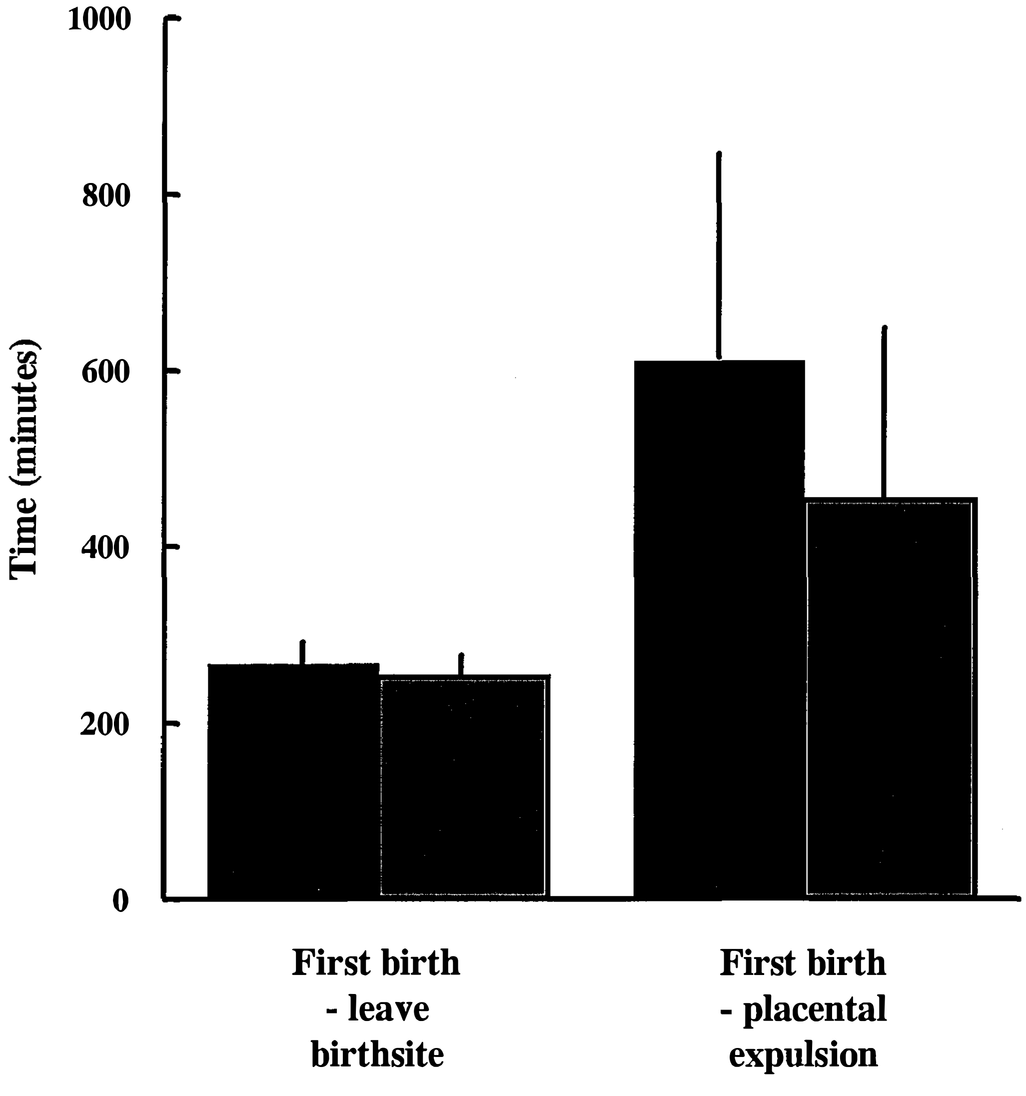


Figure 4.7 Mean (±sem) time intervals recorded during the 1989-1991 lambing observations of the Fertility (black bars) and Random (grey bars) flocks for the time taken after the birth of the first lamb for the ewe to completely expel her placenta and to leave the birthsite.

4.4 DISCUSSION

The new born lamb has few body reserves when it is first born and must feed as soon as possible after birth. Certain conditions are essential for the lamb to survive including the survival of both the ewe and lamb during the birth process, the establishment of a strong ewe-lamb bond, the ewe having sufficient milk and allowing the lamb to suckle and the recognition of twins by the ewe. The aspects of behaviour examined in this study seemed relevant to lamb survival and could have either proved useful in identifying ewes that were superior in their ability to rear their lamb/s to weaning or at least furnished reasons for this superiority. However, of all the aspects of behaviour that were observed over the three year period, there were no significant flock differences. This result was surprising in the fact that the Fertility ewes have demonstrated their superior rearing ability (Atkins, 1980) and therefore it was anticipated that the superiority would be expressed in the "maternal" behavioural traits measured. Such elements of behaviour as a short birth time, a greater time spent on the birth site, a shorter interval between first and second births and a more intense grooming regime would all be expected to assist in the survival of the lamb, but none of these measurements resulted in a significant flock difference.

However, the Fertility ewes however did deliver their lambs slightly more rapidly and remained on the birth site slightly longer than the Random ewes. Apart from these minor differences, the parameters that were being recorded did not reveal any behavioural differences between the two flocks. The length of labour recorded in the present study ranged from 2 minutes to more than two hours with a mean birth time of 31.0 and 36.6 minutes for the Fertility and Random ewes, respectively. These figures are similar in magnitude to other studies including that of Alexander *et al* (1990a) who recorded a mean birth time of 30 - 45 minutes with a similar range to the present study. Alexander and Peterson (1961) recorded a mean time of 70 minutes while Sharafeldin *et al* (1971) reported an average time of 46.1±1.6min with a range of 35-61 minutes. Generally, the length of labour recorded in the literature ranges from as quickly as a few minutes to as long as three hours.

The interval between the first and second births in the present study were of similar magnitude to the study of Arnold and Morgan (1975) who recorded an mean interval of just under 45 minutes with a range of 1-172 minutes. The time spent on the birth site varied considerably in the present study with the Fertility ewes remaining on the birth site slightly longer than the Random ewes (266.1 vs 251.1 mins., respectively). In comparison to other studies, these figures are of similar magnitude where Alexander *et al* (1990a) recorded 4 hours as the mean time spent on the birth site, while Stevens *et al* (1982) reported 2-3 hours as the mean time.

The time of lambing recorded in the present study showed a greater proportion of lambs born during daylight hours than at night which is in contrast to a study by Arnold and Morgan (1975) where the distribution of lambing throughout the 24hr period was random. A possible explanation for less night births during the present study could be the fact that the ewes were lambing in an ‘artificial’ environment with the paddocks being illuminated at night and this may have disrupted their regular lambing pattern. The fact that the ewes were moved from one paddock to another,both morning and night, may also have disrupted their regular lambing pattern.

A possible explanation for the lack of any significant flock differences could be the fact that the parameters used were insensitive to detect any differences and therefore more subtle parameters of behaviour may have been required. On the other hand, survival is a composite of a number of behaviours and by combining these more subtle behavioural traits into an index as opposed to treating them individually, a better indicator of survival may have been obtained and differences may have been recorded between the two flocks involved.

Other studies performed have used more intense parameters. For example, Alexander *et al* (1959) recorded such parameters as rectal temperatures of both the ewe and lamb, state of teats, nature of udder secretions, weather factors as well as lamb vigour scores, while Arnold and Morgan (1975) recorded such detailed behaviour of the ewe pre-partum as circling, standing and lying, licking herself as well as recording the sequence of grooming of the lamb. More recently, Stevens (1991) showed that the collection of behavioural information on as many animals as possible overlooked more subtle behavioural differences. She found that when more intense observations were performed on smaller numbers of ewes, statistically significant differences in such characters as the amount of oro-nasal contact of lambs by the ewe, number of vocalisations and the incidence and immediacy of responses between the ewe and lamb, became apparent which were not detected in the larger study using less intensive measures.

There are so many factors that determine whether or not the lamb will survive and a decision needs to be made as to what specific aspects of survival the study is aiming to identify. By doing this more detailed observations could be made on a larger number of animals. Not only is the ewe responsible for the survival of her lamb but the lamb itself plays a major role in the development of the bond and ultimately its own survival. In the present study, the time taken for the lamb to stand and obtain its first drink were recorded but no significant flock differences were obtained. Once again more intense observations may have been needed in order to obtain more conclusive results.

Despite the numerous studies that have been performed on the maternal behaviour of the ewe and its effect on lamb survival, Alexander and Stevens (1992) reported that lamb survival is heritable as a character of the ewe and not the lamb. Therefore any selection on lamb traits would be expected to have no effect on survival. They also concluded that no measure or test of ewe or lamb behaviour made in the study could be used as an indicator of superior mothering ability or lamb survivability.

Since the direct measure of behaviour around lambing has proven either fruitless (where gross measurements are made on large numbers of ewes) or tedious (where very intensive measures are made), other means of identifying ewes of superior mothering ability are needed. These measurements would ideally be made prior to lambing, preferably in non-pregnant animals, and be genetically related to maternal ability. The following chapters describe experimental work aimed at the identification of indirect indicators of maternal rearing ability.

CHAPTER 5. EWE TEMPERAMENT

5.1 INTRODUCTION

Maternal behaviour at lambing is a determinant of the success or failure of the formation of the ewe/lamb bond and hence the chances of lamb survival. The technique of exposing animals to unfamiliar environments has been used to assess their emotional status and temperament and more recently, ewe temperament has been advanced as having a link with lamb survival by Putu (1988) who used both an open-field test and an enclosed box test. The number of squares crossed in the open-field test was shown to be significantly correlated with maternal behaviour at lambing as was the number of movements recorded in the box. These results suggest that maternal temperament could be linked with lamb survival, calmer ewes having a greater chance of rearing their lambs to weaning.

Fell and Shutt (1989) developed another measure of temperament using an arena test and recorded meaningful results in terms of the aversion of lambs to humans after mulesing. Their aim was to develop a test which could monitor behavioural indicators of stress which in turn could be readily detectable in the field situation. The arena test has also been used to demonstrate differences in the behaviour of animals under a wide range of physiological conditions such as challenge with an internal parasite (Fell *et al*, 1990), treatment with drugs (Barnett *et al*, 1989) and immunization against ACTH (Behrendt *et al*, 1991).

The following experiments were aimed at identifying possible differences between ewes of the Fertility and Random flocks in their temperament using both the open-field and arena tests. If these differences exist, these tests could ultimately assist in identifying ewes which are superior in rearing their lambs to weaning by finding a relationship between the temperament of individual ewes and their lifetime rearing performance.

5.2 MATERIALS AND METHODS

5.2.1 Tests performed and data collection

The tests performed on the ewes were as follows:

(i) Open field test (Putu, 1988):- This test was performed in an arena (16m x 16m) located outdoors which was divided into 16 squares each measuring 4m x 4m. Each ewe was placed in the arena for 5 minutes and the number of squares crossed, bleats, defaecations, urinations and eating bouts during each 30-second interval were recorded.

(ii) Arena test (Fell & Shutt, 1989):- This test was performed as described by Fell & Shutt (1989) to test the animals' aversion to a human who stood quietly at one end of the arena during the test. In contrast to the study of Fell & Shutt (1989) where 3 or 4 sheep were tested at a time in the arena, in this study ewes were tested singly. The reason for this was to keep the method similar to other open-field test procedures and to study the behaviour of each ewe in isolation. The dimensions of the arena were 3m x 13m instead of 4m x 14m, but in all other respects, the tests were exactly similar.

The parameters recorded to describe a sheep's behaviour in the arena test were:

(a) mean approach - the mean distance from the human over the test period.

(b) minimum(or maximum) approach - the closest(or furthest) distance from the human during the test.

(c) travel - the total distance travelled during the test.

5.2.2 Animals involved

The sheep involved in the temperament tests have been described previously (Section 4.2.1). In 1990, both the open-field and the arena test were performed on the ewes pre joining, while in 1991, only the arena test was performed on the ewes, both pre-joining and 2 weeks prior to the start of lambing.

5.2.3 Statistical analysis

(i) Open-field test

The effect of flock on the total number of squares crossed, the total number of bleats, the total number of grazing bouts, the total number of urinations and defaecations and whether or not the animal bleated, defaecated or grazed were analysed by least-squares analysis of variance. The effect of flock on the proportion of animals that bleated, urinated, defaecated or grazed was test for significance using χ^2.

(ii) Arena test

The effect of flock on minimum approach, mean approach, maximum approach, travel and the total number of bleats were analysed by least-square analysis of variance, as were the effects of whether or not the ewe bleated, urinated or defaecated. The effect of flock on the proportion of animals that bleated, urinated or defaecated was analysed using χ^2.

