AN INVESTIGATION OF WASTAGE ON A COMMERCIAL SHEEP FARM IN NEW ZEALAND

KAMALIAH B GHAZALI

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AN INVESTIGATION OF WASTAGE ON A COMMERCIAL SHEEP FARM IN NEW ZEALAND

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KAMALIAH B GHAZALI

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ABSTRACT

This dissertation reports the results from an investigation of wastage on a commercial sheep farm. This traditionally summer-dry 2,952 hectares farm runs an annual average of 21,000 breeding ewes and 1,100 cattle. High levels of wastage in both ewes and lambs have been observed over the past four years, and vaginal prolapse was considered to be the major cause of loss about lambing time. The investigation described in the dissertation comprised three main parts; database analysis and disease prevalence, Androvax® vaccination, and wastage in ewes and lambs.

Database analysis and prevalence studies were conducted to provide initial animal health and production information, and aimed to quantify the extent of wastage and disease prevalence. Two databases, a farm input form and Stockpol, were used. Despite poor quality animal health records and difficulties in extracting data, a temporal pattern of ewe wastage in different age groups and lamb wastage was able to be constructed and it showed consistently high wastage of ewes and lambs over the past five years. Prevalence of disease investigations confirmed high prevalences of infectious footrot and pneumonia, and a low but significant prevalence of Johne's disease.

For a clinical trial to determine the effects of Androvax® vaccination, 300 mixed age control ewes selected in March 2006 were ultrasound scanned and their pregnancy status compared with vaccinated ewes running together in the same flock. The risk of carrying multiple lambs in vaccinates and controls was the same but vaccinates were about two times more likely to carry triplets than control ewes. A partial budget indicated that discontinuing Androvax® vaccination would result in savings of about $115.06 per 100 ewes.

For the wastage study, a total of 531 mixed age ewes were enrolled after ultrasound scanning on 15th June 2006 and observed from scanning to weaning for any deaths. From 22nd August to 12th September 2006, all ewes and lambs that died and were found were necropsied to determine the cause of death. The incidences of wastage were 3.1% and 12.1% for ewes and lambs respectively. Dystocia and starvation were the main causes of death in ewes and lambs respectively.

This study identified certain issues and constraints for on-farm investigations which included incomplete data, difficulties in quantifying disease prevalence and prioritising control measures, evaluation of existing management techniques and determining causes of deaths. Solutions were found for most of the issues and the study in particular highlighted the usefulness of sentinel groups for investigation of causes of wastage and the value of field trials for evaluating interventions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

1 LITERATURE REVIEW

1.1 General introduction

Efficiencies introduced through improved farm management techniques are recognised as important ingredients for determining the profitability of farming enterprises. Two elements of efficiency in production systems have been described, technical efficiency and allocative efficiency (Fraser & Hone, 2001). Technical efficiency measures the ability to produce maximum output given a set of inputs, while allocative efficiency measures ability to optimise the use of inputs, given their respective costs. In sheep farming, maximising lamb production is one of the targets pursued to ensure a sustainable and profitable enterprise. Many management techniques have been proposed to increase farm efficiency over time but only some have been taken up by farmers.

Over the past 20 years, the sheep population in New Zealand has decreased from close to 65 million to 39.9 millions in 2005 (MacLeod & Moller, 2006; Statistics New Zealand, 2006). However, lambing rates have increased by 1.7% per year from 1991 onward to 115% in 2001 (MacLeod & Moller, 2006) and total mutton and lamb production has stayed relatively constant during this period. The changes reported over time for sheep production are summarised in Figure 1. The increase in lambing percentage from 100% in 1961 to 123% in 2005 (MacLeod & Moller, 2006; Meat & Wool New Zealand, 2006) is testament to the higher rates of multiple lambs now achieved than those of earlier times.

Data from four farm production monitoring schemes in New Zealand showed that in 1996 scanning percentages in Romney and crossbred ewes varied between 120% and 180%, and in Merinos between 90% and 150% (Geenty, 1998). Lamb losses or wastage between scanning and tailing were 20% for Romneys and crossbreds and 26% for Merinos. These losses decrease the availability of lambs for market and reduce farm profits and it was estimated that reducing average lamb mortality from birth to weaning from 20% to 15% would increase New Zealand's export income by $105 million (Barry *et al.*, 2004). This estimate would be increased if wastage due to deaths of ewes and their lambs could be reduced. Morel and Kenyon (2006) suggested that many factors contribute to profitability of New Zealand sheep farms and by using sensitivity analysis found that lamb price and growth rate had the largest impact on farm gross margins in weaner lamb production systems.

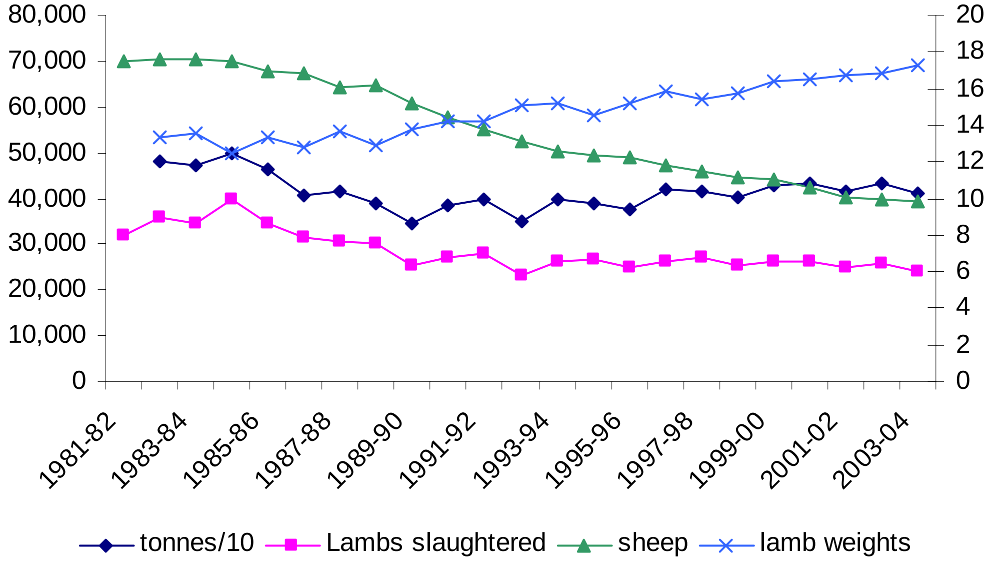

Figure 1 Production of lambs (tonnes x10), numbers of lamb slaughtered, number of sheep and lamb weights over time from 1981/82 to 2003/04. The y-axis on the left shows values for production of lambs, numbers of lamb slaughtered and number of sheep, while the y-axis on the right shows values for lamb weights.

This review summarises some of the important literature to date on wastage and its causes on sheep farms, and also deals with relevant aspects of reproductive efficiency and on-farm disease surveillance systems.

1.2 Wastage

1.2.1 Wastage definition

The term wastage has been used to describe losses of farm animals due to death, and slaughter or otherwise disposed of due to disease. It can be applied to lamb crop or adult sheep associated losses. Reproductive wastage is used to describe failure to achieve expected targets set for breeding ewes to produce lambs. Most authors exclude losses from ewe deaths when calculating reproductive wastage, but a few (Kelly, 1982) argue for their inclusion. Different formulae used to describe reproductive wastage include those for losses of potential lambs from ovulation to weaning (Kleemann & Walker, 2005; Willingham *et al.*, 1986), from ovulation to birth (Branca *et al.*, 2000; Lassoued *et al.*, 2004) and ovulation to conception (Holst & Hall, 1984).

Others describe lamb losses with regard to a particular period of interest, such as scanning to docking (Tarbotton & Webby, 1999), perinatal (Sargison, 1997) or post natal (Barry et al., 2004). Most define lamb wastage as the proportion of lamb losses to the expected or potential population, either using differences between expected lambs and lambs produced or incorporating counts of deaths, when those data are available. Mortality rate has also been used synonymously as a measure of lamb loss (Kerslake *et al.*, 2005; Nicoll *et al.*, 1999; Sargison, 1997).

It would be fair to say that ewe wastage has not received due attention from researchers despite its economic importance.

1.2.2 Lamb wastage

In New Zealand, lamb wastage has been reported and variously estimated from deaths or combinations of deaths and unseen losses, but overall there seems to have been little change in the extent of losses over time. Reported lamb wastage estimates have ranged from 3% to 54% with high between-farm variability (Gumbrell & Saville, 1986; Hight & Jury, 1969; Marshall, 1945; Nicoll et al., 1999; Tarbotton & Webby, 1999; Wallace, 1952; Watt, 1980). Differences between the period of interest also need to be taken into account when evaluating wastage; from mating to tailing (Kelly, 1982), perinatal period to tailing (Quinlivan & Martin, 1971), perinatal to weaning (Dalton *et al.*, 1980), pregnancy scanning to weaning (Nicoll et al., 1999; Tarbotton & Webby, 1999), birth to weaning (Hight & Jury, 1969; Hinch *et al.*, 1983; Kerslake et al., 2005; Knight *et al.*, 1988; Wallace, 1952) and birth to docking (Marshall, 1945).

Various studies have investigated the effects of breed, age of ewes, year, birth weight, lowland *vs* hill flocks, and number of lambs per ewe at scanning and at lambing.

1.2.2.1 Temporal and spatial effects

Lambs are most at risk during the perinatal period which is usually taken to mean the last week of pregnancy to 3 days after birth (Dalton et al., 1980; Hight & Jury, 1969;

Nicoll et al., 1999). Reported estimates of perinatal lamb wastage range from 8% (Nicoll et al., 1999) to 20 – 26% but variation in study design may be partly responsible for the differences.

Early studies found considerable between-farm and between-year variation in lamb wastage (Gumbrell & Saville, 1986; McFarlane *et al.*, 1952). Gumbrell and Saville (1986) reported 3% to 20% wastage over 5 years for 21 commercial farms in central Canterbury. Tarbotton and Webby (1999) reported a range of 26% to 54% for scanning to weaning lamb wastage on 8 farms in the King Country and Taupo regions. Quinlivan and Martin (1971) observed between-location variation ranging from 6.6% to 10.4% from the perinatal period to tailing but no significant between year variation in a two-year study. Environmental factors on the farms were not taken into account in these studies, but it seemed that year-to-year seasonal variation was an important influence on the magnitude of lamb wastage.

Lamb wastage was expected to be higher in hill country settings than on flat or gently sloping country (Watt, 1980) but factors other than slope and steepness appear to be more important in determining lamb wastage (Dalton et al., 1980; Hight & Jury, 1969). Knight (1989) found that slopes of more than 30 degrees were only associated with high mortality due to abandonment by dams in the first 6 to 12 hours after birth.

1.2.2.2 Birth rank

A number of studies have indicated that single lambs survive better that twins or triplets (Dalton et al., 1980; Hinch et al., 1983; Kelly, 1982; Tarbotton & Webby, 1999), but one study Quinlivan and Martin (1971) found poorer survival for singles and another Hight and Jury (1969) reported no difference. Typical losses of lambs from birth to weaning are 15% for singles, 25% for twins and 35% for triplets (Barry et al., 2004) with differences between multiples and singles ranging from 2% to 14% (Dalton et al., 1980; Johnson *et al.*, 1982; Kelly, 1982; Knight et al., 1988; Nicoll et al., 1999; Quinlivan & Martin, 1971; Tarbotton & Webby, 1999).

Lamb survival was markedly decreased in triplets or more lambs (Kerslake et al., 2005; Nicoll et al., 1999) and Nicoll et al (1999) found that triplet mortality rates were more than twice those of twins or singles after adjusting for flock-year and ewe age. Dystocia was the most frequent cause of death in single lambs while starvation-exposure occurred more often in multiples (Dalton et al., 1980; Hight & Jury, 1969). However, a recent study suggested that dystocia was responsible for half of all deaths within three days of birth in all-birth ranks (Kerslake et al., 2005). Some studies have found that the effect of birth rank in lamb survival was associated with birth weight (Dalton et al., 1980; Hight & Jury, 1969; Hinch et al., 1983) but Kerslake et al (2005) suggested that birth weight, albeit recorded as weight at death, was unlikely to be the main reason for the high rates of dystocia in large litters observed in their study.

1.2.2.3 Ewes breed differences, maternal behaviour and age

Many studies have observed breed differences in lamb survival. Hight and Jury (1969) found that lamb survival in hill country improved more through Romney to Romney F1 and F2[1] crosses than in Romney F3 and F4 crosses. Pure Romney and Merino lambs had the poorest survival in a comparative study involving Perendales, Coopworths, Dorset-Romneys, Merino-Romneys, Cheviots, Drysdales and Corriedales (Dalton et al., 1980). Poor maternal behaviour, such as abandonment of lambs after birth, was considered the major contributor to higher lamb mortality rates in conventional Romneys than in Marshall Romneys (Knight *et al.*, 1989). Lambs of Marshall Romneys had significantly fewer deaths due to dytocia and starvation. .

Ewe age and breed effects on maternal behaviour have been reported (Everett-Hincks et al., 2004; O'Connor et al., 1985). Younger ewes have higher rates of wastage than older ewes and rates are highest for hogget and two tooth dams (Dalton et al., 1980; Nicoll et al., 1999).

1.2.2.4 Sire effect

Sire effects on lamb survival has been studied in Romney flocks and it seems that high survival rams leave smaller lambs with fewer deaths from dystocia but sometimes with higher death rates from multiple births (Knight *et al.*, 1979; Meyer & Clarke, 1978). Meyer and Clarke (1978) identified a sire effect in a study which showed Romney lambs and Romney-East Friesian crosses had the lowest lamb mortality rates among

[1] F1 is first Romney cross and F2 is second crosses.

nine other breeds. However, possible confounders such as age of dam were not controlled for in the study. Gudex (2005) observed differences in lamb wastage due to starvation-exposure within four days of birth between sire-lines, but the method of measurement used in the study may have resulted in overestimation of deaths due to this cause.

1.2.3 Ewe wastage

1.2.3.1 Ewe mortality

The first reported observation of a 4.9% adult sheep annual death rate in New Zealand came from a study on nine farms in Hawke's Bay in 1971 to 1972 (Davis, 1974) There was an indication, based on data from one year, that the risk was greatest in July and August. Of seven disease conditions, pregnancy toxaemia, pneumonia and lambing difficulty were responsible for > 3% mortalities.

A reproductive performance survey conducted from 1964 to 1968 indicated that 1.8% ewes from 184,217 ewes in registered Romney stud flocks died between mating and lambing, and 1% died during lambing (Quinlivan & Martin, 1971). Causes of death could not be precisely identified and almost half were categorised as 'unknown'. Ewe death rates from scanning to docking averaged 3.9% for nine farms in the King country (Tarbotton & Webby, 1999), and based on the average scanning percentages of the flocks in 1997, it was estimated that at least 21% of lamb losses were directly attributable to deaths of their dams.

1.2.3.2 Diseases contributing to ewe wastage

A number of diseases contribute directly or indirectly to ewe wastage and the occurrence of some, such as pregnancy toxaemia and footrot, is linked to seasonal conditions. On most New Zealand farms about 0.5% to 1% of ewes are affected annually with vaginal prolapse, but individual farms occasionally experience outbreaks with up to 10% of ewes affected (Hilson *et al.*, 2003). In a survey covering 1954 to 1957, the average death rate among prolapse affected ewes was 27% and 13% of ewes were humanely euthanised (McLean, 1959). Well fed ewes have been considered by some to be more prone to vaginal prolapse (Hosie *et al.*, 1991), but an experimental study did not confirm that (Litherland *et al.*, 2000). An epidemiological investigation involving 113 farms in 2000 and 88 which remained in the study throughout 2001 found higher risks for ewes carrying multiple lambs, steep terrain during lambing, and gaining body weight between the start of mating and scanning time, and protective effects from shearing within 72 days prior to the start of lambing (Hilson et al., 2003).

Footrot has been associated with weight loss, decreased wool production and poor reproductive performance in Australian Merino sheep (Mulvaney, 2002). In New Zealand, a qualitative survey of farmer perceptions in 2001 suggested that losses from footrot on wool weight and wool quality, culling rates, lambing percentages and mortality rates was costing the Merino industry about $11.4 million per annum (Hickford *et al.*, 2005). There is little information about footrot in sheep breeds other than Merinos, but high prevalences, such as were encountered on Castlepoint station, could conceivably be indirectly responsible for ewe losses in late pregnancy.

Johne's disease was first recognised in New Zealand sheep flocks in 1952 and it is now thought to be endemic on 60 -70% of sheep flocks (West, 2002). Johne's disease has not been shown to have a major impact on sheep productivity in New Zealand (Thompson *et al.*, 2002; West, 2002), although the combination of a low incidence of clinical disease and a high prevalence of infected farms make the disease worthy of serious consideration by the industry. There is limited information available about within-flock spread of the disease and predicting its effect in newly infected flocks and in flocks where it is already present is difficult. Clinical cases are generally reckoned to occur in <1% of animals (West, 2002), and de Lisle (2002) estimated that adult ewe mortality rates due to the disease were about 1%. Johne's disease is a chronic disease and because clinical diagnosis is difficult due to low test sensitivity, the true prevalence of the disease is higher than the apparent prevalence, though how much higher is uncertain and can only be speculated upon. Physiological stress, such as due to winter shearing and late pregnancy, has been associated with clinical expression of the disease (Lugton, 2004).

Pneumonia is generally considered to be a complex disease involving interaction between host, multiple infectious disease agents and environmental factors (Goodwin *et al.*, 2004). In New Zealand, pneumonia mainly affects lambs (Alley, 2002; Goodwin et al., 2004) and hoggets (Davis, 1974), whereas in United Kingdom it also affects ewes at lambing (Rodger, 1989). Acute fibrinous pneumonia, which is easy to recognise at necropsy, is characterised by a rapid onset and affected animals are often found dead without clinical signs (Alley, 2002). Chronic non-progressive pneumonia, which is difficult to diagnose clinically, is associated with reduced weight gain and poor exercise tolerance in lambs (Alley, 2002; Goodwin et al., 2004). No studies have been carried out in New Zealand to determine the prevalence of pneumonia in adult ewes or its effects on ewe productivity.

Gastro-intestinal nematode parasitism affects sheep production, most notably in growing lambs (Bishop & Stear, 2001), but breeding ewes are recognised as a source of larval contamination for pasture (Herve *et al.*, 2003). Bishop and Stear (2001) found high faecal egg counts in the periparturient period were associated with ewes with multiple lambs and younger age group ewes. A New Zealand study failed to find any significant association between mixed age ewe fecundity and faecal egg counts, but was in agreement with high faecal egg count susceptibility of two-tooths and hoggets (Herve et al., 2003). The prevalence of anthelmintic resistance is increasing on sheep farms in New Zealand and the relationships between faecal egg counts, age and stress may change as resistance becomes more widely established and severe.

