beef+lamb new zealand

Hogget Performance

Unlocking the potential of hogget lambing

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CHAPTER 1

The advantages and disadvantages of hogget breeding

A number of potential advantages are stated for ewe hogget breeding*. However, given that a greater proportion of farmers choose not to breed their ewe hoggets than those that do, there are obviously some potential disadvantages or limitations to this management option.

Potential advantages include:

- the production of a lamb within the first year of life
- more efficient use of herbage in spring
- more lambs produced on farm within a given year
- higher net income through the sale of more lambs
- an early selection/screening tool for ewe replacements
- an increase in ewe lifetime reproductive performance
- more progeny born on farm which can increase selection pressure if replacements are selected from those born to hoggets
- a reduction in the generation interval when progeny born to ewe hoggets are selected as replacements
- a reduction in lifetime greenhouse gas emissions per unit of product produced when lifetime productivity is increased.

Potential disadvantages include:

- often low and variable reproductive performance of ewe hoggets
- increased feed requirements during the hogget's first year of life, especially during their first winter
- the need for hoggets to achieve liveweight targets at eight months of age, adding more pressure to the farming system during the summer/autumn period
- if the ewe hogget experiences 'hardship' during her first pregnancy and lactation, or is poorly managed, there is the potential for reduced two-year-old liveweight and reproductive performance, which may have negative impacts later in life
- progeny born to ewe hoggets often have lower survival rates and lower liveweight gains to weaning
- ewe hogget breeding is often associated with extra costs – such as the requirement for more rams and vasectomised (teaser) rams
- breeding ewe hoggets adds another priority stock class to the farming system which reduces flexibility
- hogget breeding can increase workload
- the potential for a higher death rate in lambing hoggets
- reduced wool production at hogget and two-tooth shearing
- the potential for reduced longevity in the ewe flock.

Each farmer must weigh up the potential advantages and disadvantages for their own system before deciding whether or not to breed ewe hoggets.

*In this guide, the term 'ewe hogget breeding' is used as this is standard in the scientific literature and as it includes both the commonly used terms 'hogget lambing ' and 'hogget mating'.

Economic analysis of hogget breeding

Concern regarding the profitability of hogget breeding is likely a factor in the relatively low uptake of this management technique. In a fixed feed supply scenario, which many New Zealand sheep farms are in, a change to breeding hoggets necessitates a reduction in the size of the mature ewe flock due to a lack of significant amounts of brought-in-feed. Anecdotal farmer evidence suggests that for every seven to eight pregnant ewe hoggets, the additional feed requirements for pregnancy and lactation over traditional non-pregnant hoggets requires a reduction of approximately one mature ewe from the flock. Therefore, the reproductive performance of the hoggets must outweigh the reduced mature ewe flock performance.

Farm-based modelling indicated that, in scenarios with an average mature ewe weaning percentage of 135%, it was more profitable to breed hoggets if their weaning percentage was above 26% (break-even point, see Table 1). Profitability further increased as hogget reproductive performance increased. A separate analysis indicated that the profitability was the same for a base scenario where the weaning rate of mature ewes and hoggets was at the industry average of 135% and 60%, respectively, compared with lifting mature ewe weaning percentage to 142% and not breeding hoggets (Table 1). This later scenario is likely easier to achieve for some farmers than trying to breed hoggets and explains why many farmers focus on improving the reproductive performance of the mature ewe flock before adopting the breeding of ewe hoggets. This is further supported by an analysis that showed that the cash operating surplus of a mature ewe flock achieving 150% weaning without breeding hoggets was the same as a flock achieving 135% in mature ewes and 104% in their hoggets. The latter scenario would be very difficult to achieve in terms of ewe hogget weaning rate, while many farmers are already achieving 150% in their mature ewes.

Table 1: Economic modelling of different hogget and mature ewe weaning rate scenarios

Scenario	Mature ewe weaning rate	Hogget weaning rate	% Increase in cash operating surplus
Base system	135	0	
Break-even	135	26	0%
Lift hogget weaning rate	135	60	6%
Lift mature ewe weaning rate	142	0	6%
Lift mature ewe weaning rate	150	0	17%
Lift hogget weaning rate	135	104	17%

Weaning rate = number of lambs weaned per 100 ewes presented for breeding

CHAPTER 2

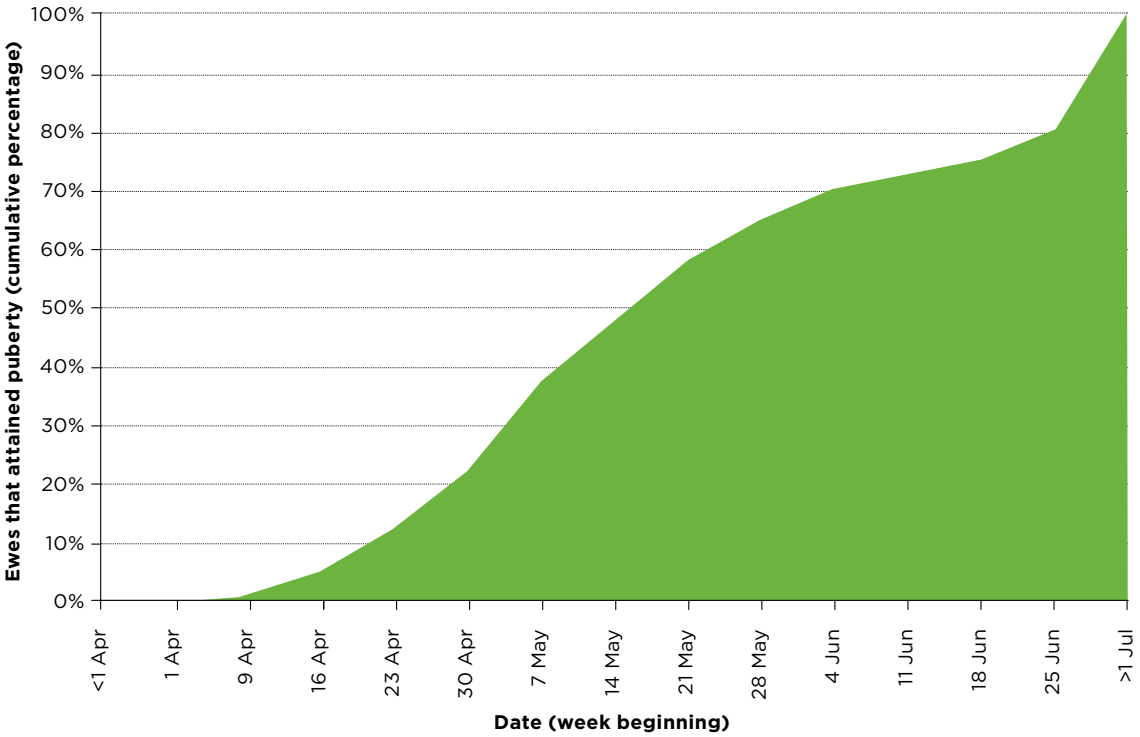
Pre-mating management of ewe hoggets

Breeding season and matching feed supply

The timing of hogget breeding is determined by the onset of reproductive activity. In traditional breeds, such as the Romney, Coopworth and Perendale, this is usually four to six weeks later than for mature ewes. A hogget must first reach puberty before she can be bred. Finnish Landrace and East Friesian ewe hoggets and composites which include these breeds generally reach puberty earlier than traditional breeds. Finnish Landrace and East Friesian ewe hoggets are more likely to start reproductive activity in early to mid-April, compared to late April/early May for the traditional breeds. As can been seen in Figure 1, a significant number of hoggets do not cycle until the late April and early May period, which can impair a compact breeding period and high pregnancy rates.

Figure 1: Cumulative percentage of ewe hoggets that attained puberty

Adapted from Edwards *et al.* 2017



Breeding in early May allows for pregnancy and early lactation periods to coincide with increased herbage growth on many farms. However, a side effect of this in some areas, especially summer dry regions, is that feeding levels in late lactation can be a problem due to a decline in herbage quality and quantity. Therefore, timing of breeding is not only important for breeding success but also for potential impacts later in the year.

An earlier breeding date, for example mid-April, might be considered as it allows for an earlier weaning of lambs born to ewe hoggets, giving the young dam more time to gain liveweight prior to rebreeding as a two-tooth. However, due to the timing of the onset of reproductive activity in hoggets, the performance achieved with a mid-April mating might be disappointing. Earlier breeding may result in the late pregnancy period occurring before spring herbage growth, which might limit the performance of the hogget and her offspring.

Researchers encourage farmers to utilise help from a farm advisor to determine the impact of breeding date on the feed demand profile on their farm and matching it with feed supply. Breeding ewe hoggets results in an additional class of priority stock during the winter period. Therefore, extra feed is necessary for these pregnant hoggets, over and above that which would be otherwise required for non-pregnant ewe hoggets. In a fixed total feed supply situation, this may require a reduction in mature ewe numbers. If handled correctly this response can still be very profitable (see Table 1).

Stage of hogget breeding season and its effect on conception rate

Poor egg quality has been stated as one of the factors responsible for low conception rates in hoggets. However, hogget egg quality and conception rates appear to improve after the first oestrous cycle. This further strengthens the argument for not trying to breed hoggets too early in the season. Pregnancy rates might be higher if hoggets can be induced to achieve puberty slightly earlier than at the normal breeding date.

The use of teasers (the ram effect)

There are three reasons for utilising the "ram effect" with ewe hoggets. Firstly, the ram effect can result in more ewe hoggets being bred in the first cycle (17 days) for a May breeding. Secondly, inducing hoggets to cycle earlier so that, at the normal breeding date, pregnancy rates are higher due to improved fertility. Thirdly, there is the potential of bringing forward the start of mating, allowing for the breeding of ewe hoggets to occur in early to mid-April by using teaser rams.

Using teaser rams for 17 days immediately before ewe hogget mating has consistently increased the proportion of ewe hoggets pregnant.

The introduction of vasectomised rams (teasers) for a period of 17 days immediately prior to ewe hogget breeding has consistently been shown to increase the proportion of hoggets bred in the first 17 days of breeding for a traditional 1 May breeding date. The optimal teaser to ewe hogget ratio is in the range of 1:70 to 1:100. It is important that teasers are used in teams to ensure ewe hoggets get maximum exposure to the male. It is his pheromones (smell) that are thought to induce the breeding activity in the ewe hogget. Studies have shown that teaser to ewe hogget ratios as large as 1:200 can result in more ewe hoggets being bred early in the breeding period, in comparison to not utilising a teaser at all. However, a teaser ratio of 1:200 is not as effective as a lower ratio (1:70 to 1:100).

It is very important that teasers are used for a period of 17 days only directly before the start of planned breeding. This is because exposure to the teaser results in reproductive activity, and therefore breeding activity, starting 17 to 26 days after the introduction of the teasers to responsive ewe hoggets. A common mistake is to expose ewe hoggets to vasectomised rams for 21 days. This results in some ewe hoggets displaying reproductive activity in the 4 days before the entire ram is introduced and therefore they will not be receptive to the ram again until 13 days after the ram is introduced, resulting in a later than expected average mating date. It is also important to note that for the ram effect to work ewe hoggets cannot have been recently (within 2 months) exposed to rams prior to teasing. It is the *novel* exposure to a male that induces the effects.

The Hogget 150 Group of farms have been investigating hogget lambing for some time. By contrast, they put teaser rams, or rams with a no-mate harness, out for around 60 days. This is around three times longer than the recommended 17 days. This is because they want to put entire rams out to coincide with the 3rd and 4th cycle, which have increased ovulation rates. Importantly, the group also have well grown hoggets, a minimum of 50kg at mating.

Hoggets which have already reached puberty themselves will not respond to teasing. Therefore in relatively heavy mobs of hoggets, with average liveweights of 45kg or greater (or greater than 65% of mature weight), there may be little advantage in using teasers. At the other end of the spectrum, teasing can induce lightweight hoggets to achieve puberty early. However, teasing should not be used as a tool to get the lightweight hoggets cycling so they can be bred. As will be outlined in later sections, lightweight hoggets are more likely to fail to rear their lamb, and are less likely to be pregnant as a two-tooth and less likely to be in the flock in later years.

Some farmers might try to breed ewe hoggets in early to mid-April. If successful, this will have the flow on effect of allowing for a relatively early weaning date or heavier lambs during lactation at a given date. The use of teasers in late March and early April has met with some success. However, for it to be successful, hoggets still need to achieve the same target breeding liveweights and it appears that ewe hoggets of better body condition score (i.e. 2.5 or better) are more likely to respond to such an early teasing.