For the test performed in 1991 pre-lambing, the stage of pregnancy (dry or weeks until expected lambing date) was also included in the analysis in an attempt to identify any behavioural differences that may be associated with the physiological state of the ewe, as was the flock x stage of pregnancy interaction.

The coefficients of repeatability for the four movement parameters and the numbers of bleats were calculated as the intraclass coefficient of correlation and their confidence intervals calculated as described by Bogyo and Becker (1963).

Frequency distributions were performed on minimum and maximum approach, travel and number of bleats. Square root and log transformations were performed on skewed distributions in an attempt to normalise them.

5.3 RESULTS

5.3.1 Open-field test

There was no effect of flock on the number of squares crossed with the Random ewes crossing only slightly more squares than the Fertility ewes (34.9±2.0 vs 32.8±1.7). There was no effect of flock for the number of bleats despite the Random ewes bleating 17% more often than the Fertility ewes (29.8±1.8 vs 25.4±1.6). The effect of flock on whether the ewe urinated, defaecated or grazed did not reach significance.

Ewes that urinated or defaecated did not differ in the number of squares crossed nor in the number of times that they bleated. However, ewes that grazed crossed significantly ($P<0.001$) fewer squares than those that did not graze (26.7±2.0 vs 38.5±1.6) and bleated significantly ($P<0.01$) less than those that did not graze (21.2±1.7 vs 31.8±1.5).

Because of the lack of significant flock effect on any parameters, ewes were not subjected to the open field test in 1991.

5.3.2 Arena test

(i) Pre-joining 1990

There were significant effects of flock on minimum ($P<0.01$) and maximum ($P<0.05$) approach, on travel ($P<0.01$) and on the number of bleats ($P<0.001$) (Table 5.1) but there were no effects of flock on the proportion of ewes that bleated, urinated or defaecated (Table 5.1).

The frequency distributions of minimum and maximum approach were both markedly skewed; most of the ewes approached to within 2m of the human in the arena and most of the ewes reached the squares that were furthest from the human (Figure 5.1). However, both square root and log transformations failed to normalise their distributions.

Table 5.1. Mean (± s.e.m.) minimum, mean and maximum distance from the human being, mean (± s.e.m.) total distance travelled and number of bleats in the arena test carried out pre-mating 1990, pre-mating 1991 and pre-lambing 1991 on ewes from the Fertility and Random flocks.

Parameter	Pre-mating 1990		Pre-mating 1991		Pre-lambing 1991	
	Fertility (n=84)	Random (n=82)	Fertility (n=89)	Random (n=83)	Fertility (n=84)	Random (n=80)
Minimum distance (m)	2.37^{***a} ± 0.19	1.65 ± 0.11	2.59^{***} ± 0.22	1.36 ± 0.12	1.87 ± 0.24	1.37 ± 0.17
Mean distance (m)	6.24 ± 0.21	6.10 ± 0.19	6.39 ± 0.22	6.07 ± 0.21	4.81 ± 0.31	5.19 ± 0.27
Maximum distance (m)	11.15^{*} ± 0.18	11.65 ± 0.10	11.46 ± 0.14	11.76 ± 0.13	10.23^{*} ± 0.31	11.45 ± 0.19
Travel (m)	54.39^{**} ± 3.87	88.54 ± 4.25	67.41^{***} ± 4.89	101.05 ± 4.07	44.59^{***} ± 3.70	83.84 ± 4.13
Number of bleats	31.24^{***} ± 2.75	48.06 ± 3.62	20.40^{**} ± 2.51	30.31 ± 2.89	20.02^{*} ± 3.53	28.09 ± 3.34
Proportion of ewes that						
- bleated	0.88	0.96	0.75^{***}	0.92	0.77^{***}	0.94
- urinated	0.40	0.54	0.33	0.43	0.37	0.48
- defaecated	0.17	0.20	0.18	0.13	0.21	0.21

[a] at any one testing period, the following refer to the significance of differences between the Fertility and Random flock ewes:
* P<0.05
** P<0.01
*** P<0.001

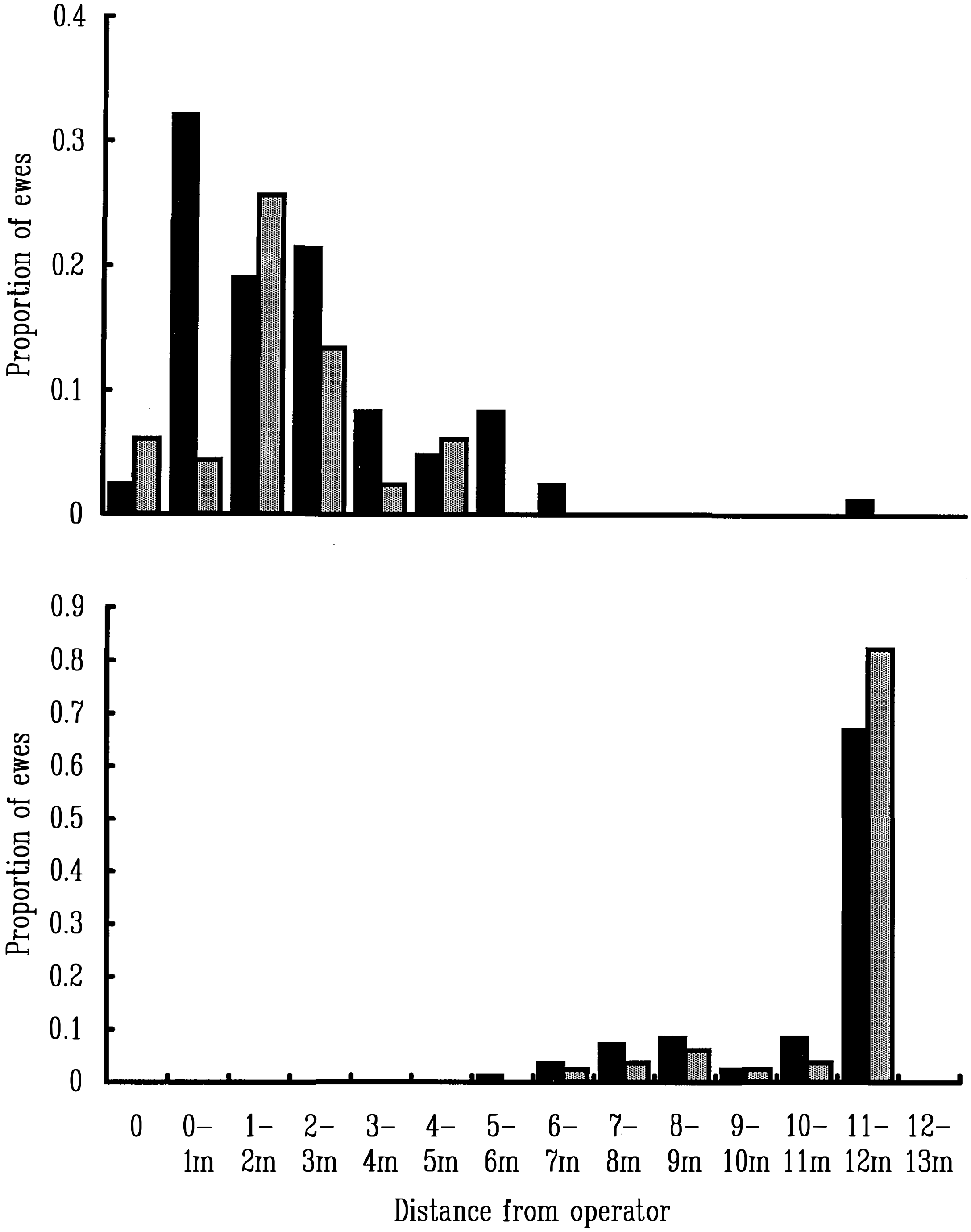


Figure 5.1 The distribution of minimum approach (upper) and maximum approach (lower) for ewes from the Fertility (black bars) and Random (grey bars) flocks in the 1990 pre-joining arena test.

The number of bleats was also skewed in its frequency distribution (Figure 5.2) and the log transformation stabilised the variance. The number of bleats ranged form 0 to 84 for the Fertility ewes, with 12 not bleating at all while for the Random ewes, number of bleats ranged from 0 to 131 with six ewes not bleating. Travel distance was normally distributed and ranged from 0 to 166m for the Fertility ewes and from 4.5 to 183m for the Random ewes.

(ii) Pre-joining 1991

There were significant effects of flock on minimum approach ($P<0.001$), travel ($P<0.001$) and number of bleats ($P<0.01$) (Table 5.1). There was also a significant effect of flock on the proportion of ewes that bleated ($\chi^2_{1df}=10.21$, $P<0.001$) with a lower proportion of Fertility ewes bleating during the test compared to the Random ewes (Table 5.1). There was no effect of flock on the proportion of ewes that urinated or defaecated.

Once again, the frequency distributions of minimum and maximum approach were skewed. The greater proportion of ewes from both flocks approached to within 2m of the human in the arena, and most reached those squares that were furthest from the human (Figure 5.3).

The frequency distribution of bleats was normal and ranged from 0 to 100 in the Fertility ewes and 0 to 127 in the Random ewes. Twenty-seven (31%) Fertility ewes did not bleat, while nine (11%) Random ewes did not bleat.

Travel was also normally distributed and ranged from 2.8 to 197.0m in the Fertility ewes and from 13.5 to 192.3m in the Random ewes.

(iii) Pre-lambing 1991

Random ewes had a higher maximum approach ($P<0.05$) and also travelled ($P<0.001$) and bleated ($P<0.05$) more than the Fertility ewes (Table 5.1). There was no significant effect of stage of pregnancy for any of the parameters measured.

A significantly lower proportion of the Fertility ewes bleated during the tests compared to the Random ewes ($\chi^2_{1df}=11.39$, $P<0.001$), while flock had no effect on the proportion of

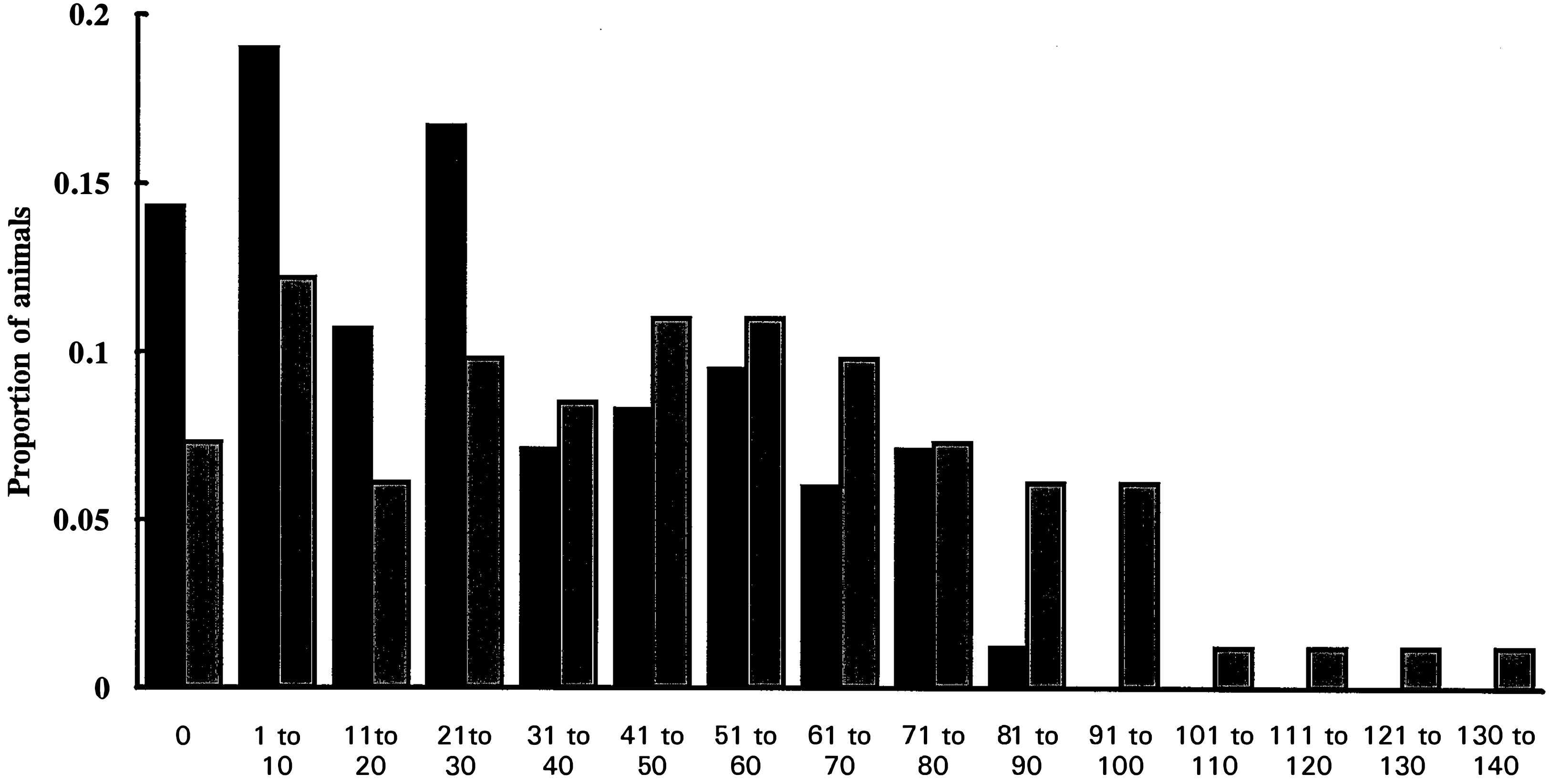


Figure 5.2 The distribution of the number of bleats in an arena test for ewes from the Fertility (black bars) and Random (grey bars) flocks in the 1990 pre-joining arena test.

