Report prepared for M&WNZ

Project: **Survival and performance of multiple lambs (03OFR01)**

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Lamb Survival
(03 OFR01)

Final Report

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Executive Summary

Historically, lamb survival rates at the Poukawa Research Station are high in singles and twins (90% and 88% respectively), falling to 77% in triplets. A large number of factors appear to influence triplet lamb survival – including weather, ewe genotype, litter size, lamb birth weight, ewe behaviour, ewe age, ewe nutrition, ewe health, ewe colostrum and milk production, mineral status, stress and uterine environment. However, perhaps the biggest contributor to lamb mortality is the stress the ewe is under prior to lambing. Ewes that had higher beta-hydroxy butyrate (BOH) levels prior to lambing had more dead lambs at birth and this suggests a poorer uterine environment. Lambs that died of starvation also appeared to be born to ewes with higher BOH levels. Lambs that died around or soon after birth tended to be smaller and were probably less vigorous, had limited nutrition in utero, were more vulnerable to adverse weather and less competitive for the ewe's milk in a multiple feeding situation

Transferring scanned triplet ewes from an extensive property to an intensive property for lambing significantly improved lamb survival (extensive 171% lambing vs intensive 222% lambing) and also reduced ewe mortality (9% vs 4%). Ewes under intensive management weaned 58.2 kg lamb/ewe whereas the triplet ewes left on the extensive property weaned to 47.4 kg lamb/ewe. There is the opportunity to transfer a problem mob (i.e. the scanned triplet ewes) from extensive hill country, to more intensive downland properties for lambing. Ewes would be returned after weaning and returns from lambs split between the two properties.

Lamb survival can be improved by rearing orphan and at-risk lambs using the principles of the once-a-day feeding of calves. Lambs can be successfully weaned at 8 kg – at or around 4 weeks of age. Best results were achieved using cow colostrum. The biggest animal health issue was abomasal bloat and this was overcome by adding yoghurt to the colostrum/milk. Another issue encountered was lack of palatability of meal. It appears that products such as palm kernel (often incorporated into calf pellets), is unpalatable making early weaning difficult. Best results were obtained with a meal based on maize and peas. Under good feeding conditions (colostrum and high quality meal) lambs can be reared for $24 (labour and facilities excluded) and achieve liveweights of 26.7 kg at 15 weeks of age. .

Two lifetime performance studies were initiated as part of this project - the effect of hogget lambing and the effect of birth rank on lifetime performance. Both projects are only part way through but early indications are that ewes lambed as hoggets produce more total lamb weaning weight. However, the gap is closing with each successive lambing by the ewes first lambed as two tooths. Ewes born as twins or triplets are maintaining a slight advantage over ewes lambed as singles in terms of lifetime lambs born and total lamb weaning weight/ewe.

The historical data collected within the Elite Lamb and Lamb Survival projects has been incorporated into a sheep flock model to test the impact of different management strategies. The biggest impacts came from strategies which enabled more output from fewer ewes. Lambing hoggets had the biggest impact on flock efficiency and increased gross farm income by 14.6%. Delaying culling from 5 to 6 years meant less replacements were needed

and gross farm income increased by 6.2% Lifting scanning % from 160% to 180% lifted gross farm incomes by 5.4%. The cumulative effect of these strategies has the potential to lift gross farm income by 22%.

Background and Industry Context

The Poukawa Elite Flock was originally established in 1998 to investigate the milking ability and performance of East Friesian and Finn x ewes. This project continued to evolve in response to farmer needs and became an umbrella project for sheep research relevant to the East Coast of both islands. In 2003, a new project was initiated which looked at improving lamb survival in triplet lambs using the original East Friesian x, Finn x, Poll Dorset x and Romney ewes. Subsequently, and in conjunction with AGMARDT, work was initiated on ways to commercially rear orphan and at-risk lambs as a way of improving lamb survival and reducing a potential welfare issue. The project continued to evolve and in 2005, research was initiated to look at the effects of hogget mating and birth rank on lifetime performance. In 2008, a Sheep Flock Efficiency model was developed (in conjunction with MAF) incorporating much of the data previously collected from the Elite Lamb and Lamb Survival projects. Much of this data could not have been collected from experiments run on a project by project basis.