1.2.4 Fecundity

Improving lambing percentage is the most important determinant for higher profits on sheep farms (Geenty, 1998) and can be achieved through improved ovulation rates and/or minimising losses between mating to docking. High fecundity breeds have been used to increase lambing percentage, but ewe fecundity can be manipulated by vaccination to increase lamb numbers (Gomez *et al.*, 2006; Henderson *et al.*, 1989; McNatty *et al.*, 1988; Smith *et al.*, 1981). In recent years, a commercially available vaccine, Androvax, has been used to increase twinning in sheep (Agvax Development, 2004) and so increase lambing percentages and profit margins.

Increasing average flock prolificacy from 1.5 and 2.3 lambs born per ewe lambing has been shown mathematically to increase the incidence of triplet and quadruplet litters (Amer *et al.*, 1999) but it has been suggested that reproductive wastage (ewe and lamb deaths) increases with increasing ovulation rates due to increased losses between ovulation and birth (Kelly, 1982). A lamb mortality rate of 13% between birth and tailing at a 161% ovulation rate was reported in the latter study. A recent study reported dystocia as an important cause of lamb deaths for multiple lambs. This was an interesting observation because in the past dystocia was thought to mainly be associated with births of single lambs (Kerslake et al., 2005). Thus, it seems, albeit from limited information, that increasing ovulation and scanning percentages can bring new problems such as increased rates of dystocia and in high fecundity breeds increased prevalences of triplet and quadruplet lambs which require special management for dams and lambs.

1.2.4.1 Androvax

Androvax is a vaccine developed by AgResearch New Zealand to increase ovulation rates (Agvax Development, 2004). It is composed of a steroid androstenedione which is chemically joined to a protein alpha-lactalbumin. The vaccine functions by raising antibodies against androstenedione to cause a temporary hormonal imbalance, causing more ovarian follicles to mature and become available for fertilisation (Hudson & McNatty, 2002). Increased plasma follicle stimulating hormone (FSH) occurs in ewes treated with Androvax (McNatty et al., 1988) and stimulates more follicles to mature.

In the first year, two subcutaneous injections of Androvax need be given with the first dose 8 to 10 weeks before ewes are mated and the booster 4 to 6 weeks before mating. In subsequent years only a booster is given at 4 to 6 weeks before mating(Agvax Development, 2004).

1.3 Farm surveillance

Surveillance of endemic diseases of farm animals has largely been the province of private veterinarians and farmers have come to rely on this source of knowledge and expertise for investigating animal health and production problems. However, in remote areas this dependency limits opportunities for identifying causes of death and illness and introduction of simple procedures that could be undertaken by farmers themselves could be helpful for providing more timely and effective information.

Many sheep farmers record farm events in a calendar or database and some use commercially available software for analysis. Most available programmes for sheep farmers are designed with emphasis on financial expenditure and/or feed budgeting. Many farmers do not record disease events (Eales *et al.*, 1986) unless they have been investigated by their veterinarian. Surveillance systems for capturing disease data such as syndromic surveillance as with vetPAD (Vourc'H *et al.*, 2006) are too technical for general use by farmers who, for the most part, only have a basic knowledge of diseases. A simple system for recording disease events and data pertaining to disease such as deaths for farmer use would be useful. It has been suggested that this type of recording can be used effectively at the farm level, and furthermore is likely to be more beneficial when it been supervised by the farmer’s own veterinarian (Eales et al., 1986).

1.4 Conclusion

Increased fecundity and higher weights of lambs at slaughter in recent years has compensated for decreased numbers of female sheep of breeding age in the New Zealand sheep population. However, although the potential for further improvements in efficiency by reducing wastage is acknowledged and work has been done to identify risk factors for wastage in lambs, little has been done to quantify levels of wastage and identify the most important causes in ewes. Wastage and disease prevalence differ between flocks and any investigation of wastage on individual farms needs to establish disease occurrence and prevalences for diseases that adversely affect productivity on the farm under consideration.

There have been multiple studies on the efficacy of vaccines for increasing fecundity but published information about their side effects is lacking. Individual farms employ different types of management which are tailored to their location and availability of inputs. In large flocks, fecundity vaccines offer opportunities for increased farm productivity but easy care management and minimum supervision management practices reduce opportunities to remedy individual animal disease events during lambing which may adversely impact on profitability (Fisher, 2003).
Monitoring flocks with high lambing percentage is a critical part of effective planning (Geenty, 1998) and parameters for monitoring include pasture cover, ewe weight, ewe condition score, pregnancy scanning, lamb growth rate and animal health. Easy and practical tools that help farmers to identify most of these issues have been developed over time, but tools to identify more complex issues such as animal health are still needed. Simple and effective tools to identify causes of death in sheep could provide

farmers with useful information on animal health issues relevant to their farm's particular circumstances.

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Chapter 2

2 PRELIMINARY INVESTIGATION

2.1 Introduction

2.1.1 Background

Marked changes in farm management practices over the past two decades have resulted in increased efficiency of usage of pasture, higher lambing percentages and faster growth rates (Kenyon *et al.*, 2002; MacLeod & Moller, 2006). Improved genetics and management practices along with judicious use of therapeutic drugs and vaccines have all contributed to increases in lambing percentages and lamb growth rates. These improvements have been reflected by greater numbers of lambs weaned and sold and subsequent potential for higher farm profit margins. Key performance indicators are scanning percentages and subsequent ewe and lamb survival rates during pregnancy and lambing, and between lambing and weaning. For commercial sheep farms, business survival of the enterprise depends on achieving a balance between expenditures used in managing resources and minimising losses.

The case farm described in this paper is a large commercial sheep farm running on average 21,000 sheep and 1,100 cattle and which was experiencing high losses of ewes and lambs. The aims of the study were to identify factors associated with wastage of lambs and ewes and formulate efficacious control procedures and management procedures that might be applied to benefit net profitability.

2.1.2 Farm description

The farm, Castlepoint Station, is located at Castlepoint, Wairarapa, in the North Island of New Zealand. This 2,952 hectares property which includes 12 km of coastline, is managed by its owners in consultation with a management team which includes a stock manager, a veterinarian, a farm advisor and an agronomist. The property receives an average annual rainfall of 970mm and rises to 300 m above sea level. It is a mixed sheep and cattle farming enterprise. Romney sheep were farmed exclusively for many years but in recent years extensive cross breeding with other breeds has been undertaken. Coopworth, Finn and Texel breed genetics were introduced for their mothering and milking abilities, high fecundity and hardiness, and good lamb carcass yields. The predominantly Angus cross cattle only play a supporting role for control of pasture growth which is central to sheep performance, and if the carrying capacity of the farm is threatened by adverse conditions some cattle are sold to accommodate the sheep requirements.

The Castlepoint Station flock consists of five main sheep mobs; mixed age ewes (MA ewes), two-tooth ewes, ewe hoggets, rams and lambs. Breeding begins in March firstly for MA ewes, then later for two-tooths, and lastly for hoggets. Most capital stock rams are with the ewes for three oestrus cycles, after which terminal rams are introduced. Scanning is carried out in June when the ewes are in the second trimester of pregnancy. Ewes carrying more than one lamb are separated from single-lamb ewes to ensure that their different feed requirements during pregnancy and lambing can be met. Lambing begins in early August when spring grass normally becomes abundant and finishes at the end of September. Lambs are weaned in December. If spring conditions are poor, inferior ewes are culled and sold with lambs at foot. Lambs are docked about one month after the peak of lambing which normally occurs about 10 days after the mobs start to lamb.

The owners and their management team have been working on this farm for the past 7.5 years and in that time lamb weaning weights have increased by 9.2kg and lambing tallies risen by 37% on average. The overall scanning percentage[2] in 2005 was 170%.

2.1.3 Problem description

In 2005, the ewe mortality rate was 8%, lamb wastage[3] ranged from 20% to 30%, and there was an apparent increase in vaginal prolapse or ‘bearings’ and this condition was perceived to have become a significant cause of ewe and lamb wastage (Castlepoint Station, 2005). It was estimated that for 2003 to 2005 years, the number of ewe deaths

[2] $Scanning\ \% = \frac{number\ of\ lambs\ scanned}{number\ of\ ewes\ scanned} \times 100$

[3] $Lamb\ wastage\ scanning\ to\ weaning\ \% = \frac{number\ of\ potential\ lambs\ (scanned) - number\ of\ lambs\ weaned}{number\ of\ potential\ lambs\ (scanned)} \times 100$

due to vaginal prolapse was between 600 to 1000 per year. In the winter of 2004, autopsies recorded deaths due to Johne's disease and listeriosis. Deaths due to listeriosis did not appear to occur in 2005. A perinatal mortality survey done in 2003 of 35 newborn lambs found that 46% died due to starvation, 26% dystocia or death at birth, 6% exposure and 22% miscellaneous causes (S. Bruere, 2006). The average weight of the lambs in this study was 4.65 kg.

In the last three years significant progress has been made in improving ewe fecundity, with the scanning percentage (with triplet adjustment[4]) increasing from 154 to 187% in MA ewes and 118 to 182% in two-tooths in 1999 to 2005. Mixed age ewes were vaccinated annually during that period with Androvax® and two-tooths onwards from 2003. For the last two years, composite rams (¼ Finn, ¼ Texel, ½ Coopworth) have been employed to increase ewe fecundity and gradually phase out usage of Androvax®. These interventions designed to improve fecundity were tempered by a concern that they might increase the risk of vaginal prolapse.

Improved reproductive performance should be manifested by increased numbers of lamb weaned and sold. However, there were concerns that improvements in scanning percentage were not being matched with concomitant increases in weaning percentage. Therefore identification of causes for the poor weaning percentage performance was given priority for investigation. The objectives of this preliminary study were to provide accurate assessments of productivity in recent years, to quantify the prevalences of production limiting diseases in various mobs, and to identify the main causes of death during lambing.

2.2 Materials and Methods

2.2.1 Farm data

Previously recorded production data were used to investigate loss of production performances in the farm. Two databases were used; Farm input forms as Excel worksheets; and an Access database from the Stockpol Pastoral Monitoring System. Both had monthly information for pasture cover, stock reconciliations, stock

[4] $\%Triplet\ ewes\ (Triplet\ calculator) = (0.0044 \times \%Singles^2) - (0.6921 \times \%Singles) + 27.625$

transactions and climate. Animal health treatment, shearing and fertiliser information were recorded by date of action. A summary description of the variables recorded in the databases is provided in Table 1. Monthly pasture cover for each paddock was recorded in Farm input forms, while only average of monthly pasture cover was recorded in Stockpol. Total stock density and liveweight per hectare data had been entered in the Stockpol database but not in Farm input forms. Scanning, lambing and loss percentages were available from the Stockpol database. Rainfall, soil temperature, average pasture cover, total stock density and liveweight per hectare data were incomplete for the whole period of analysis.

The databases held data from March 1997 to April 2005, but complete 12-month data only for 2000 to 2004. The Stockpol records covered March 1997 to June 2003, and Farm input forms from July 2000 to April 2005.

Table 1 Description of variables in the databases used to analyse production performance of Castlepoint Station from March 1997 to April 2005

Variables	Description
Pasture cover	Monthly dry matter yield per hectare in paddocks
Stock reconciliation	Monthly opening stock numbers (only in Farm input forms data), recovered stock, sales, purchases, and death, purposive kills and missing. Death, kills and missing numbers were combined to give a single estimate
Farm climate condition	Monthly data of rainfall and soil temperature
Animal health	Veterinary drugs and related products usage records for various classes of stock with details of date of use, type, stock classes, numbers of sheep treated and withholding period from slaughter end dates
Shearing	Shearing date, wool type, numbers shorn, cost of shearing per head, weight of total clip and net return
Fertiliser	Date of application, paddock ID for the area to which it was applied, amounts used and application rates
Annual sheep data	Annual data for scanning and lambing percentages and losses

2.2.2 Footrot investigation

During shearing in January 2005, ewes were screened for lameness, poor body condition, old age and other conditions that might adversely affect performance during the coming breeding season. A total of 2,200 affected ewes were drafted and run separately from the main mobs and it was estimated at the time that more than 10% of MA and two-tooth ewes had footrot. The feet of 200 ewes in the affected mob were closely examined on 8th February 2006 to more precisely estimate the prevalence of footrot. The mob was yarded and the first 200 ewes through the drafting race were carefully examined for footrot lesions.

Footrot status was scored based on the severity of lesions. The scores were 0 to 3 with score 0 for non-infected, 1 for mild interdigital infection or water maceration, without under-running of the sole, 2 for moderate under-running at the sole area, and 3 for advanced or severe footrot with hoof overgrowth and under-running of the whole sole. The sample size, calculated using Win Episcope version 2.0, to give 95% confidence with a 10% accepted error about an assumed prevalence of 50% was 97.

2.2.3 Investigation of poor condition ewes at slaughter

An opportunity to examine poor condition or body constitution ewes for pneumonia and Johne's disease was taken when 376 culls were drafted from the main mob and sent to slaughter in April 2006. Severity of pneumonia was evaluated by using a scoring system from 0 to 4 based on visual inspection of the lung surfaces. The scoring system was based on a similar study by Goodwin (2004); Score 0 for an unaffected lung, 1 when the lung had <5% affected, 2 for 5 to <10% affected, 3 for 10 to <20% affected and 4 for >20% affected.

Johne's disease had been previously diagnosed at Castlepoint Station but at an undetermined prevalence. Presence of suspicious lesions such as thickening of terminal ileum and visible lymphatic vessels on the mesenteric serosa have been shown to have a test sensitivity of 53 to 87% and specificity of 97 to 100% (Bradley & Cannon, 2005). Histopathology of intestinal lymphoid tissues, mainly ileocaecal valves, has also been used to detect ovine Johne's disease (Bradley & Cannon, 2005; Perez *et al.*, 1996). Ileocaecal valves from 102 ewes at the beginning and end of the slaughter line were examined histologically. The sections were fixed in 10% buffered formalin before processing and testing at the Massey University pathology laboratory with acid fast and haematoxylin-eosin staining for evidence of acid fast organisms and granulomatous lesions. Granulomatous lesions were scored using the criteria described by Perez (1996).

2.2.4 Data analysis

The two databases were combined for analysis. Farm input forms data were used when discrepancies between the two databases were found. The type of stock classes or mobs was condensed from 16 classes into six classes; MA ewes, two-tooth ewes, ewe hoggets, other hoggets, lambs, and rams. Ewes in the MA mob were two years and older, one year old ewes were classified as two-tooths, and younger females for breeding as ewe hoggets. Monthly stock numbers were adjusted when discrepancies occurred between stock numbers at the start and end of the month by adding or subtracting stock numbers to derive a reconciled estimate. Definitions of scanning percentage, ewe and lamb wastage and other reproductive parameters are shown in Appendix 1.

Deaths, missing and killed data could not be separately distinguished, and were therefore combined for mortality estimates. Mortality rates were adjusted in accord with changes in the population at risk during the time periods specified. Monthly and yearly mortality rates were calculated from the numbers of deaths in the population-month at risk. An approximate calculation was used to calculate population-month at risk as mortality was only recorded at the end of each month. Population-month at risk was defined as the starting stock number minus half of the total deaths and sales, plus half of the total stock purchased and recovered in the month. Relationships between mortality rates and recorded environmental factors were assessed using Spearman's rank correlation since the mortality rates were not normally distributed.

The prevalence of footrot was defined as the total number of ewes with at least one foot infected divided by the total number of ewes examined. Ileocaecal valves were considered positive for granulomatous lesions scoring 2 or more. Sections with score 1 were considered positive if acid fast organism were seen. Prevalences for pneumonia and Johne's disease were calculated as the number of positive samples divided by the total number of samples.

Analysis of farm data, footrot status and poor condition ewes was done in Excel version 2003 and R version 2.2.1 (R development team 2004).

2.3 Results

2.3.1 Farm data

The average overall opening monthly sheep population from March 1997 to April 2005 was 21,283 (range 12,109—35,349). The median number of sheep was highest in December, coinciding with weaning time. The lowest overall tally for the period under consideration was less than 15,000 sheep in March and April 2005. Mixed age ewes numbers were highest in 1997 and lowest in 2002, while two-tooths were lowest in 2005 and showed high variability in 1997 due to incomplete monthly data. The variability in monthly stock numbers for ewes was greater than for two-tooths. Opening stock, deaths, sale, and purchased data were not normally distributed. Descriptive statistics for mobs in the farm and environmental factors are shown in Table 2 and 3.

On average, 158 sheep died per month (range 0—1,094) and mortality was highest in the spring at lambing time. Monthly data were incomplete for 1997 to 1999 and 2005. There was no indication of increased mortality due to an increased population at risk except in 2003. However, the data may not represent mortality accurately because tallies were only done at times when sheep were yarded, such as for shearing or scanning. The annual mortality rates per 100 sheep for six years based on a farming year of July 1 to June 30 are shown in Table 4.

Table 2 Median monthly opening stock numbers, sales, purchased and deaths in mobs at Castlepoint Station for 88 months from March 1997 to April 2005. Deaths include deaths, killed and missing animals.

Mobs	Opening stock (min-max#)	Sales (min-max #)	Purchased (min-max #)	Deaths (min-max #)
Mixed age ewes	8122 (6372 - 12000)	0 (0 - 2629)	0	30 (0 - 718)
Two-tooth ewes	3813 (2817 - 5528)	0 (0 - 326)	0	10 (0 - 360)
Ewe hoggets	4760 (3926 - 5912)	0 (0 - 1497)	0 (0 - 192)	6 (0 - 152)
Other hoggets	0 (0 - 234)	0 (0 - 48)	0	0 (0 – 20)
Lambs	5200 (3270 - 18326)	0 (0 - 11120)	0 (0 – 2267)	0 (0 – 150)
Rams	193 (121 - 332)	0 (0 - 34)	0 (0 – 128)	0 (0 – 38)

min - max = minimum value and maximum value

Table 3 Descriptive statistics for five environmental factors recorded at Castlepoint Station from March 1997 to April 2005.

Environmental factors	N	Mean	Median	Std	Min	Max	NA
Average pasture cover (kg/ha)	88	1554	1485	284.62	1100	2383	26
Total stock density (su/ha)	88	13.72	13	3.07	8.93	20.09	25
Liveweight per hectare	88	555	553	49.9	426	646	25
Rainfall (mm)	88	71.3	69	32.5	23.5	165.4	20
Soil temperature (^oC)	88	15	14	4.6	6	24	23

N = number of months, Std = standard deviation, Min = minimum value,
Max = maximum value, NA = missing values

Table 4 Annual mortality rates per 100 sheep from 1999 to 2004 farming year at Castlepoint Station. Farming year was July 1 to June 30. Only 6 years are reported as monthly data for other years was incomplete.