Some farmers may not wish to use teasers, as they can be relatively expensive to produce and are only utilised for a very limited period of the year. Alternatives include exposing ewe hoggets to short scrotum ram lambs (often termed cryptorchid) and mature intact rams. At a ratio of 1:60 for short scrotum ram lambs, studies have shown no effect. It is possible that lower ratios maybe more effective, although this has not been experimentally examined. The use of entire mature rams for 17 days prior to the normal start of breeding is very likely to have the same effect as a 17-day teasing period with vasectomised rams. However, it comes with the added risk of early pregnancies. Therefore, if farmers wish to utilise this approach to induce puberty in ewe hoggets, the use of ram harnesses are advocated as a means of identifying which and when hoggets are mated. Another option is to utilise 'teaser harnesses' which when fitted to entire rams prevent them from mating with the ewe hoggets. These can be fitted to breeding rams, or to large works lambs which can then still be slaughtered after their 'teasing' role is complete.

Liveweight at mating

To be bred successfully, hoggets must have reached puberty. In sheep, puberty occurs when the animal is somewhere between 40 and 60% of its mature liveweight. Therefore, hogget breeding liveweight is one of the major determinants of the number of hoggets successfully bred, and the performance of the hogget and her offspring to weaning.

Target breeding liveweights and body condition scores

"Hogget weight is key. The heavier the better."
Bevan Hopcroft, Farmer, Southland

Figure 2 indicates that high reproductive performance occurs when hoggets achieve greater than 65% of their mature weight (pre-breeding weight at three years of age). Therefore, in flocks with a mature weight of 65kg, ewe hoggets should not be bred unless they are a minimum of 42kg if high reproductive performance is to be achieved. Consider the flock's mature weight and then set minimum hogget breeding weight depending on your farming situation. Across a number of studies it has been clearly shown that there is a positive relationship between ewe hogget liveweight at breeding and reproductive performance, up until at least 50kg, although there is some evidence to suggest a tapering off effect as liveweights get closer to 50kg (~80% for a 65kg ewe; see Figure 2). A suggested rule of thumb is that for every 1kg of liveweight at breeding there will be an extra 2% in lambing percentage. Therefore, there are clear advantages of having ewe hoggets as heavy as possible at breeding. However, it should be noted that ewe hoggets can become pregnant, at liveweights well below 40kg, therefore care should be taken to ensure lightweight hoggets are kept away from rams.

For every 1kg of liveweight on a ewe hogget at breeding, there will be an extra 2% in lambing percentage.

Instead of selecting ewe hoggets suitable for breeding based on liveweight, an alternative approach is to use body condition score as well as liveweight (while still maintaining the minimum liveweight before mating). It has been shown that ewe hogget body condition score affects the proportion of hoggets successfully bred early in the breeding period, overall pregnancy rates and the scanning percentage. Farmers could use body condition scoring as a screening tool to identify hoggets most suitable for breeding. Figure 3 shows the effect of body condition score approximately two months prior to breeding on subsequent hogget breeding performance and scanning percentage. The data clearly indicates that it is possible to identify ewe hoggets most suitable for breeding well before the start of mating. Figure 3 indicates that, to achieve high reproductive performance, hoggets with a body condition score below 2.5 should not be presented for breeding. Therefore, body condition score also be used as a selection tool for which hoggets are suitable for breeding in conjunction with liveweight.

Hogget liveweight at breeding has a clear positive effect on the liveweight of the ewe hogget offspring at weaning (Table 2). The weight of the ewe hogget at weaning also has implications for the ewe as a two-tooth. It is probable that well-grown hoggets at breeding are also less likely to suffer birthing difficulties (dystocia) as their pelvic size in relation to lamb birth size will be more appropriate. It has been shown that for every kilogram a single-bearing/rearing ewe hogget is heavier at breeding, her lambs will be 327g heavier at weaning and she herself will be 1.36kg heavier at weaning, as she will be more able to cope with the rigours of pregnancy and lactation. The table also indicates how small the impact ewe hogget liveweight is on lamb birth weight, indicating the importance of genetic control on birth weight.

It is important that farmers monitor the liveweights of their ewe hoggets from weaning until the start of breeding, to ensure they reach target breeding liveweights. The earlier a potential problem is identified, the easier it can be rectified. If a ewe lamb is weaned at 30kg in late December and gains liveweight at just 100g/d, she will weigh approximately 43kg on 1 May (see Appendix 1). Alternatively, if she gains liveweight at 150g/d, she will weigh approximately 48kg on 1 May. To monitor the liveweight of a mob, only 50 ewe hoggets need to be weighed monthly. To achieve liveweight gains in excess of 100g/d, ewe hoggets should be offered good quality herbage with grazing masses above 1200kgDM/ha and allowances above 3kgDM/day (Figure 4). Once pasture covers fall below this level, intakes will begin to be restricted. Table 3 indicates the daily requirements for ewe hoggets either maintaining or gaining liveweight.

For precise hogget feed requirements, use Beef + Lamb New Zealand's 'Feedsmart' tool: **www.feedsmart.co.nz**

Figure 2: Relationship between ewe hogget mating weight and scanning percentage (% ewes diagnosed as pregnant of those presented for breeding)

From: Kenyon *et al.* 2014b

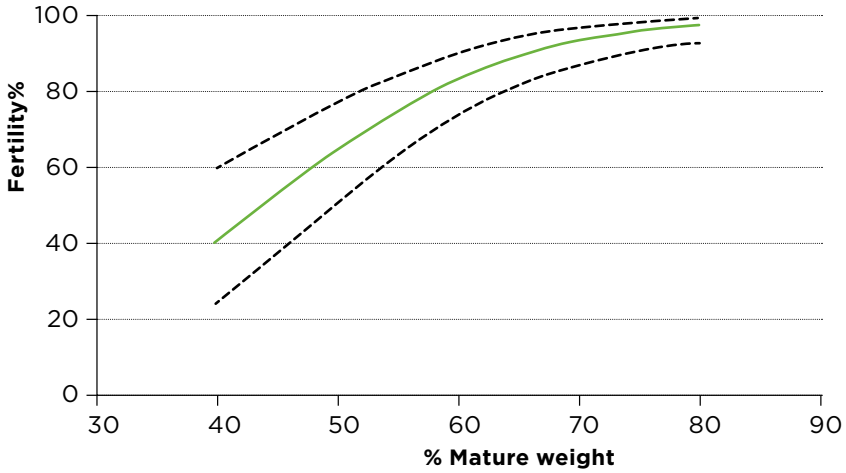


Figure 3: Effect of body condition score at breeding on ewe hogget pregnancy rate (% of ewes pregnant of those presented for breeding) and fecundity rate (number of lambs identified at pregnancy scanning per 100 ewes presented for breeding)

From: Corner *et al.* 2013b

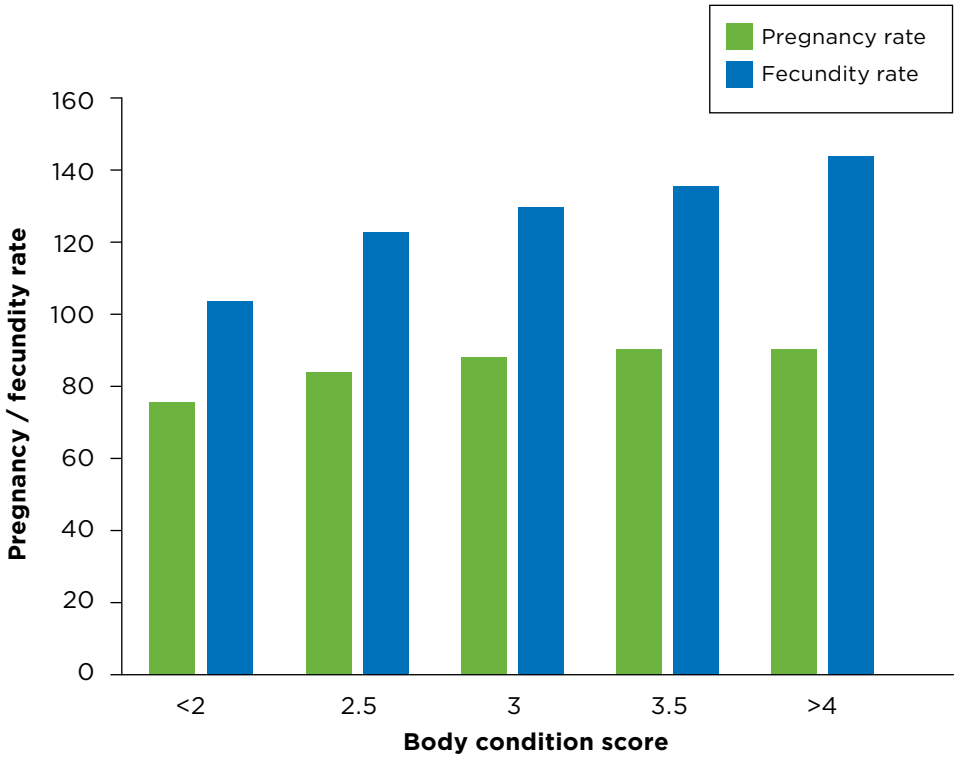
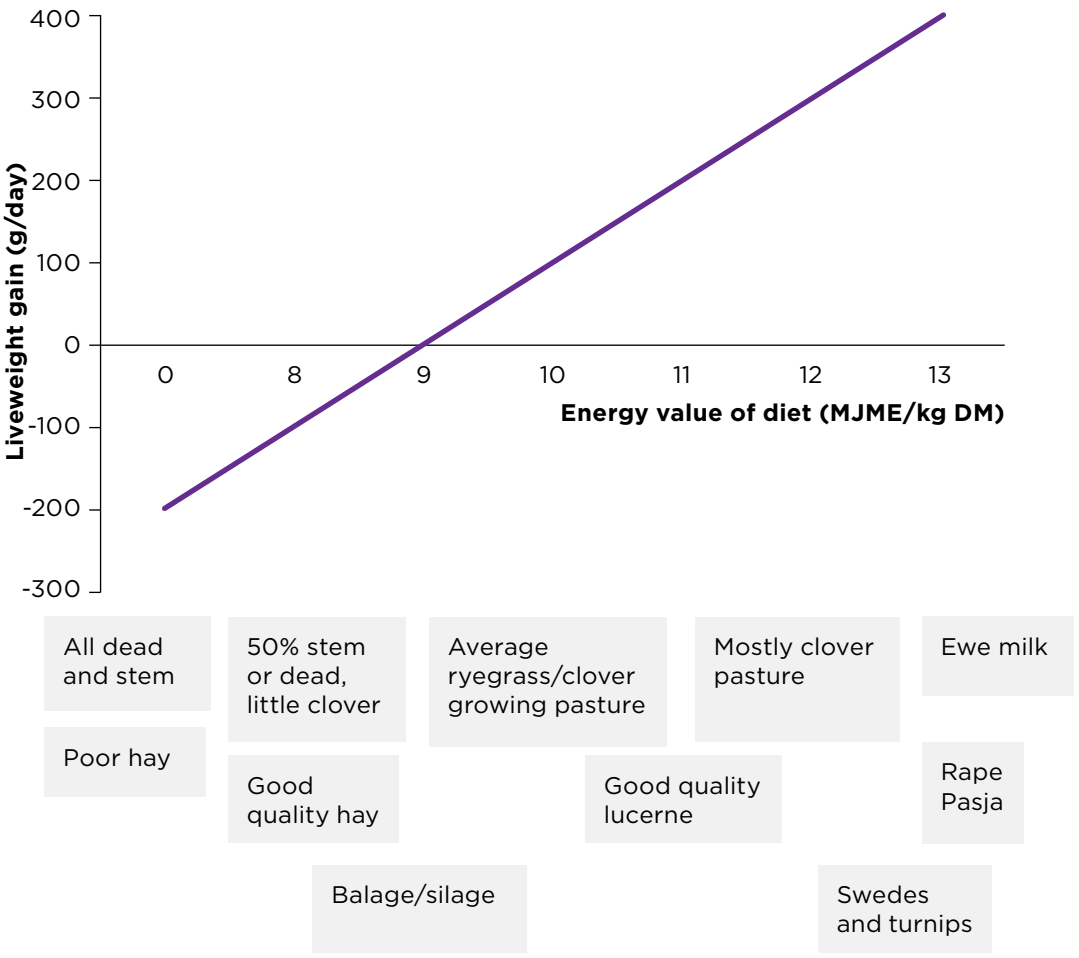


Figure 4: Effect of diet energy value on the growth rate of a 30kg lamb



Breed differences

Finnish Landrace, East Friesian and composite hoggets based on these breeds can reach puberty at relatively low liveweights (e.g. 30 – 35kg) in early to mid-April. However, minimum breeding liveweights of 40kg are still advocated if these breeds/ composites are to express their natural reproductive advantage. The use of these genetics should not be considered as a substitute for inadequate hogget breeding liveweights. While mating these breed types at low liveweights might allow farmers to achieve suitable pregnancy scanning results, the weaning percentage and the weight of the lambs and that of the ewe hogget at weaning will likely be disappointing.

Research has shown that, in comparison to Romneys, hoggets with 1/16 to 1/2 East Friesian or Finnish Landrace genes had 13.5% more lambs tailed per hogget presented for breeding. While those with at least 50% of these genes or greater had a 23% increase in docking percentage above that observed in Romneys. Coopworth ewe hoggets were reported to have an almost 11% greater docking percentage than Romneys.