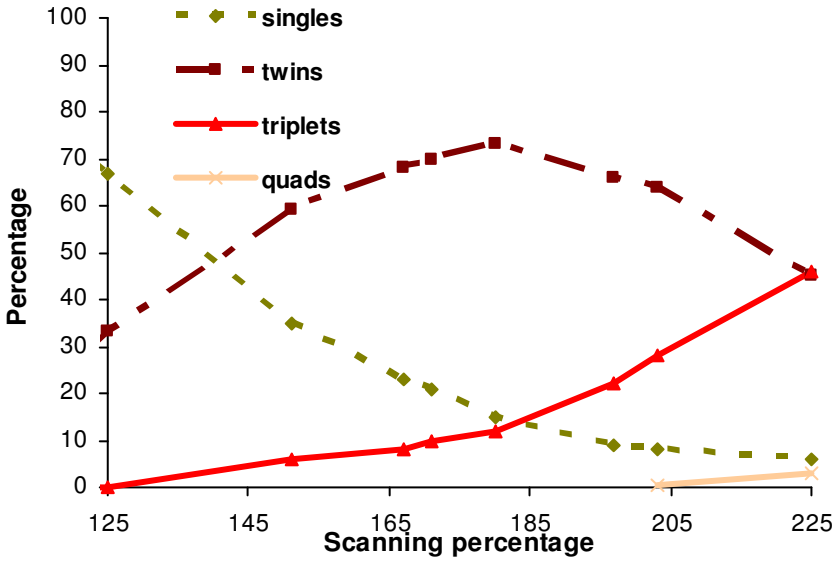
Main Results and Findings

Lamb survival

Introduction. The introduction of new genetics and improved nutrition within the New Zealand sheep industry has improved the national lambing percentage. As the lambing percentage increases, so does the number of triplets (Fig 1). The survival rates of triplets can vary widely (particularly in extensive hill country) with anecdotal reports ranging from 50 to 80%. Strategies to improve these variable survival rates need to be developed as low survival rates have welfare implications and affect the potential profitability of the sheep farming operation. To do this we need to better understand the factors affecting lamb survival.

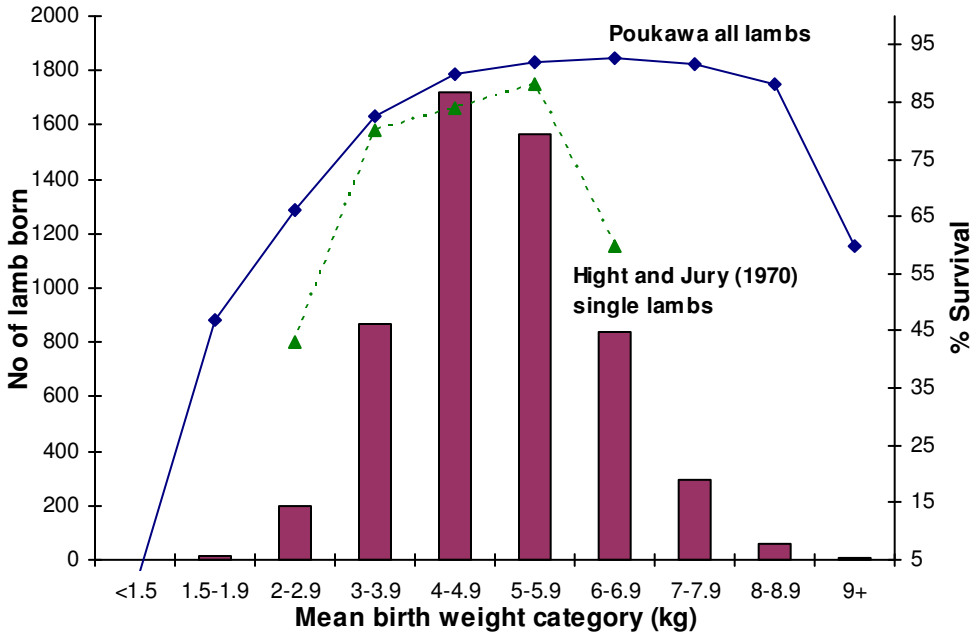
The Poukawa ewe flock has relatively high survival in singles (90%) and twins (88%) declining to 79% in triplets. Over 5 years, the Poukawa flock was studied to identify reasons for the higher mortality in triplets relative to singles and twins.