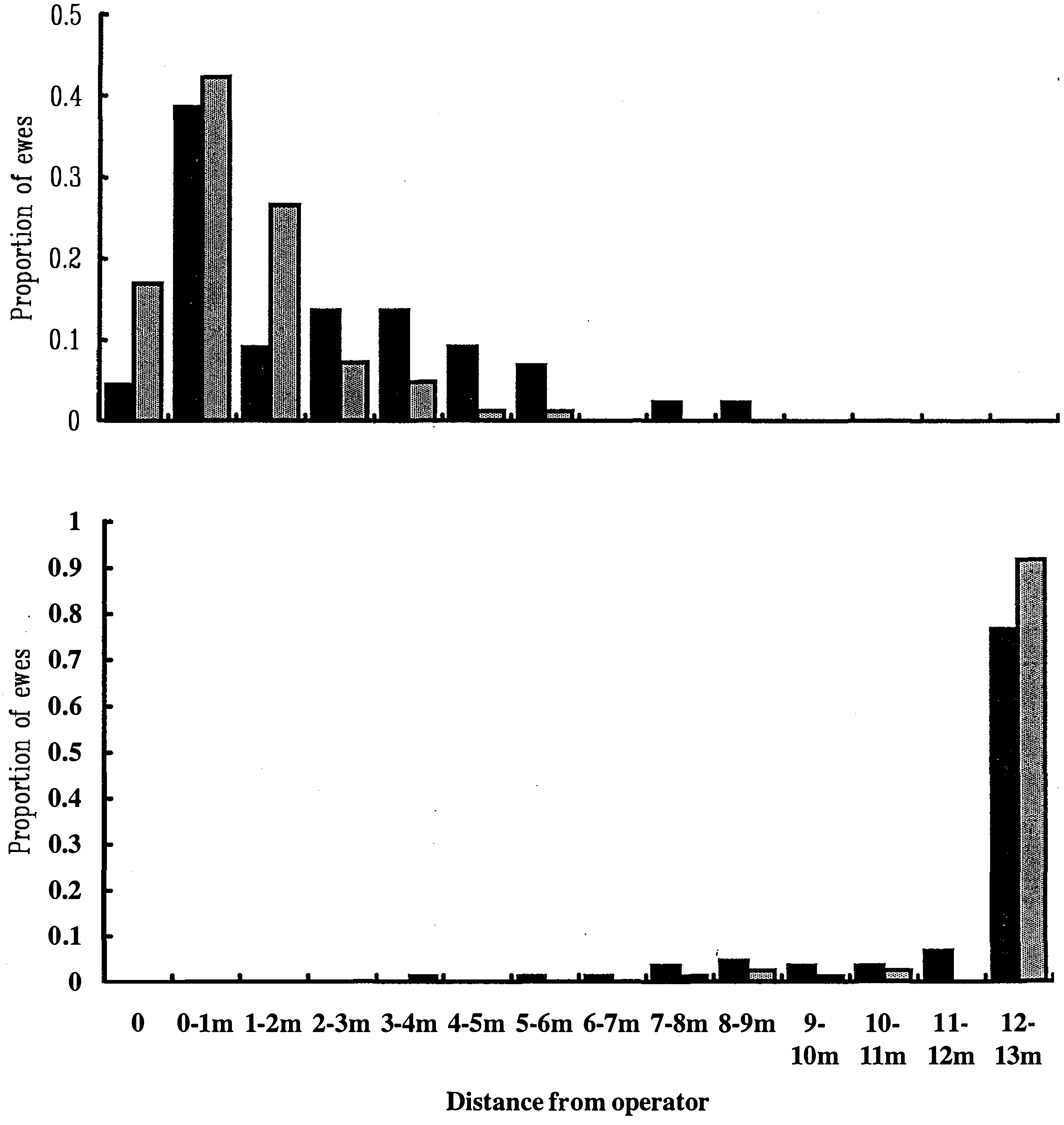


Figure 5.3 The distribution for the minimum and maximum approach in the 1991 pre-joining arena test for ewes from the Fertility (black bars) and Random (grey bars) flocks.

ewes that urinated or defaecated (Table 5.1).

The frequency distribution for minimum and maximum approach distances were skewed in a similar fashion to those seen at the previous testing times (Figure 5.4). Neither the square root nor the log transformations stabilised the variances.

Both travel and number of bleats were normally distributed. The number of bleats ranged from 0 to 81 and from 0 to 91 for the Fertility and Random ewes respectively, while travel ranged from 1.0 to 175.6m for Fertility ewes and 4.0 to 160.3 for Random ewes.

(iv) Repeatability

All the measurements were moderately to highly repeatable as indicated by their coefficients of repeatability and their confidence intervals (Table 5.2).

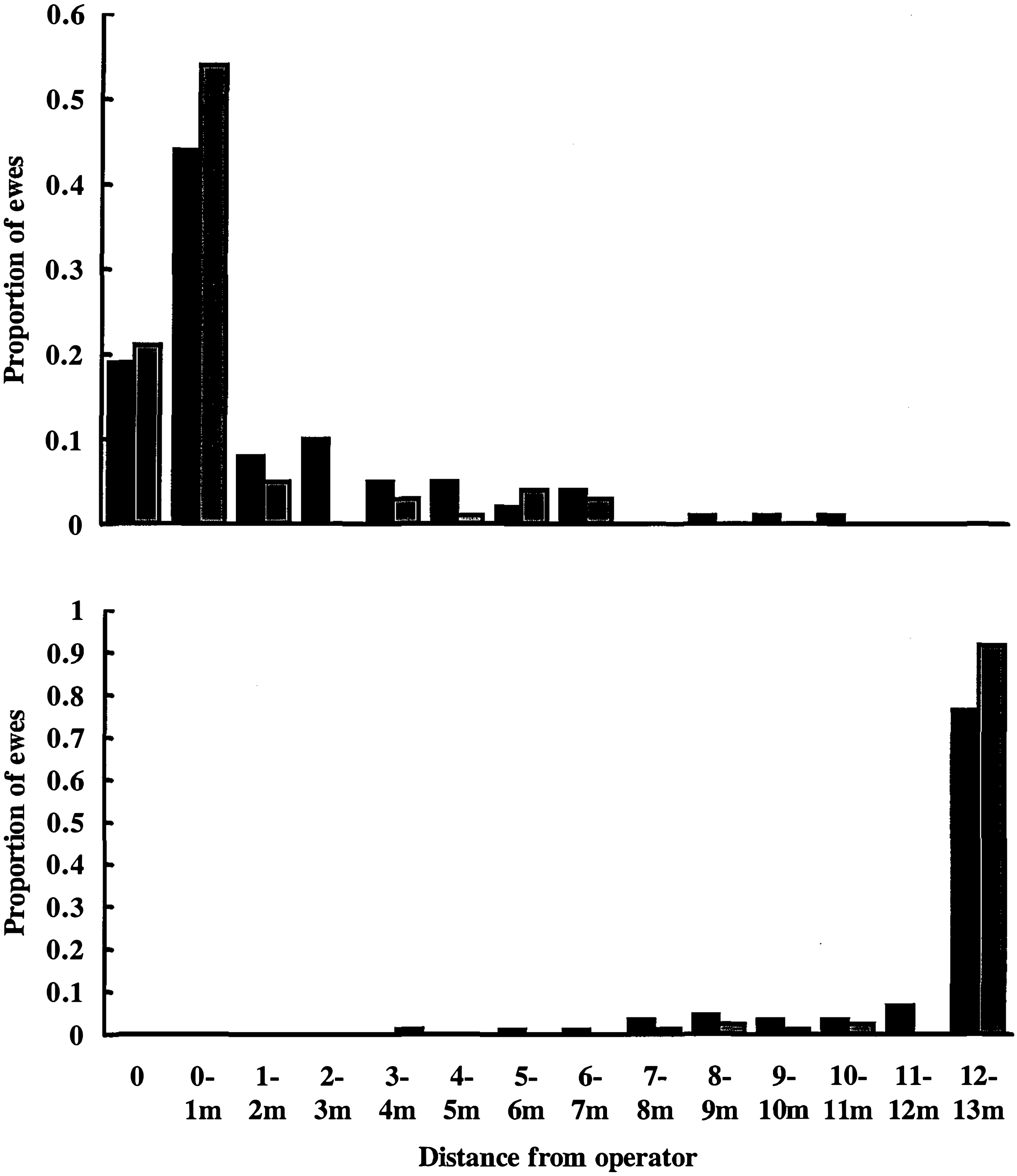


Figure 5.4 The distribution for minimum approach (upper) and maximum (lower) approach in the 1991 pre lambing arena test for ewes from the Fertility (black bars) and Random (grey bars) flocks.

Table 5.2. Coefficients of repeatability and their 95% confidence intervals for the parameters measured in the arena tests carried out pre-mating 1990 and 1991 and pre-lambing 1991.

Parameter	Coefficient and confidence interval
Minimum distance	0.51 (0.41, 0.58)
Mean distance	0.27 (0.17, 0.36)
Maximum distance	0.18 (0.08, 0.27)
Travel	0.48 (0.38, 0.55)
Number of bleats	0.57 (0.48, 0.64)

5.4 DISCUSSION

5.4.1 Open-field test

This experiment detected no differences between the ewes from the Fertility and Random flocks in any of the parameters measured. Only animals that grazed during the open-field test behaved differently to those that didn't in that they crossed fewer squares and bleated less frequently. This could indicate that they used grazing as a displacement behaviour.

The above results are different to those of Putu (1988) who found flock differences in the open-field behaviour between ewes of the TRA (1/2AMS x 1/2Trangie Fertility) flock and those that had not been selected for maternal ability. The TRA ewes were less active than the other two genotypes in the open-field test and were therefore considered to be less emotive despite the fact that they vocalised more during the test. A significant correlation was then found between the temperament of the ewes (number of squares crossed) and subsequent maternal behaviour at lambing (0.65).

Maternal behaviour in ewes is an activity that is likely to be highly dependant on the temperament of the animal concerned and therefore some prediction of maternal behaviour could possibly be obtained by measuring temperament. However, in this experiment, the complete absence of any significant differences between the Fertility and Random flocks in all the parameters measured suggests that the behavioural traits used to detect possible differences were not correlated with the maternal ability of the animals involved or that no differences in maternal behaviour existed between the animals involved. Several workers have been cautious in their use of open-field tests as a 'true' measure of temperament and Kilgour (1975) suggested that the choice of behaviours such as ambulation or defaecation may not be discrete enough to detect differences between the groups involved.

5.4.2 Arena test

What is being measured in the arena test is still uncertain but basically the sheep that enters the arena is faced with a motivational choice of whether to approach the end of the arena where the other sheep are situated or to avoid approaching the person situated near these sheep. This is called an approach-avoidance conflict situation. From the tests performed, the Fertility ewes travelled and bleated less than the Random ewes, suggesting that they were less agitated or stressed whilst in the arena. The proportion of Fertility ewes that bleated during the test was significantly less, on two of the three occasions, than the Random ewes, also suggesting that they were less stressed. These results support the work of Putu (1988) where the 1/2 Fertility ewes appeared less agitated than the other two flocks in both the open-field and temperament box tests.