Year	Deaths	Population at risk	Mortality rate per 100 sheep per year
1999	1704	20708	8.2
2000	1761	19863	8.9
2001	1429	19778	7.2
2002	1452	20631	7.0
2003	2192	20343	10.8
2004	1996	20285	9.8

The mortality rate was higher in older than in younger ewes as shown in Figure . The mortality rates for MA ewes and two-tooths were highest at 7.9 deaths per 100 ewe-months in October 2003 and 7.1 in February 2004 respectively. The high rates for two-tooths in 2004 were most likely due to the timing of tallies rather than representing the true state of nature since they appear to be balanced by low rates in the spring of 2003 as shown in Figure 3.

Relationships between ewe mortality rate and five environmental factors were tested using Spearman's Rank correlation statistic. Ewe mortality rate was negatively associated with average pasture cover (APC), liveweight per hectare (LW/ha), rainfall (RF) and soil temperature (ST) and positively associated with total stock density (TotSD). While the association between ewe mortality rate with APC (rho = -0.348, p-value=0.006) and TotSD (rho = 0.337, p-value = 0.007) were statistically significant, the magnitude of the effect was small, suggesting that other factors not able to be considered in the analysis were also involved. The relationship between MA ewe mortality rate and TotSD was more pronounced than the two-tooth rate relationship.

The overall scanning percentage at Castlepoint Station increased from 141% to 176% during 1999 to 2004. The twinning percentage increased by 31% and the weaning percentage by 74%. Scanning and weaning percentages for MA ewes and two-tooths are shown in Figure 4. The average annual lamb wastage was 26%, and was highest in 1999 (35%) and lowest in 2000 and 2003 (20%). The highest ewe losses were recorded in 2003 and 2004.

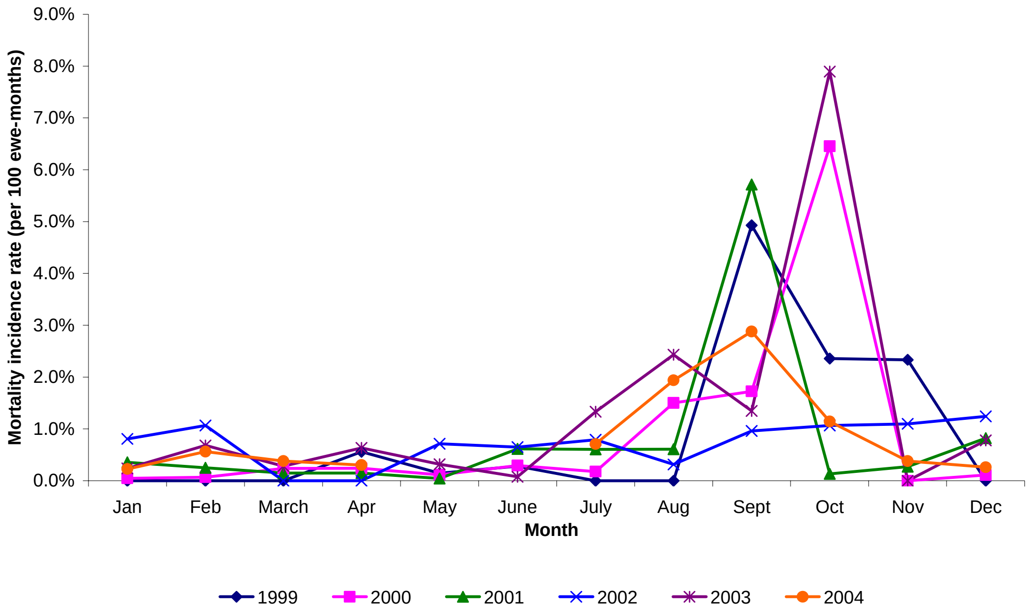

Figure 2. Mixed age ewe mortality rates per 100 ewe-months from 1999 to 2004 farming year at Castlepoint station

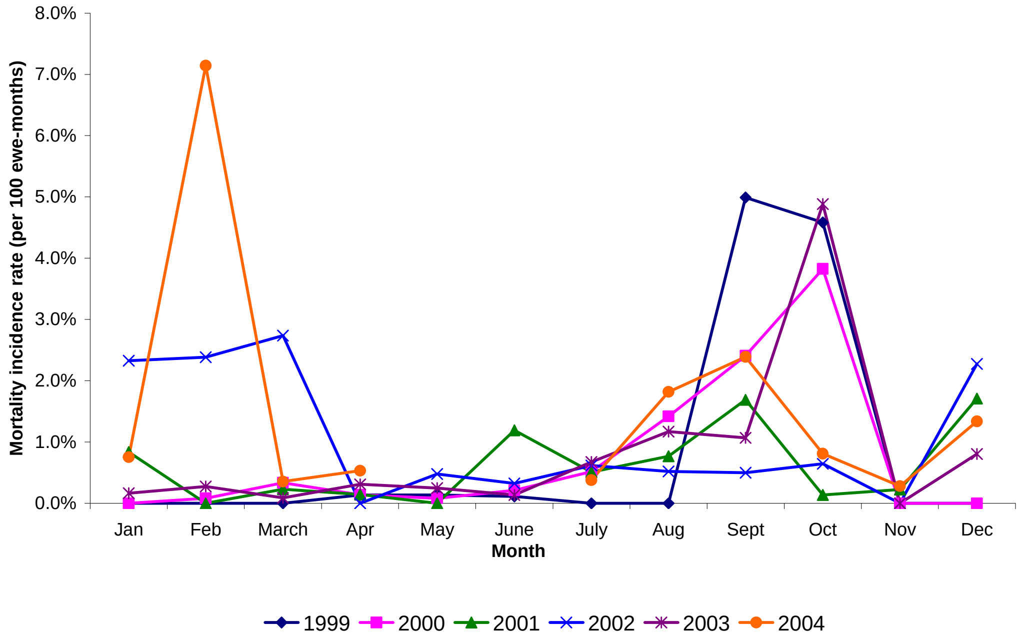

Figure 3. Two-tooth ewe mortality rates per 100 ewe-months from 1999 to 2004 farming year at Castlepoint Station.

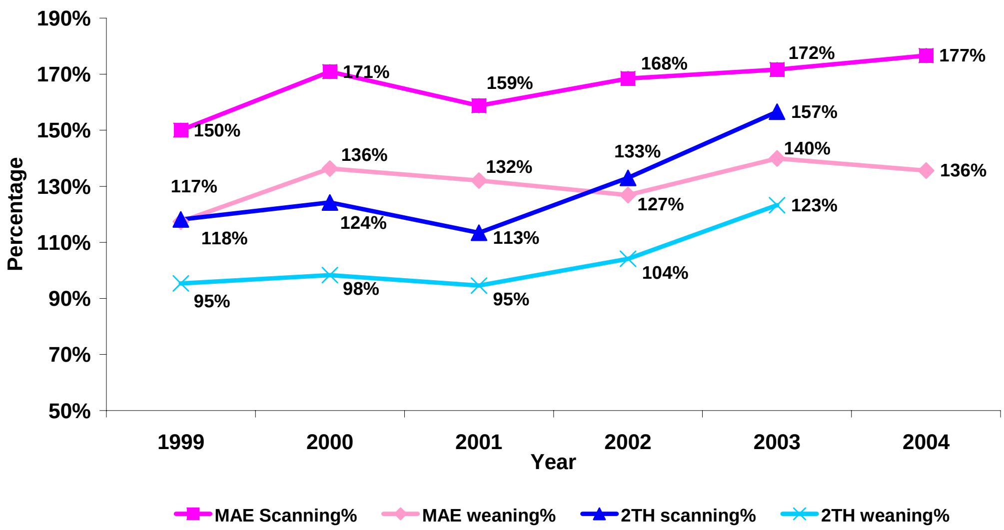

Figure 4. Scanning and weaning percentages for mixed age ewes (MAE) and two-tooth (2TH) ewe mobs at Castlepoint Station from 1999 to 2004. The canning percentage for two-tooth ewes could not be calculated for 2004 due to mixing of two-tooth and mixed age ewe mobs during scanning

2.3.2 Footrot status

A total of 167 ewes, comprising 22 two-tooths, 69 four-tooths, 72 MA (three or more years-old) and 4 broken mouths from the 2,200 ewes drafted out at shearing in January, were examined for footrot. The overall prevalence of footrot with at least one foot affected with a score of 1 or more was 32% (95% CI 25%—39%). The prevalences in two-tooths and older ewes were 45% and 30%. Extrapolating the results to the mob of 2,200 and assuming the 167 were truly representative of the group examined, then the number of infected ewes was 698 (95% CI: 553—861). Severe footrot (footrot score 3) with overgrowth of affected toes was present in 27% of infected ewes. There was no statistically significant association between age and footrot status.

2.3.2.1 Footrot in rams with resistant allele test information

Data from a group of Castlepoint Station rams for which footrot resistant allele test results were available were examined for associations between allele scores and footrot status. Of 32 rams for which test information was available, 22 (69 %) were described as ‘poor footed’ to denote some degree of footrot by the stock manager. When footrot status was compared to allele scores, all rams with allele scores 1,5; 2,3; 3,5; 5,5 were affected as shown in Figure . All rams with allele score 1,4 were not infected and some rams with allele scores 1,3; 2,3; 2,4; 3,3 were infected. The numbers are too few to support any conclusion about the value of the test but the results are reported here for addition to future observations. It is recommended that test and footrot status for rams continue to be recorded when rams are examined for footrot in order to build a database from which inferences about the value of allele testing for Castlepoint Station may be made.

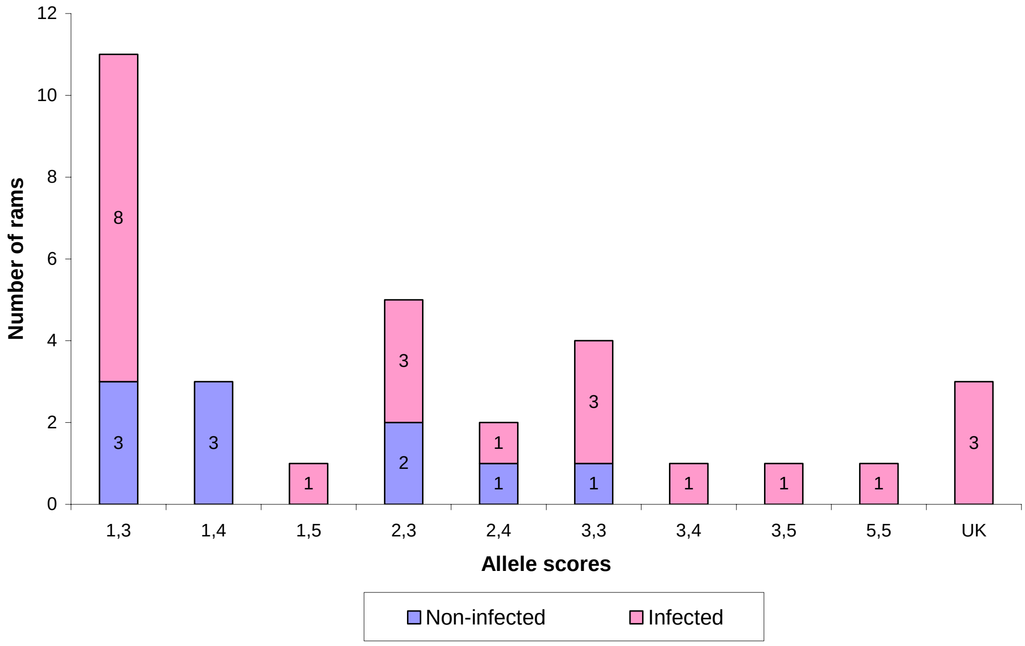

Figure 5 Numbers of rams tested on resistant alleles for footrot in Castlepoint Station. The pink colour bar shows number of rams with footrot and the blue colour bar shows numbers of non-infected rams.
 # UK = incomplete test

2.3.3 Investigation of poor condition ewes at slaughter

A total of 107 lungs and 102 ileocaecal valves were examined for severity of lung lesions and presence of lesions associated with Johne's disease from 376 cull ewes sent to slaughter. Johne's disease lesion scores from 1 to 3 were classified using granulomatous lesion scores described by Perez (Perez et al., 1996), and lungs were scored from 0 to 4 (Goodwin, 2004). The results are shown for lungs in Table 5 and for Johne's disease in Table 6. Most of the lung lesions were consolidation and congestion in the ventral lobes. Almost 20% of ewes had severe lung lesions with 20% or more of the lung surface affected. The prevalence of Johne's disease in the 376 cull ewes was 6% (95% CI: 3—12%) which was considered lower than expected if Johne's disease was a major cause of poor condition in ewes. The prevalence of Johne's disease increased to 12% (95% CI: 7—19%) if samples with mild lesions (score 1) were included. An incidental finding was a high prevalence of histological evidence of gastro-intestinal parasitism.

Table 5 Prevalence of lung scores in 107 lungs from 376 cull ewes sent to slaughter from Castlepoint Station on 5th April 2006.

Lung Score	N positive	Prevalence (95% confidence interval)
0	22	20.6 % (14.0 – 29.2 %)
1	35	32.7 % (24.6 – 42.1 %)
2	19	17.8 % (11.7 – 26.1 %)
3	11	10.3 % (5.8 – 17.5 %)
4	20	18.7 % (12.4 – 27.1 %)

Table 6 Histopathology results for 102 ileocaecal valves from 376 cull ewes sent to slaughter from Castlepoint Station on April 2006.

Criteria	Samples positive	Prevalence (95% confidence interval)
Johne's histopathology score 1	7*	7% (3 - 14%)
Johne's histopathology score 2	5	5% (2 - 11%)
Johne's histopathology score 3	0	0
Acid fast organisms present	3*	3% (1 - 8%)
Evidence of parasitism	88	86% (78 - 92%)
Positive on histopathology and acid fasts	6	6% (3 – 12%)

* Only one sample with score 1 was positive for acid fast organisms. Two of 5 ewe samples with score 2 were positive for acid fast organisms

2.4 Discussion

2.4.1 Farm Databases

The first step in the investigation of animal health and productivity on the farm was analysis of historical data. The data presented considerable difficulties for interpretation since its precision depended on the way data were collected and the purposes for which they were recorded. The Farm input forms were designed mainly for financial purposes whereas the Stockpol Pastoral Monitoring System's major emphasis was on feed budgeting (Marshall *et al.*, 1991). While these databases can readily identify shortfalls in performance targets, they are limited in their ability to identify effects of disease. Animal health and production analysis relies on basic information from accurate tallies of sheep over time throughout each year and in particular at significant events such as mating, shearing, scanning, set stocking, docking and weaning. On Castlepoint Station, ewes are individually age marked with coloured ear tags but disease and mortality reporting are complicated by large flock and mob sizes and the considerable movement of sheep that occurs between mobs for management purposes.

However, although the monthly farm data captured in the databases were unsuited for monthly ewe mortality rate analyses and descriptive statistics of underlying patterns of disease, overall seasonal patterns of mortality were able to be constructed, albeit with considerable effort. Accurate tallies were generally only available for shearing around December, at scanning in June, and at set stocking before lambing and weaning. As expected, seasonally aggregated data showed the highest mortality rates during lambing. No major changes were observed in population size or the pattern of deaths over the past six years. However, the average annual mortality of 8% experienced on this farm is higher than the generally accepted level of about 4%. The high mortality rates observed during each spring coincided with lambing time, with an exception for two-tooths in 2004, which was attributed to imprecise tallies and data recording problems. The pattern of mortality is clearly seasonal and although the causes were largely speculative they were almost certainly associated with diseases and disorders of late pregnancy and parturition.

Tarbotton and Webby (1999), in a study involving 8 farms, reported ewe mortality rates between mating and weaning of 2.5 to 7.5% (mean = 3.9) and estimated that those deaths were responsible for at least 21% of the total lamb wastage. On the other hand, earlier studies indicated that ewe deaths were not major contributors to lamb mortality (Kelly, 1982; Quinlivan & Martin, 1971) although fecundity was lower then than in more recent times. Davis et al (1983) showed that when the mean litter size increases to 1.7 and above, the percentage of triplets bearing ewes increases and mathematical modelling by Amer et al (1999) corroborated that finding. The risk of dystocia in multiple lamb bearing ewes can be expected to increase on farms undertaking breeding programmes aimed at increasing flock fecundity through crossbreeding with known high fecundity breeds. These programmes also have the potential to increase ewe mortality at lambing time under currently widely adopted easy-care lambing styles of management. Some cases of dystocia progress to vaginal prolapse and in the absence of close examination those cases would be attributed to vaginal prolapse, especially if diagnosis was only based on visualisation from a distance.

Vaginal prolapse or ‘bearing’ has been perceived as the main reason for the high ewe mortality rates experienced at lambing time on Castlepoint Station but the extent of losses could not be quantified from farm data. Hilson et al (2003) found that multiple lambs, lambing on moderately steep to steep lambing paddocks, and gaining weight between the start of mating and scanning at about 85 days were positively associated with risk of prolapse. More than 50% of paddocks are steep with >15^{o} slope at Castlepoint Station and this topographical feature in conjunction with multiple bearing ewes would be expected to predisppose to vaginal prolapse. However, better identification and differentiation of dystocia and vaginal prolapse, in other words a better case definition, could be expected to provide a better understanding of causes of ewe deaths.

At Castlepoint Station, scanning percentages for both mixed age and two-tooth ewes have trended upwards in recent times in line with national trends. Increased scanning percentages in two-tooth ewes in recent years was attributed in part to the introduction of Androvax®, a vaccine designed to increase fecundity. The incidence of lamb losses between scanning and weaning has remained fairly constant over time even though scanning and weaning percentages have improved. Farm data could not be used to identify specific causes of wastage from scanning to weaning, but a perinatal mortality survey done in 2003 by the farm’s veterinarian found most lamb deaths were due to starvation, followed by dystocia.

An hypothesis that Androvax® vaccine usage was contributing to an increased risk of mortality during lambing season could not easily be discounted. As a crossbreeding programme using high fecundity breeds was proceeding at the same time as Androvax® usage, there was potential for an increased prevalence of triplet and quadruplet bearing ewes. Extra efforts at scanning can identify triplet bearing ewes but if ewes are only classified as empty, single and multiples, the triplet ewes will be managed no differently than twin bearing ewes. Their requirements differ from single and twin bearing ewes since more energy is needed to rear triplet lambs than single or twins and they are at greater risk of vaginal prolapse.