Figure 1 Effect of scanning % on number of ewes carrying singles, twins, triplets or quads.



Lamb birth weight. The effect of birth weight on lamb survival was examined in the full database of 9569 lambs born between 1998 and 2006. Average lamb birth weight in this data set was 4.8 kg (6.32 kg in singles, 5.31 kg in twins and 4.34 kg in triplets) and there was little difference in lamb survival over the weight range 3-9 kg (Fig 2). This data makes the current recommended lamb birth weight range of 3.2-5.5 kg seem light as it is based on data pertaining to ewes with mating weights of 45-50 kg.

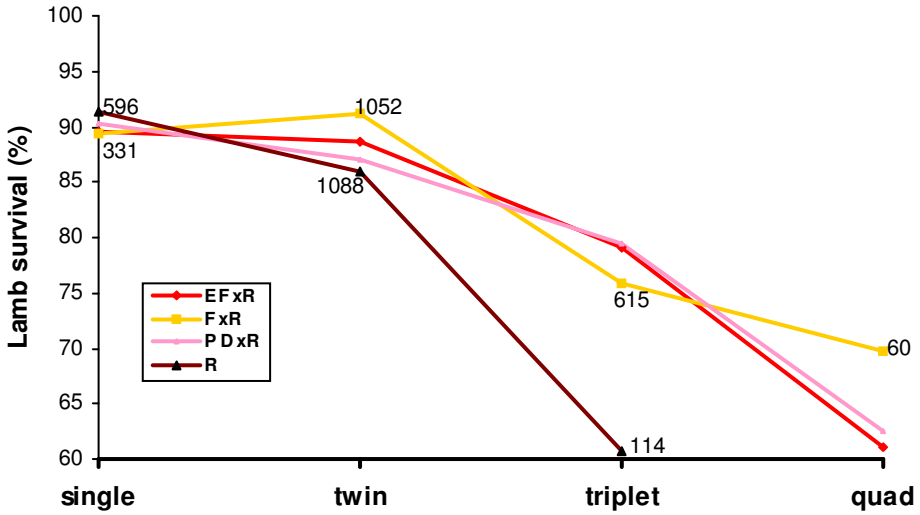
Figure 2 Survival rates of lambs of differing birthweight



Variation in birth weight within a litter. Data from 2364 triplet lambs was analysed to determine the effect of variation in birth weight within a litter on lamb survival. Within each litter, lambs were sorted and ranked on their birth weight and the weights of the lightest two lambs expressed as a proportion of the heaviest lamb. Birth weights, survival and 12 week weights were examined both within litter and between litters with different weight spreads. On average, the smallest lamb was 75% of the weight of the largest lamb and was less likely to be still on the ewe at 12 weeks. This was true even when the range in birth weights was relatively narrow. Ewe liveweight and condition score did not affect the range of birth weights within a litter. Ewe genotype and age affected birth weights but not the spread of birth weights within a litter. Focusing on good birth weights and vigorous lambs born to good mothers producing plenty of milk is probably more important than trying to reduce the range in birth weights within a litter.

Ewe genotype. Lambing percentage (lambs born/ewes lambing) was 186% in Finn cross ewes, 171% in East Friesian cross ewes, 155% in Poll Dorset cross ewes and 153% in Romney ewes. Ewe genotype also affected the mortality rate of triplet lambs, with survival in triplets ranging from 81% in East Friesian x to 62% in Romney (Fig 3).