Many studies have used measures of defaecation as a means of assessing the degree of stress exhibited by the animal in tests of emotionality (Archer, 1973). Ivinski (1966) confirmed the reliability of defaecation as a consistent measure of emotionality in different test situations for rats. Therefore, in the absence of any flock differences for the proportion of ewes that defaecated or urinated whilst in the arena test, these measures of emotionality did not contribute to the significant difference in the levels of agitation exhibited by the ewes from the Fertility and Random flocks. In the absence of any flock differences, overall, the proportion of ewes that urinated was greater on all three occasions than the proportion of ewes that defaecated (Table 5.1). Therefore, it could be suggested that defaecation is a more subtle assessment of nervousness than urination and has been used more extensively in studies reviewed by Archer (1973).

However in the above studies, ewes that defaecated and urinated were no more likely to bleat and did not differ in their arena behaviour compared to ewes that did not defaecate or urinate and ewes that bleated in the arena did not differ in their arena behaviour to those that did not bleat. This suggests that the differences found between the two flocks in their behaviours, may not be related to stress and what the arena test actually measures may not be stress related.

The arena test consistently revealed differences between the two flocks for travel and number of bleats, and on two of the three occasions, significant flock differences were also recorded in minimum approach, maximum approach and the proportion of ewes that bleated during the test. No flock differences were seen over the entire test period for the mean approach distance. The lack of significant flock difference in the mean approach distance was surprising since it gives an average measure of what the animal did during the whole test, rather than just one of forty measurements as is the case for minimum and maximum approach.

Perhaps a more valid measure may have been to record every movement of the animal during the 10 minute period instead of just every 15seconds. During the observations in this study, some ewes were seen to travel the entire length of the arena and return to the exact square before the next 15 second recording and therefore their movement would have been recorded as zero when in fact it should have been much more.

On all but one occasion, the frequency distributions for travel and number of bleats recorded during the test were normally distributed whereas the distributions for minimum and maximum approach were always skewed. A possible explanation for this skewness would be the fact that these two measurements only require the animal to be at their minimum and maximum distances briefly during the entire test for it to be recorded and therefore do not represent an overall picture of what the animal did. Another interesting observation was that almost all animals tested attained these maximum and minimum distances (Figures 5.1, 5.3 and 5.4). What may have been more productive could have been a measure of the time spent at these two distances sinceh some ewes were observed to spend the entire test at the maximum distance away from the human in the arena.

As mentioned previously, it is difficult to ascertain exactly what the arena test measures, although other studies give some insight. In the study of Fell and Shutt (1989), the behaviour of the animals towards the human operator following a surgical operation, the stress of which had been ascertained using cortisol and β endorphin, showed that a difference between the two groups of animals was evident immediately the animals entered the arena. Control animals moved towards the handler whereas surgically treated animals moved in the opposite direction. Fell and Shutt (1989) described the result as a cognitive response to the stress associated with the operation which, when added to the hormonal and behavioural measurements, provides a more complete picture of the stress response.

Fell *et al* (1991) used *Haemonchus contortus* infection as well as the introduction to a feedlot for some of the animals as chronic stressors. The infected sheep approached significantly closer to the person than the control sheep (3.6 vs 5.4m) and this was true for both the feedlot and paddock sheep. While at pasture, the infected sheep from the feedlot walked significantly further than those not infected (41 vs 31m) and the sheep from the feedlot walked about twice the distance of sheep at pasture (36.0 vs 17.3m). The treatment effect observed between animals exposed to internal parasites and the controls may have stemmed, not from the parasite burden itself, but from the action of acquired immunity. This is supported by the fact that only very low levels of infection resulted and outward symptoms of parasitic disease were not evident. Further work needs to be performed before the arena test can be applied to other studies of the immune response or psychophysiological factors affecting sheep.

Another study measured the effect of active immunization against ACTH (1-24) on the behaviour of animals in the arena test after being exposed to stress (Behrendt *et al*, 1991). They found that animals immunized against ACTH exhibited a marked increase in avoidance behaviour and locomotor activity. This however was not associated with increased fearfulness in their temperament and suggests that the immunization resulted in a lack of feedback of ACTH or cortisol in response to stressful stimuli.

From the above observations, the arena test consistently detected differences in the behaviour of ewes that differed genetically in their capacity to rear lambs but the open-field test did not. The arena test has generally been used as a measure of stress and welfare in animals and although the studies presented above are generally not consistent with the findings of this study, they show that the arena test has provided some meaningful measures of the behaviour of sheep in their reaction to a novel environment. In the present study, the fact that the ewes from the two flocks exhibited differences in their behaviour raises the possibility that the test, in a more applicable form, may be a useful technique for the genetic improvement of lamb survival, possible through maternal ability.

The level of repeatability of the arena behaviour parameters indicate that the test measures aspects of behaviour that are consistent over time and this was especially true of the two parameters, namely distance travelled and number of bleats, that consistently differed between the two flocks. Their high levels of repeatability indicate that these two parameters may be useful as indirect criteria for the genetic improvement of the rearing ability of Merino ewes.

One possible means of making the test more applicable is to measure the arena behaviour of animals in a group rather than singly. This would have the advantage of an increased throughput. However, before this can be advocated, it must be verified that the differences that appear when ewes are tested singly also appear when they are tested in a group.

Such an experiment may also be useful in resolving just exactly what the results of the arena test mean since, in the literature so far published, the arena behaviour of animals has been measured in groups of three or four animals in the arena at any one time (Barnett *et al*, 1989; Behrendt *et al*, 1991; Fell *et al*, 1990; Fell *et al,* 1991; Fell and Shutt, 1989; Gates *et al*, 1992) as opposed to only one animal in the case of the studies here. Since sheep are, by nature, gregarious animals, their behaviour in the arena when they are on their own will possibly differ from that when they are in a group. The following chapter tests this hypothesis.

CHAPTER 6. COMPARISON OF ARENA TEST BEHAVIOUR WHEN SHEEP ARE TESTED INDIVIDUALLY OR IN GROUPS

6.1 INTRODUCTION

In the the study presented in Chapter 5, significant differences in the arena behaviour between ewes from the Fertility and Random flocks were detected on each of the three occasions. However, the procedure used in the earlier study tested animals on their own. This is a significant departure from the procedure of other workers who used an arena test. They have always tested their animals in groups of either three or four (Fell and Shutt, 1989; Barnett, 1990; Barnett *et, al.*, 1990; Behrent *et al.*, 1990; Fell et al 1990). Since sheep are, by nature, flocking animals, it is possible that their behaviour in the arena on their own differs from that when they are tested in a group.

This chapter reports the results of an experiment designed to study whether differences in the behaviour of sheep when they are tested singly in the arena are maintained when they are tested in a group of four.

6.2 MATERIALS AND METHODS

6.2.1 Animals

The sheep were ewes from the Fertility and Random Flocks and were a sample of the ewes tested just before lambing in Chapter 5. Their ages ranged from two-and-a-half to eight-and-a-half years. All had given birth to at least one lamb four months prior to arena testing and had their lambs weaned two weeks prior to testing.

6.2.2 Tests performed

Ewes were tested in the arena described in Chapter 5, and the same four parameters were calculated. Ewes were tested either singly or in groups of four. When tested in a group, Fertility ewes were only ever tested with Fertility ewes and Randoms with Randoms.

Apart from this, the group composition was random. In order to overcome any effects of prior testing, half of each flock was tested first as singles and second in a group while the other half of each flock was tested in the reverse order.

6.2.3 Statistical analysis

Data were analysed as a 2x2x2 factorial with two levels for flock, type of test and order of testing. The significance of the main effects of flock, type of test and order of testing and of all first-order interactions on the four movement parameters and on the number of bleats were tested using least-squares analysis of variance. The effect of flock and type of test on the proportion of animals that bleated, urinated and defaecated was tested for significance using χ^2.

6.3 RESULTS

The behaviour of the animals in the two tests was strikingly different. When one ewe only was in the arena, there was the normal ambulatory activity accompanied in almost all cases by bleating. In the group test, the silence was "almost deafening" and the ewes generally stood in a group and hardly moved more than a few paces over the whole test. Specific effects are as follows.

(i) Travel

There were significant main effects of flock ($P<0.001$) and type of test ($P<0.001$) in that Random ewes travelled further than Fertility ewes and ewes travelled further in the single test than in the group test (Fig 6.1). There was also a significant flock x type of test interaction ($P<0.001$) whereby the significant flock effect that was demonstrated when the ewes were tested alone disappeared when they were tested in a group (Fig 6.1).

(ii) Minimum approach

There was a significant ($P<0.05$) flock x order interaction so data were analysed adjusted for order. In the single test, ewes approached closer ($P<0.001$) to the human in the arena than in the group test and this was the only significant main effect (Fig 6.1). However,

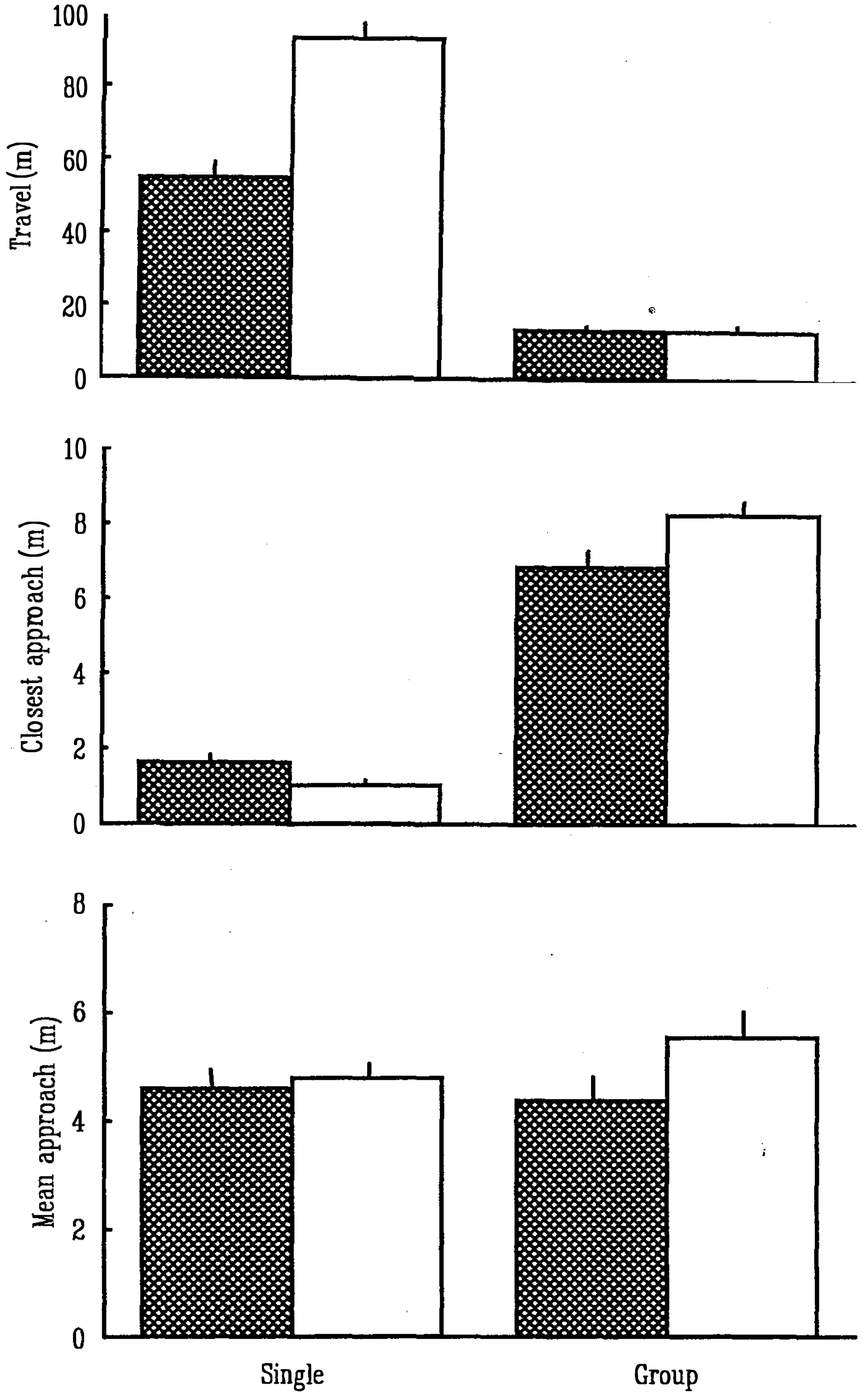


Figure 6.1 Mean (±sem) distance travelled (upper), closest approach (middle) and mean approach (lower) of ewes from the Fertility (shaded bars) and Random (white bars) flocks in an arena test when tested either singly or in a group of four.

there was also a significant (P<0.001) flock x type of test interaction whereby Random ewes approached closer in the the single tests and Fertility ewes approached closer in the group tests (Fig 6.1).