2.4.2 Footrot study

Bruere and West (1993a) have indicated that transmission of footrot causing organism, *Dichelobacter nodosus* occurs when ambient temperatures rise above 10^{o}C and with at least three months of rainfall averaging 50mm per month. These conditions prevail at most times of the year for most of New Zealand. No farm data were available for ambient temperature, but the median soil temperature of 14^{o}C indicated that the ambient temperature was >10^{o}C. Castlepoint Station experiences an average monthly rainfall of 71.3 mm but the farm is in a summer dry area and the other essential requirement for transmission, *viz* wet pasture conditions causing water maceration of the interdigital region, is absent during the summer months. Although no studies on seasonality of occurrence of footrot have been done, suitable conditions for footrot transmission at Castlepoint are highly likely to be seasonal and occur mainly in late autumn through to early spring. Some culling for poor feet condition had been carried out on the farm but there was no set programme which involved a systematic examination of feet of all sheep.

Based on age of lesions, the high prevalence of severe footrot scores and the inherent difficulties in detecting footrot at shearing, it was assumed that only half of the infected ewes were detected at shearing, and half of the infected ewes would have self-cured during the dry conditions experienced during late spring and early summer (Appendix 2). Using these assumptions, the true prevalence of footrot in the ewe population on the farm in late spring-early summer was estimated to be 16.4% (95% CI: 13—20.3%). This albeit crude estimate of prevalence in the ewe population strongly suggested that that footrot was a serious problem on the farm and would be contributing to weight loss and increased stress during pregnancy and at lambing time.

Painful conditions such as footrot may cause pregnant ewes to lie down more and forage less than healthy ewes and lead to reduced feed intake and available energy for affected ewes and their lambs. Increased intra-abdominal pressure has been associated with increase risk of vaginal prolapse (Bruere & West, 1993b) and pregnant ewes, especially multiple lamb bearing ewes, that lie down frequently may be at greater risk for vaginal prolapse. Thus, footrot could conceivably indirectly influence mortality rates at lambing time.

2.4.3 Poor condition ewe study

Post-mortem examination of cull ewes at slaughter revealed a high prevalence of pneumonia (79.4%; 95% CI 70.8 – 86%), with almost 20% ewes with >20% of the lungs affected. This could indicate that pneumonia in adult sheep is contributing to ill thrift in the ewe population. Pneumonia has not been implicated in illthrift in ewes, but has been implicated as a cause of mortality by Davis (1974) and in lambs, lesions affecting >20% of lungs have been associated with reduced growth rate (Goodwin et al., 2004). Pneumonia in adult ewes at Castlepoint may be worthy of more study to quantify the significance of the disease for health and production.

It was expected that if the incidence of Johne's disease is high on Castlepoint Station that the prevalence of this disease in the cull mob would be higher than observed. Histopathology has been used as confirmatory test when other tests such as Agar Gel Immunodiffusion, ELISA or lesion visualisation were used as screening tests (Bradley & Cannon, 2005; Kurade *et al.*, 2004; Rast & Whittington, 2005; Reddacliff *et al.*, 2004). Reddacliff et al (2004) showed that histopathology is less sensitive than culture for early stage infections. As the stage of infection was not known in the culls, it is likely that early stage infections were not detected. However, based on the description of the disease by Perez et al (1996), Johne's score type 1 lesions indicate early infection or successful suppression by an immune response. Fixation with formalin is a practical approach for sampling in remote areas, and the worst case scenario based on severity of granulomatous lesions could be a useful guide for estimates of prevalence when considering the worth of control programmes.

The Johne's study was seriously biased because the sample examined was only representative of cull ewes and not the whole population. Another, but far less important bias, could be present because lung samples and ileocaecal valves examined at slaughter were not truly random due to difficulties in handling amount of samples and speed of slaughtering process. However the sample size was large and any selection effect bias would be expected to be insignificant.

2.4.4 Limitation of the study

Prevalences of pneumonia and Johne's disease were derived from cull ewes at slaughter and while the results provided information about the disease prevalence in cull ewes, they gave no clear indication of prevalence in the farm population other than establishing presence of disease.

The footrot prevalence study was carried out in ewes that have been removed for foot conditions at shearing and calculation of the prevalence in the main flock relied on assumptions about self-cure over summer and reliability of detection at shearing. However, the spreadsheet model (Appendix 2) allows some stochasticity for the assumptions which could be further developed if required using AtRisk software.

Furthermore, the prevalence studies were conducted in a one year production cycle and differences between years and seasonal variation could give a somewhat different picture of disease status. However, the likelihood of any major differences between years for chronic and established diseases such as pneumonia, Johne's disease and footrot is unlikely. For chronic diseases, changes tend to occur slowly and major changes are seen mainly in the early stages of outbreaks or after successful control programme interventions.

2.5 Conclusion

The preliminary studies show that this property has a high mortality rate during lambing time, high lamb wastage from scanning to weaning, a high prevalence of footrot at shearing and a high prevalence of pneumonia in cull ewes at slaughter. The low prevalence of Johne's disease in cull ewes suggests a low incidence of disease on the farm but consideration of a longitudinal study to more accurately measure incidence is recommended. Despite their limitations, the studies suggest possible contributions from footrot and pneumonia to an increased risk of mortality, even though these findings could not be truly generalized to the whole ewe population.

Farm databases are used by many researchers for preliminary analysis, but often present difficulties for making confident inferences due to database design limitations, nonpurposively collected data, and/or through changes to data collection over time. Thus, although the farm data did allow seasonal patterns of mortality and wastage to be constructed over time, albeit with considerable difficulty, it did not provide reliable information about specific causes of ewe deaths over time.

The increased scanning and weaning percentages over time are clear indicators of increased reproductive efficiency at Castlepoint Station. High fecundity breeds have been used to increase flock fecundity concurrently with Androvax® vaccination and the overall value of the vaccination regime needs to be evaluated since it may increase the risk for triplets bearing ewes.

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Chapter 3

3 AN INVESTIGATION OF THE EFFECTS OF ANDROVAX VACCINATION OF MIXED AGE EWES

3.1 Introduction

3.1.1 Androvax vaccination

Androvax® is a vaccine with pre-hormone androstenedione as its antigen which has been widely used in New Zealand for increasing ewe fecundity. The vaccine was developed by McNatty and his team at the Wallaceville Animal Research Centre, Ministery of Agriculture and Fisheries New Zealand (McNatty et al, 1988) and its use was first described by Henderson and his colleagues in 1989 (Henderson *et al.*, 1989; McNatty *et al.*, 1988). Two commercial androstenedione vaccines have been evaluated, Fecundin® first used commercially in 1983 (Scaramuzzi *et al.*, 1983) and Androvax® in 1988 (Agresearch, 2006; Henderson et al., 1989).

The two vaccines differ in their protein conjugates, with Fecundin® using human serum albumin (Geldard, 1984), and Androvax® bovine-α-lactalbumin (McNatty et al., 1988). Another product, Ovastim, which has a similar protein conjugate as Fecundin® is currently available commercially in New Zealand. Androvax® has been used by the New Zealand farmers since 1994 (Agvax Development, 2004), but few reports of its efficacy have been published.

3.1.2 Mechanism and role of androstenedione immunisation

Androstenedione is a naturally occurring steroid present in both male and female mammals (Hudson & McNatty, 2002). It is a weak androgen secreted by ovaries and adrenal glands and is a precursor to the synthesis of testosterone and oestrogen (Baird *et al.*, 1971; Hudson & McNatty, 2002; Scaramuzzi *et al.*, 1977). Androstenedione is a low molecular weight steroid and is unable to produce an immune response under normal conditions (Scaramuzzi *et al.*, 1983). However, by linking androstenedione to a heterologous protein, Scaramuzzi *et al* (1983) produced a high molecular weight steroid-protein conjugate which evokes an immune response.

The effect of androstenedione immunisation on ovulation rates has been reported in New Zealand and other country studies (Cox *et al.*, 1982; McNatty *et al.*, 1988; Scaramuzzi *et al.*, 1977; Smith *et al.*, 1981). Its effect on ovulation rate was an unexpected discovery (Scaramuzzi *et al.*, 1983) which led to further studies by Scaramuzzi et al (1977) which confirmed their original finding and showed that immunisation with androstenedione conjugated with bovine serum albumin produced antibodies with a high degree of specificity to androstenedione. Problems of high rates of non-pregnant ewes after immunisation (Gibb *et al.*, 1981; Smith et al., 1981) were resolved by changing from Freunds complete to dextran adjuvant and adjusting the time interval from booster to start of to a minimum of two weeks (Geldard, 1984; Scaramuzzi et al., 1983).

An overall mean increase of 22 lambs born per 100 ewes mated was observed, although responses varied widely among studies (Smith, 1985). Studies have been done to examine the effects of breed, age, body weight at mating, plane of nutrition, season, geographical location and dose of immunogen. It was found that common New Zealand breeds such as Romneys and Coopworths responded well, unlike Merinos, where the response effect was less marked (Geldard, 1984; Scaramuzzi et al., 1983). Immunisation gave a greater increase in ovulation rate in Romneys than in Coopworths and Perendales in one study (Knight *et al.*, 1985), but not in another conducted by Clarke et al (1986). Age was found to have no effect in response to immunisation (Geldard, 1984; Scaramuzzi et al., 1983), but a study in hill country sheep found that older ewes had higher ovulation rates and produced more lambs per ewe at lambing and at weaning than younger ewes (Knight et al., 1985).

Body weight at mating has also been identified as an important factor for increasing ovulation rates after immunisation. Ewes with an average body weight of 60 kg produced 40 more lambs per 100 ewes treated, while 40 kg ewes at the lower end of the weight range only produced an extra 13 (Scaramuzzi et al., 1983). This same effect was also observed by Geldard et al (1984), but Smith et al (1985) found no difference between treated and non-treated ewes. It should be noted, however, that Scaramuzzi et al (1983) and Geldard et al (1984) studies used scanning data as a proxy for lambing percentage, whereas Smith et al (1985) recorded ovulation rates and followed the groups through to weaning.

Differences in responses were mostly attributed to confounding from other factors and partial failure of multiple ovulations where ovulation rate was not reflected by lambs born per ewe mated (Knight *et al.*, 1985; Smith, 1985; Smith *et al.*, 1985). The early studies, however, mostly involved Fecundin® or developmental preparations of androstenedione-protein conjugate (Geldard, 1984; Knight *et al.*, 1985; Scaramuzzi et al., 1983; Smith *et al.*, 1982; Smith et al., 1981; Smith *et al.*, 1985).

3.1.3 Financial gain assessment

The expected monetary gain from using fecundity enhancing vaccines is an important consideration for commercial farmers and a variety of economic methods can be used to evaluate the success of management programmes in monetary terms. One such method is partial budgeting, which is useful for comparing benefits from specific programmes that do not involve specific time patterns or high levels of uncertainty. Partial budgets are used to estimate the change that will occur in farm and enterprise profit from changes in the farm or enterprise plan by considering only those items of returns and costs that change (Huirne & Dijkhuizen, 1997). Partial budgets consider the benefits and costs directly related to plan changes, but do not calculate the overall income and expenses gain. It uses the current plan or base plan as the basis for comparison with alternative plans or changes being considered (Huirne & Dijkhuizen, 1997).

3.1.4 Objectives of the study

The objectives of the study described here were to assess the efficacy of Androvax® vaccination with fecundity in adult ewes that were sensitised in previous years and calculate the economic consequences of vaccination.

3.2 Materials and Methods

3.2.1 Selection of ewes

Ewes enrolled for this study were selected from a mixed age (MA) ewe mob of about 4,000 ewes in March 2006. A sample size of 300 ewes was calculated using Win Episcope version 2.0, to be sufficient to detect, with 95% confidence and 80% power, a difference of ±10% about an expected level of 79% of multiple bearing ewes. A sample size of 244 ewes was needed for each group to identify differences of 5% in triplet bearing ewes with the same levels of precision and confidence.

All ewes in the mob of 4,000 MA ewes were booster vaccinated, with the exception of 300 untreated controls which were selected as the first 300 through the drafting race at the pre-mating vaccination time. Non-treated ewes were colour marked for identification and grazed together with the treated ewes until scanning time.

3.2.2 Scanning

At ultrasound scanning, 600 treated ewes and the previously selected 300 controls were drafted out from the main mob. The additional 300 treated ewes were selected to ensure sufficient numbers for enrolment in a concurrent wastage study and a nitrogen application paddock trial conducted over the lambing season, for which ultrasound scanning results were required for allocation to study groups. Ultrasound scanning was conducted by an independent commercial contractor on 15th June 2006 and pregnancy status was recorded as not pregnant (empty), single, twins and triplets.

3.2.3 Partial budgets

A partial budget was used to estimate the effect of discontinuing vaccination as a new plan in comparison to maintaining vaccination programme as a base plan. The partial budget identified two components of costs and two components of benefits. The benefit components were additional returns, i.e. returns from the new plan that would not come from the existing plan, and reduced costs, which were costs that would be avoided or saved with the new plan. Cost components included returns foregone, i.e. returns from the existing plan that would not be received, and extra costs which are costs required by the new plan and not needed in the existing plan.

The calculated net result from the new plan is benefit components minus cost components. A change to a new plan should be adopted when the sum of benefits is more than the sum of costs, while a negative net result would indicate that the new plan would be undesirable and a financial burden (Huirne & Dijkhuizen, 1997; Sprecher *et al.*, 1989). The effects of discontinuing Androvax® vaccination were identified and included in benefits and costs calculations. The calculation of benefits and costs incorporated assumptions for ewe and lamb mortality, lamb value at weaning, ewe value at optimum sale price, and cost of labour. A sensitivity analysis was done as a final step by varying each parameter in turn while all other parameters were kept constant.

3.2.4 Data analysis

Analysis of scanning data was conducted in R (R development core team, 2004). Differences between proportions in ewes categorised at scanning with single, twin and triplet lambs were calculated using 'epi.conf' with 'prop.unpaired' method in the R Epicentre library. The Chi-square test was used to test for differences between vaccinated and non-vaccinated groups, and relative risk and attributable fractions were calculated to quantify the risk of multiple and triplet lamb bearing ewes (outcomes) with treatment and the contribution of vaccination towards the outcomes. Microsoft Excel® spreadsheets were used for the calculation of partial budget benefits and costs.

3.3 Results

3.3.1 Fecundity study

Ultrasound scanning results for 592 vaccinated and 264 non-vaccinated ewes are shown in Table 7. The differences between vaccinated and non-vaccinated ewes was 0.25% (95%CI -1.8% – 1.5%) for not-pregnants, 4.9% (95%CI 1.5% – 7.7%) for triplets, -2.7% for twins (95%CI -8.2% – 2.7%) and 0.7% (95%CI -4.7% – 5.8%) for single lamb bearing ewes. The overall scanning percentage was 177%, and for vaccinates and controls was 178% and 175% respectively.

Table 7 Numbers and percentages of ewes scanned as not pregnant (empty), single, twin and triplet bearing in vaccinated and non-vaccinated groups and overall.

Status	Non-vaccinates	Vaccinates	Overall percentage (95% CI)
Single	71 (26.9%)	167 (28.3%)	27.7 (24.8 - 30.8)
Twins	182 (68.9%)	366 (61.8%)	63.8 (60.5 - 66.9)
Triplets	9 (3.4%)	53 (9%)	7.2 (5.7 - 9.2)
Empty	2 (0.7%)	6 (1%)	0.9 (0.5 - 1.8)
Total	264	592	177

The risk of ewes pregnant with multiple lambs in the non-vaccinated ewes was not significantly different than in the vaccinates (Risk ratio 1.02, 95% CI 0.93 – 1.12) but the risk of triplets in the vaccinated group was higher (Risk ratio 2.7, 95% CI 1.4 – 5.3) than in the unvaccinated ewes with 60% (95% CI 26% - 81%) of triplet outcomes attributed to Androvax® treatment. Vaccination increased the percentage of triplets by 8% (95% CI 4% – 12%).

3.3.2 Partial budget

Vaccine and labour costs were identified as reduced costs in the partial budget. Manufacturer recommendations are for an initial sensitiser and an annual pre-mating booster vaccination, and for the budget the cost of the sensitising dose was amortised over 4 years. The cost of vaccine was based on 2006 costs of $142.50 per 100 doses and labour at $5 per 100 sheep, based on vaccinating 300 sheep per hour and a wage rate of $15 per hour.

Assumptions for the budget were:

- an extra 5% of triplet bearing ewes due to vaccination, and a mortality rate of 8%;
- a mortality rate of 5% for twin bearing ewes;
- $100 value for in-lamb triplet bearing ewes;
- triplet lambs mortality from birth to weaning of 29% (Kerslake *et al.*, 2005);
- average value of weaned lambs of $39 based on a 30kg weaner and $1.30 per kg.

Extra lambs resulting from vaccination were considered returns forgone in the partial budget. The total return for discontinuing vaccination would be $115.06 per 100 ewes as shown in Table 8. The major contribution to benefits was from cost of vaccine. Details of the assumptions and calculations are appended in Appendix 3.

Discontinuing Androvax® vaccination would give benefits from ceasing vaccination and saving the extra triplet bearing ewes resulting from vaccination. Extra lambs would be forgone if vaccination was discontinued.

Sensitivity analysis identified several factors that could contribute to net returns. Vaccination cost had the greatest influence. Labour and vaccine costs are unlikely to reduce over time and will always be the major contributor to benefits if other assumptions are kept constant. Benefits from ewes carrying twins rather than triplets would only increase if mortality rates of triplet bearing ewes were higher than for twin bearing ewes. No additional returns would come if triplet bearing ewe mortality is less than 5%. Additional returns from extra ewes saved would exceed benefits from vaccination cost if mortality in triplet bearing ewes exceeds 42%. The value of ewes has little effect on the net returns unless the value of triplet bearing ewes drops by 40% compared to twin bearing ewes. Extra lambs foregone would affect the net returns if vaccination increased extra lambs by more than 7%, and lamb value would only influence the benefits of the plan if it increased three times more than the price assumed for the calculations.

Table 8 Partial budget for discontinuing Androvax vaccination at Castlepoint Station.

BENEFITS			
	Reduced Costs		
		Sensitiser dose	$35.63
		Booster dose	$142.50
		Labour cost	$5.00
	Additional Returns		
		Extra ewes saved	$15.00
	Total Benefits (A)		$198.13
COSTS			
	Additional Cost		
			$0.00
	Returns Foregone		
		Extra lambs	$83.07
	Total Costs (B)		$83.07
NET RETURNS		**A - B**	$115.06

3.4 Discussion

In this study Androvax® vaccination of mixed age ewes produced 3% more scanned lambs which were derived from 5% more triplet bearing ewes. This is lower than that achieved in an Australian androstenedione immunisation study (Scaramuzzi et al (1983) in which the average increase was 23 lambs per 100 ewes mated (range 7% - 47%) although Smith (1985) had similar overall results but a wide range of responses of -2 to +53 extra lambs (based on ovulation rates and not on ultrasound scanning) per 100 ewes mated.