Figure 3 Effect of ewe genotype in lamb survival



Causes of lamb death. Detailed fate data was collected on 5447 lambs born to ewes at Poukawa between 2005 and 2008. During this time the lambing percentage ranged from 168-203% with an average of 184% lambs born/ewe lambing. Survival rates were 88%, 86%, 70% and 43% for singles, twins, triplets and quads, respectively. Of the 694 lambs autopsied, 14% died prior to the birth process, 16% died of hypoxia, 26% of starvation and 20% of infection, although relativities of the different categories varied slightly between years, ewe genotypes, and birth ranks. Treating lamb navels with iodine in 2007 and 2008

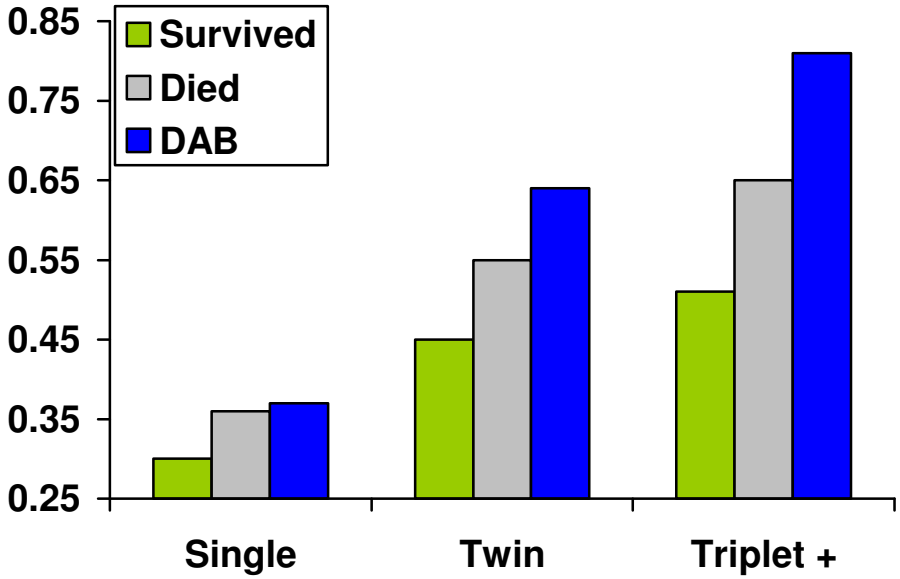
reduced the percentage of lambs that died as the result of an infection but had no effect on the overall death rate post tagging. Birth weights in this flock are typically heavy (e.g. 6.44 kg for singles) but there was no evidence that increasing birth weight caused an increase in birth trauma. There were many causes of lamb deaths. Many had multiple symptoms making it difficult to determine primary cause of death.

Iodine treatment. In 2005, 20% of the lambs that were autopsied had a thyroid to birth weight ratio above normal. Iodine deficiency results in an increase in size of the thyroid gland and increases the number of still born lambs and the number of small and weak lambs. This is because thyroid hormones have a role in the development of the lungs and the immune system as well as being involved in temperature regulation in newborns. Iodine treatments were initiated in 2006, with half of the ewes being treated. However, in all lambs (even in the lambs from untreated ewes) the thyroid to birth weight ratios were down on those measured in 2005. Variability between years means that any benefit to be gained from iodine treatment needs to be assessed over a number of years.

Ewe milk production. East Frisian x, Finn x and Romney ewes rearing triple lambs were milked in 2006 to determine if variability in milk production could be contributing to increased mortality in triplet lambs. Milk production in ewes rearing triplets was higher than in previous reports. Milk production decreased from 3 to 9 weeks of lactation across the breed groups. Although there were no significant effects of ewe genotype on milk production, the EFxR ewes were consistently higher than the Romney and FxR ewes and the Romney ewes showed the most variability. Fat and total solids decreased over time while protein content increased. Romney ewes had higher fat and protein percentages than the EFxR or FxR ewes but these differences disappeared when the values were adjusted for the volume of milk produced.

Ewe metabolite levels. Ewes were blood sampled before lambing to determine whether the metabolic status of the ewe was affecting her ability to rear lambs. There appeared to be differences between ewes in their ability to cope with stress. Blood beta hydroxybutyrate (BOH) levels are a measure of tissue breakdown and are an indicator of metabolic stress. Ewes carrying triplets had higher BOH levels than ewes carrying twins which were in turn higher than ewes carrying singles. Romney ewes carrying triplets had higher BOH levels and higher lamb mortality. Ewes that had one or more dead lambs at birth had significantly higher BOH concentrations than ewes whose lambs were all alive at birth (Fig 4). Non-esterified fatty acids and triglycerides are indicative of tissue breakdown especially fat reserves. Ewes carrying singles had lower levels of non-esterified fatty acids and triglycerides than those ewes carrying multiples.