(iii) Mean approach

There were no significant main effects or interactions (Fig 6.1).

(iv) Maximum approach

There was a significant (P<0.01) test type x order interaction, so data were analysed adjusted for order. Again, there was a significant (P<0.001) main effect of type of test in that ewes moved further away from the human in the single test than they did in the group test (Fig 6.2). There was also a significant (P<0.01) effect of flock, with the Random ewes moving further away from the human than the Fertilty ewes in both types of test (Fig 6.2).

(v) Number of bleats

Flock and type of test significantly affected number of bleats (both P<0.001), with Fertility ewes bleating less than Random ewes and ewes bleating less in the group tests than in the single tests (Fig 6.2). However, the significant (P<0.01) flock x type of test interaction meant that the difference between the two flocks in the single test disappeared when the ewes were tested in a group.

(vi) Proportion of animals that bleated, urinated and defaecated

A lower proportion of the Fertility ewes urinated during the tests compared to the Random ewes ($\chi^2_{1df}=9.01$, P<0.01) while flock had no effect on for the proportion of animals that bleated or defaecated during the tests (Table 6.1). In all cases, a significantly lower proportion of ewes bleated ($\chi^2_{1df}=126.4$, P<0.001), urinated ($\chi^2_{1df}=5.07$, P<0.05) and defaecated ($\chi^2_{1df}=4.59$, P<0.05) in the group test compared to the number of ewes that bleated in the single ewe test (Table 6.1). The Fertility ewes urinated ($\chi^2_{1df}=9.48$, P<0.01) and defaecated ($\chi^2_{1df}=10.04$, P<0.01) significantly less than the Random ewes when tested in a group (Table 6.1).

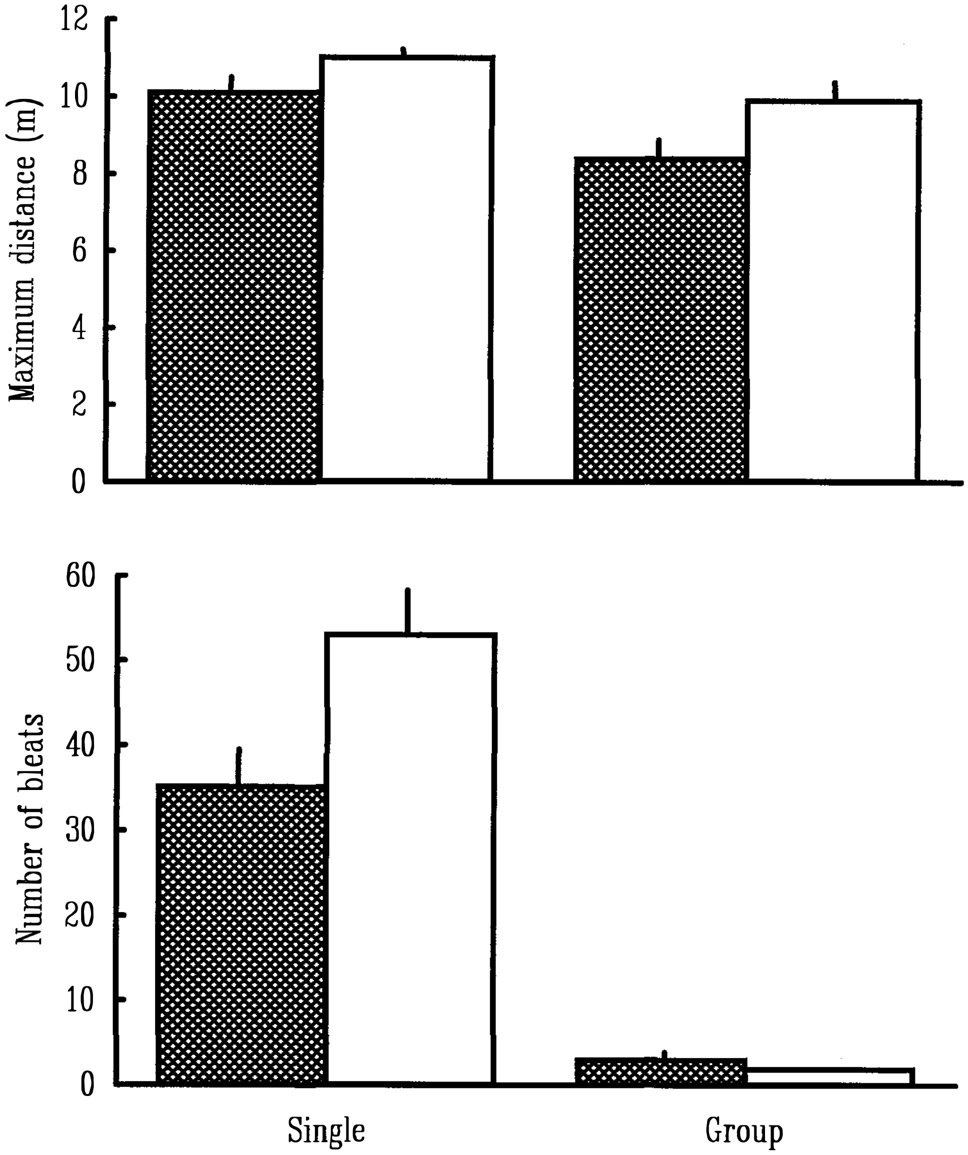


Figure 6.2 Mean (±sem) maximum approach (upper) and number of bleats (lower) of ewes from the Fertility (shaded bars) and Random (white bars) flocks in an arena test when tested either singly or in a group of four.

Table 6.1. Numbers (proportion in parentheses) of ewes from the Fertility (n=46) and Random (n=56) Flocks that bleated, urinated and defaecated in the arena test when tested either singly or in a group of four.

Attribute	Single ewe test		Group test	
	Fertility	Random	Fertility	Random
Bleated	0.96 (44)	0.98 (55)	0.28 (13)	0.25 (14)
Urinated	0.52 (24)	0.59 (33)	0.22 (10)	0.46 (26)
Defaecated	0.37 (17)	0.25 (14)	0.09 (4)	0.25 (14)

6.4 DISCUSSION

The results of this study show that differences in behaviour between two flocks of sheep in an arena test, present when ewes are tested alone, disappear when the ewes were tested in a group. When ewes were tested alone, differences were seen between the two flocks in distance travelled, closest approach and number of bleats. When they were tested in a group of four, differences between the two flocks were seen in maximum approach and once again in minimum approach, except that this time, the order of the two flocks was reversed.

The direction and magnitude of the differences seen in the single-ewe test are similar to those reported in Chapter 5, and strengthens the previous finding of a high degree of correlation between arena behaviour measured at different times.

It therefore appears that differences in behaviour between ewes of the Fertility and Random flocks may only be detected by the arena test when the ewes are tested one ewe at a time, and that the social interactions between the animals when they are tested in a group mask the individual differences seen when they are tested individually. This was highlighted by the significantly lower proportion of ewes that bleated, urinated and defaecated when tested in a group as compared to when tested singly (Table 6.1).

However, the arena test when animals are tested in a group has demonstrated differences under a wide range of experimental conditions (Fell and Shutt, 1989; Barnett, 1990; Barnett *et al.*, 1990; Fell *et al.*, 1990; Behrent *et al.*, 1991), and what has probably happened is that the differences under these conditions are large enough to override any social effect of being in a group. In conclusion, the results suggest that for the characters measured in the arena test, the testing of ewes in a group did not provide any conclusive results and therefore the testing of ewes singly was considered the appropriate method to study further.

CHAPTER 7. HORMONAL RESPONSE TO STIMULI TO THE HYPOTHALAMIC-PITUARY-ADRENAL AXIS

7.1 INTRODUCTION

In Chapter 5, differences between the Fertility and Random flocks in arena behaviour were detected, and the aim of the experiment reported in Chapter 6 was to improve the applicability of the test by measuring animals in groups of four rather than singly. However, Chapter 6 showed that in a group test, the differences between the two flocks disappeared so this avenue of investigation was curtailed.

However, another way of interrogating the behaviour of the animals without the time-consuming arena test might be to measure their response to a hormonal stimulus. The results of Chapter 5 demonstrated behavioural differences between ewes from the Fertility and Random flocks which may reflect differences in the degree of agitation following introduction to a novel environment or to novel stimuli. Previous studies have shown that introduction to a novel environment leads to marked increases in plasma cortisol levels whereas animals which are familiar with the environment do not show these increases (Echternkamp, 1984). Similar increases in cortisol have also been seen in animals subjected to acute stresses such as physical restraint, fright and thermal heat (Thatcher, 1974).

Shutt *et al* (1987) recorded increases in cortisol following such surgical procedures as castration, tail docking and mulesing. It was later shown (Fell and Shutt, 1989) that animals subjected to the mules operation not only showed an immediate rise in cortisol but their long-term cognitive behaviour, as reflected in the arena test, differed greatly from those animals that were not mulesed. Barnett *et al* (1989) reported changes in behaviour after administration of endogenous opiates and histamine. Behrendt *et al* (1991) showed that active immunization against ACTH (1 24) clearly influenced cognitive behaviour.

Therefore it is likely that arena behaviour will be correlated with some measure of stress, and one that warrants investigation is cortisol response to ACTH. This is indirectly supported by the study of Brown and Nestor (1973) who developed two lines of turkeys on the basis of their plasma corticosterone level after cold stress - high and low levels. Similar responses were to heat stress and ACTH injections with the response to ACTH suggesting that genetic selection altered the adrenal response to ACTH. The two lines also varied in their reproductive performance. A cortisol response has also been shown to be repeatable by Hennessy *et al* (1988) and therefore may be a reliable indicator of an animal's response to stressors.

7.2 MATERIALS AND METHODS

7.2.1 Experimental design

The experimental animals were mature Merino ewes from the Trangie Fertility and Random flocks. Animals were selected from each flock on the basis of their ranking according to their total distance travelled in the arena test (Chapter 5). Thirty-two animals were selected from each flock such that 16 of these travelled the maximum distances in the previous test while 16 travelled the minimum distances in the previous test. These were allocated at random after stratification on "temperament" to one of the following treatments:

Treatment 1: Infusion of 0.2mg ACTH 1-24 (number of animals = 22).
Treatment 2: Infusion of 0.4mg ACTH 1-24 (number of animals = 22).
Treatment 3: Exposure over 10 min to a barking dog running down the aisle between the penned ewes (number of animals = 24).
(Source of ACTH 1-24: Auspep, Melbourne, Australia)

7.2.2 Procedure

Animals were housed in pens in an animal house for ten days prior to the start of ACTH/stress treatment to acclimatize them to a novel environment and to allow blood cortisol levels to decrease to a concentration as low as possible. After 10 days catheters were inserted into one jugular vein of each ewe and ewes were bled twice daily until the treatment day. Animals were fed ***ad lib*** throughout the experiment. Sufficient 'spare' animals were also introduced to pens to allow for animals that did not eat the ration. For any treatment, 32 animals were initially introduced and this number was reduced to 24 immediately prior to the commencement of pre-bleeding. For Treatment 1 and 2, several animals did not adapt to the ration provided and had to be removed. Because of the limited number of animals available, only 22 experimental animals were available for each treatment.

Treatment 1 was performed after 7 days of pre-bleeding while animals on the other two treatments were still bled twice that day. Treatment 2 was performed the following day while animals on Treatment 3 were again bled twice that day. Treatment 3 animals were bled twice daily for the following two days and on the third day the treatment was performed. All animals were removed from the animal house at the conclusion of Treatment 3.

Prior to the commencement of treatment, animals were bled at intervals of 20 minutes for a period of two hours (pre-bleeding) in order to establish a baseline level of cortisol. Immediately following the last bleed of the pre-bleeding period, treatment was commenced. For Treatment 1 and 2, animals were bled immediately following cessation of treatment and at 10-minute intervals thereafter for two hours whereas for Treatment 3, bleeding commenced 10 minutes after the cessation of treatment. Bleeding then continued at 15-minute intervals for two hours then at 20-minute intervals for two hours.

Blood was centrifuged as soon as possible after collection and the plasma poured off and frozen at -20 degrees celcius until assayed for cortisol.