In this study, which involved Romney ewes, no difference between the proportions of multiple lamb bearing ewes was observed between immunised and non-immunised ewes but immunised multiple lamb bearing ewes were about two times more likely to have triplets than their non-immunised counterparts. Increased rates of triplet lamb bearing ewes have also been observed in other androstenedione studies. Geldard et al (1984) found a shift from single bearing to twin bearing ewes on farms with low incidences of twinning in contrast to high twinning flocks where the shift was from twin bearing to triplet bearing ewes. Furthermore, a litter size study involving 72 New Zealand flocks with varying levels of fecundity indicated that when litter size was >1.7, the proportion of ewes having triplets was increased (Davis *et al.*, 1983). Thus there is evidence from multiple studies that point to high fecundity flocks experiencing more triplets after immunisation whereas for lower fecundity flocks with ovulation rates of <1.5, such as those studied by Scaramuzzi et al (1983), the greatest effect was increased twinning rates.

High incidences of ewes with triplets are associated with problems at lambing which can only be addressed if ewes carrying triplets are identified at scanning. Embryonic loss from ovulation to birth is generally conceded to be higher in immunised than in non-immunised ewes and a study in hill country farms in New Zealand found that the number of potential lambs, as measured by ovulation rates, was reduced through higher rates of embryonic loss and only manifested by 9% and 4% increases in weaned lambs in the first and second years respectively (Knight et al., 1985).

Management practices in early studies were different from current practices on most commercial farms. Ewes were mostly lambed together without consideration of specific management and nutritional requirements for different levels of fecundity, with the exception of some farms in the Geldard et al (1984) study where triplet bearing ewes were kept separate from others in the pre-lambing period. Nowadays, farmers generally use easy care management practices and set stock ewes at density levels and planes of nutrition that are based on their pregnancy status and it is possible that findings from the early studies may not hold for current management practices and newer breeds of sheep.

The partial budget, given the assumptions used, clearly showed a saving of $115.06 per 100 ewes from discontinuing Androvax® vaccination.

3.5 Study limitations

This study identified differences between the numbers of lambs scanned in treated and non-treated ewes but the study design did not stratify for possible confounding factors such as live weight at mating, and age of ewes. The distribution of ages in the treatment and control ewes should have been similar given the selection process, although the unknown age structure of the MA mob from which the ewes were selected may have influenced the results and any application of the study findings to other farms should be done with that proviso in mind. Live weight at mating was not recorded for the study ewes but historically recorded live weights at mating at Castlepoint station range from 61 to 67 kg and these are generally higher than those reported in earlier studies.

Not-vaccinated ewes were selected at mating and vaccinates at scanning but because the study groups were run together in the main mob until set stocking, any possible selection bias from the different selection times was considered to be negligible. Occurrences of missing ewes from the control ewes were considered to be random events with no effect on the results of the study.

3.6 Conclusion

On the study farm, vaccination with a commercial androstenedione-protein conjugate vaccine did not increase the prevalence of ewes with multiples lambs but did increase the prevalence of triplet lamb bearing ewes, which amounted to a 3% increase in lambs scanned. A partial budget indicated that the benefit of not vaccinating ewes was greater than the additional income from vaccination.

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Chapter 4

4 INVESTIGATION OF WASTAGE FROM SCANNING TO WEANING

4.1 Introduction

The reason for introducing high fecundity genes into a flock is to increase the number of lambs available for sale and replacement. However, it has been shown that flocks with an average prolificacy of greater than 1.5 lambs tailed per ewe mated have higher proportions of triplet bearing ewes (Amer *et al.*, 1999). Increases in fecundity require special management practices that can provide sufficient feed to meet the extra demands from the additional ewes and lambs. Failure to provide sufficient feed required by ewes during early to middle pregnancy can be expected to reduce lamb birth weights and their survival (Smeaton *et al.*, 1999) and any increases in lamb wastage may reduce the income expected from lambs, and increase financial losses from investment in ewes at the beginning of breeding season.

Most sheep farmers in New Zealand use easy-care management of ewes during lambing so as to reduce the stress on ewes at that time (Fisher, 2003), lessen the amount of mismothering due to over zealous shepherding, and keep labour costs low. Sheep have been purposely selected for better survival, for the most part by crossbreeding and natural and selective culling of undesirable traits. However, high rates of wastage during lambing can be due to multiple causes, the identification of which requires careful investigation.

4.1.1 Reproductive wastage

The term reproductive wastage has been used to describe failure to achieve expected targets set for breeding ewes to produce lambs, but a more generally accepted definition is the loss of potential lambs from conception to weaning or lambing. Ewe losses over this period have been found to have a small impact on overall farm productivity, with the exception of a King Country study in 1997 (Tarbotton & Webby, 1999), and recent wastage studies have mainly focused on lamb losses and ewe losses have been given little attention. Due consideration should be always given to ewe losses n wastage studies because of variable and occasionally high ewe death rates associated with pregnancy and lambing, and the deaths of the lambs that they carry.

4.1.2 Causes of reproductive wastage

Analysis of ewe mortality data on the case farm over recent years indicated that most ewe deaths occurred about lambing time and vaginal prolapse was perceived by farm staff to be the main cause of ewe deaths. However, count data were not available and other common causes of loss, such as dystocia and pregnancy toxaemia, or effects of other conditions such as Johne's disease and infectious footrot could not be ruled out.

The perinatal period is the time of greatest risk for death of lambs (Dalton *et al.*, 1980; Hight & Jury, 1969; Nicoll *et al.*, 1999). Single lambs have been shown to have a higher survival rate than multiple lambs in some studies (Dalton et al., 1980; Hinch *et al.*, 1983; Kelly, 1982; Kerslake *et al.*, 2005; Nicoll et al., 1999; Tarbotton & Webby, 1999) but Quinlivan and Martin (1971) observed an opposite result and Hight and Jury (1969) found no difference. Recent observations have indicated that triplet lambs are about two times more likely to die than twin or single lambs (Kerslake et al., 2005; Nicoll et al., 1999) with starvation accounting for most deaths in twins and triplets, and dystocia as the main cause in singles.

4.1.3 Objectives of the study

The objectives of the study were;

1. To determine important causes of death at lambing time;
2. To determine the incidences of ewe and lamb wastage from scanning to weaning.

4.2 Materials and methods

4.2.1 Wastage study

A total of 531 single and twin bearing mixed age (MA) ewes were randomly selected after ultrasound scanning from the Androvax® study group and individually identified with numbered ear tags. All 299 vaccinates and 232 not-vaccinated ewes were grazed together in the main mob until set stocking, at which time they were vaccinated with a 5-in-1 clostridial vaccine. Signs of lameness were recorded on the selection day and the cohorts were followed until weaning. Twin bearing ewes were set stocked in six paddocks in two separate blocks along with an additional 80 twin bearing ewes which were added to match stocking rate with pasture cover. The paddocks had been topdressed with different rates of nitrogen application as part of a nitrogen effect study. Single bearing ewes were set stocked separately in one paddock.

Ewe deaths were recorded from scanning to weaning, and all ewes and lambs that died and were found between 22 August and 12 September 2006 were necropsied. During this time necropsies were also performed on sheep from other mobs on the farm. Study group ewes were observed at least once a day over the lambing period.

Body condition scores, based on a score of 1 to 5 (Appendix 4) were recorded for all twin bearing ewes at scanning, set stocking, docking and weaning. Ewe weights were recorded at set stocking, docking and weaning, and lambs weights at docking and weaning. Five and 37 single bearing ewes were weighed at set stocking and docking respectively. The timing of wastage study events is shown in Figure 2.

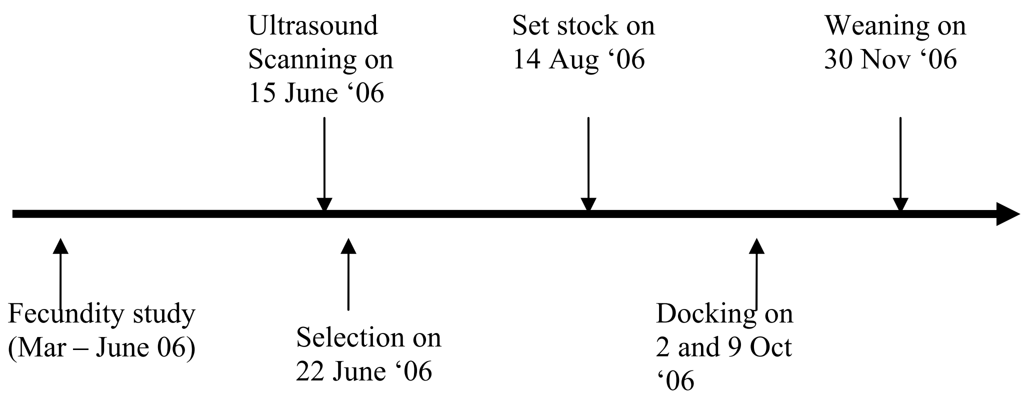

Figure 2 Timing of the 2006 wastage study events from scanning to weaning for 531 mixed age ewes at Castlepoint Station

4.2.2 Post mortem examinations and diagnosis

All dead ewes and lambs at lambing were examined according to the procedure described in Appendix 5 as soon as possible after ewes and lambs were found. Tissue samples were fixed in 10% buffered formalin and sent to the pathology department at the Institute of Veterinary and Biological Sciences at Massey University. Causes of death were determined based on presence of gross lesions at post mortem and results of laboratory examinations.

Ileocaecal valves from all dead ewes at lambing were examined for granulomatous lesions and presence of acid fast bacteria. Positive Johne's disease cases were defined as samples with granulomatous lesion scores of ≥2 (Perez et al 1996) and/or presence of acid fast bacteria.

4.2.3 Data analysis

A summary description of the data recorded for the study is set out in Table 9. Lambs could not be individually identified at lambing and weaning percentages were therefore derived from the total number of ewes set stocked and incorporated the additional non-study ewes. The number of ewes at the beginning of the study was assumed to be equal to the number of ewes mated. Definitions of weaning percentage, and lamb and ewe wastages are set out separately in Appendix 1. Missing ewes that could not be accounted for at set stocking were included in the wastage analysis but excluded from calculations involving expected lamb and weaning percentages.

Independent and paired t-tests were used to test for differences between means of ewe weights between groups and over time. Histograms and quartile plots were used to assess normality of data and the Bartlett test for homogeneity of variance. The effect of rates of nitrogen application and covariates on weights of twin bearing ewes and their lambs was assessed with repeated measures analysis of variance (linear mixed model package 'nlme'in R, R Development Core Team.). Nitrogen application was entered in the model as a categorical variable with 0 for no application and 1 for 60 or 100 units per ha. Lamb data at docking and weaning were analysed separately because lambs were not individually identified.

Ewe mortality rate was calculated as the percentage of individually identified study ewe deaths during the period from scanning to weaning. Differences between mortality rates for vaccinated and not-vaccinated ewes and between twin bearing and single bearing ewes were tested with Chi-square tests using ‘epi.2by2’ in the R Epicentre software package.

Table 9 Summary data recorded for the wastage study

Parameter	**Description**
Body weight	Ewe body weights (kg) were recorded at set stocking, docking and weaning. Lamb weights were recorded at docking and weaning.
Body condition score	Ewe body condition scores from 1 (emaciated) to 5 (obese) were recorded at scanning, set stocking, docking and weaning.
Event date	Dates for scanning, set stocking, docking and weaning events.
Scanning status	Single or twin pregnancy status at scanning.
Year born	Ewe birth year; 2000, 2001, 2002.
Vaccination status	Pre-mating Androvax® booster vaccination given or not given
Set stocking paddock	ID for 7 paddocks used for set stocking with stocking density based on pasture cover;
Nitrogen application status	Amount of nitrogen (kg/hectare) applied to the paddocks; (0, 60 and 120kg)
Removal date	Date of removal, either found dead or purposive kills.
Reason of removal	Reason for removal

4.3 Results

4.3.1 Ewes

Reconciliation of data at weaning showed that of the 351 MA ewes enrolled, 15 ewes died, one ewe was euthanased and 35 ewes could not be accounted for (Table 10). The ewe mortality rate for the study period was 3.1% (95%CI 1.9% - 5%). Two ewes died before set stocking and the remainder before docking. No deaths were reported from docking to weaning with the exception of one unidentified ewe which was excluded from the analysis. No between-paddock differences in death rates were observed.

Dystocia was the main cause of death and was responsible for 37% of deaths in the 16 ewes that were able to be examined. Of the six dystocias, four were associated with abnormal lamb presentation, one was due to uterine rupture and one was due to obstruction of the birth canal by intestine. Causes of deaths of the study ewes are shown in Table 11. Causes of deaths for 28 ewes in the main flock in the same period are shown in Table 12 for comparison. No footrot was seen post mortem in the study ewes but two main flock ewes had footrot scores of 1 and 3. All but one of the necropsied ewes had the same number of lambs as were diagnosed at scanning. The exception was diagnosed as twin bearing but was carrying triplets.

There was no significant difference between the risk of death between Androvax vaccinates and controls (mortality rate ratio 0.5, 95% CI 0.2 – 1.3). There was some indication of a greater risk for twin bearing ewes than for single bearing ewes, but the difference was not significantly different (mortality rate ratio 2.4, 95% CI 0.5 – 10.7) and the sample size was too small to detect small differences.

Table 10 Status of single and twins bearing ewes in Androvax treated and control groups at the end of the 2006 Castlepoint Station wastage study

Status\Group	Vaccinates		Controls		Total
	Single	Twins	Single	Twins	
Present	58	215	55	152	480
Died	1	5	1	8	15
Euthanased	0	0	0	1	1
Missing	12	8	8	7	35
Total	71	228	64	168	531

Table 11 Cause of deaths between scanning and weaning among 531 mixed age ewes enrolled in the 2006 Castlepoint Station wastage study

Deaths/Purposive kills Reason	Count	Percentage
Dystocia	6	37%
Vaginal prolapse	3	19%
Cast	1	6%
Bloat	1	6%
Mastitis	1	6%
Misadventure	2	13%
Not known/autolysed	2	13%
Total	16	100%

Table 12 Cause of deaths of 28 ewes at lambing time from 22 August to 12 September 2006 in mobs other than the wastage study group at Castlepoint Station

Causes of deaths/euthanased	Count	Percentage
Dystocia	9	32%
Vaginal prolapse	12*	43%
Cast	0	0%
Bloat/Cast	0	0%
Mastitis	1	4%
Misadventure /Traumatic Injury	3#	10%
Not known/Autolysed	2	7%
Johne's	1$	4%
Total	28	100%

*8 ewe hoggets and 1 mixed age ewe were euthanased
1 mixed age ewe died due to asphyxiation
$ 1 2-tooth ewe was euthanased

Average ewe weights at set stocking, docking and weaning were 72.8, 63.1 and 67kg respectively (Table 13). The study ewes were set stocked in seven paddocks at three sites, A, B and C (Table 14). Twin bearing ewes were set stocked in six paddocks; Oxen, Horse, Cob (A), and in Waite, Olivia, Marlow (B). Single bearing ewes were set stocked in one paddock (C). The variation between weights at set stocking, docking and weaning are shown in Figure 3, and show the greatest weight loss occurred after lambing with some weight recovery between set stocking and weaning. Weights at set stocking were only recorded for twin bearing ewes and only a sample of the single bearing ewes was weighed at docking. Average ewe weights were slightly higher in paddocks at site B than at site A, although their distributions were similar. Figure 4 and Figure 5 boxplots show the distributions of changes in ewe weights between set stocking to docking, and docking to weaning for the various paddocks. It appears that that twin bearing ewes in Cob and Horse had greater weight gains than ewes elsewhere.

Based on the 37 single ewes that were weighed, their average weights at docking were 4.9kg less than for twins bearing ewes. At weaning, the average weights of single bearing ewes were 2.7kg lower than for twin bearing ewes. There was no significant difference between Androvax® treated and non-treated average ewe weights at weaning. However, Androvax® treated ewes were on average 1.5 kg (95% CI 0.1 – 2.9 kg) heavier at docking. The average weight of vaccinates increased by 4.1 kg (95%CI 3.5 – 4.8 kg) between docking and weaning, and by 4.6 kg (95% CI 4 – 5.3 kg) for controls. The average weight of single bearing ewes increased by 8.9 kg (95% CI 7.7 – 10.1 kg) from docking to weaning and by 3.9 kg (95% CI 3.4 – 4.4 kg) for twin bearing ewes.