Should all hoggets be presented for breeding?

The answer to this question will vary from one farming situation to another. If all ewe hoggets are above 65% of their expected mature weight (i.e. approximately 42kg for an animal with a 65kg mature weight) and in good body condition at breeding – and the predicted feed budget indicates that there is the feed available for this additional priority class of stock during the winter period – then all hoggets could be presented for breeding. However, on many farms, dry environmental conditions over the summer and autumn period (reducing herbage growth and quality) may mean that not all hoggets will reach their target liveweights. Dry conditions can also result in herbage covers going into winter being lower than optimal. In these situations, consider only breeding a limited number of their heavier hoggets or, in some years, not breeding any hoggets. However, there will also be a number of farms that the annual feed profile and the quality of herbage over summer/autumn mean that hogget breeding is not a viable option. Hogget breeding is a flexible management option, unlike the breeding of the mature ewe flock, so farmers should not be afraid to vary the number of hoggets bred from one year to the next.

When breeding ewe hoggets for the first time, the authors strongly advise to only breed a proportion of their hoggets in the first year (the heaviest and best conditioned) as you adjust to the changes in management required. Over the following years, you might slowly increase the proportion bred.

If a ewe hogget is bred at too low a liveweight, she will require more feed in the following 12 months to reach a suitable two-tooth breeding weight compared with those hoggets which were heavier at hogget breeding.

The effect of shearing ewe hoggets prior to and during breeding

Shearing ewe hoggets between their weaning as a lamb and the month prior to breeding has been associated with a small increase in lambing percentage. The mechanism for this effect is unclear. It may be due to improved feed intake and liveweight gain, as some studies have reported that shearing can stimulate appetite in response to heat loss. There are very few reported studies which have specifically examined the effect of shearing ewe hoggets less than one month prior to breeding. However, shearing is one of the greatest stressors a sheep faces in its life and stress is known to affect cycling in mature ewes. Therefore, shearing just prior to and during the hogget breeding period should be avoided.

Animal health management

Ewe hoggets are prone to abortion caused by Toxoplasmosis and Campylobacteriosis. It is recommended that hoggets are vaccinated against both of these diseases pre-breeding. Salmonella brandenburg also causes abortion in some (particularly southern) areas of New Zealand. In these areas, it is recommended that hoggets are vaccinated against this also.

Discuss with your veterinarian other health issues that might affect hogget performance such as internal parasites, pneumonia, facial eczema, mineral deficiencies and other potential causes of abortion. Have an animal health plan in place and consult with your veterinarian. Any health issues that negatively affect growth of the hogget will have negative flow-on effects in terms of hogget reproductive performance.

Table 2: Effect of an extra kg in single-bearing ewe hogget liveweight at various stages of pregnancy on lamb birth weight, lamb weaning weight and weight of the ewe hogget at weaning in grams

Day of gestation	Effect on lamb birth weight	Effect on lamb weaning weight	Effect on hogget weight at weaning
0	16g	327g	1361g
50	9g	248g	1093g
100	5.4g	143g	745g
At term	3.7g	106g	550g

Table adapted from Schreurs *et al.* 2010a

Table 3: The metabolisable energy requirement per day (MJ ME/d) for ewe hoggets prior to hogget breeding

Liveweight gain /day (g)	Liveweight (kg)				
	28	**32**	**36**	**40**	**44**
0	6.0	6.8	7.5	8.3	9.1
50	8.4	9.4	10.4	11.4	12.4
100	10.9	12.1	13.4	14.6	15.7
150	13.4	14.9	16.4	17.8	19.1
200	16.0	17.7	19.4	21.0	22.5
250	18.6	20.5	22.5	24.2	25.9

This is based on a pasture with an ME of 11 and includes an 8% wastage factor (Brookes unpublished)

CHAPTER 3

Management of ewe hoggets during the breeding period

Hoggets gaining liveweight during breeding will display greater reproductive performance than those either maintaining or losing weight. There is some evidence from the United Kingdom that, using concentrate rations to achieve very high liveweight gains (in excess of 200g/d), can be associated with poorer conception rates. This response has generally not been found under pastoral based systems in New Zealand. However, due to this potential issue, during the breeding period hoggets should be gaining liveweights in the range of 100 – 200g/d.

A further advantage of hoggets gaining liveweight during the breeding period is that those which have not reached puberty may do so.

To achieve the appropriate liveweight gains of 100 – 200g/d during the breeding period, hoggets must be offered good quality herbage. If on a ryegrass/ white clover sward, post grazing pasture masses should not be below 1200kgDM/ha. There is a lack of information available on the use of various short-term and more permanent cropping options over the breeding period. But the same principle of not restricting intake would likely hold. However, some of these cropping options can potentially have adverse health outcomes and these should be discussed with the provider of the seed, or your local veterinarian or farm consultant.

Breeding behaviour

Ewe hoggets are shy breeders, meaning they are less likely to seek the ram and to stand for him. They are in oestrus (heat) for a shorter period than mature ewes (12 to 24 hours compared to 24 to 36 hours, respectively). Therefore the chance that the ewe hogget comes into contact with a ram during the breeding period needs to be maximized. To achieve this, it is suggested that the breeding of hoggets occurs in smaller, flatter paddocks and not in the same flock or mob as the mature ewes.

Ram to ewe hogget ratio

A number of studies have shown that conception and pregnancy rates improve as the ratio of rams to ewe hoggets decreases from 1:200 to 1:30 (Figure 5). Although lower ratios (i.e. 1:30) can result in slightly higher pregnancy rates, than 1:100, they may not be cost effective. The optimal ewe hogget to mature ram ratio is likely to be approximately 1:50 to 1:80, depending on paddock conditions. It is also very important that rams are used in teams, because ewe hoggets are receptive to the ram for a shorter period than mature ewes. One study showed that only 70% of ewe hoggets which displayed tup marks (evidence of being mounted) from just one ram, had spermatozoa inside their reproductive tract. It was not until they displayed evidence of three separate tup marks that they all had spermatozoa in their reproductive tract.

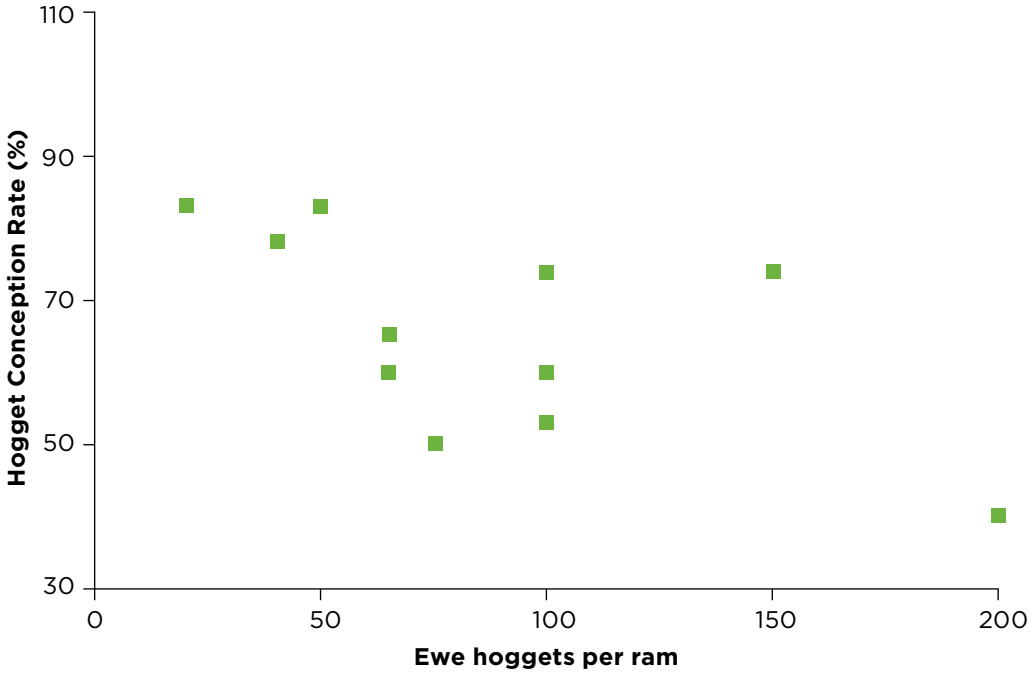
Some farmers commented that they prefer a 1:50 ratio and to achieve this at a lower cost have used entire ram lambs born to last year's ewe hoggets. These ram lambs are then slaughtered after mating.

Which age class of rams to use?

If extra rams are sourced specifically for hogget breeding, they add cost to the farming system. There are three types of rams that could be used to breed with hoggets: fresh mature rams (unused previously in the season with mature ewes), mature rams (already used in the same season with the mature ewe flock), and ram hoggets. Studies have shown that mature rams that have been used for a 17-day period (one reproductive cycle) with the mature ewe flock at a ratio of 1:100 just prior to hogget breeding can be reused with ewe hoggets and achieved the same pregnancy rates as fresh mature rams. Therefore these 'used' rams offer a relatively cheap source of rams in situations where rams are removed from the mature ewe flock after 17 days and replaced with terminal sires. Well-grown hogget rams can be used for breeding with ewe hoggets, however, these need to be used in teams at ratios of 1:50 or lower. If used at the ratios suggested for mature rams, lower pregnancy rates may be achieved.

Figure 5: Effect of ram ratio on hogget conception rate

Adapted from: Stevens and McIntyre 1990.



Does breed of ram matter?

It is often stated that breed of ram influences the mortality rates of lambs born to hogget ewes. Although there is a lack of scientific data to support this, it is considered prudent when selecting rams for breeding with ewe hoggets, that the size of the ram and the shape of his shoulders are taken into account because of potential birth difficulties (dystocia). It is probable that sires from the larger breeds may predispose ewe hoggets to dystocia, as their genes influence the growth of the foetus. But again, there is a lack of scientific evidence to support this. To avoid the potential effects of breed, it has been suggested rams of the same breed as the ewe hogget or of a smaller breed (e.g. Cheviot, Perendale, Southdown) be used. If hoggets are of adequate liveweight at breeding and continue to gain liveweight at appropriate levels throughout pregnancy, the potential influence of ram breed on dystocia may be of little concern.

Length of joining

Ewe hoggets are generally bred for one or two reproductive cycles (17 to 34 days). Because ewe hoggets are bred a month or so later than the mature ewes, extending the breeding period beyond 34 days can lead to a long, drawn-out lambing period, and a tail end of late hogget lambs and/or result in a later than ideal weaning date. Not only will these tail-end lambs be difficult to manage, delayed weaning reduces the time the young dam has to gain liveweight before two-tooth breeding. The length of breeding should consider two important points. Firstly, what is the target number of pregnant hoggets and, secondly, what is the likely impact (for those lambs and the hogget) of later-born lambs. The use of teasers pre-breeding offers a means of reducing the breeding period to just 27 days. This is because those that respond to the teaser will display reproductive activity (heat) within 10 days of the entire ram being introduced. Then, if they fail to conceive to this mating event, they will come on heat again approximately 17 days later. Therefore, within a 27-day breeding period, there will be two opportunities to get hoggets, which respond to the teaser, pregnant.

Use of crayon harnesses on rams

Crayon harnesses on rams are a great tool to use with ewe hoggets. Those hoggets which do not display crayon marks on their rumps are unlikely to be pregnant. Therefore, these can be managed in the post-breeding period as a traditional, non-bred hogget, with lower liveweight gain targets over winter. This will allow feed to be saved for their pregnant counterparts. Farmers should change the crayon colour at least every 17 days.

In addition, harnessed teaser rams could be utilised after the entire rams have been removed from the ewe hoggets (i.e. at the end of the breeding period) to identify hoggets that did not hold to their breeding or that lose their pregnancy early. Again this allows these animals to be removed, saving feed for their pregnant counterparts.

Because the success of hogget breeding relies on ensuring hoggets continue to gain liveweight during pregnancy there are clear gains to be made from early identification of hoggets that require higher levels of feeding by using crayon harness marks. The importance of feeding levels in the early period of pregnancy will be discussed later. However, it is important to recognise that waiting until pregnancy scanning to identify which hoggets would benefit from additional feeding limits the ability of the farmer to manipulate the liveweight of the pregnant hogget and to influence her performance and that of her lambs to weaning and likely her performance as a two-tooth.

A further advantage of utilising crayon marks is that farmers can determine which are early and later lambing ewe hoggets. With this knowledge they can further target their feeding programmes. In addition, they can manage set stocking based on time of lambing and focus their management over the lambing period based on when a hogget is lambing (i.e., lamb early and later lambing hoggets in separate areas).

CHAPTER 4

Management of ewe hoggets in pregnancy

The in-lamb ewe hogget flock should be a priority stock class over winter. Feeding levels must not only meet the maintenance and liveweight gain requirements of the hogget, but also the needs of the developing foetus and mammary gland. Pregnancy is the period when farmers need appropriate management strategies in place to ensure maximum performance of the ewe hogget and her offspring to weaning, and to ensure the young mother is well set up for two-tooth breeding and longevity within the flock.