7.2.3 Blood analysis

The assay for cortisol was the direct double-antibody radioimmunoassay for cortisol in human serum (Farmos Diagnostica, Turku, Finland). According to information supplied with the kit, the assay has negligible (<2%) cross-reactivity with other endogenous corticosteroids and cortisol metabolites and binding to cortisol binding globulin is inhibited by cortisol analogues. The sensitivity of the assay was 5nmol/l, intraassay coefficients ranged from 1.5% at 520nmol/l to 4.6% at 70nmol/l and interassay coefficients of variations ranged from 3.5% at 650nmol/l to 7.1% at 85nmol/l.

7.2.4 Statistical analysis

The data were analysed by least-squares analysis of variance for the significance of the effect of flock on the following four parameters for the three treatments:

(i) initial (mean) - this incorporated the first 7 bleeds of the experiment prior to the commencement of treatment in order to obtain a baseline for cortisol levels in the animals prior to treatment.

(ii) first hour post-treatment (mean) - this incorporated bleed 8-14 for Treatment 1 and 2 and bleed 9-14 for Treatment 3 in an attempt to measure the immediate response to the treatment and its possible effect on cortisol levels.

(iii) response - this was calculated from (ii) - (i).

(iv) total - this was the overall response to each treatment calculated by the sum of all the bleeds (cortisol levels) during the experiment. For Treatment 1 and 2 there were 33 bleeds and for Treatment there were 32 bleeds incorporated into the 'total' response.

Data were also analysed by least-squares analysis of variance for the significance of flock, treatment and flock x treatment interaction for all animals for the above four parameters (i-iv) as well as the following parameters:

(v) pre-total - this was the sum of the bleeds prior to the commencement of treatment.

(vi) first hour total - this was the sum of the bleeds for the first hour post-treatment.

(vii) second hour total - this was the sum of the bleeds for the second hour post-treatment.

(viii) first two hours total - this was calculated by (vi + vii).

Data were then analysed within each flock, using the pooled ACTH treatment groups, by assigning animals to quartiles based on arena travel (top 25%, next 25%, next 25% and bottom 25%). The effect on cortisol levels (parameters i-viii), when the ACTH treatments were pooled, of whether or not the animal bleated, urinated or defaecated during the previous arena test was also analysed within each flock.

7.3 RESULTS

7.3.1 Flock effects within each Treatment

(i) Treatment 1 - low dose of ACTH
There were no significant effects of flock on the four parameters measured although the Random ewes generally had higher cortisol levels (Table 7.1).

(ii) Treatment 2 - high dose of ACTH
Once again there were no significant effects of flock for the four parameters measured although the Random ewes had higher levels of cortisol for all the parameters measured except for the initial levels (Table 7.2).

(iii) Treatment 3 - exposed to dog
In this case the Fertility ewes had higher levels of cortisol for the parameters measured but none of the differences were significant (Table 7.3).

(iv) Overall treatment response
As shown in Figure 7.1, although there was no significant flock effect on the levels of cortisol at different stages of each treatment, there was an overall trend for cortisol levels to increase sharply after bleed 7 for both flocks, (with the exception of Treatment 3 which wasn't so sharp) which corresponded to the last bleed prior to treatment. After the treatment was applied, cortisol levels remained high for at least the first hour post-treatment (up to bleed 14) before they began to decrease. When the data were analysed for the pooled ACTH treatments, no significant flock effects were seen for any of the parameters measured (Figure 7.2).

Table 7.1. Mean (±sem) levels of cortisol (ng/ml) for the initial, first hour, response and total measurements for animals in the Treatment 1 group.

Attribute	Fertility flock (n=10)	Random flock (n=12)
Initial (ng/ml)	38.6±5.6	32.5±5.2
First hour (ng/ml)	147.6±15.3	181.9±31.3
Response (ng/ml)	109.3±14.4	149.3±30.4
Total (ng/ml)	1983.1±199.9	2643.8±484.8

Table 7.2. Mean (±sem) levels of cortisol (ng/ml) for the initial, first hour, response and total measurements for animals in the Treatment 2 group.

Attribute	Fertility flock (n= 11)	Random flock (n=11)
Initial (ng/ml)	13.5±2.9	10.3±1.1
First hour (ng/ml)	133.2±12.0	140.1±14.5
Response (ng/ml)	119.7±12.0	129.8±13.9
Total (ng/ml)	1846.3±170.6	2019.5±255.9

Table 7.3. Mean (±sem) levels of cortisol (ng/ml) for the initial, first hour, response and total measurements for animals in the Treatment 3 group.

Attribute	Fertitliy flock (n=12)	Random flock (n=12)
Initial (ng/ml)	23.2±3.8	14.8±2.6
First hour (ng/ml)	71.9±6.8	58.1±10.7
Response (ng/ml)	48.7±5.7	43.2±9.3
Total (ng/ml)	1661.4±169.9	1473.8±199.7

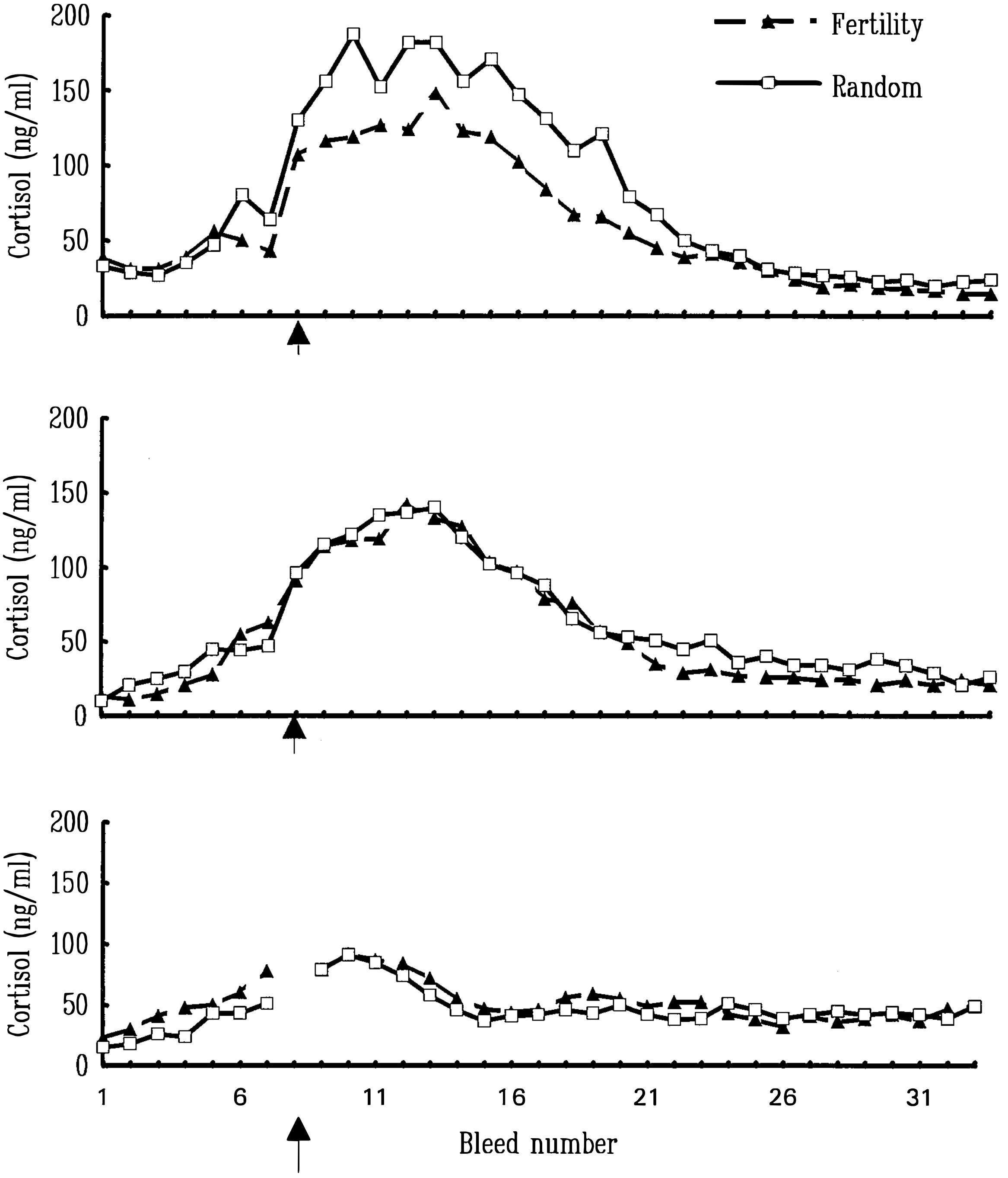


Figure 7.1 Mean cortisol levels (ng/ml) recorded for the Fertility and Random flocks over the entire bleeding period for the three treatment groups: low-dose of ACTH (upper), high dose of ACTH (middle) and exposure to the dog (lower).

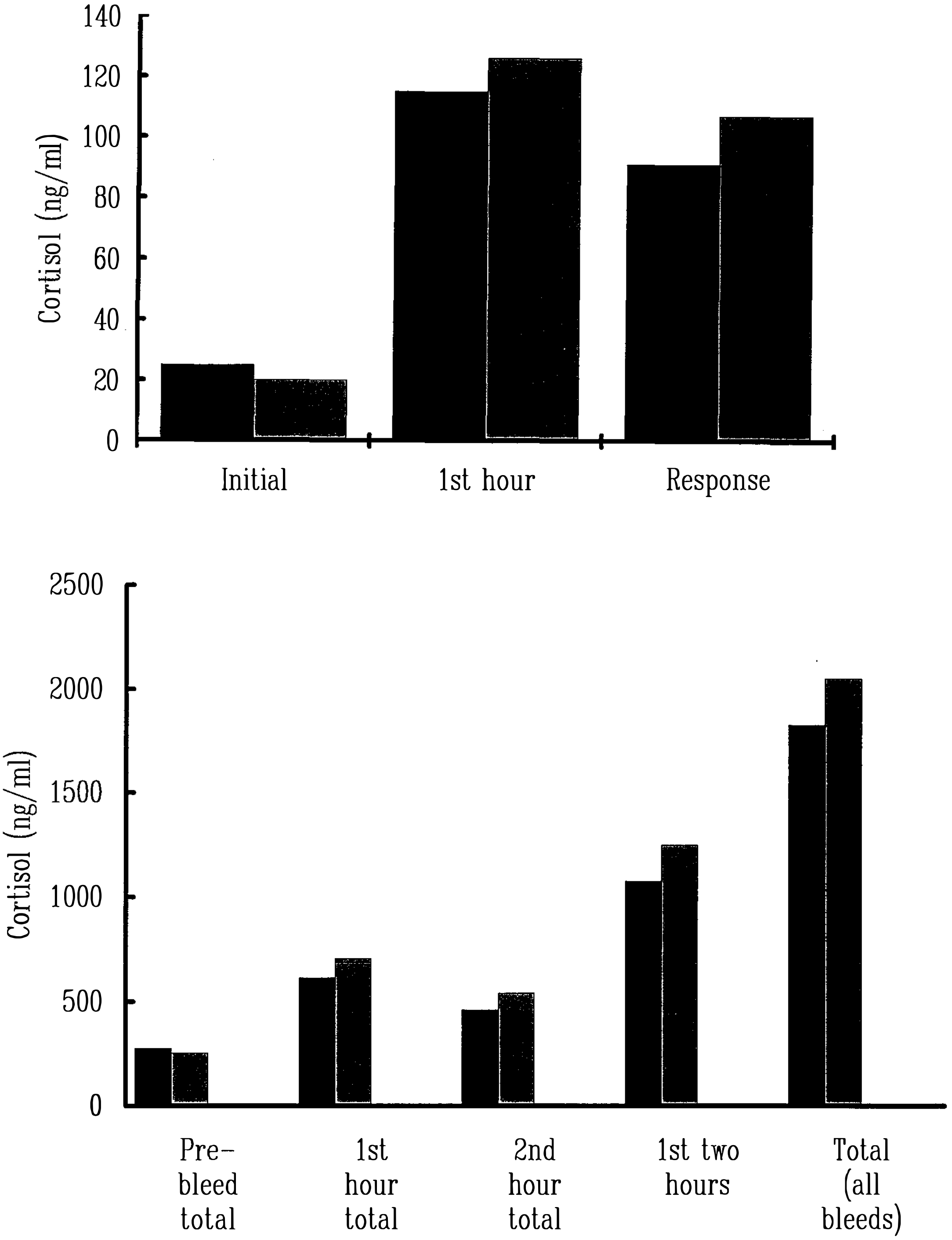


Figure 7.2 Mean cortisol levels (ng/ml) recorded for the Fertility (black bars) and Random (grey bars) flocks pooled over the two ACTH treatments for the initial, 1-hour, response, total, pre-bled total, 1st hour total, 2nd hour total and 1st two hour total.