Table 13 Descriptive statistics and quartile distributions of weights at set stocking, docking and weaning for 518 mixed age ewes in the 2006 Castlepoint Station wastage study

Time of weighing	Mean	variance	std	Q25	Q50	Q75	Min	Max	Missing values
At set stocking	72.8	34.1	5.8	69.0	73.0	76.5	56	93	144
At docking	63.1	51.0	7.1	58.5	63.0	67.9	38	86.5	129
At weaning	67.0	41.9	6.5	63.0	66.5	71.0	48	91	51

Table 14 Paddock and site distribution of 518 mixed age ewes enrolled in the 2006 Castlepoint Station wastage study, paddock nitrogen treatment, and average weights at set stocking, docking and weaning

Paddock	N*	Site	Nitrogen	Average weight at set stocking (kg)	Average weight at docking (kg)	Average weight at weaning (kg)
Cob	50	A	60	70.0	60.5	69.7
Crumps	123	C	0	NA**	57.1	64.6
Horse	73	A	0	70.9	57.9	65.6
Marlow	61	B	60	74.7	67.4	69.8
Olivia	88	B	120	73.8	67.3	68.0
Oxen	70	A	120	72.8	62.6	66.5
Waite	53	B	0	74.9	65.8	67.4
Overall	518			72.8	63.1	67.0

*N = number of MA ewes at set stocking; 2 ewes died and 11 ewes were missing at set stocking
** NA = not recorded

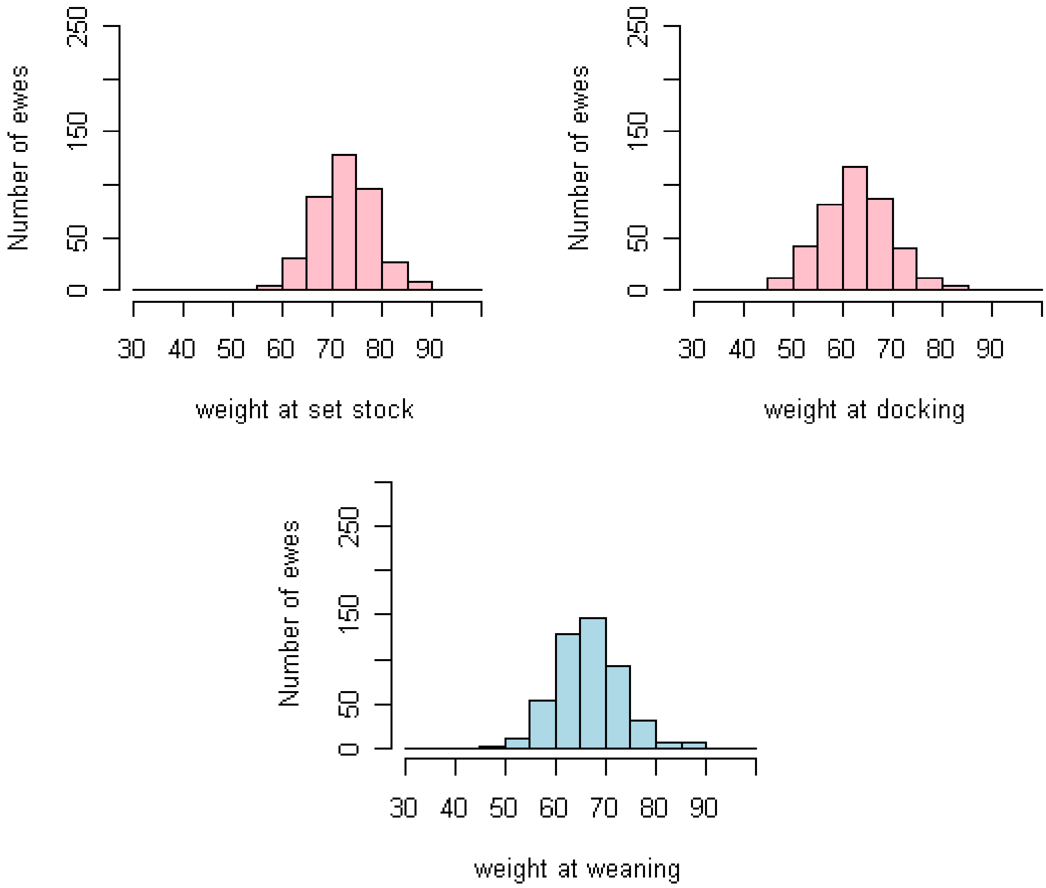

Figure 3 Distribution of 518 mixed age ewe weights at set stocking, docking and weaning in the 2006 Castlepoint Station wastage study

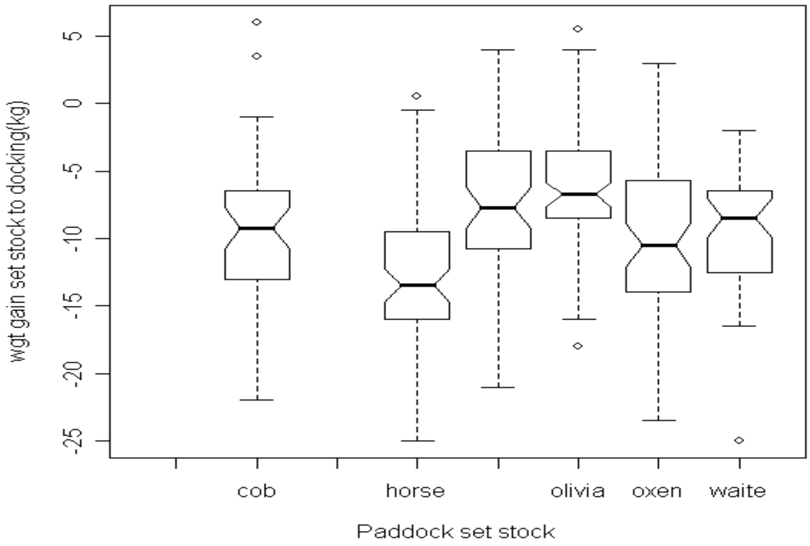

Figure 4 Weight gains from set stocking to docking for 518 mixed age ewes in the 2006 Castlepoint Station wastage study

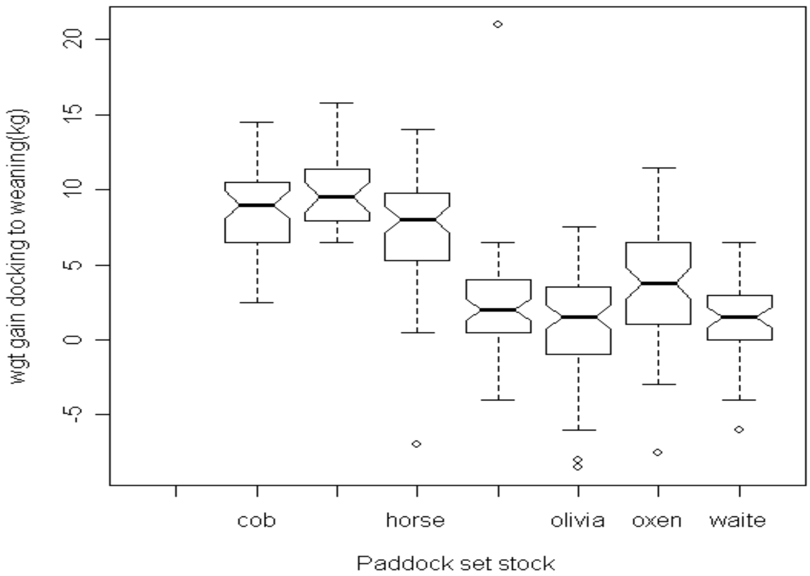

Figure 5 Weight gains from docking to weaning for 518 mixed age ewes in the 2006 Castlepoint Station wastage study

The distribution of body condition scores recorded from scanning to weaning indicated a drop in condition at docking, and an increase at weaning (Figure 6). Six ewes went from condition score 2 and 3 at set stocking to condition score 1 at docking. All but one of these ewes survived to weaning and the exception had the lowest weight at docking (38 kg). One ewe with a score of 1 from the main flock which was euthanased because of emaciation was histopathology and acid fast staining test positive for Johne's disease.

Average pasture covers in the nitrogen (N_2) trial paddocks in control, 60 unit N_2 and 120 unit N_2 from 31 July to 1 December 2006 were 1185, 1316 and 1291 kg dry matter per hectare respectively. Pasture cover was greater in paddocks with nitrogen treatment than in the control paddocks (Figure 7). However, pasture cover in the 120 unit N_2 paddocks decreased towards the end of the study. There was also an effect on location/block in response to nitrogen treatment. Repeated measure ANOVA results, after adjusting for the effects of time of measurement events, indicated that nitrogen application was associated with increases of ewe weights of 2.4 kg and 2.1 kg in 60 and 120 unit N_2 nitrogen treatment paddocks over ewes in the control paddocks. No significant difference in ewe weights was observed between the two rates of nitrogen application.

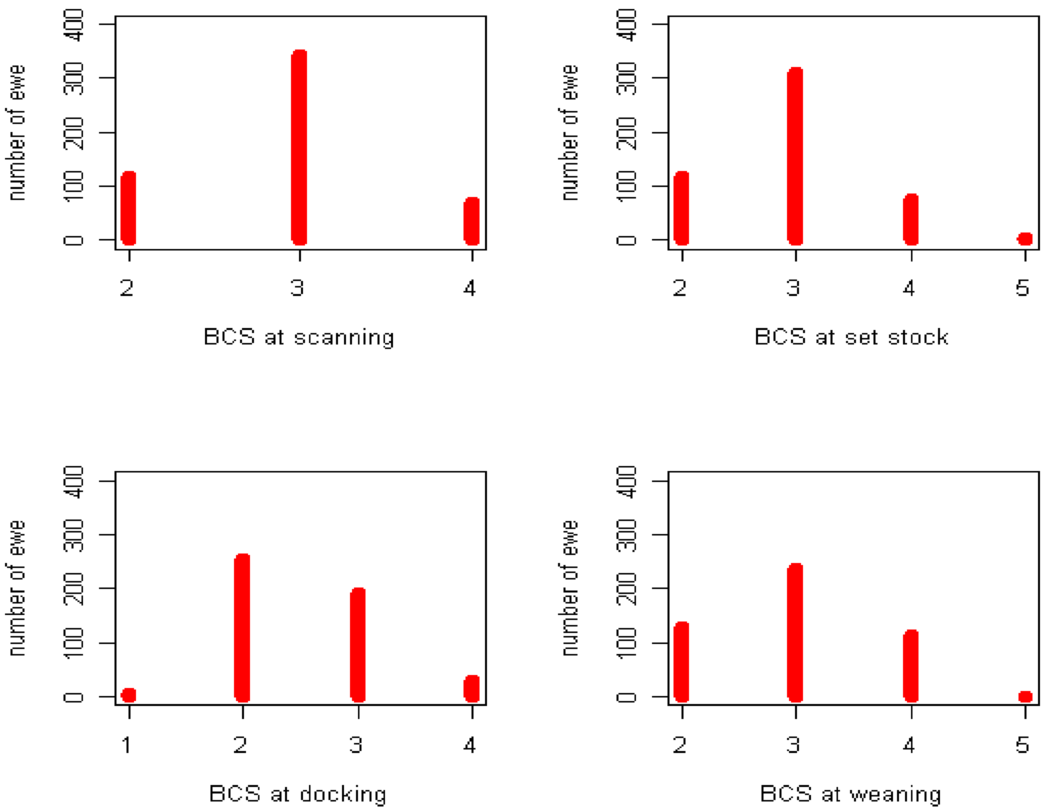

Figure 6 Distributions of body condition scores (BCS) in 531 mixed age ewes in the 2006 Castlepoint Station wastage study

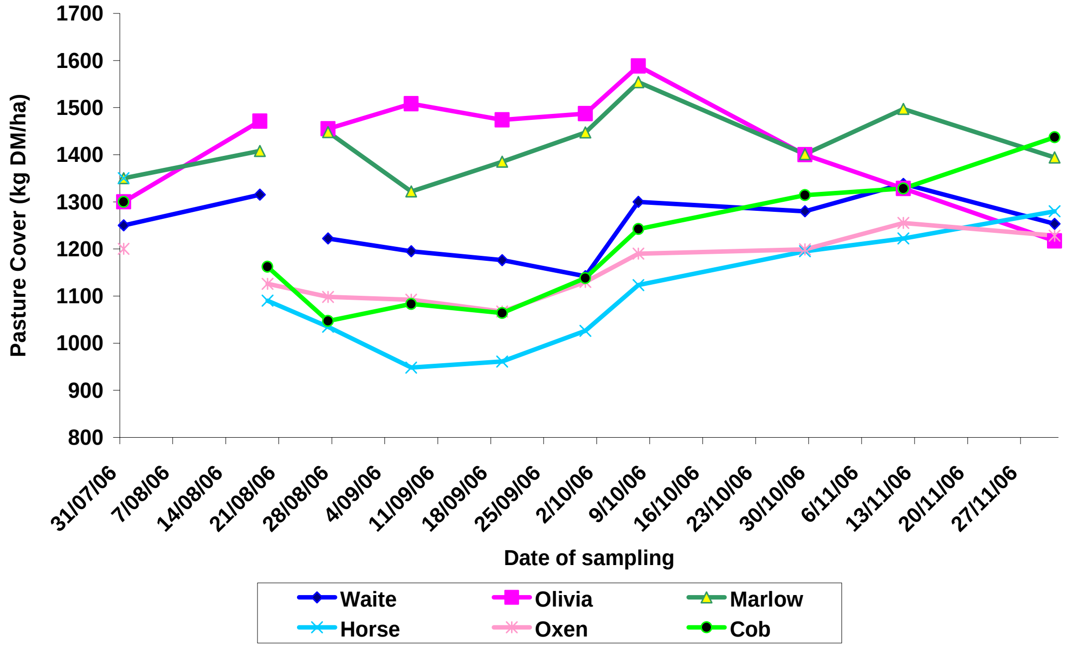

Figure 7 Pasture cover in paddocks set stocked with twin bearing ewes from 31 July to 1 December 2006. Nitrogen was not applied to Waite and Horse, and applied at a rate of 60 units/ha on Marlow and Cob, and at 120 units on Olivia and Oxen. Paddock Waite, Olivia and Marlow were located in the southern block, and Horse, Oxen and Cob in the northern block.

4.3.2 Lambs

A total of 953 lambs were weaned, comprising 121 from the singles paddock and 832 from the twin bearing ewe stocked paddocks. Numbers of lambs per paddock at weaning varied from 1.1 to 2 lambs per ewe. The expected percentage of lambs was 179%, and the weaning percentage was 159%. A total of 19 lambs were necropsied in the 3-week period from 22 August to 12 September 2006. Starvation was the main cause of lamb deaths (74%), one was stillborn, two were stillborn with signs of dystocia, and there were two for which the cause could not be determined. Lamb wastage from scanning to weaning was 12.3% and accounted for all but 16 (1.5%) of those expected from scanning results.

Average lamb weights at docking and weaning weight were 14.3kg (sd 3.1) and 29.8kg (sd 4.7) respectively. The average weights and standard errors of lambs in the various paddocks are shown in Figure 8. Single lamb average weights were 4.9 kg and 4.2 kg higher at docking and weaning than those of twin lambs and the ANOVA analysis indicated a significant effect from nitrogen application on lamb weights at docking and weaning, although it was only manifested by increases of 1 and 1.1kg over control paddocks for the high rate of 120kg/ha at docking and the low rate of60 kg/ha at weaning. Ratios of lamb weaning weights to ewe weaning weights in the various paddocks are shown in Table 15.

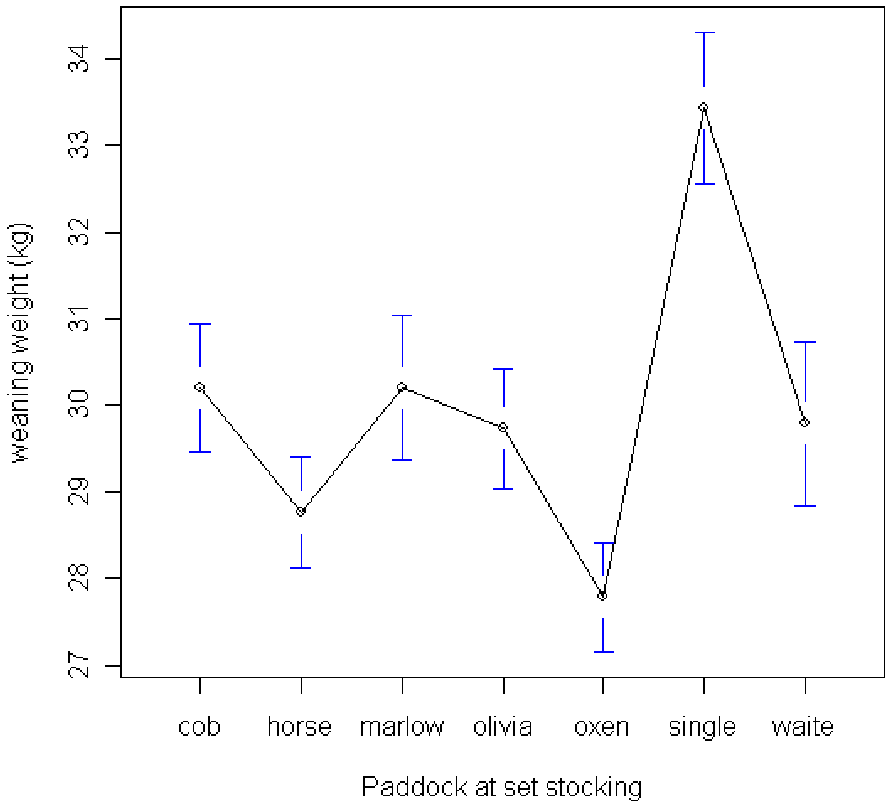

Figure 8 Point estimates and their confidence intervals (—) for average lamb weights in the various paddocks at weaning.

Table 15 Numbers of lambs at docking and weaning, and ratios of lamb weaning weights to ewe weaning weights for each paddock location.

Paddock	Site	N lambs at docking	N lambs at weaning	Kg lamb/kg ewes at weaning
Cob	A	125	127	3836.5/4545 = 0.84
Single	C		121	4345/7279.5 = 0.60
Horse	A	181	179	5148.5/6482 = 0.79
Marlow	B	107	111	3352/3911 = 0.86
Olivia	B	157	161	4786.5/5789.5 = 0.83
Oxen	A	170	165	4584/6374 = 0.72
Waite	B	90	89	2651/3359.5 = 0.79

4.4 Discussion

Ewe and lamb wastage was lower in the study period compared to previous years. In the study group, dystocia and starvation were the main causes of ewe and lamb deaths respectively. Dystocia was identified as an important cause of ewe deaths in a 1971-1972 study (Davis, 1974), but ewe deaths at lambing does not seem to have been elsewhere investigated and reported . Based on the post mortem findings in our study, more than half of the dystocias were associated with abnormal lamb presentation at birth. Thomas (1990), also found dystocia in live ewes was mostly due to abnormal lamb presentation.

Starvation was the main cause of deaths of lambs and is in agreement with a 2003 study conducted by the farm's veterinarian. However it contrasts with the results from another study (Kerslake, 2005) in which dystocia was deemed to be responsible for half of all lamb deaths within three days of birth. Exact causes of death are difficult to determine since there are many reasons for starvation, such as failure to suck adequately due to weakness or disease, competition from litter mates, poor maternal instincts and mismothering, and insufficient colostrum or milk (Mellor & Stafford, 2004).

Three major interventions were done during the period of the study; foot bathing in 10% zinc sulphate for control of footrot, identification of triplet bearing ewes, and earlier set stocking than in previous years. It is difficult to assess the several or combined impact of these interventions. There was no footrot observed post mortem in study group ewes and only two cases in ewes from the main flock. However, the feet of individual study ewes were not examined during the study period and the prevalence of footrot was therefore not determined.

Identification of triplet bearing ewes by ultrasound scanning was done to allow better nutrition better aligned to their special needs. Only single and twin bearing ewes were enrolled for the study and while any effect from the separation of triplet bearing ewes could not be determined, the mortality rate observed would almost certainly have been higher if they had been included.

Earlier set stocking than in previous years was employed as a measure to reduce stress and prevent the effect of a sudden increase in feed intake and changes in quality in late pregnancy, which could conceivably lead to increased intra-abdominal pressure and occurrence of vaginal prolapse. Anecdotal reports from other farms in the region indicated that there were fewer vaginal prolapses generally and again it is difficult to determine whether the intervention was influential in reducing the incidence of prolapses.

Nitrogen application at 60 and 120kg/ha had a positive effect on ewe and lamb weights which may be explained by improved pasture cover.

Ratios of lamb weight to ewe weights were calculated to assess the statistic's worth as an indicator of efficiency of production among the various paddocks. However, using ewe weights as a denominator could be misleading if the distribution of ewe weights was not the same for all paddocks. The ratio would be expected to be useful if the weight distribution is narrow.

4.5 Study limitations

The study was cross-sectional and although there was an apparent marked improvement in performance compared to previous years, seasonal effects could not be evaluated due to limited data that might explain differences. Multiple interventions based on disease occurrence observations made through the year and from historical records were carried out to improve productivity and reduce wastage. Overall, the interventions seemed to have been successful but the contributions that each made could not be determined. It is unfortunate that 35 ewes were lost to follow-up. The most likely explanations for the losses were death or mixing with other mobs at mustering or through fences. Although searches for dead animals were made, some ewes may have died and not been discovered since the terrain was steep and there were places which were difficult to search thoroughly. Keeping track of individual animals on a large commercial farm where there are occasional opportunities for mixing of mobs presents considerable difficulties and contrasts with research facilities where animals are more easily supervised.