Figure 4 Effect of ewe BOH concentrations on lamb survival



Colostrum intake. Gamma glutamyl transpepsidase (GGT) was measured in colostrum and lamb blood as an indicator of immunoglobulin concentration. Ewes with multiples had higher GGT levels in their colostrum than ewes with single lambs. This was consistent across years and ewe genotypes. Colostrum intake in lambs varied widely but surprisingly did not vary with litter size in either year. In other words, the higher concentration of immunoglobulins in ewes with multiple lambs seemed to compensate the lambs for any reduced colostrum intake. Although lambs that died tended to have lower GGT levels, GGT concentration only explained a small proportion of the variation in lamb survival.

Management strategies to improve lamb survival. Smaller, intensive properties have better survival generally than extensive properties and a scenario was envisaged where scanned triplet ewes could be taken from extensive properties, lambed under more intensive conditions, ewes returned at weaning and with appropriate revenue sharing of the weaned lambs. A cohort of triplet bearing ewes from a large, extensive, late lambing property was transported to the Poukawa Research Farm six weeks prior to lambing. It proved possible to take ewes from an extensive property within 6 weeks of lambing, train them to hard feed and run an intensive lambing programme and even lamb indoors. There were no differences in ewe liveweight or lamb birthweight between extensive and intensive systems in spite of differences in feeding management for 6 weeks prior to lambing. Weaning percentages were higher under intensive management (222% lambs present/ewes present) than under extensive management (171%). This meant that the extensive property had lower lamb weights per ewe (47.4 vs 58.2 kg lamb weaned/ewe). Ewe liveweights were also heavier at weaning on the extensive property (76.8 vs 67.5 kg). Financial returns for the two properties were modelled using Farmax. Since data on pasture covers and ewe and lamb liveweights was only available over the period of the trial, financial returns were calculated for the two trial groups between lambing and weaning. Over this period, returns from ewes on the intensive property were 21.1 c/kg DM consumed and 17.1 c/kg DM consumed on the

extensive property. There will be an added benefit to the extensive property from removing the triplet ewes and providing better covers and feed supply for the remaining stock. However the extent of this benefit is hard to quantify without further research.

Lamb rearing

As part of the lamb survival project, options for rearing at-risk lambs were examined. The development of a financially viable, commercial scale system should improve overall lamb survival and output as well as reducing potential welfare issues in the future. This work was undertaken in conjunction with funding from AGMARDT.

Over 3 years, 360 lambs were reared on a range of different milk powders – calf replacer, lamb replacer, cow colostrum and whole milk. Some milk treatments were fed with and without added yogurt. The objective was to rear lambs using similar principles as the once a day, low volume calf rearing systems with early access to meal. In Years 1 and 2, abomasal bloat was an issue in lambs but this was significantly reduced when yoghurt was added. Abomasal bloat is caused by bacteria (*Sarcina* species) which builds up in the abomasum and gives off a gas which can kill lambs by putting pressure on the vital organs. Adding yoghurt to the diet reduces the pH of the abomasum making the environment less favourable to the sarcina bacteria. This means they are less likely to build up to dangerous levels. Feed intakes were low in Years 1 and 2 and growth rates slow. We strongly suspect that the calf meals we were using had significant byproducts added (e.g. palm kernel, copra meal, tapioca). The success of an early rumen development system depends on lambs eating the meal offered. Any issues with palatability will compromise the system. In Year 3 we fed lambs on yoghurtised cow colostrum and made up our own feed rations – based on maize and peas. This regime resulted in significantly lower death rates (4.3%) and increased feed intakes. Lambs were reared in 24.7 litres of colostrum and 18.2 kg of meal. Lambs were fed three times daily in week 1, twice daily in week 2, once a day in week 3 and 4. By week 4, 74% of lambs were over 8 kg liveweight and were able to be weaned. Lambs weighed 26.7 kg at 15 weeks of age. In Year 3, the cost of rearing a lamb to 15 weeks was $24 (excluding cost of labour and pasture).