7.3.2 Flock and Treatment effects

When the data was analysed for all animals across the three treatments, there was no significant effect of flock on the first four parameters measured (i iv), however there were significant effects of treatment for all four parameters. Animals in Treatment 1 showed significantly ($P<0.001$) higher levels of cortisol in the initial period than the animals in Treatment 3 and 2, respectively (Table 7.4). For the first hour after treatment ($P<0.001$), the response to treatment ($P<0.001$) and the total of all the bleeds ($P<0.05$), animals in Treatment 1 showed significantly higher levels of cortisol than the animals in Treatment 2 and 3, respectively (Table 7.4). There were no significant flock x treatment interactions recorded for the above four parameters.

For the following four parameters measured (v viii) there was no significant effect of flock or flock x treatment interaction. There was however significant effects of treatment on three of the four parameters. For the first hour after treatment total ($P<0.001$), the second hour after treatment total ($P<0.001$) and the total of the first two hours after treatment ($P<0.001$), animals in Treatment 1 showed higher levels of cortisol than the animals in Treatment 2 and 3, respectively (Table 7.5).

7.3.3 Within flock effects for ACTH treatments

When the animals were assigned to quartiles according to their arena behaviour, no significant effects were found for any parameters measured for either flock. The association between cortisol levels and whether or not an animal urinated (Figure 7.3 and 7.4) or defaecated (Figure 7.5 and 7.6) during the arena test, was not significant for any of the parameters measured.

Table 7.4. Mean (±sem) levels of cortisol (ng/ml) recorded for Treatment 1, 2 and 3 for the initial period, first hour after treatment, response and total of all the bleeds.

	Treatment		
Attribute	1	2	3
Initial (ng/ml)	35.3±3.8	11.9±1.6	19.0±2.4
First hour (ng/ml)	166.4±18.4	136.7±9.2	65.0±6.3
Response (ng/ml)	131.1±18.0	124.8±9.0	46.0±5.4
Total (ng/ml)	2343.5±283.0	1932.9±151.3	1567.6±129.7

Table 7.5. Total (sum) levels of cortisol (ng/ml) recorded for Treatment 1, 2 and 3 for the pre-treatment period, first and second hour and first two hours after treatment.

	Treatment		
Attribute	1	2	3
Pre-treatment total (ng/ml)	302.7±27.5	214.6±29.6	275.6±34.9
First hour total (ng/ml)	875.8±85.1	731.2±43.5	400.7±32.2
Second hour total (ng/ml)	711.6±108.6	533.6±40.3	279.9±27.1
First 2 hours total (ng/ml)	1587.4±192.3	1264.7±73.4	680.6±55.7

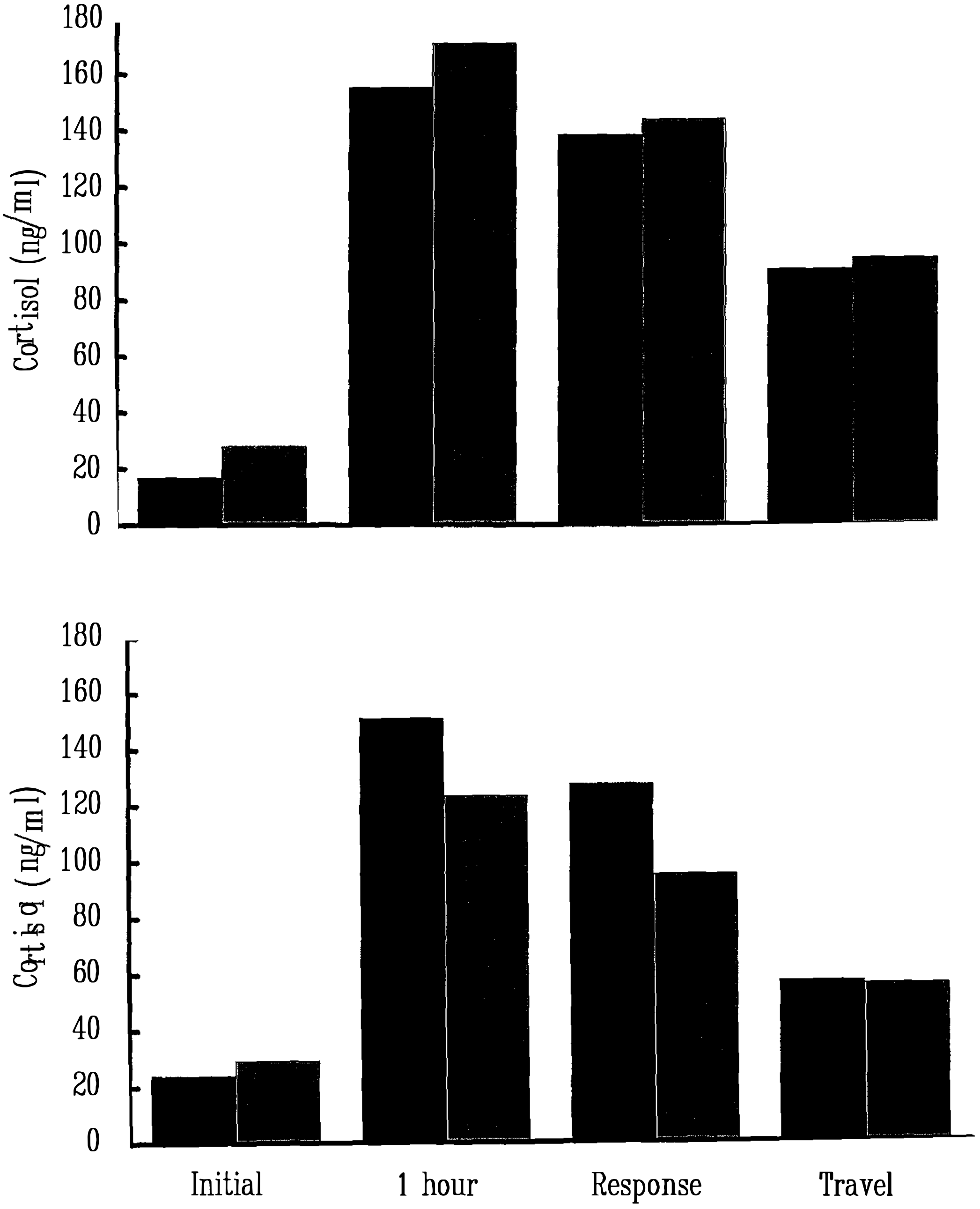


Figure 7.3. Mean cortisol levels, pooled over the two ACTH treatments, for ewes from the Fertility (lower) and Random (upper) flocks which had (black bars) or had not (grey bars) urinated during the arena test, recorded for the initial, 1-hour, response and travel parameters.

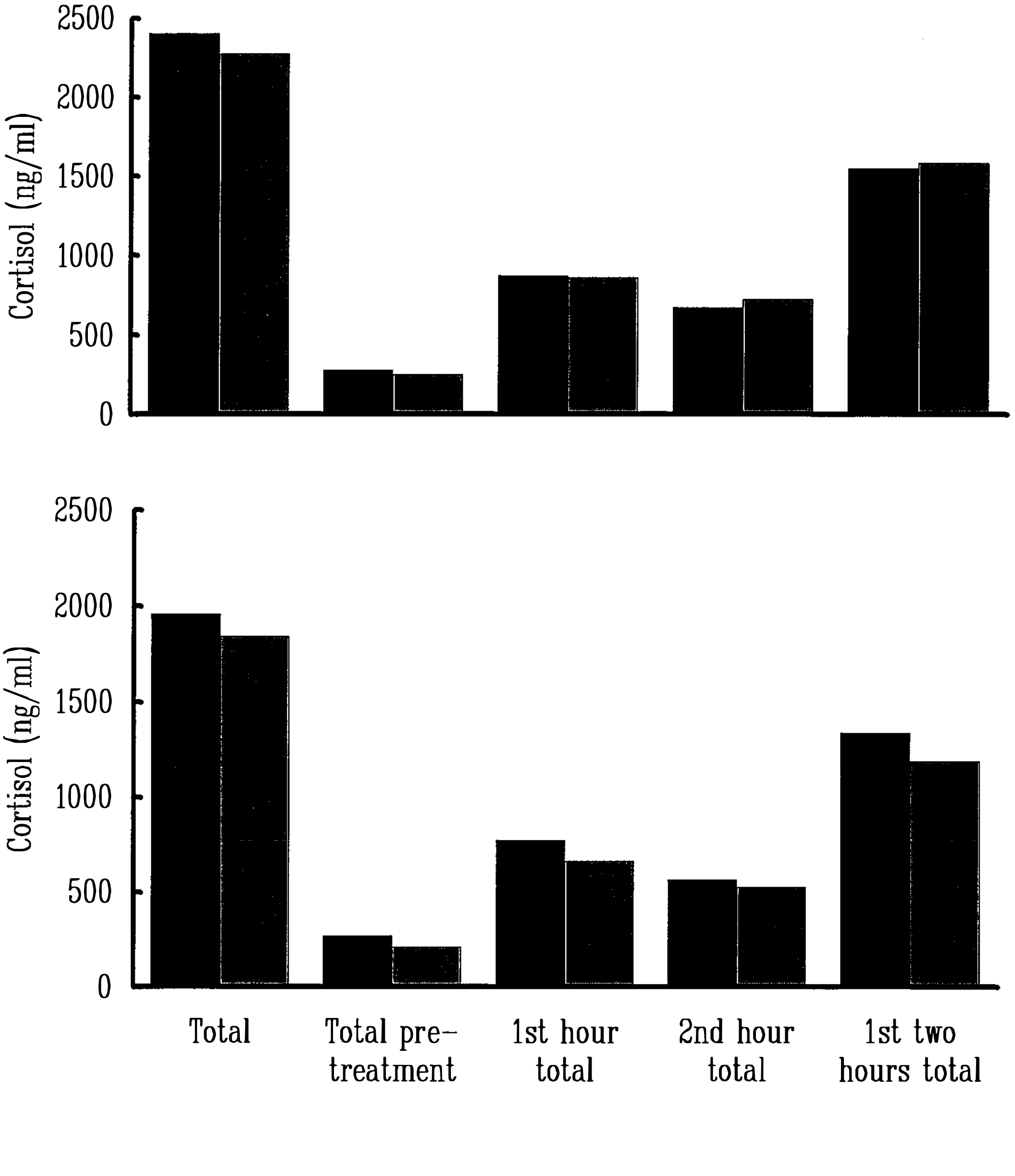


Figure 7.4. Mean cortisol levels, pooled over the two ACTH treatments, for ewes from the Fertility (lower) and Random (upper) flocks which had (black bars) or had not (grey bars) urinated during the arena test, recorded for the 1st hour total, 2nd hour total, 1st two hour total and total over all bleeds.