The importance of meeting liveweight gain targets during pregnancy

The traditional approach to feeding pregnant mature ewes has been to control their intake until approximately the last third of gestation. This is based on the principle that the ewe has reached her mature liveweight and that the largest nutritional demand for pregnancy occurs in that last third of pregnancy. However, ewe hoggets are different. There are two clear aims for the feeding of hogget ewes in pregnancy. Firstly, to ensure she successfully weans an adequately-sized lamb and, secondly, although some might argue most importantly, she needs to continue to gain liveweight herself, so that her future performance is not impaired.

The ewe hogget needs to be gaining liveweight throughout the entire pregnancy period, not just in the last third of gestation.

In fact, it is important for farmers to realise that, during the last third of pregnancy, it is very difficult for hoggets to gain weight due to the demands of the foetus. Therefore, it is the first two-thirds (or 100 days) of pregnancy that have the greatest impact on the success of hogget breeding and future two-tooth liveweight and performance. It is only in this period of pregnancy that the ewe hogget has any real capacity to continue to gain liveweight and grow herself.

Several studies examining the effects of liveweight gain during pregnancy have noted that weight gains of less than 100g/d throughout pregnancy (including the pregnancy gains) had a negative impact on the liveweight of the ewe hogget and her offspring to weaning. In comparison, a hogget gaining 130 to 150g/d throughout pregnancy is more likely to rear adequate-size lambs and is more likely to achieve two-tooth breeding targets. There is little improvement in the performance of the hogget or her offspring from gaining above 200g/d throughout pregnancy, indicating that gains above 200g/d are an inefficient use of feed.

Interestingly, pen-feeding trials conducted in the United Kingdom using concentrate rations reported that excessive feeding of single-bearing ewe hoggets, resulting in gains in excess of 230g/d (230 to 320g/d including pregnancy gains) in total weight, increased the risk of lost pregnancies and resulted in lower lamb birthweights and survival rates. It is unlikely that these levels of total weight gains in pregnancy would be achieved under pastoral-based grazing conditions during winter in New Zealand. There are only a few New Zealand studies in which hoggets under experimental pastoral-based conditions have gained in excess of 200g/d (200 to 240g/d). Across those studies, high gains generally did not have negative consequences. However, farmers should be aware of the potential negative impacts of excessive overfeeding of pregnant ewe hoggets. However, any impact of so-called 'overfeeding' is likely to be much smaller in New Zealand conditions than underfeeding the hogget in pregnancy, and not allowing her to gain 130 to 150g/d.

Assuming a birthweight of 4 to 5kg for a lamb born to a hogget, the total conceptus mass (placenta, fluids, foetus) will be approximately 9 to 10kg just prior to lambing (Figure 7). Two-thirds of this weight gain occurs during the last third of pregnancy. If ewe hogget liveweight at breeding is assumed to be 42 to 45kg (Figure 8), with a target liveweight of 52 to 54kg the day after she lambs (and a aim of 63 to 65kg at two-tooth breeding), then the hogget needs to gain at least 20kg in total weight throughout pregnancy (10kg for her own liveweight gain and 10kg for the pregnancy). In this scenario, over the entire 147 days of pregnancy, the ewe hogget needs to gain total weight at a rate of approximately 130g/d. Therefore, a further advantage of having hoggets as heavy as possible at breeding is that it reduces the amount of weight gain required in pregnancy. For example, a 45kg ewe hogget at breeding only needs to gain 17kg in total weight throughout pregnancy if the aim is for her to weigh 52kg (i.e. 7kg for her own growth and 10kg for the pregnancy) the day after lambing (Figure 8). Note that, for a hogget carrying twins, the conceptus mass is likely to be 12 to 13kg at term, requiring an even greater total liveweight gain in pregnancy. This further indicates the importance of using pregnancy scanning to target nutrition of multiplebearing hoggets.

Figure 6: Increases in weight of the foetus, placenta and udder during pregnancy

Source: D Revell

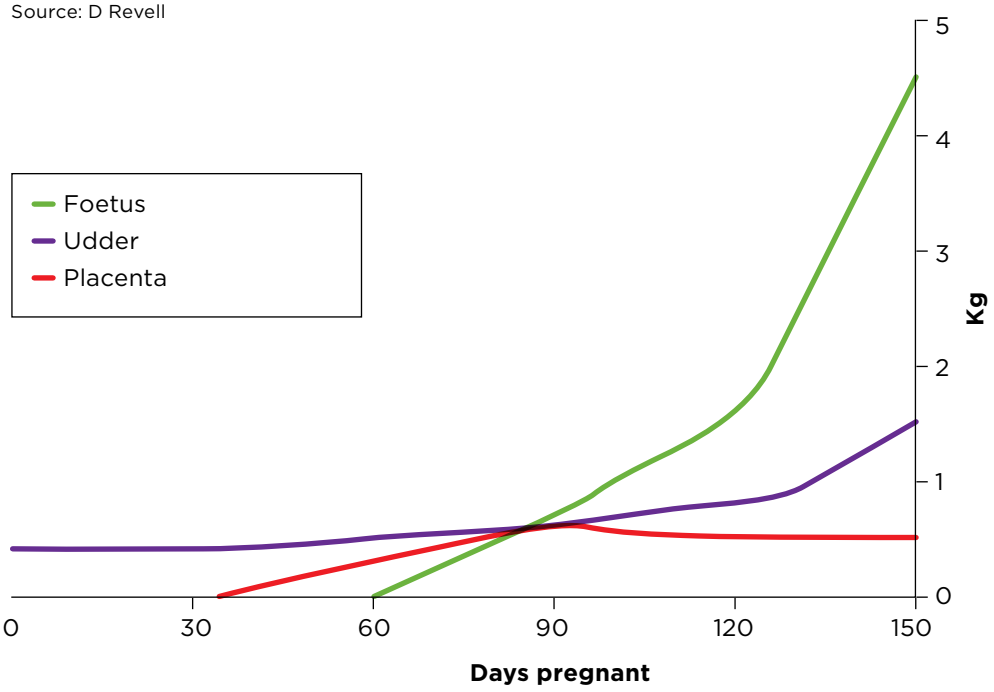
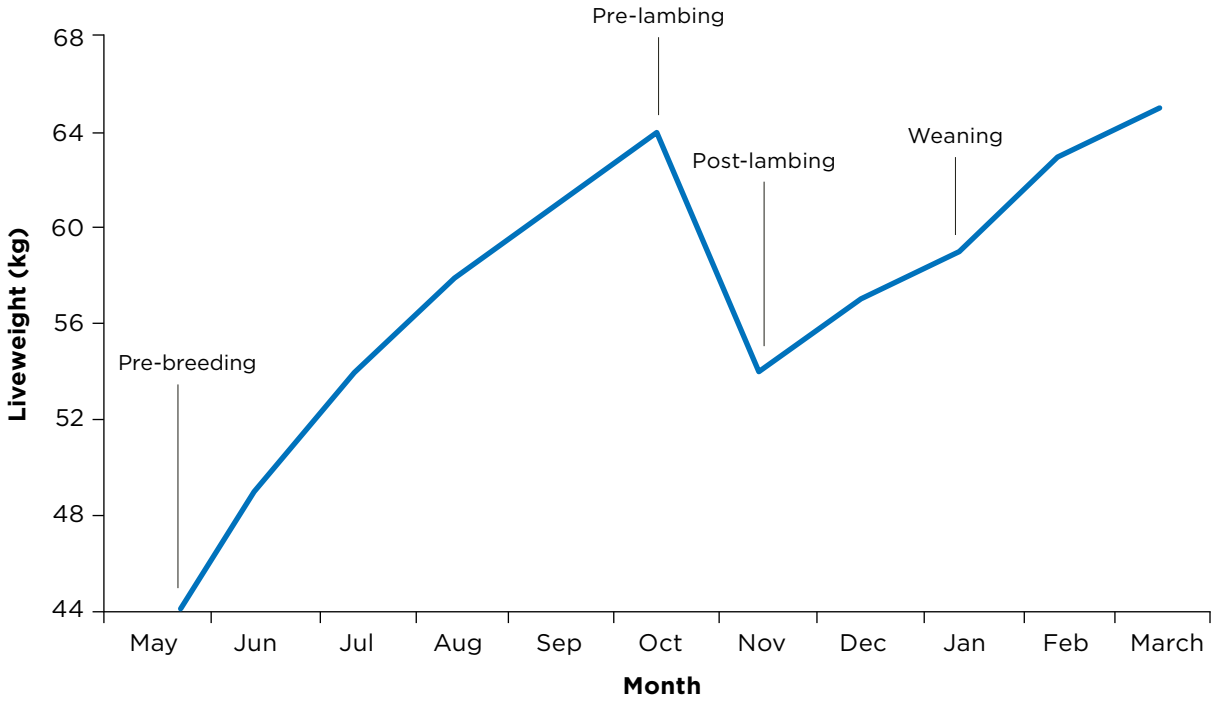


Figure 7: Target liveweight profile from just before hogget breeding to two-tooth rebreeding

Source: P. Kenyon, Massey University (2021)



The achilles heel of hogget breeding is the inability to feed the hogget enough during the entire pregnancy period so that she continues to gain liveweight. Adjustments need to be made to either total farm feed supply or demand. Reducing the numbers of other classes of stock may be required. Anecdotally, the extra feed demand for 7 to 8 pregnant hoggets, compared to the same number of non-pregnant ones, is equivalent to one mature ewe. That is, to keep the feed balance the same on farm one mature ewe could be dropped per 7 to 8 pregnant hoggets. One mature ewe cannot wean the same total weaning weight as 7 to 8 pregnant hoggets. Table 4 shows the average daily requirements for a 40kg single-bearing pregnant hogget that gains 100g/d of her own liveweight during the first 100 days of pregnancy and then gains 10kg in total pregnancy weight over the last third of pregnancy. She should weigh approximately 50kg the day after she lambs (which is below the ideal of 52 to 54kg, but gives an idea of the feeding levels required). Although this might seem artificial, it is actually very difficult for the hogget to gain her own liveweight in late-pregnancy, due to the demand and growth of the pregnancy.

If a typical non-pregnant ewe hogget gained liveweight at approximately 70g/d during the late winter/ early spring period, she would have a daily requirement of approximately 12.5 MJ ME/d when she weighed 40kg, and approximately 14.1 MJ ME if she weighed 50kg. This is much less than the scenario in Table 4, when a hogget might be 100 to 140 days pregnant, clearly indicating the extra winter demands that hogget breeding puts on a farming system. As indicated earlier, having the ewe hogget heavier than 42 kg at breeding is an advantage as it puts less pressure on the farm system over the winter, because lower liveweight gains are needed to achieve 52 to 54kg the day after she lambs.

To achieve target total liveweight gains of approximately 130 to 150g/d throughout pregnancy, hoggets should be managed to ensure ryegrass/ white clover pasture pre-grazing masses of 1400kgDM/ha or above, and post-grazing masses above 1200kgDM/ha. If using sward height as a measure of feed availability, this equates to moving the hoggets before the sward height is below 3 cm. Figure 8 indicates that, as sward height drops, liveweight gain is reduced. It is important to note that these pasture mass guidelines are for the entire pregnancy period and that the pasture should be of high quality. Various winter crops could be used to ensure hoggets gain weight at the required levels throughout pregnancy. With these, it is important to ensure intake is not limited (i.e. the hoggets are not forced to consume all of the herbage and/or to graze to low levels) and that the crop is of high quality.

Nutritional studies involving hoggets have shown that it is relatively difficult to manipulate the birthweight of their lambs. For example, in studies where hoggets were managed to gain approximately 80 to 120g/d (i.e. total liveweight gain of 12 to 17kg) throughout pregnancy, the birthweights of their lambs were 3.7 to 4.0kg, while hoggets managed to gain approximately 200g/d (at total liveweight gain of near 30kg in pregnancy) their lamb's birthweight was in the order of 3.9 to 4.2kg. This indicates that foetal growth is primarily under genetic rather than nutritional control. It also helps explain why dystocia is an issue in hoggets. This is because if the hogget is not well-grown, the foetus is still somewhat pre-programmed to be within a certain birthweight range. Therefore, a poorly-grown hogget is likely to suffer from dystocia, regardless of how well she is fed in late-pregnancy. (I.e. her pelvic opening is relatively smaller in proportion to her lamb's birth size, compared with a larger, well-grown hogget.) However, if a hogget is well fed in early to mid-pregnancy, allowing her to grow (i.e. gaining 130 to 150g/d), her bone structure and thus the pelvic opening will be larger and she will be more able to successfully give birth to the lamb unaided (even if the lamb is heavier).