Effect of hogget mating on lifetime performance

Hogget lambing is claimed to generate an extra 0.7 lambs over a ewe's lifetime. Yet there is no data to substantiate this and it is simply assumed that the 70% lambing from hoggets (early data) was an extra or "free lamb". There is also debate about whether a ewe mated as a hogget gets culled from the flock earlier.

Over two years, 780 composite ewe lambs were either mated as hoggets or as two tooths. The ewe hoggets in the hogget mating group were run with a teaser ram from early April and joined with entire rams in late April. The ewe hoggets assigned to the two tooth mating group were still run with teaser rams as hoggets. Ewe hoggets averaged 43 kg at mating and were mated over two cycles. Hogget lambing percentage was 126% lambs scanned/hogget

mated. Lamb survival rates were 90% in the singles lambs and 81.7% in the twin lambs. Lambs were weaned at 10 weeks of age and averaged 22 and 18 kg for single and twin lambs respectively. Whereas the un-mated hoggets were 60 kg at two tooth mating in early March, those that had been mated were only 57 kg. These differences in liveweight had narrowed by the four tooth mating and had disappeared by the six tooth mating. By the six tooth mating, only 78% of the group that had been lambed as hoggets were still remaining, compared to 84% of those that had been first mated as two tooths. This reflects the greater risk associated with the extra pregnancy. The extra lambing as a hogget meant those ewes had still weaned more lambs/original ewe mated (3.29 vs 2.49) and weaned more total lamb weight/original ewe mated (85.6 vs 70.1 kg) although the size of this difference is reducing over time because there are fewer ewes in the group that lambed as hoggets. This work is not yet complete.

Effect of birth rank on lifetime performance

As lambing percentages increase, lamb growth rates decrease, particularly in the triplet lambs. This makes it less likely that these lambs will be kept as replacements – particularly if hogget lambing is being practiced. Yet overseas data suggest that lambs born as triplets are more prolific when lambed as a hogget. This project set out to measure the lifetime performance as ewe lambs born as singles, twins and triplets.

Two separate cohorts of composite ewe lambs were farmed, with 260 in each single, twin and triplet birth rank group. At hogget mating, single, twin and triplet ewe lambs averaged 44, 43 and 43 kg, respectively. Lamb weaned per hogget mated were 17.3, 18.5 and 18.7 kg for single, twin and triplet born ewe hoggets. After four tooth weaning, twin and triplet born ewes still had a small advantage in terms of total lambs weaned (2.6, 3.02 and 3.03 lambs weaned/original ewe hogget for the single, twin and triplet born ewes) and in total lamb weaning weight (70.3, 82.2 and 80.6 kg/original ewe hogget for the single, twin and triplet born ewes). This work is not yet complete.

Flock efficiency

The historical data collected within the Elite Lamb and Lamb Survival projects has been incorporated into a sheep flock model to test the impact of different management strategies. Originally funded by MAF to look at methane production, it has been modified to look at the effect on gross farm income. Around 65% of the feed eaten by a flock is used to maintain the breeding ewes and feed the replacement stock. Therefore the biggest impacts came from management strategies which enabled more output from fewer ewes. Lambing hoggets had the biggest impact on flock efficiency and increased gross net farm income by 14.6%. Delaying culling from 5 to 6 years meant fewer replacements were needed and gross farm income increased by 6.2%. Lifting scanning % from 160% to 180% lifted farm income by 4.3%. Unfortunately these improvements in efficiency are not necessarily cumulative, as a ewe flock is a complex dynamic system and altering one factor will alter other components in the system. For example, if the flock has a higher lambing percentage, lamb mortality is

also higher and lamb growth rates are slower because there are more multiples. More lambs and slower growth rates mean more feed is consumed, so ewe numbers have to drop. Nevertheless, the combined effect of hogget lambing, increasing longevity from 5 to 6 years and increasing the scanning percentage from 160% to 180%, increased gross farm income by 22%.

Progress in delivery to end users

Since 2003, Paul Muir and Beverley Thomson have made 44 presentations to farmer and student groups. There have been 10 client reports, 7 scientific papers and 4 radio/TV segments (Appendix A). We are also aware of 33 media articles. However, one of the difficulties in tracking articles is that journalists attend seminars and write articles that we are not aware of.