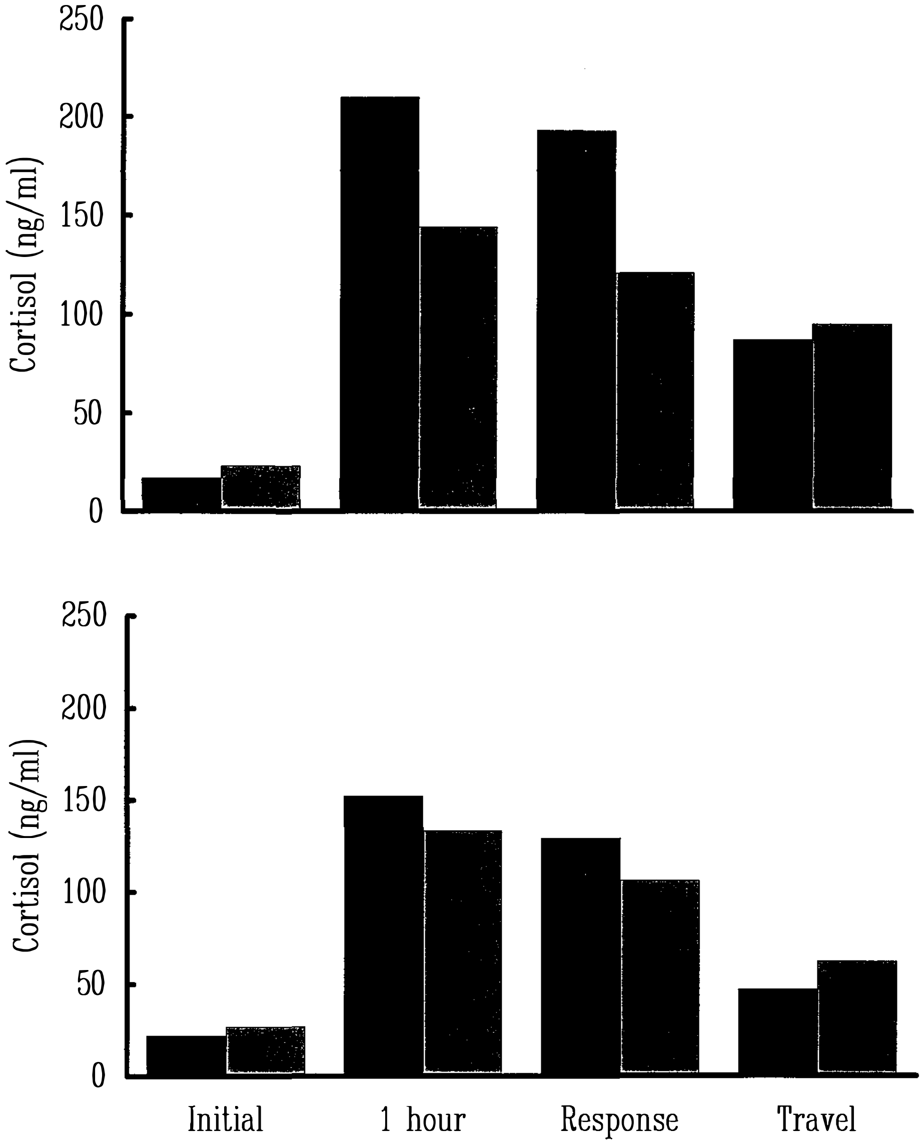


Figure 7.5. Mean cortisol levels, pooled over the two ACTH treatments, for ewes from the Fertility (lower) and Random (upper) flocks which had (black bars) or had not (grey bars) defaecated during the arena test, recorded for the initial, 1 hour, response and travel parameters.

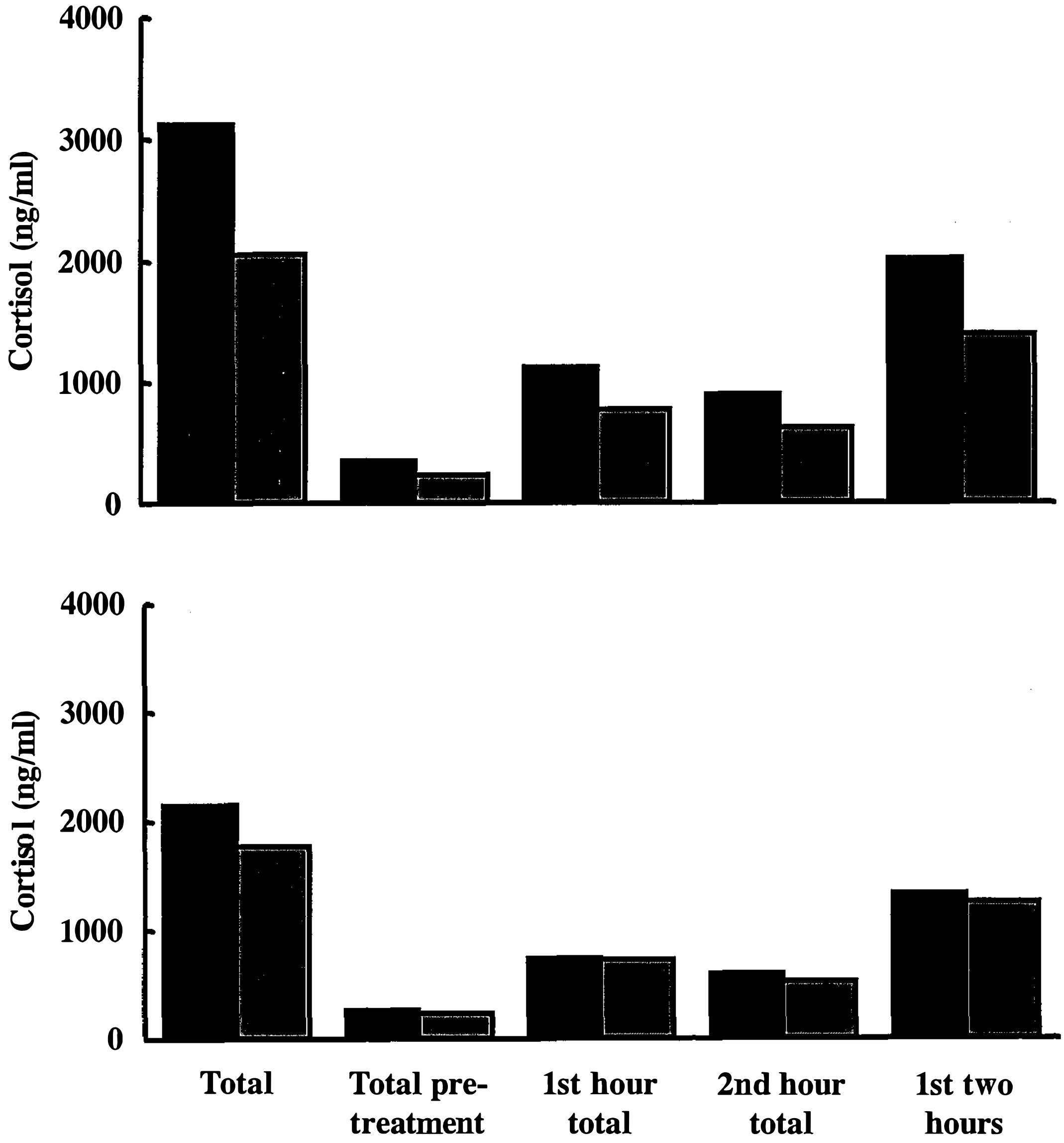


Figure 7.6. Mean cortisol levels, pooled over the two ACTH treatments, for ewes from the Fertility (lower) and Random (upper) flocks which had (black bars) or had not (grey bars) defaecated during the arena test, recorded for the 1st hour total, 2nd hour total, 1st tow hour total and total over all bleeds.

7.4 Discussion

The hormonal response of animals, in terms of plasma coritsol concentrations, showed no flock differences for any of the three treatments. Differences in adrenocortical responsiveness to ACTH stimulation between the Fertility and Random ewes did not reachsignificance for either dose of ACTH used but a similar response to the effect of ACTH on the hypothalamic-pituatary-adrenal axis was seen in both flocks and for all treatments. After the infusion of ACTH, cortisol levels rose within the first 10 minutes for both doses and reached peak levels at about one hour after treatment. The effect of exposure to the dog on cortisol levels showed a similar trend to the other two treatments with a rise in levels soon after exposure to the dog. This rise was not as sharp as for the previous treatments and tended to plateau more rapidly following treatment. Despite a lower cortisol response to the presence of the dog, it was observed that when the ewes were exposed to the dog during the treatment, there was a definite reaction towards its presence with the majority of ewes facing and watching the dog as it passed them in the race.

Although there were no flock differences for any treatment, the Fertility ewes did show lower levels of cortisol in response to ACTH treatment than did the Random ewes. One possible explanation may be that the ewes included in the low dose ACTH treatment may have had higher base levels of cortisol. For the total number of bleeds and the response to treatment, animals in Treatment 1 showed significantly higher levels of cortisol. This result suggests that the dose rate used was sufficient to obtain a response in the animals involved but the amount of variation between animals within flocks in their response to ACTH was too large (30-35%) to detect any significant differences.

As no significant flock effects were found and the dog treatment failed to provoke a response, the within flock for the pooled ACTH data was used to determine if cortisol response was related to other measures of stress such as bleating, urinating and defaecating. The animals were also assigned to quartiles based on their travel in the arena test in an attempt to identify a possible association between this and stress response in the arena. As no conclusive associations were identified for any of the parameters measured it would seem that the arena test behaviours are not primarily controlled by hypothalamic-pituitary-adrenal axis.

Differences in methodology or assay make comparison of the levels of cortisol recorded in the present study with those recorded in previous studies difficult. However the maximum levels of cortisol recorded in the present study were 166.4ng/ml for the low dose of ACTH and 139.3ng/ml for the higher dose of ACTH. These levels were recorded approximately 60 minutes after treatment and this compares well with previous studies performed on pigs. A preliminary study by Sebranek *et al* (1973) to establish the time of maximal response to ACTH in porcine animals showed a peak is achieved in 60 minutes followed by a decline. Hennessey *et al* (1988) also found that maximal cortisol response was 60 minutes after ACTH administration.

In the study of Fell and Shutt (1989), it was shown that animals surgically stressed and with high cortisol levels, behaved differently in an arena test to animals not surgically. This suggests that the arena test may be a means by which the behavioural response of sheep can be detected. What aspect of behaviour the arena test actually measures is still unsure and this raises the question of what the present study was actually measuring. One possible explanation for no flock difference in cortisol levels for any of the treatments could be that what was actually being measured in the arena test to result in a flock difference may not be related to stress at all and hence no difference in cortisol levels were recorded when the animals that behaved differently in the arena were exposed to external stressors in the animal house. What the animal expressed in the arena test and the cortisol response to ACTH may be indicative of different things, therefore not producing any flock differences.

PART C. GENERAL CONCLUSIONS

Of the studies described in this thesis, only that on the arena behaviour of ewes indicated a character that may be useful in the genetic improvement of maternal ability. Fertility ewes consistently moved about the arena and bleated less than the Random ewes and had lower minimum approach distances. These between-flock differences may suggest that selection for improved lamb survival has resulted in differences in these arena behaviours, and also indicates that the two may be genetically correlated. It is for this reason that arena behaviour may be a useful selection criteria for improving rearing success in ewes.

The underlying mechanisms contributing to the differences identified in the arena test are unclear. Certainly the behaviours relate to "isolated" or "fearful" individuals, since the differences between flocks disappear when the animals were tested in a group. It could also be possible to conclude that it is related to agitation since the Random ewes, the ewes of the poorer maternal ability, move around more, bleat more and move closer to the human in the arena, which in turn brings them closer to their flockmates, than the Fertility ewes. The open-field test that was performed with no conclusive results may have been measuring something apart from stress or agitation and therefore no flock differences were recorded which suggests that the arena and open-field tests appeared to measure different aspects of behaviour.

The reason why ewes were tested individually in the arena was that lambing is an individual behaviour when a ewe has to make the transition from being a flocking animal to an individual faced with a newborn lamb/s. However, the differences seen in the arena behaviours were not reflected in differences in behaviour around parturition. A possible explanation for this is that the observations of ewes in the paddock measured behaviour that were too gross. This has been shown by Stevens (1991) who reported flock differences in behaviour around birth only when more subtle measurements were recorded, differences which were not apparent when more gross measurements were used in the same flocks earlier. The fact that when ewes were tested in groups, no flock differences were detected but on an individual basis, the differences were apparent, therefore suggesting that further observations of a more detailed nature may be required in order to pick up differences in the paddock.

In addition to recording more subtle measurements around parturition, another possible approach could have been to develop an "index" for behaviour based on a number of these behaviours around parturition as opposed to analysing the behaviours individually. This in turn may give a better measure of what is happening given the fact that many behavioural events contribute to the overall establishment of the ewe/lamb bond and hence lamb survival.

The behaviour in the arena may not be related to stress as evidenced by the lack of cortisol response to ACTH. While the ACTH challenge appears capable of measuring flock differences, the greatest response was achieved at the lower dose which raises the question of why the higher dose did not achieve a greater response? One possible explanation could be that an optimum dose rate may exist and a more detailed dose-response experiment may have been required initially in order to achieve significant results to the ACTH challenge. Cortisol may not have been an underlying factor responsible for the differences recorded in the arena test with some other aspect of behaviour involved or a whole range of factors all working together and not detectable individually.

In conclusion, the major difference was the behaviour measured in the arena and in order to assess its usefulness as a possible selection criterion, it will have to be measured in males, and in a random-breeding flock. Whether the behavioural traits are a useful attribute to measure, whether they are heritable and how closely do they relate to lamb rearing ability of the ewes are all questions that need to be answered before extensive use can be made of the arena test as a selection criterion. Its exact relationship with maternal behaviour will probably only be known when detailed observations of lambing behaviour are made. When this occurs, we may have some idea of the physiology involved and be able to use some physiological measure, which would replace the time consuming arena test, to select rams as sires that generate ewes of strong maternal ability.

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