4.6 Conclusion

The study detected a higher risk of deaths in twin bearing ewes than in single bearing ewes but neither Androvax® usage nor nitrogen application had any detectable effect on mortality rates. Lamb and ewe wastage was lower in the study season than in previous seasons but the contributions that individual interventions or natural seasonal effects made could not be determined.

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Chapter 5

5 GENERAL DISCUSSION

The first step in the overall investigation of wastage and losses on the farm was evaluation and analysis of existing data. This proved difficult because while there were good financial and management records they were poorly integrated with animal health information. Our requirements were relatively simple but important information e.g. tallies of ewes at significant events such as mating, shearing, scanning and weaning, was not readily available. However, after considerable effort and time it was eventually possible to show temporal patterns of wastage for broadly different age groups of ewes and these patterns were particularly useful for focusing attention on times of greatest loss.

Quantifying disease prevalence in the farm was also difficult. Three infectious diseases, Johne's disease, pneumonia and infectious footrot, that could have been conceivably contributing significantly to wastage were investigated from the onset. Conversely, investigations into the role of vaginal prolapse, which was perceived to be a major contributor to ewe wastage, could not be investigated until lambing time. An attempt was made to introduce syndromic surveillance as a method for quantifying disease prevalence but for various reasons the technique was not adopted by farm staff.

Insights into the prevalence of Johne's disease and pneumonia came from examination of a sample of ewes at a slaughter plant and occasional opportunistic sampling of debilitated or sick sheep on the farm. These methods, although useful, suffer from selection bias and results are difficult to extrapolate to disease rates for populations at risk on the farm. Nevertheless, they were particularly useful for identifying diseases that could be prioritised for more detailed investigations of the benefits of special interventions, such as vaccination for Johne's disease.

An overall impression from necropsies, high prevalences of coughing and a history of an outbreak in hoggets was that the prevalence of pneumonia on the farm is very high. The cost of the disease in adult ewes is unknown, but may be substantial. Unfortunately, there are no reliable control measures that can be implemented. On the other hand, a vaccine is available for control of Johne's disease and an economic evaluation of control options for Johne's disease in New Zealand has been made which ranks possible disease control options for different levels of infection (Brett, 1998). The indications are that vaccination for Johne's disease is worthwhile if the annual incidence of clinical cases is 2% or higher, and worthwhile in farms with 1% annual incidence when there is no carcass downgrading from vaccine induced lesions. A longitudinal study would be required to give a reliable estimate of the incidence of clinical Johne's disease, and for that type of investigation individual animals would need to be identified and followed over time in a sentinel mob. Clinical footrot cases, on the other hand, can be accurately identified with a visual examination and this was done to establish the prevalence in a mob that was screened out at shearing. The high prevalence of infectious footrot found was unexpected and control measures were promptly introduced and appear to have been reasonably successful. The capital costs involved with construction of foot bath facilities was high, but the facilities are permanent structures and the cost can be amortized over time.

Evaluation of existing practices or any new farm plans can be done in a variety of ways. Partial budgets were used for the Androvax® vaccination study. This technique is easy to perform as only specific changes that occur enter into the calculations. Details of the methods used for calculation of samples size and partial budgets in the study are provided elsewhere in the thesis and maybe useful as templates for others to use for benefit cost evaluations.

The investigation of wastage on this large commercial farm involved the use of sentinel animals. This approach is useful and has considerable potential for on-farm investigations of the occurrence of particular diseases or the efficacy of interventions. However, the required sample size for sentinel mobs is dependent on expected incidence and the stipulated level of confidence and may not be practicable for low incidence diseases on small farms.

The wastage study quantified the losses from scanning to weaning and identified starvation and mismothering as important causes of perinatal lamb mortality. Dystocia was the major cause of deaths in ewes and while there is no readily available solution to this problem under the current management system it was reassuring to find a lower level of wastage than in previous years, possibly as a result of the interventions.

The lower than usual ewe wastage may have been due to multiple factors which include early set stocking, usage of Nilvax®, running triplets bearing ewes separately from twin bearing ewes, a reduction in the prevalence of footrot, or season. Nilvax® is a clostridial vaccine incorporating levamisole and was used to fit with the earlier than usual time of mustering for set stocking, at which time ewes receive their pre-lamb vaccine. This preparation is claimed by the manufacturer (Cooper Schering-Plough Animal Health Ltd) to induce a higher and longer antibody response in ewes and is considered to give a longer duration of maternal immunity in lambs than other antigen only vaccines.

Seasonal variation has been suggested as a contributing factor in the reduction of wastage. There was a slight lower pasture cover than usual but any relationship between wastage and cover could not be easily determined.

References

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Appendices

Appendix I

Definitions of calculations in the analysis

Scanning data

Scan denominator:

$$\text{Scanning \%} = \frac{\text{number of lambs scanned}}{\text{number of ewes scanned}} \times 100$$

$$\text{\% Multiples scanned} = \frac{\text{number of ewes scanned with multiple lambs}}{\text{number of ewes scanned}} \times 100$$

$$\text{\% Singles scanned} = \frac{\text{number of ewes scanned with single lamb}}{\text{number of ewes scanned}} \times 100$$

Lamb calculations

Number of potential lambs (scanned) = #single ewes + (2×#twinning ewes) + (3×#triplet ewes)

% Triplet ewes (Triplet calculator)[5] *= (0.0044 × %singles squared) + (0.6921 × %singles) + 27.625*

Number of potential lambs (calculated) = #single ewes[6] *+ (2×#twinning ewes*[7]*) + (3×#triplet ewes derived from Triplet calculator)*

Mating denominator

$$\text{\% Singles (mated)} = \frac{\text{number of ewes scanned with single lamb}}{\text{number of ewes mated}} \times 100$$

$$\text{\% Multiples (mated)} = \frac{\text{number of ewes scanned with multiple lambs}}{\text{number of ewes mated}} \times 100$$

$$\text{\% Twinning ewes (mated)} = \frac{\text{number of ewes scanned with two lambs}}{\text{number of ewes mated}} \times 100$$

$$\text{\% Triplet ewes (mated)} = \frac{\text{number of ewes scanned with three lambs}}{\text{number of ewes mated}} \times 100$$

$$\text{\% Dry (empty)} = \frac{\text{number of ewes scanned dry (empty)}}{\text{number of ewes mated}} \times 100$$

[5] Formula removed dry ewes from calculation
[6] Removed dry ewes from calculation of single ewes
[7] Removed dry ewes from calculation of twinning ewes

Lambing and weaning

$$\text{Lambing \%} = \frac{\text{number of lambs tailed}}{\text{number of ewes mated}} \times 100$$

$$\text{Weaning \%} = \frac{\text{number of lambs weaned}}{\text{number of ewes mated}} \times 100$$

Mortality and wastage

Lambs:

Lambs lost from scanning to tailing1= number of potential lambs (scanned) – number of lambs tailed

Lambs lost from scanning to tailing2=number of potential lambs (calculated) – number of lambs tailed

$$\text{Lamb wastage scanning to tailing \%} = \frac{\text{number of potential lambs (scanned)} - \text{number of lambs tailed}}{\text{number of potential lambs (scanned)}} \times 100$$

$$\text{Lamb wastage scanning to weaning \%} = \frac{\text{number of potential lambs (scanned)} - \text{number of lambs weaned}}{\text{number of potential lambs (scanned)}} \times 100$$

Ewes:

$$\text{Annual ewe mortality \%} = \frac{\text{number of ewe deaths in one year}}{\text{number of ewes at start of year (tally at mating)}} \times 100$$

$$\text{Annual ewe mortality incidence risk} = \frac{\text{number of ewe deaths in one year}}{\text{Ewe population at risk in each year}} \times 100$$

$$\text{Monthly ewe mortality \%} = \frac{\text{number of ewe deaths in each month}}{\text{number of ewes at start of month}} \times 100$$

$$\text{Monthly ewe mortality incidence risk} = \frac{\text{number of ewe deaths in each month}}{\text{Ewe population at risk in each month}} \times 100$$

$$\text{Ewe mating to scanning wastage \%} = \frac{\text{number of ewes mated} - \text{number of ewes scanned}}{\text{number of ewes mated}} \times 100$$

$$\text{Ewe mating to docking wastage \%} = \frac{\text{number of ewes mated} - \text{number of ewes at docking}}{\text{number of ewes mated}} \times 100$$

$$\text{Ewe mating to weaning wastage \%} = \frac{\text{number of ewes mated} - \text{number of ewes at weaning}}{\text{number of ewes mated}} \times 100$$

$$\text{Ewe scanning to weaning wastage \%} = \frac{\text{number of ewes scanned} - \text{number of ewes at weaning}}{\text{number of ewes scanned}} \times 100$$

$$\text{Ewe scanning to docking wastage \%} = \frac{\text{number of ewes scanned} - \text{number of ewes at docking}}{\text{number of ewes scanned}} \times 100$$

Appendix II

Estimation of prevalence of footrot in mixed age ewes at Castlepoint Station

Results			
agegroup	Footrot>=1	Non-infected	Total
1	10	12	22
2	25	44	69
3	16	56	72
6	2	2	4
Total	**53**	**114**	**167**

Footrot severity score results					
Score	RF*	LF*	RH*	LH*	Total
1	2	3	1	2	8
2	0	1	3	4	8
3	18	9	18	15	60
Total	**20**	**13**	**22**	**21**	**76**

Only cells coloured [ ] may be changed

Calculations for the cull mob	
Number of ewes with footrot	53
Number of ewes examined	167
Number of ewes in the cull mob	**2200**
Prevalence estimate	31.7%
Lower 95% confidence limit	25.2%
Upper 95% confidence limit	39.1%
Estimated number of ewes with footrot	698
Lower 95% confidence limit	553
Upper 95% confidence limit	861

100.0%

Assumptions	
Detection rate at shearing	**50%**
Self cure over summer	**50%**
Number of ewes on the farm	
Total ewes on the farm	**17000**

Calculations for all the ewes on the farm	
Number of ewes with footrot now	**1396**
Lower 95% confidence limit	**1107**
Upper 95% confidence limit	**1722**
Number with footrot 4 months ago	**2793**
Lower 95% confidence limit	**2214**
Upper 95% confidence limit	**3444**

Detection rate at shearing is	50%
Prevalence now	**8.2%**
Lower 95% confidence limit	**6.5%**
Upper 95% confidence limit	**10.1%**
With self cure rate over summer	50%
Prevalence 4 months ago	**16.4%**
Lower 95% confidence limit	**13.0%**
Upper 95% confidence limit	**20.3%**

Appendix III

Assumptions and calculation of Partial Budget

in the Androvax® vaccination trial

Situation: Effect of not using Androvax to increase fecundity
for mixed age ewes 100

Additional returns:		
a.Saving extra ewes with triplets in vaccinated group		
Extra ewes with triplets	0.05	5%
	5	
Mortality	0.08	8%
Extra ewes died	0.4	
Ewe saved	4.6	
Price	$100.00	per ewe
Total saving	$460.00	
b.Saving extra ewes with triplets in unvaccinated group		
Extra ewes with triplets	0.05	5%
Ewes carry twins	5	
Mortality	0.05	5%
Extra ewes died	0.25	
Ewe saved	4.75	
Price	$100.00	per ewe
Total saving	$475.00	
Overall saving	$15.00	
Total additional returns	**$15.00**	

Additional costs:	
Total additional costs	**$0.00**

Reduced costs:		
a.Vaccination cost;		
Sensitising dose	$1.425	ewe/dose
Benefit average	4	years
	$35.63	
Booster dose	$1.425	
	$142.50	
Labour cost;	$0.05	per ewe
	$5.00	
Total vaccination cost	$183.13	
Total Reduced costs	**$183.13**	

Reduced returns/returns foregone:		
a.Extra lambs	0.03	3%
	3	
Mortality, birth to weaning	0.29	29%
	0.87	
Extra lamb at weaning	2.13	
Average kg at weaning	30	kg
Price at weaning	1.3	per kg
Total extra lambs returns	$83.07	
Total reduced returns	**$83.07**	

Net Return	**$115.06**

Appendix IV

Body condition scores

How to do:

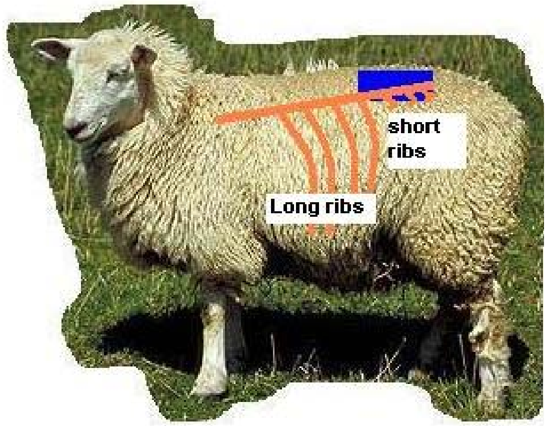


Figure 9: Location of short ribs and long ribs in the live sheep.

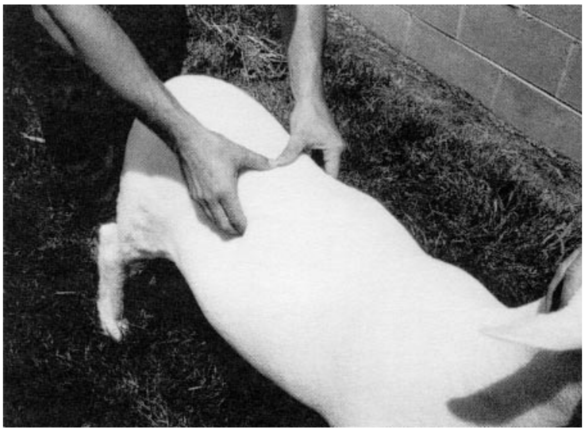
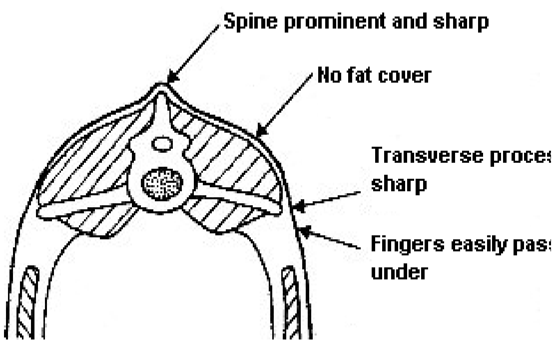
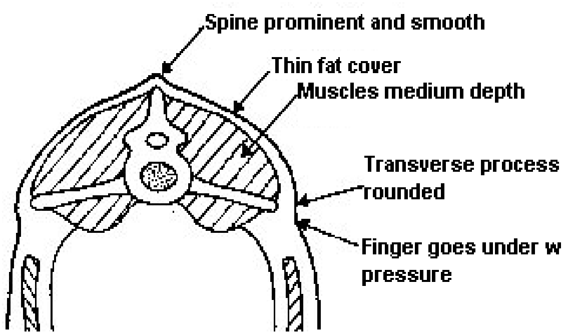


Figure 10: Feel of the backbone and short ribs to estimate body condition score

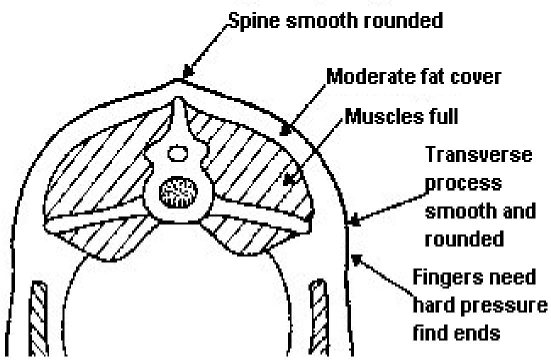
Classification of Body condition scores (score 1 to 5*):



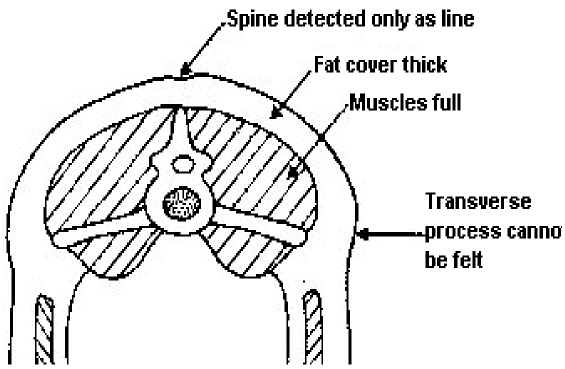
Score 1 (Emaciated): **Backbones (spine) are sharp and prominent. Loin eye muscle is shallow with no fat cover. Short ribs (transverse processes) are sharp; one can pass fingers under ends. It is possible to feel between each process.**



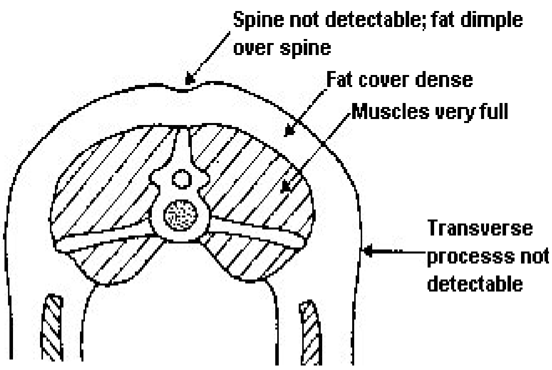
Score 2 (Thin): **Backbones (spine) are prominent and smooth. Loin eye muscle has little fat cover but is full, tending to feel flat. Short ribs (transverse processes) are smooth and slightly rounded. It is possible to pass fingers under the ends of the short ribs with a little pressure.**



<u>Score 3 (Average):</u> Backbones (spine) are smooth and one can feel individual processes only with pressure. Short ribs (transverse processes) are smooth and well covered, and firm pressure is needed to feel over the ends. Loin eye muscle is full with some fat cover.



<u>Score 4 (Fat):</u> Backbones (spine) can be detected only with pressure as a hard line. Short ribs (transverse processes) cannot be felt. Loin eye muscle is full with a thick fat cover.



<u>Score 5 (Obese):</u> Backbone (spine) cannot be detected. There is a depression between fat where spine would normally be felt. Short ribs (transverse processes) cannot be detected. Loin eye muscle is very full with a very thick fat cover.