In a farmer survey, lamb losses decreased by around 3% for every 1kg increase in hogget weight gain over the range 4 to 10kg (Figure 9). A more recent study indicated that heavier hogget liveweights a few weeks pre-breeding (broadly aligned with vaccination timings) was associated with fewer lamb losses. These beneficial effects on lamb survival are likely due to improved placental development, increased ease of birth, improved lamb birthweight and vigour, increased early colostrum and total milk production, and better mothering ability of the ewe hogget.

Liveweight targets as an alternative to liveweight gains in pregnancy

An alternative to target liveweight gains is target liveweights at strategic time points during pregnancy (Appendix 1). An analysis of a large dataset from a number of studies has shown that liveweight of the hogget at breeding, days 50 and 100 of pregnancy and just prior to lambing all have relationships with lamb birth and weaning weight and the liveweight of the ewe hogget at weaning (see Table 2). However, what is interesting about

this table is that it is the liveweight at breeding and at day 50 of pregnancy that have the biggest impact on the performance of ewe hogget and her offspring to weaning. In other words, the heavier the hogget is in early-pregnancy the greater the ability the hogget has to cope with the rigours of being pregnant and lactating. This further enforces the importance of a minimum liveweight target at breeding and ensuring hoggets continue to gain liveweight in early-pregnancy. A further point Table 2 illustrates is that hogget liveweight in late-pregnancy has only a very small influence on lamb birthweight, supporting the concept that birthweight is predominately under genetic control. The effect of hogget liveweight on lamb birthweight is greater in twin- than single- bearing hoggets. Birthweight of lambs born to hoggets influences their survival chances (Figure 9 and 10).

Pregnancy diagnosis (ultrasound scanning)

Hoggets should be pregnancy diagnosed between days 50 and 80 of pregnancy (i.e. approximately 50 days after the ram is removed from the ewe hogget flock). Scanning allows the identification and differential feeding of dry, single- and twin-bearing hoggets. It also allows for planning for the lambing period and paddock allocation. As for mature ewes, multiple-bearing hoggets should be offered the best lambing paddocks and appropriate pasture covers. Some flocks are now scanning in excess of 25% of hoggets with twins, and in this situation, separating single and twinning mobs in pregnancy and lactation is recommended.

Timing and effect of mid-pregnancy or pre-lamb shearing

Shearing of mature ewes in mid-pregnancy (days 60 to 100) increases lamb birthweight and survival to weaning. The response is most consistent in multiple-bearing ewes. In hoggets, the effect of mid-pregnancy shearing has not been extensively studied in New Zealand. However, one study has shown that mid-pregnancy shearing can increase single lamb birthweights, but it had no effect on twin lamb birthweights. The increase in birthweight was not associated with a change in lamb survival to weaning. Any means that increases lamb birthweight without altering the size of the hogget may increase the risk of dystocia. In multiple-bearing mature ewes, the birthweight response consistently occurs when the ewes are in good body condition and therefore the ewe has the ability to partition 'extra' body reserves to the growing foetuses. It is unlikely that hoggets carrying twins have 'extra' body reserves available to enhance foetal growth.

The survival response from lambs born to mid-pregnancy shorn mature ewes is mainly due to the lamb being larger at birth and better able to cope with poor weather. Hoggets tend to lamb later than the mature ewe flock, when the weather is generally more settled, thus the survival response from being heavier at birth is less relevant.

Shearing can also be done much later in pregnancy (during the last third of pregnancy). The concept here is that the ewe with her wool recently removed feels the cold and seeks shelter at lambing. However, ewes shorn in mid-pregnancy will have grown enough fleece by lambing that they will not feel the cold. Late-pregnancy shearing should ideally be no later than four weeks prior to the commencement of lambing.

Shearing in both mid and late-pregnancy increases heat loss from ewe hoggets and may stimulate appetite, although this has not always been reported and, when found, has generally been less than a 10% increase. Sheep shorn during winter must be protected from exposure. Depending on the region, genuine winter combs, winter combs plus lifters, or blades should leave sufficient wool for protection from all except the worst weather. The time removed from pasture should be limited. After shearing, pregnant hoggets should be placed in sheltered paddocks with adequate feed (pasture covers above 1200kgDM/ha). Shelter is essential to prevent cold stress, especially in adverse weather. Wind and rain increase heat loss and, in extreme conditions, can cause death due to exposure. Farmers may want to stop shearing earlier in the day, as hoggets shorn late in the day will have had a longer period off feed and, when it is dark, may be less inclined to graze.

Animal health management

Develop an animal health plan with your veterinarian for the ewe hoggets in late-pregnancy and lactation. Ewe hoggets need to have the full course of recommended pre-lamb vaccinations as they are at higher risk.

Well grown hoggets will have developed reasonable immunity to internal parasites. Hoggets lambing on high allowances of good quality forage with low worm larval contamination are unlikely to need extra support to deal with worms. However the demands of late pregnancy and lactation can cause their immunity to break down. Where nutritional conditions are not ideal and/or pasture larval contamination is likely to be high, lambing hoggets may need extra support to deal with worms. Discuss with your animal health advisor. If long-acting products are used, make a plan to manage and minimise the drench-resistant worm population that will have established where the hoggets have been lambed.

Table 4: The metabolisable energy requirement per day (MJ ME/d) for a 40kg ewe hogget gaining 100g/d for the first 100 days of pregnancy plus requirements in late-pregnancy

	Day of pregnancy								
	0	**20**	**40**	**60**	**80**	**100**	**120**	**140**	**147**
Total liveweight of hogget including pregnancy (kg)	40.0	42.2	44.4	46.9	49.8	53.2	55.4	58.6	60.0
Pregnancy free liveweight gain (kg/d)	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
MJ ME/d	14.8	15.3	15.8	16.5	17.7	19.7	16.4	20.5	22.3

This is based on a pasture with an ME of 11 and includes an 8% wastage factor (Brookes unpublished).

In this scenario, it is assumed the hogget will gain 10kg of her own liveweight in the first 100 days after pregnancy. After this point, any gain in weight is weight associated with the gain for the pregnancy only (approximately 10kg in total weight). It is assumed she will weigh 50kg after she has given birth to the lamb.

Figure 8: Effect of pasture height on the liveweight gain of ewe lambs

Adapted from: During et al. 1980

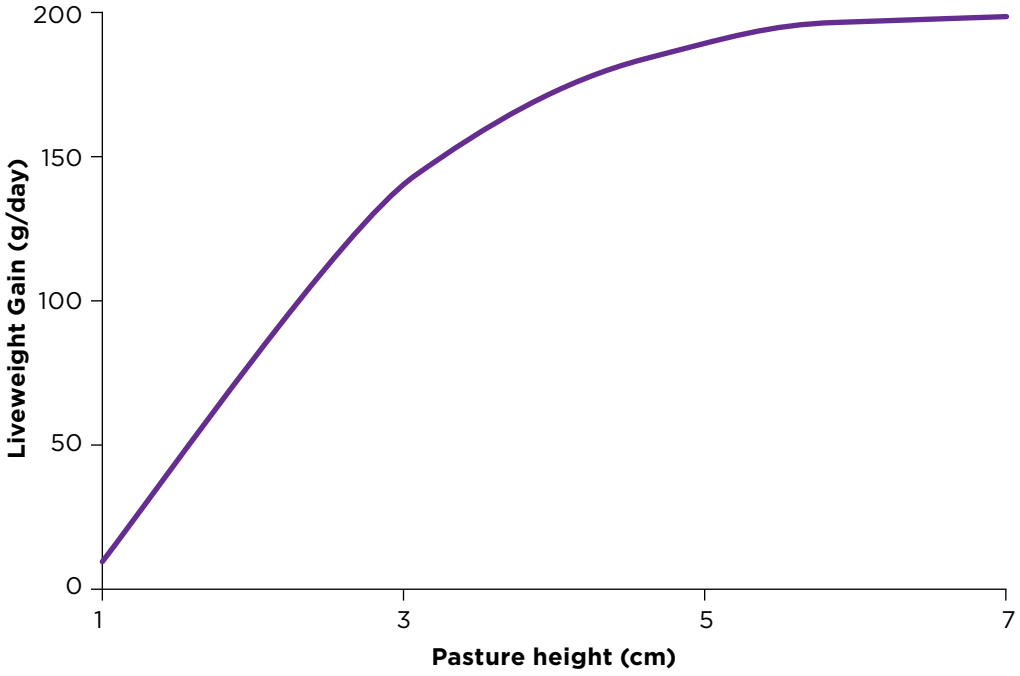


Figure 9: Effect of hogget liveweight gain during pregnancy on lamb losses
Adapted from 'A Guide to Hogget Lambing, Meat & Wool New Zealand'

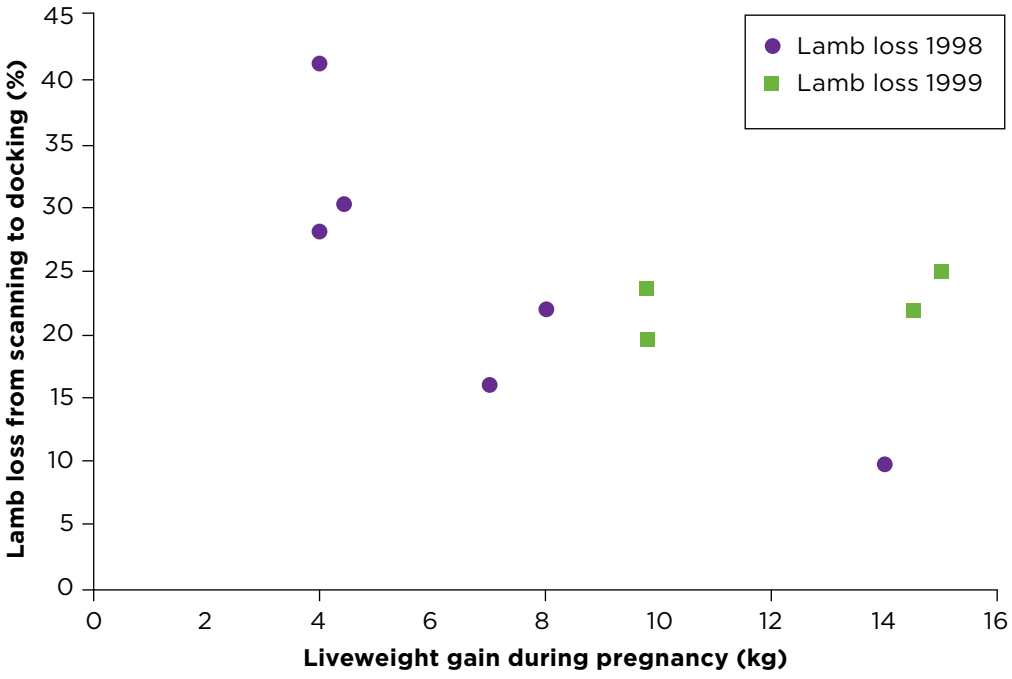
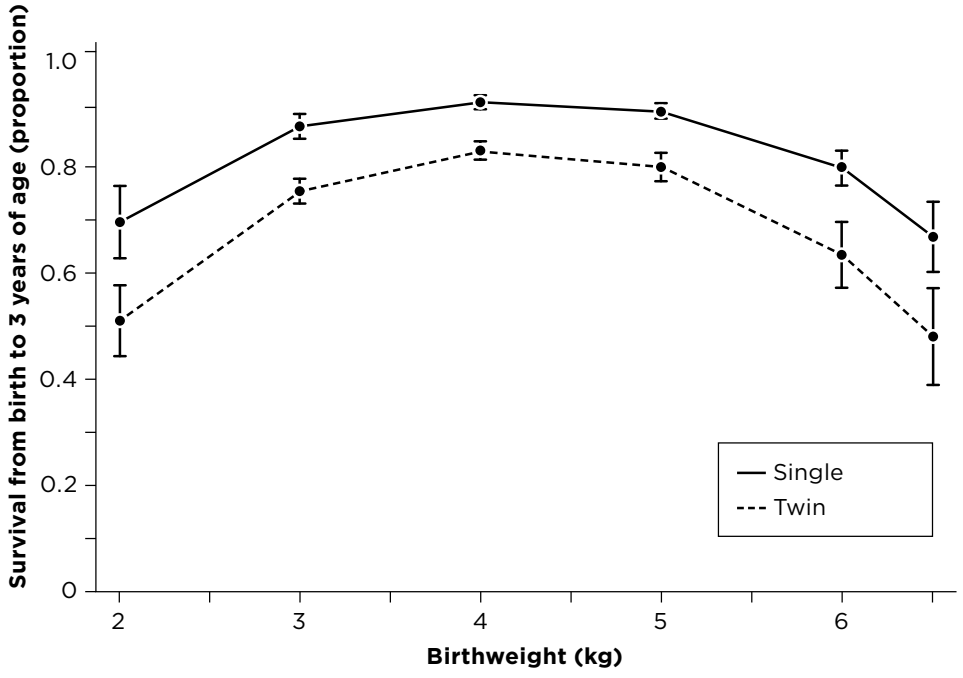


Figure 10: Regression of survival from birth to 3 days of age (proportion) on lamb birth weight (BWT, kg) for singles and twins
From: Adapted from Young *et al.* 2010



CHAPTER 5

Management of ewe hoggets during lambing and lactation

Once lambs are born to ewe hoggets, it is important to grow them as quickly as possible and ensure the hogget herself is still gaining liveweight. Lambs born to hoggets tend to be lighter at weaning and are generally weaned later in the season than lambs born to mature ewes. Therefore it is important that these lambs grow to their potential.