Impact on sheep and beef industries

The lamb survival programme is in many ways an extension of the Elite Lamb Programme and has enabled the lifetime performance work of hogget lambing and the effect of birth rank to be initiated. It has enabled the collection of a major dataset (6000 ewe and 8000 lamb records) which has in turn allowed the creation of a sheep flock efficiency model. This model has enabled us to calculate where the major gains in a sheep flock are likely to come from. Ironically, the model has demonstrated that improving lamb survival by 10% when lamb survival is already high will only lift gross farm income by 1%. This is modest in comparison with the benefits from hogget lambing and keeping ewes for another year.

Recommendations

The work on flock efficiency has demonstrated that the biggest contributor to increasing gross farm income is hogget lambing. Yet this relies on a key assumption – that hogget lambing will not affect the lifetime performance of the hogget. Since this work is already underway at Poukawa, it would seem prudent to complete this work and answer this question. This work on hogget lambing on lifetime performance could be included in a wider research programme on ewe efficiency.

Appendix A: Sheep Extension

Industry seminars/presentations

Feb 24th 2003	North Canterbury Farm Discussion Group, Poukawa
May 1st 2003	Autumn Field Day, Poukawa – Elite Lamb
June 20th 2003	FB 2000, Farm benchmarking group, Fairlie
June 30th2003	Rimanui Farm Staff, Poukawa
July 5th 2003	AGMARDT trustees, Chairman of Meat Board
Aug 6th 2003	Visiting scientists from Rutherglen Research Institute
Sept 9th 2003	Focus 1000 Discussion Group– Elite Lamb
Oct 2nd 2003	Massey University Dip Ag class – Elite lamb
Oct 16th 2003	Roy Fraser and visiting farmers from New South Wales – Elite lamb
Oct 22nd2003	North Island stud sheep breeders – Elite lamb
Nov 5th 2003	Northland farm discussion group – Elite lamb and calf rearing
Nov 13th 2003	Te Anau monitor farm – Elite Lamb
Dec 10th2003	South Island stud sheep breeders – Ashley Dene Progeny Test
Apr 6th 2004	Monitor farm, Gore
Apr 7th 2004	High performance sheep systems farmer group, Wellington
Apr 20th 2004	ASB conference, Hastings
May 3rd 2004	North Canterbury (Waiau) farm discussion group, Poukawa
May 13th 2004	Montalto monitor farm, Ashburton
July 22nd 2004	Field Day, Poukawa
Aug 12th 2004	Manawatu/Rangitikei Women in Farming, Poukawa
Jan 20th2005	Sheep council/scientist meeting on lamb survival, Wellington
Feb 9th 2005	Meat and Wool NZ Regional Conference, Hastings
May 11th2005	Sheep Council lamb survival seminar, Gore
May 12th 2005	Sheep Council lamb survival seminar, Mosgiel
May 27th 2005	Farm Discussion Groups at Maungatoroto and Waiotira
June 21st 2005	Southland Farm Discussion Group, Poukawa
July 1st 2005	Monitor Farm, Kaitaia
July 26th 2005	Landcorp Farm Managers, Poukawa
July 28th 2005	Annual Field Day, Poukawa
Aug 16th 2005	Women in Farming, Stratford
Sept 6th 2005	Focus 1000 Farm Discussion Group, Poukawa
Nov 15th 2005	Kaiwaka Farm Discussion Group, Poukawa
Dec 6th 2005	Waitomo Monitor Farm Group, King Country
Jan 23rd 2006	Sheep council/scientist meeting, Wellington
Mar 15th 2006	Meat and Wool NZ AGM, Poukawa
May 10th 2006	Sheep Council Seminar, Gore
May 11th 2006	Sheep Council Seminar, Mosgiel
Oct 10th 2006	Women in Farming, Poukawa
Oct 18th 2006	Lower Northland Monitor Farm, Kaukapakapa
July 3rd 2008	Poukawa Field Day,
July 22nd 2008	EIT students, Poukawa
Aug 28th 2008	Weber Farmer Group, Poukawa,
Nov 5th 2008	Wairarapa Farmer Group, Poukawa,
March 5th 2009	HB Secondary students, Poukawa
June 25th 2009	SIL Workshop, Lincoln