* References

1. Tectra. *Condition scoring at flushing pays dividends at lambing.* http://tectra.co.nz/NR/rdonlyres/ on 12th Jan 2006.
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3. Mathias, C.P., http://www.cahe.nmsu.edu/pubs/_b/100B15.pdf on 5th Jan 2006.
4. New Mexico State University, USA, *Assessing Nutritional Status*, http://www.cahe.nmsu.edu/sheep/sheep_nutrition/assess_nutrition.html on 8th March 2007.

Appendix V

Manual for post mortem examination of sheep

MANUAL FOR POST MORTEM EXAMINATION OF SHEEP

Aim of the manual

This manual is designed to help an animal handler or farm worker to carry out a simple post mortem examination of a sheep to help identify the cause of death. It is not intended to replace a veterinary diagnosis, but rather to complement or increase the chances of making a useful diagnosis in the absence of a veterinarian. It is strongly recommended that any findings are discussed with a veterinarian before reaching any conclusions about the cause of death and making plans for further action.

NECROPSY INSTRUCTION – ADULT SHEEP

1. Cut underneath the left foreleg and shoulder blade.

2. Cut the area underneath left hind leg, hip joint and abdominal wall.

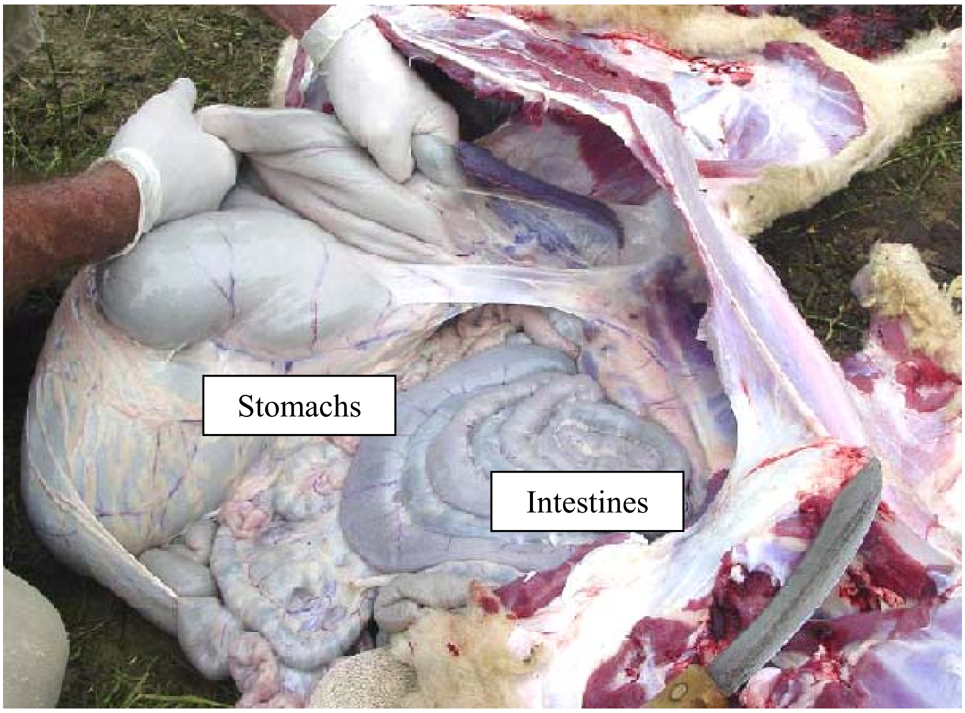
3. Pull the stomachs from the abdominal wall. Check fat layers on the stomachs and abdominal fluids.

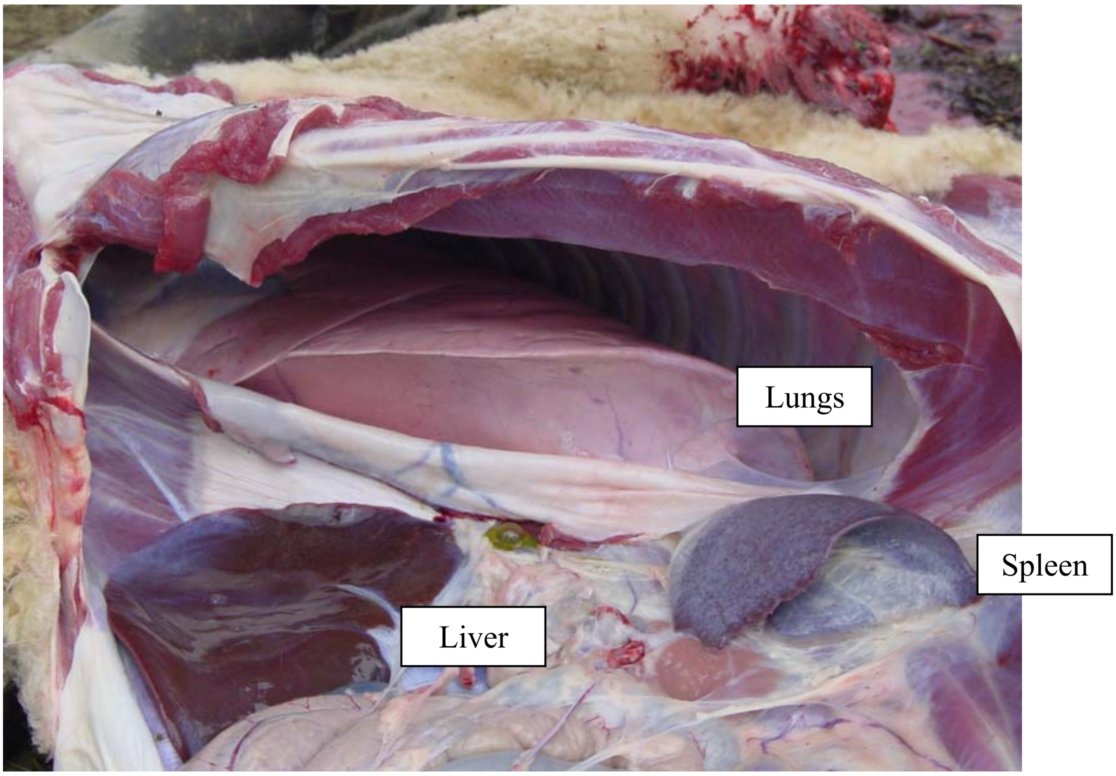
4. Cut the diaphragm wall to expose the lungs. Check for presence of adhesions between the lung and rib cage.

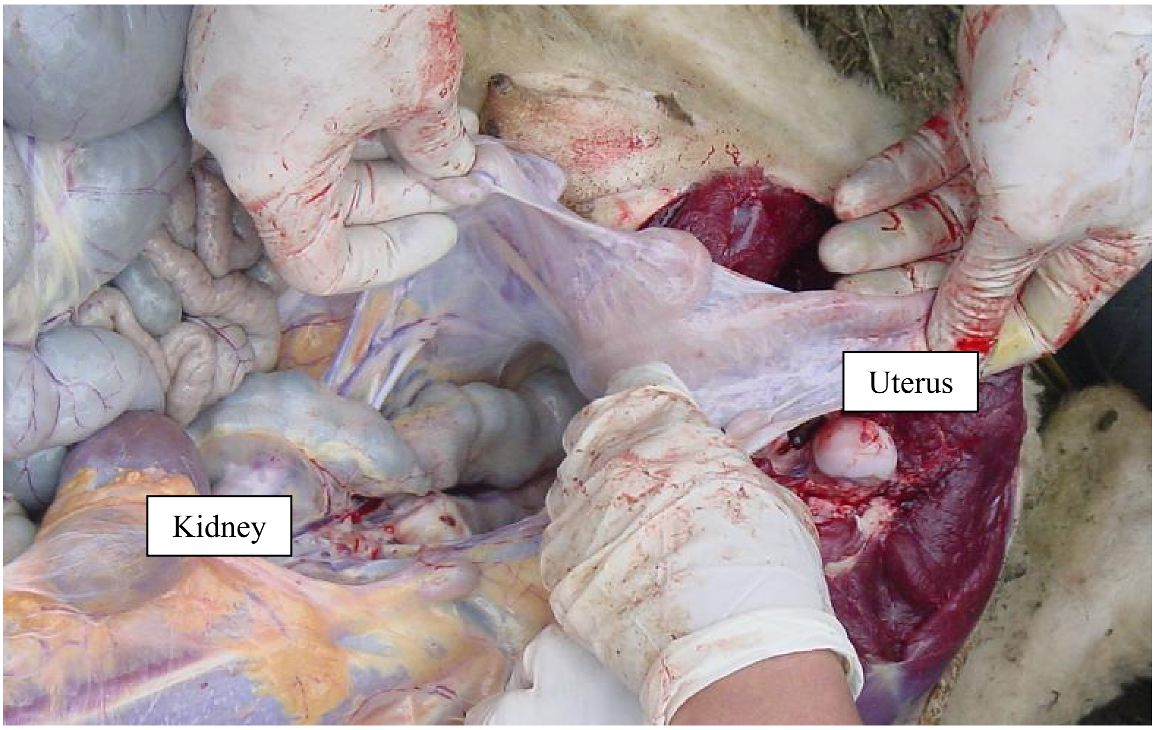
5. Cut the ribs. Check the lung surface and note any changes in colour

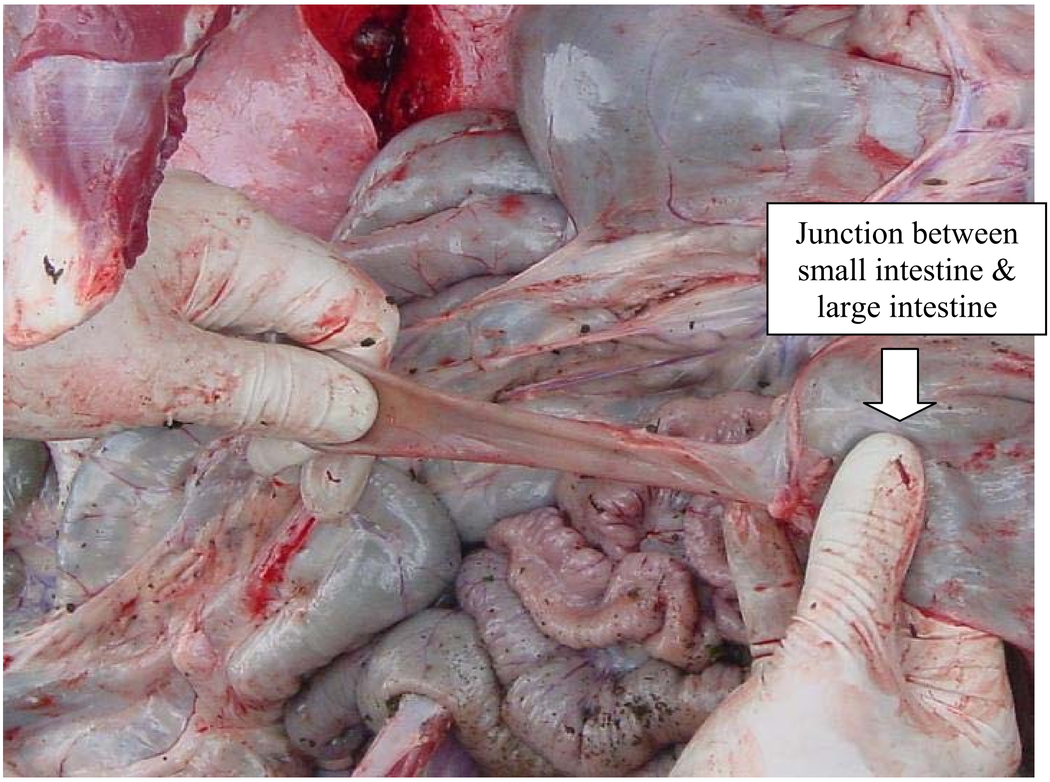
6. Organs exposed for thorough examination. Check the consistency of the lungs and look for any abnormalities in organs in the abdominal cavity.

ORGANS IN THE ABDOMINAL AND THORACIC CAVITIES






Uterus
Kidney


Junction between small intestine & large intestine

NECROPSY INSTRUCTION - LAMB

1. Check external body, feet and navel. Lambs that have not walked will have intact hoof cartilages.

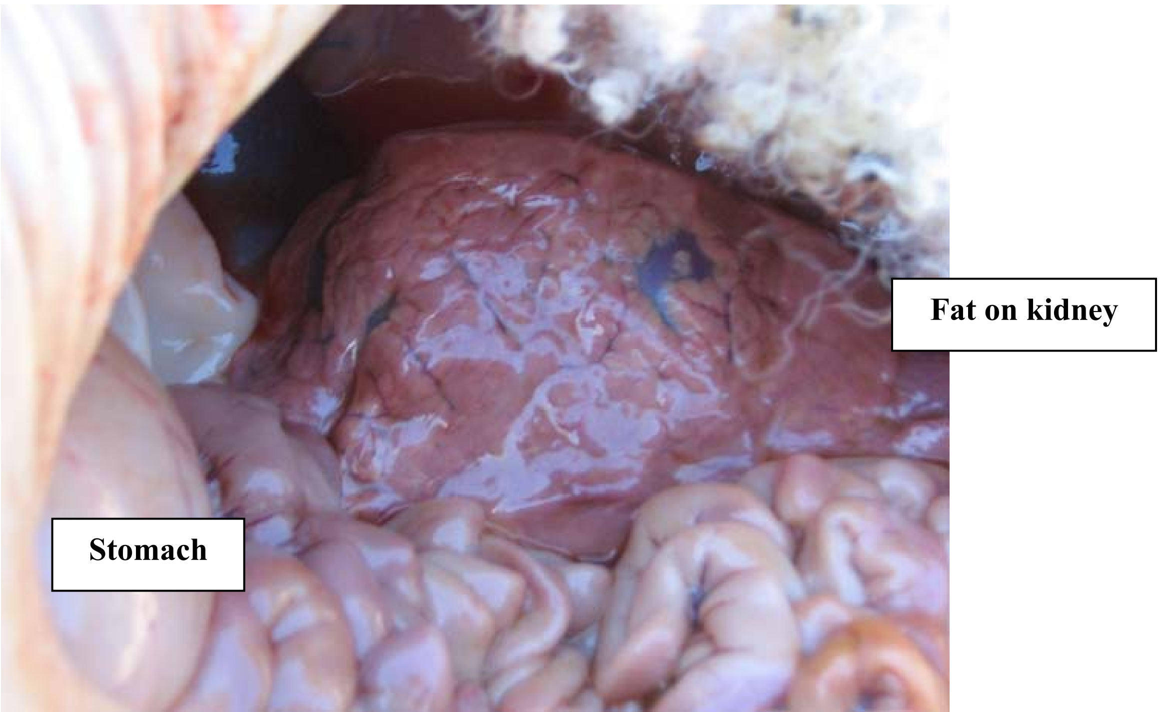
2. Place the lamb on the back and cut the skin and abdominal wall. Check the condition of the stomach, intestine and kidney.

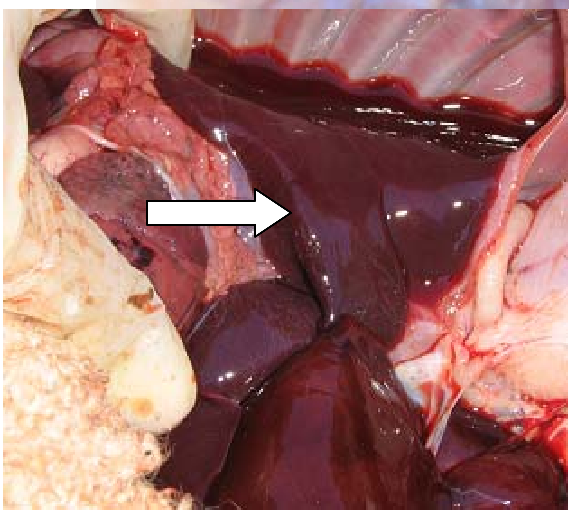
3. Cut the thoracic cavity and check condition of the lung. Lung that has not breathed will sink if put in water.

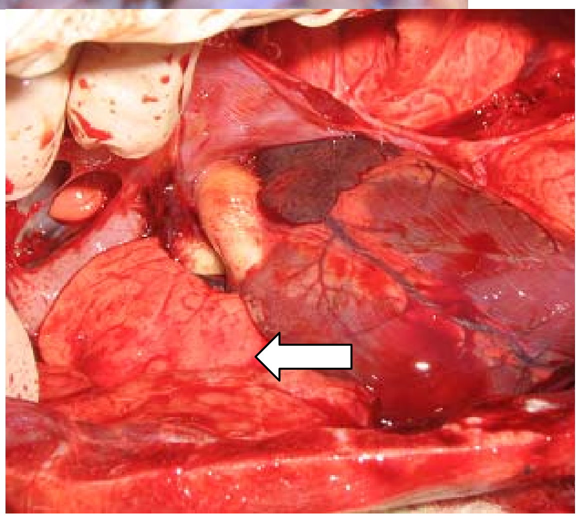
4. Cut the throat to expose the thyroid glands for detection of iodine deficiency if needed. Lamb should be weighed first for this purpose to get ratio of thyroid (gram) and weight (kg).

Worn hooves – no cartilage - walked

Intact hoof cartilage – has not walked







Non-breathed lung

Breathed lung

TAKING SAMPLES FOR DIAGNOSIS

Important measures when taking samples during necropsy

1. Samples should be clearly identified
2. Findings and type of samples taken should be recorded
3. Samples to be preserved with formalin should be thinly cut to ensure good fast penetration of formalin
4. Fresh samples should be kept cold and transported to a laboratory as soon as possible

Common findings:

FINDINGS	SUSPECTED DISEASE	SAMPLE TO TAKE	PRESERVATIVE TO USE
A. EXTERNAL Large mass from vulva	- Vaginal prolapse (bearing)	-	-
B. INTERNAL Lungs - attached to thoracic wall - red in colour - red-spotted	- Pneumonia - Septicaemia (blood poisoning)	Affected part of the lung	Formalin
Liver - yellowish & fatty - white-spotted - enlarged, fatty liver	- Pregnancy toxaemia - Leptospirosis - Salmonellosis	Affected part of the liver	Formalin
Intestines - Soft faecal material in large intestine - gas-filled - red intestine, diarrhoea	- Johne's disease - Clostridial diseases - Salmonellosis	- Part of the intestine at the junction between large intestine and small intestine - Affected part of intestine	- Formalin - Fresh intestine
Uterus - red and pus-filled	- Metritis - Recent abortion	- Whole uterus	- Formalin
- foetus inside	- Sleepy sickness/ Pregnancy toxaemia	-	

SAFETY MEASURES DURING AND AFTER NECROPSY

To ensure the safety of the handler during and after necropsy:

1. Make sure that necropsy is done at a safe location
2. Wear gloves when doing necropsies (kitchen gloves are ideal). Hands and gloves should be thoroughly cleaned after the necropsy, especially if an infectious disease was suspected
3. Handle sharp knives with care
4. Handle preservative with care
5. Handle samples with care