Set stocking

As with mature ewes set stocking single- and multiple-bearing hoggets separately increases lamb survival to weaning. Twin-bearing ewe hoggets should be offered the most sheltered paddocks, and grazed at a lower stocking rate. A lower stocking rate has two potential advantages. Firstly, it lowers the chance of mis-mothering and, secondly, it allows for more feed available per twin-bearing hogget. Paddocks with a slope of greater than 30 degrees should be avoided. To ensure ewe hogget and lamb performance is not limited, the hogget and her offspring need to be offered high quality pasture with ryegrass/white clover masses not falling below 1200kg DM/ha (ideally not below 1400kgDM/ha) throughout lactation.

Lambing beats

Lambs born to hoggets are smaller than those born to mature ewes which increases the risk of death due to starvation or exposure. The risk is increased in poor weather conditions. Although, generally, hoggets lamb after the mature ewe flock and are less likely to experience adverse weather. Further, as the young dam is not fully grown, dystocia can also be an issue. Studies indicate that the rate of still births (born dead without an obvious cause) can be a lot higher in hoggets than mature ewes. In addition, the death rates of lambing hoggets over the spring period is greater than non-lambing hoggets. Therefore, farmers may wish to consider a lambing beat. However, hoggets must be accustomed to the presence of the farmer to ensure any intervention does not risk increased death rates due to separation and mis-mothering.

Feeding lactating hoggets

As indicated earlier, if a single-bearing hogget weighs approximately 62kg the day before she lambs, she will weigh around 52kg the day after. If we assume a hogget lambed on 1 October and two-tooth breeding is on 1 April, with a target liveweight of 65kg, she needs to gain approximately 80 g/d during that period. The hogget should be in good condition and fed to allow her to lactate to her potential so that her lambs survive and are as heavy as possible at weaning. Further, depending on the location of the farm, the hogget may face a dry summer/autumn period prior to re-breeding. Theoretical requirements are given in Table 5.

Ewe hoggets should lamb and lactate in paddocks where pasture covers do not fall below 1200kgDM/ha (ideally above 1400kgDM/ha). This should maximise hogget intakes and ensure optimal liveweight gain of both the ewe and her lamb(s). Pasture quality can also have a significant impact on hogget growth, lactation performance and lamb growth. Pasture quality declines as spring advances and grasses begin to produce stem and seed head. Therefore, pasture covers should not be allowed to get above 1800kgDM/ha. Once the lambs are mobile and the period of potential lamb mis-mothering is over, hoggets and their lambs can be moved to ensure the pasture masses are within the optimum range (1200 to 1800kgDM/ha). Alternative forages, such as herb/clover mixes (i.e. chicory, plantain, red and white clover) and pure lucerne swards have been shown to significantly increase (Table 6) the liveweight of lambs born to hoggets at birth and weaning, and the weight of the hogget herself compared to ryegrass/ white clover pastures. Based on Table 6, it may be worth considering weaning a couple of weeks early, to allow the young dam more time to recover before two-tooth breeding. It is possible the other cropping options in spring may have similar positive effects, but these have not been evaluated.

Table 5: The metabolisable energy requirement per day (MJ ME/d) for a 50kg ewe hogget rearing a single lamb (including requirements for the lamb) in lactation

Note: The ewe in Part A is not changing liveweight, while the ewe in Part B is gaining liveweight at a rate of 85g/d.

	Approximate weeks since lambing					
	1	3	5	8	10	12
Part A (0g/d)						
Ewe requirements	21.6	22.6	22.5	21.9	20.8	18.9
Lamb requirements	0.0	0.5	1.5	2.8	4.6	6.8
Total requirements	21.6	23.1	24.0	24.7	25.4	25.7
Part B (85g/d)						
Ewe requirements	25.6	26.7	27.0	26.6	25.7	24.1
Lamb requirements	0.0	0.5	1.5	2.8	4.6	6.8
Total requirements	25.6	27.2	28.5	29.4	30.3	30.9

This is based on a pasture with an ME of 11 and includes an 8% wastage factor (Brookes unpublished). The values include the maintenance requirements of the ewe hogget. The lamb is assumed to weigh 23kg at weaning.

Table 6: Percentage (%) increase in hogget and lamb liveweight at weaning for ewes offered a herb/ clover mix or lucerne compared with ryegrass pasture during lambing and lactation

From: Adapted from Corner-Thomas *et al.* 2014

	% Increase in liveweight at weaning	
Pasture type	**Hogget**	**Lamb**
Herb-clover	21%	14%
Lucerne	20%	24%

CHAPTER 6

Weaning and post-weaning management of ewe hoggets and their lambs

Lambs born to ewe hoggets are on average 1.0 to 1.5kg lighter at birth than those born to mature ewes, and approximately 3 to 5kg lighter at weaning. As lambs born to ewe hoggets are generally born a month later than those born to mature ewes, at a given calendar date they can be even lighter. This lighter lamb liveweight influences when weaning should occur. There is some debate as to whether hoggets should be weaned on a given calendar date, at a certain age, or at a target weaning liveweight. While circumstances differ from farm to farm, and region to region, there are many factors to consider when deciding when to wean.

When to wean hogget lambs?

While it may be beneficial for the lamb to be weaned as late as possible, late weaning limits the time the young dam has to gain liveweight before two-tooth breeding. Unlike the situation for mature ewes, it is unlikely that any lambs born to hoggets will be weaned directly to slaughter. Therefore, the vast majority of the lambs born to hoggets will be either sold store or require finishing. Given this, the aim should be to time weaning to ensure that the lamb is in the best possible position to continue to grow well post weaning, while still ensuring the young dam has enough time to achieve a suitable two-tooth breeding liveweight and body condition.

Lambs weaned from hoggets need to be offered a high-quality ryegrass/white clover sward, with a high clover content and covers in the range of 1200 – 1800kgDM/ha. An ideal pasture should be clover dominant and the grasses should be mainly new green leaf, with little stem or dead leaf material. Such pastures have an ME value of 11 – 12 MJ ME/kgDM (Figure4). Pasture masses above 1800kgDM/ha should be avoided, as pasture quality will have begun to decline. Alternatively, they can be weaned onto forage crops with a high ME and legume content (i.e. herb clover mixes or lucerne), with unlimited intake. They should be adapted to these crops prior to weaning. Appropriate animal health plans also need to be in place. Lambs born to hoggets can then be successfully weaned at 9 to 10 weeks, at a liveweight of 20kg.

Managing ewe hoggets post weaning

Hoggets that wean a lamb are generally lighter than their counterparts that were either not bred or failed to rear a lamb. If hogget breeding results in lightweight two-tooth ewes, it will affect the overall flock productivity, though reduced performance. Therefore, after the weaning of their lambs, weigh a sub-sample of the hoggets (at least 50). Regular monitoring and setting target liveweights can help ensure adequate two-tooth weights are achieved. Regular monitoring ensures that any ewes below target liveweights are identified early and management plans can be implemented. To ensure liveweight gains are not limited, pasture should be high quality (11 - 12MJ ME /kg DM) and within 1200 to 1800kg DM/ha. As with their weaned lambs, forage crops can be used to ensure target liveweight gains are met and animal health plans should be in place. Table 7 indicates intake requirements for a hogget post weaning, either maintaining or gaining liveweight.

Table 7: The metabolisable energy requirement per day (MJ ME/d) for ewe hoggets post weaning and prior to two-tooth breeding.

Liveweight gain / day (g)	Liveweight (kg)					
	42	**46**	**50**	**54**	**58**	**62**
0	8.5	9.3	10.0	10.7	11.5	12.2
50	11.7	12.6	13.5	14.4	15.2	16.0
100	15.0	16.0	17.1	18.0	18.9	19.8
150	18.2	19.5	20.6	21.7	22.6	23.6
200	21.5	22.9	24.2	25.3	26.4	27.4
250	24.9	26.4	27.8	29.0	30.2	31.2

This is based on a pasture with an ME of 11 and includes an 8% wastage factor (Brookes unpublished).

CHAPTER 7

Potential long-term impacts of hogget breeding

The potential long term advantages from successfully breeding ewe hoggets include: an early selection/screening tool, increased lifetime performance and a potential reduction in the generation interval if progeny born to ewe hoggets are selected as replacements. There are also some potential long term disadvantages which are of concern to many farmers. These include: reduced two-tooth liveweight and reproductive performance and decreased longevity within the flock.

Early selection of ewe replacements

It has been shown that ewe hoggets which are presented for breeding but that fail to get pregnant are heavier at two-tooth breeding than those that lambed as a hogget. Two-tooth fertility is genetically correlated with the occurrence of puberty as a hogget. This suggests that hogget breeding could be an early screening tool where ewes of suitable liveweight at breeding that failed to become pregnant could be culled. A possible management option for farmers is to present more hoggets for breeding than they require as replacements ewes and cull those which fail to get pregnant. Another option is to use harnessed teaser rams with hoggets, but not breed them to entire rams and only keep as replacements those that were marked by the teaser.

Increased lifetime performance

The lifetime reproductive performance of ewes that lambed as a hogget is greater than those that did not lamb. However, the size of this benefit depends on the success rate of hogget breeding and any negative impact on two-tooth reproductive performance. Both liveweight and nutrition of the ewe hogget have a large influence on reproductive performance and therefore success as a hogget and two-tooth. Studies have also indicated the potential for poor condition two-tooths, bred as a hogget, to have reduced longevity in the flock. Therefore, to maximise the potential lifetime benefit from hogget breeding, it is important that target hogget liveweights are met pre-breeding, during pregnancy, post-weaning and at two-tooth breeding. This will help maximise the chance the ewe hogget will successfully rear an adequately sized lamb, and at two-tooth breeding will be at a suitable liveweight and body condition.

Reduction in the generation interval from selecting replacements born to ewe hoggets

Some farmers suggest that a means of improving genetic progress within their flock is to select replacements born to ewe hoggets and therefore reduce the generation interval. However, few farmers actually do this. (There is little data on the performance of progeny born to ewe hoggets versus those born to mature ewes, when both groups of ewes have been bred at the same time and to the same rams, i.e. thereby removing any potential benefit of the lambs born to mature ewes being older.)

The issues with selecting replacements from lambs born to hoggets is the reduced time they have to achieve target breeding weights, and their often lighter weights at weaning, compared to those born to mature ewes. Single lambs born to hoggets are generally lighter until 8 – 12 months of age, compared to those born to mature ewes. In fact, comparisons of the productive performance of singles born to either ewe hoggets or mature ewes show little or no difference in reproductive performance at one year of age, if adequate liveweights are achieved, and no difference in later years. However, studies to date suggest that twins born to hoggets may remain slightly lighter throughout their lifetime compared to those born to mature ewes, without showing reduced lifetime reproductive performance. Before firm conclusions can be drawn further lifetime studies are required. Studies are also required to determine the lifetime impacts of very heavy hogget breeding liveweights on efficiency. The sparse data available suggests that heavier hogget breeding weight can increase reproductive performance as a hogget, but has no influence on two- and three-year-old performance or efficiency to three years of age.

The potential for reduced two-tooth liveweight and performance

An often stated concern about hogget breeding is the potential for negative effects on two-tooth liveweight and performance. Indeed, some studies have shown that breeding ewe hoggets can reduce two-tooth breeding liveweight by up to 6kg. However, this liveweight effect had either no effect or only a minor negative effect on two-tooth reproductive performance. Conversely, many studies have shown a positive effect of hogget breeding on two-tooth performance. Across studies, it is apparent that when there is no effect of hogget breeding on two-tooth liveweight there can either be no impact or a positive impact of hogget breeding on two-tooth performance. Meeting target hogget liveweights and body condition score will ensure the full benefit from hogget breeding is achieved.

Any reduction in two-tooth liveweight from hogget breeding generally dissapears by the weaning of their second set of lambs.

The potential for decreased longevity and productivity in the flock

A commonly heard concern among farmers is that ewe hoggets which lamb will have reduced longevity in the flock. However, this is generally not the case in flocks were ewes have been kept to six years of age and fed well to ensure liveweight and body condition score targets are met. In contrast, it has been shown that low body condition score as a hogget can reduce longevity in the flock, through increased wastage when bred as a hogget. The death rates of bred hoggets over the lambing period can be higher than that of non-bred hoggets, over the same time period, resulting in reduced longevity in the flock.