Media articles

Oestrus onset variable, Country-Wide, Jan 2003
Fat cover of Finn cross lambs surprising, Country-Wide, Jan 2003
Late mating suits Finn, Country-Wide, Jan 2003
Early lambing works, say farmers, Wool Innovation, Autumn 2003
Late lambing improves farmers bottom line, Rural News, June 23rd 2003
Hand-rearing orphaned lambs can be profitable, Hawkes Bay Today, July 31st 2003
How fast can lambs grow, Wairere client newsletter, Aug 2003
Heavy birthweights boost survival, Hawkes Bay Today, June 3rd 2004
Answers coming on multiple lamb survival, Country Wide, June 2004
Indoor option for lamb triplets, Hawkes Bay Today, July 29th 2004
Triplet survival under scrutiny, Country-Wide, Aug 2004.
Calf rearing techniques applied to lamb, Rural News, Sept 7th 2004.
A million sheep ranked, Hawkes Bay Today, Oct 21st 2004
Help at hand to identify best ram source, Country-Wide, Nov 2004
Assn recognizes role of members in tech transfer, Country-Wide, Nov 2004
Gestation length has little effect on lamb mortality, Country Wide, June 2005
On-Farm Research plans field day, Farmers Weekly, July 18th 2005
Study highlights birthweight importance, July 26th 2005
Triplets need full survival package, Hawkes Bay Today, Aug 4th 2005
Trial focuses on triplet survival, Straight Furrow, Aug 9th, 2005
Effect of pasture on lamb growth tested, Straight Furrow, Aug 9th 2005
Share farming triplet ewes brings success, Country-Wide, Aug 2005
Benefits in shifting triplet ewes to easy country, Country-Wide, Oct 2005
CPT, NZVA Sheep and Beef Conference, Palmerston North May 25th 2006
Ryegrass persistence, Central Progeny Test, Poukawa July 19th 2006
Lamb survival, NZ Society of parasitologists, Poukawa Sept 6th 2006
Private researcher enjoying variety, May 2008
Carcass size best, Country-Wide, July 2008
Rearing orphan lambs, CHB Mail, Sept 2nd 2008
Incremental gains made with lamb survival, Heartland Sheep, Oct 2008
Lamb rearing system being refined, Country-Wide, Dec 2008
Hogget lambing must be done well, Country-Wide, March 2009
Should we be selecting for ewes that last, Country-Wide, October 2009

Scientific and conference papers

P.D. Muir, N. B. Smith and J.C. Lane (2003). Maximising lamb growth rates – just what is possible in a high performance system. *Proceedings of the New Zealand Grasslands Association.* **65**: 61-63.

Knight, T.W., Knowles, S.O., Death, A.F., Cummings, T.L. and Muir, P.D. (2004). Conservation of conjugated linoleic, *trans*-vaccenic and long chain omega-3 fatty acid content in raw and cooked lamb from two cross breeds. *New Zealand Journal of Agricultural Research* **47**: 129-135.

Thomson, B.C., Muir P.D. and Smith, N.B. (2004). Litter size, lamb survival, birth and twelve week weight in lambs born to cross-bred ewes. *Proceedings of the New Zealand Grasslands Association* **66**: 233-237.

Muir, P.D., Thomson, B.C. and T.W. Knight (2005). Factors affecting lamb survival. *Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the NZVA,* 73-82.

Muir, P.D., Thomson, B.C. and Clarke N. (2006). Variation in the New Zealand sheep industry – results of the Poukawa Progeny Test. *Proceedings of the New Zealand Society of Animal Production*. **66**:373-375

Thomson and Muir, P.D. (2009). An option for managing triplets on extensive properties. *Proceedings of the New Zealand Society of Animal Production.* **69**:71-74

Cruickshank, G.J.; Thomson, B.C. and Muir, P.D. (2009). Effect of management change on methane output within a sheep flock. *Proceedings of the New Zealand Society of Animal Production* **69**:170-173

Other

93 FM, Radio Interview – Elite Lamb, Feb 25th 2003
Grassroots Farming, TV1, Sept 20th, 2003 Late lambing project,
93.5 FM: July 26th Field Day Outline *Elite Lamb*:
Rural Delivery, October 2008 Episode 32. Programme on Poukawa research – lamb rearing