APPENDIX I

An example timetable for ewe hogget breeding

Below is an example of a management plan for hogget breeding. In this timetable, it has been assumed that the ewe lamb was born on 1 September and then weaned on 1 January at 30kg. The ewe hogget is then presented for breeding on 1 May weighing 42kg. She is re-bred as a two-tooth weighing 62kg.

Month of year	Age (months)	Target weight (kg) at 1st of the month	Tasks for month
January	5	30	Shearing, clostridial vaccination
February	6	33	Second clostridial vaccination
March	7	36	Campylobacteriosis vaccination Toxoplasmosis vaccination
April	8	39	Second campylobacteriosis vaccination Teasers introduced 14 April. Teasers in teams at a ratio of ratio 1:70
May	9	42	Ram in 1 May. Rams in teams at a ratio of 1:70. Ram in for maximum 34 days. Rams should have crayon harnesses.
June	10	45	Remove hoggets with no harness marks on rumps
July	11	48	Pregnancy diagnosis. Remove non pregnant hoggets
August	12	52	If mid-pregnancy shearing, schedule for early in the month. Use cover or snow comb.
September	13	56	Hoggets should weigh 60kg the day before they lamb. Pre-lamb vaccination in early September. Set stock two weeks pre-lambing at a rate, such that covers will not drop below 1200kgDM/ha or a sward height of 4 cm. Twin-bearing hoggets should be offered paddocks with more shelter and that are not too steep.
October	14	50	
November	15	52	Docking, remove wet/dry hoggets, weigh and condition score a subset of hoggets
December	16	54	
January	17	56	Wean in early January to give time for the young ewes to recover. Shear ewe post weaning. Weigh and condition score a sub set post shearing
February	18	58	Campylobacteriosis vaccination
March	19	60	
April	20	62	Re-breed

APPENDIX II
Summary of the literature on ewe hogget breeding

Comparison of reproduction of mature ewes and hogget

Quirke & Hanrahan (1977), Beck *et al.* (1996), Mulvaney (2011), Kenyon *et al.* (2014b) and Shorten *et al.* (2021) have all reported that ovulation rate was lower in ewe hoggets than mature ewes. Similarly, hogget fertility and conception rates have also been reported to be lower than for mature ewes (Keane 1976; McMillan & Kitney 1983; Smith & Knight 1998;Corner *et al.* 2013; Hutchison *et al.* 2022). McMillan & McDonald (1985) reported that ewe hogget ova were less viable. They suggested that this was a major reason for lower fertility in ewe hoggets. Similarly, Quirke & Hanrahan (1977) reported ewe hogget ova had a lower capacity for survival than ova from mature ewes. In addition, Mulvaney (2011) reported that when ewe hoggets and mature ewes were bred together, ewe hoggets were less likely to be mated than mature ewes.

Beck *et al.* (1996) found that ewe hoggets had increased rates of late (days 15 to 30) embryonic loss compared to mature ewes. Similarly, Edwards and Juengel (2017), Paganoni *et al.* (2014), O'Connell *et al.* (2021) and Shorten *et al.* (2021) reported greater early-pregnancy loss and Mulvaney (2011) reported greater pregnancy losses to day 69 of pregnancy.

Lambs born to ewe hoggets are lighter at birth and weaning than those born to mature ewes (Mulvaney 2011). Further, lambs born to ewe hoggets display poorer bonding behaviour, are less vigorous and the young dam herself exhibits poorer mothering ability than those born to mature ewes (Mulvaney 2011, Pettigrew *et al.* 2021a). Overall survival rates to weaning are lower as are weaning weights (Corner *et al.* 2013; Pettigrew *et al.* 2021a and Shorten *et al.* 2021). Combined, these reports help explain why ewe hogget performance is lower than mature ewes (Corner-Thomas *et al.* 2015; Kenyon and Corner-Thomas 2022).

Timing of the breeding season and puberty

The reproductive activity of the ewe hogget is dependent on the breeding season and ewe hoggets must reach puberty before they can be successfully bred. The onset of breeding in hoggets is later than that of two-tooth or adult ewes and the breeding season is shorter (Dyrmundsson 1973; Smith & Knight 1998). In New Zealand, the peak reproductive activity of ewe hoggets does not occur until the mid-May to mid-June period, with only a small proportion of ewe hoggets reaching puberty and therefore oestrus (heat) before mid April (Lewis 1959; Smith & Knight, 1998; Edwards and Juengel 2017). Age influences timing of puberty (Thompson *et al.* 2021; Kenyon and Corner-Thomas 2022) therefore earlier-born lambs are more likely to achieve puberty prior to a May hogget breeding than those born later the previous spring. There are breed differences in the timing of reproductive activity (onset of puberty) with Finnish Landrace showing oestrus earlier in the year. Muir (2001) found with crossbred hoggets that the mean number of oestrous cycles (range in brackets) per hogget for East Friesian, Finn, Poll Dorset crosses and Romneys were 5.0 (2-8), 5.0 (2-8), 3.4 (0-5) and 3.1 (0-6), respectively; with mean season lengths (days) of 101 (21 April – 3 August), 105 (24 April – 3 August), 72 (3 May – 13 July) and 58 (9 May – 6 July), respectively.

Ovulation rates in ewe hoggets do not differ between the first, second and third reproductive cycles (Hare & Bryant 1985). However, there will be fewer viable embryos in ewe hoggets mated at the first cycle than for those mated at the second or third (Hare & Bryant 1985). Overall, Hare & Bryant (1985) reported that fertility increased by approximately 20% when breeding occurred at the second rather than first oestrus (heat). Similarly, Beck & Davies (1994) reported that fertility improved to the third oestrus (heat). The stage of the breeding season affects hogget ovarian activity, non-return rate and lambing rate (El-Din Zain & Mousa 1999).

Several techniques may be used to advance the breeding season and/or induce puberty. These include: the use of progestagen sponges or CIDR®s followed by hormone therapy; and use of Regulin® (melatonin) implants (Smith & Knight 1998; Gordon 1999). However, the cost, their reliability and the extra management required for the use of these treatments make them unsuitable for most pastoral-based farming situations.

Management to ensure high performance levels

Breeding behaviour of ewe hoggets

Ewe hoggets are 'shy' breeders. They are less likely to seek out the ram and to stand for him (Dyrmundsson 1981, Smith & Knight 1998) and have shorter less intense oestrus (heat) periods (McMillan & Parker 1981, Schick 2001). Keane (1976) found that the sexual behaviour of hoggets was different from mature ewes and reported that rams had more difficulty breeding with ewe hoggets. They noted that, although rams mounted the ewe hoggets, they actually often failed to mate successfully with them. Edey *et al.* (1978) also reported poor breeding behaviour in ewe hoggets compared to mature ewes and that they were only in oestrus (heat) for 18 hours compared to 29 hours in mature ewes. Similarly, Allison *et al.* (1975) found that failure of males to actually get semen inside the hoggets reproductive tract was an issue until the ewe hogget had been mounted by at least three rams at one oestrus (heat) event. Keane (1976) reported higher breeding performance in ewe hoggets when kept separately from mature ewes. For this reason, ewe hoggets should not be bred in the same mob with mature ewes (Kenyon and Corner-Thomas 2022) for breeding, as the results of Mulvaney (2011) and Corner *et al.* (2013) indicate. Both reported that oestrus (heat) without ovulation can be common in hoggets around the time of puberty. This would result in the hogget failing to become pregnant to that oestrus (heat) event.

Genetic influences on reproductive performance as a ewe hogget

A number of genetic parameters affecting puberty and first oestrus have been examined (Kenyon and Corner-Thomas 2022). Selection for date of lambing has a significant effect on date of first hogget oestrus, and has been suggested as a screening tool in the selection process (Smith *et al.* 1995). Heritability of traits such as age and liveweight at puberty, fertility, fecundity, and weaning rate are low to moderate (Kenyon and Corner-Thomas 2022) indicating genetic progress can be made but progress will be relatively slow. Work in Australia has indicated ewe hoggets with higher breeding values for post weaning traits, such as fat and eye muscle area, are more likely to achieve puberty as a hogget and display greater reproductive performance (Rosales *et al.* 2013a&b; Paganoni *et al.* 2014; Thompson *et al.* 2019). Fertility of two-year old Romney ewes has been shown to be genetically correlated with hogget oestrus (Chang and Rae 1972) which itself is under genetic control (Chang & Rae 1970).

Breeds, crossbreds and strains within a breed can all differ in the timing of puberty, and the proportion of the flock displaying hogget oestrus at different periods and weights (Allison *et al.* 1975; Hight & Jury 1976; Meyer & French 1979; Craig 1982; McMillan & Moore 1983; Moore *et al.* 1983, 1989; Baker *et al.* 1985; Muir *et al.* 2001; Hutchison *et al.* 2022). Using this knowledge, farmers could choose certain breeds to improve hogget breeding performance.

Moore *et al.* (1984) reported a four-year average for lambs weaned per hogget joined of 32%, 55% and 50% for Romney, Coopworth and Perendale hoggets, respectively, with an average liveweight at breeding of 32kg. Moore *et al.* (1983) report similar trends, with the Romney being the poorest of the three breeds. McMillan & McDonald (1983) reported no overall difference in reproductive rate between Border Leicester x Romney hoggets and purebred Romneys with an average joining weight of 36kg. Moore *et al.* (1989) found strain differences in hogget reproductive performance between Romneys, including Booroola Romneys.

In a survey, Kenyon *et al.* (2004a) reported that as the percentage of Finnish Landrace and East Friesian genetics increased within a composite hogget, so did the lambing percentage. They also reported that the only traditional breed to differ from the Romney in hogget lambing percentage was the Coopworth. McMillan *et al.* (1988) also reported higher reproductive rate of Finnish Landrace and Finnish Landrace crossbred hoggets. In their trial however, hoggets were bred after hormonal treatment. Similarly, Muir (2001) and Stevens (2001a, 2001b) reported higher reproductive performance with Finnish Landrace and East Friesian crosses. It is probable that the higher reproductive performance of Finnish Landrace composites is due to their ability to achieve puberty and display oestrus (heat) at relatively lighter liveweights and earlier in the season.

The number of oestrus cycles during a hogget's first breeding season is heritable, so some progress could be made selecting for this parameter. With Romneys, Baker *et al.* (1979) reported a h2 (heritability) value of 0.31 for this.

Ram effect (teasing)

The ram effect is an accepted method for advancing the breeding season in mature ewes just prior to the natural onset of the breeding season (Smith & Knight 1998). Following the introduction of rams a proportion of the ewes ovulate within 40-65 hours, without coming into oestrus. This is a so-called "silent heat" or "silent ovulation". The first oestrus with ovulation occurs 16-17 days after the first or second "silent heat", i.e. 17 to 26 days after ram introduction.

Numerous studies have shown that exposing ewe hoggets to vasectomised rams (teasers) for 17 days in mid-April can increase overall pregnancy rates and advance the mean breeding date (Kenyon *et al.* 2005, 2006ab, 2008c). It has also on occasion increased the number of twin pregnancies (Kenyon

et al. 2006b). It appears the optimal vasectomised ram to ewe hogget ratio is the range of 1:70-100 (Kenyon *et al.* 2007a). Use of the teaser before the normal start of breeding (i.e. using the teasers March/ early April) to allow for an early/mid April breeding has met with some success, although it may not be as effective in terms of a compact breeding as a teasing in mid-April (Cave *et al.* 2012). Data also suggests that the teasing response might be greater in hoggets fed to appetite rather than in those under controlled grazing conditions.

The use of short-scrotum ram lambs as teasers, or exposure to entire rams for just a few days prior to breeding, are less effective alternatives to using a traditional vasectomised rams for 17 days (Kenyon *et al.* 2008a, 2008c). An alternative use for teasers is to identify cycling hoggets in April and early May, which are subsequently not bred, as an early screening tool for more fertile/fecund two-tooths (Edwards *et al.* 2015).

Liveweight and growth influences on reproductive performance as a hogget

Environmental effects, especially the effect of year or season, can have a large influence on the proportion of hoggets showing oestrus (Moore *et al.* 1983). Any factor which affects the growth of the ewe lamb/hogget can influence whether puberty is reached in her first autumn. Birth and rearing rank and age of dam has had little effect in some studies (Baker *et al.* 1979), but not all. It has been reported that early-born lambs attain puberty at older ages and heavier weights than late-born lambs. While some late-born lambs may fail to attain puberty altogether prior to their first winter (Dyrmundsson 1973; Smith *et al.* 1995).

Heavier ewe hoggets clearly have a better chance of reaching puberty and displaying oestrus (Dyrmundsson 1973; Winn & Cumberland 1974; Meyer & French 1979; McMillan & Moore 1983) and an adequate level of nutrition has the potential to compensate for a later birth date (Moore & Smeaton 1980). Many studies have shown a positive relationship between liveweight of the hogget at breeding and her reproductive performance (Dyrmundsson 1973, 1981; Allison *et al.* 1975; Hight & Jury 1976; Keane 1976; Moore *et al.* 1978; Meyer & French 1979; Moore and Smeaton 1980; Meyer, 1981; McMillan & Moore 1983; Gaskins *et al.* 2005; Kenyon *et al.* 2005, 2006a, 2009, 2010). In summary, studies show that, while hoggets have the capability to be bred at liveweights in the low 30s, high reproductive performance is not achieved until hoggets weigh at least 40kg at breeding.

In an analysis across nine flocks McMillan & Moore (1983) showed that joining liveweight differences accounted for 60% and 71% of the between-flock differences in lambs born per hogget joined and hogget bred per hogget presented for breeding. They also reported a regression coefficient of 3.5 lambs born per hogget joined for every 1kg increase in joining liveweight. Stevens & McIntyre (1999) reported that conception rate and lambing percentage were not related to breeding liveweight over a 40-51kg range; whereas Stevens (2001) found that conception rate increased by 2% per kg liveweight increase in the 38-53kg range.

Feeding regimen and growth profile from pre-weaning as a lamb until breeding as a hogget has the potential to affect hogget oestrus and reproduction, although some of this effect is likely due to differences in liveweight at breeding (McMillan & Wilson 1983; Moore *et al.* 1978; Moore & Smeaton 1980; Moore & Miller 1982; Gaskins *et al.* 2005). McCall (1978) reported that for hoggets born to ewes aged 1, 2 or 3 years respectively, hoggets lambing per 100 hoggets exposed to the ram was greater as ewes aged. These results may reflect differences in the milk production of the dams and hence early growth rates of the lambs. Hogget liveweight data was not presented. Increased nutrition in the period just prior to breeding has been reported to increase the number of foetuses per hogget at pregnancy diagnosis (Mulvaney 2011).

McMillan & Moore (1983), who both worked widely in this area of research, reviewed the effects of level of nutrition on hogget oestrus and summarised the effects:

> "The post-weaning growth path of ewe lambs can have a profound effect on the hogget sexual season. Firstly, heavier hoggets within a flock are more likely to attain first oestrus – for every 1kg increase in autumn liveweight, about 6% more hoggets will exhibit oestrus. Secondly, the greater the autumn liveweight gain the greater the chance of hogget oestrus at the same final liveweight – this effect is analogous to the 'dynamic' effect in flushing. Thirdly, at the same autumn liveweight hoggets from well-reared flocks will have a greater chance of showing hogget oestrus than hoggets from poorly-reared flocks. This outcome can be exploited within a flock by rearing all hoggets well or preferentially feeding the lighter lambs at weaning to achieve greater post-weaning gains. Younger hoggets (i.e. later born) are less likely to exhibit oestrus only when these are poorly reared. However, under improved rearing conditions, age of hogget (i.e. birthdate) has no effect on hogget oestrus activity."

Body condition score influences on reproductive performance as a hogget

Stephenson *et al.* (1980) in a breed comparison of body composition found an association between autumn rate of increase in the proportion of body fat and the percentage of ewe hoggets bred. Body condition score (BCS) is a subjective measure of soft tissue, predominantly fat, in the lumbar region. It has been reported that ewe hoggets should be a

minimum of body condition score 2.5 at breeding, if high rates of reproductive performance are to be achieved (Kenyon *et al.* 2009, 2010). More recently, Corner-Thomas *et al*. (2015) reported hoggets should have a BCS within the range of 3.0 to 3.5 at breeding if reproductive performance is to be high. In support of the importance of BCS, Rosales Nieto *et al.* (2015, 2018) suggested that greater levels of body fat in a hogget would ensure they achieved puberty and be bred successfully.

Effect of shearing pre-breeding on hogget lambing performance

Shearing can lead to increased heat loss and potentially a stimulation of appetite (Elvidge & Coop 1974). If ample quality feed is available, liveweight gain might occur, but if feed is limiting, the increased maintenance costs, especially if it is cold, could exceed the increased intake and result in liveweight loss.

McMillan & Knight (1982) with two-tooths concluded that shearing should occur at least four weeks before breeding if lamb production is to be maximised. This subject has been less intensively studied in ewe hoggets. In hoggets, McMillan & Wilson (1982) found that shearing of ewe hoggets four or two weeks prior to joining had no effect on the percentage of hoggets mated. But in a later study they found that for hoggets shorn either four or two weeks or not shorn prior to joining, the number of hoggets lambing to first mating was greatest in those shorn four weeks prior to breeding (McMillan & Wilson, 1983). Sumner *et al.* (1982) reported that shearing hoggets pre-mating decreased non-pregnancy rates in one of four studies. Kenyon *et al.* (2004b) reported that shearing ewe hoggets pre-breeding increased the lambing percentage in comparison to those either shorn well before breeding or those not shorn at all (Kenyon *et al.* 2004b). Combined these studies indicate that ewe hoggets should be shorn at least four week prior to breeding.

Shearing immediately post-breeding might be an issue. Stevens (2001) reported on one farm that shearing hoggets 12 days after the ram was withdrawn seemed to cause an abnormally poor result. This might have been caused by the stress of the shearing event (Knight *et al.* 1982).

Nutrition around the breeding period and its effect on conception rates

Indoor studies in the UK using concentrate feeds have reported that very high levels of nutrition (resulting in liveweight gains of at least 230g/day) reduced conception rates (Wallace *et al.* 1996, 1997a, 1997b). A few studies examining the effects of nutrition around the breeding period have been undertaken in New Zealand. Kenyon *et al.* (2008b) compared ewe hoggets with liveweight gains of 134 and 223g/day respectively. A greater proportion of the higher liveweight gain hoggets returned to service. However, pregnancy scanning data and the percentage of hoggets which subsequently lambed did not differ. Mulvaney *et al.* (2010b) compared ewe hoggets with liveweight gains of 208g/d and 153g/d. The former had a greater percentage of hoggets returning to breeding in the second cycle, although overall pregnancy rates were not affected. Mulvaney *et al.* (2010a) reported conflicting results of nutrition around pregnancy on return rates. In one study, they reported no effect and in the other reported a negative effect of high liveweight gains. But, in support of previous studies, overall pregnancy rates did not differ. Overall, New Zealand studies may indicate that there is the potential for high liveweight gains around the breeding period to negatively affect conception rates. However, because the high liveweight gains result in more hoggets bred, the total overall pregnancy performance is not negatively affected. Therefore, it is likely more beneficial overall to ensure hoggets are growing well during the breeding period and achieve heavier liveweights (Kenyon *et al.*2014; Edwards and Juengel 2017). It has previously been reported in mature ewes that high liveweight gains around the breeding period can reduce progesterone concentrations leading to reduced embryonic survival (Parr *et al.* 1987).

Management of rams during the breeding period

Allison *et al.* (1975) report that, in one of two experiments, increasing the number of rams from two to four per 220 hoggets increased the number of hoggets mated and conceiving early in the mating period. The survey data of Stevens & McIntyre (1999) suggested a trend of lower hogget conception rates when mob size was larger. They also found that, as ewe hogget:ram ratio increased from around 50 to 200, conception rate declined from above 80% to below 40%. Smith & Knight (1998) suggested a ram to ewe hogget ratio of 1:50 or lower. Recent studies have suggested the optimal mature ram to ewe hogget ratio is likely to be slightly higher at approximately 1:75 (Kenyon *et al.* 2004b, 2010).

Ram lambs can be used with ewe lambs for breeding but, if used at the same ratios as mature rams, reproductive performance will be lower (Kenyon *et al.* 2007b). Therefore, if ram lambs are to be used, it is likely that ratios of 1:50 or less are required. Two-tooth ram performance has been shown not to differ from that of mature rams when bred with ewe hoggets at the same ratio (Kenyon *et al.* 2007b). It has also been shown that the performance of mature rams previously used earlier in the breeding season with mature ewes for one cycle does not differ from that of 'fresh' mature rams being used for the first time in that season (Kenyon *et al.* 2009). Ewe hoggets and mature ewes should not be bred in the same mob, as the mature ewes will dominate the ram's attention (Corner *et al.* 2013a,b) resulting in disappointing reproductive performance in the ewe hoggets.

The effect of hogget feeding during early- and mid-pregnancy

A series of UK indoor studies with ewe hoggets (Wallace *et al.* 1996, 1997a, 1997b, 2000, 2002ab, 2003, 2004, 2006b, 2019; Da Silva *et al.* 2003) using concentrate feeds reported that very high levels of nutrition, resulting in liveweight gains of at least 230g/day in pregnancy, can have negative impacts on pregnancy maintenance, foetal weight, birthweight, colostrum yield and lamb survival. Caution must be taken when trying to extrapolate this data to what might occur under pastoral grazing conditions. Indeed, Wallace *et al.* (2006a) stated that the data implied that it is the high-energy intakes are the primary cause of impaired placental development and adverse pregnancy outcomes in rapidly growing adolescents fed concentrate diets.

Under New Zealand's pastoral conditions, level of nutrition of the hogget during pregnancy has been shown to affect pregnancy loss rates, gestation length, lamb birthweight, ewe behaviour, lamb survival and liveweight at weaning (Morris *et al.* 2005; Corner *et al.* 2006a; Kenyon *et al.* 2008b; Mulvaney *et al.* 2008, 2010a, 2010b, 2012; Kenyon *et al.* 2014; Ridler *et al.* 2015, 2017; Griffiths *et al.* 2016). (Morris *et al.* 2005) reported liveweight gains of 145g/day and 210g/day throughout pregnancy compared to 80g/day resulted in higher lamb liveweights to 100 days of age. Kenyon *et al.* (2008b) reported that liveweight gains of 223g/day vs. 134g/day throughout pregnancy resulted in increased lamb and young dam liveweights to 68 days after the mid-point of lambing. However, a group which gained 237g/day from day 37 of pregnancy only, did not differ from those which gained at the high rate throughout pregnancy. The studies of Morris *et al.* (2005) and Kenyon *et al.* (2008b) reported no effect of liveweight gain on pregnancy loss in mid-to late-pregnancy or lamb survival. However, the study of Mulvaney *et al.* (2008) reported that hoggets that either maintained their liveweight to day 87 of pregnancy followed by a gain of 190g/day or gained 230g/day throughout the entire pregnancy period were more likely to lose pregnancies between day 50 and term, than those that gained at 130g/day throughout pregnancy. They also reported that lambs born to hoggets that were fed to maintain liveweight to day 87 of pregnancy followed by a gain of 190g/day, had the lowest survival and weaning liveweight. It has been suggested that the pregnancy losses in the study of Mulvaney *et al.* (2008) were confounded by Neospora caninum (West *et al.* 2006; Howe *et al.* 2008) infection; therefore those results need to be interpreted with caution. Mulvaney *et al.* (2010b) reported that liveweight gains of 151 to 158g/day compared to 194 to 216g/day throughout pregnancy did not affect pregnancy loss in mid– to late-pregnancy, lamb liveweight or survival to the end of the study. Combined, these studies indicate that liveweight gains in the region of 150 – 200g/day throughout pregnancy are likely to maximise the outcome for the young dam and her offspring, although the benefit of liveweight gains above 150g/day may not be cost effective.

Schreurs *et al.* (2010a) modelled the effect of hogget liveweight at breeding and at day 50 and 100 of pregnancy and at term on the performance of the hogget and her offspring to weaning. They reported that liveweight at breeding had the biggest impact on lamb birthweight and weaning weight and the weight of the dam at weaning. The impacts on lamb liveweight and weight of the dam at weaning, per kg of hogget liveweight in pregnancy, declined in the later stages of pregnancy. This indicates the importance of hogget breeding liveweight.

A survey by Stevens (2001) showed that liveweight gain (from breeding to 3-5 weeks pre-lambing) had a curvilinear relationship with lamb losses. Losses were reduced by approximately 3% per kg of hogget winter liveweight gain over the range of 4 to 10kg. The rate of lamb loss levelled off at liveweight gains of 10-12kg.

Abortive causes of pregnancy losses

Kenyon *et al.* (2004) reported that flocks vaccinated for toxoplasmosis and campylobacteriosis had higher lambing percentages. Although not reported in the literature, vaccination for salmonella could also reduce pregnancy losses on some farms. There has also been some evidence that *Neospora caninum* (West *et al.* 2006; Howe *et al.* 2008; Weston *et al.* 2009) causes reproductive loss in hoggets. However, even when abortive tissue and the young dam have been examined for the known causes of abortion, a significant number of pregnancy losses go unexplained in ewe hoggets.

Shearing in mid-pregnancy

Shearing mature ewes during pregnancy in New Zealand has been shown to enhance lamb liveweight at birth and at weaning and lamb survival (Kenyon *et al.* 2003, 2006c; Corner *et al.* 2006b, 2007ab, 2010). The response to shearing appears to be most consistent when ewes are shorn in the mid-pregnancy period (Kenyon *et al.* 2003). To help ensure ewes are not adversely affected by cool conditions post shearing, they should be shorn with the cover (Dabiri *et al.* 1995) or snow comb. Only one study in New Zealand has examined the effect of shearing ewe hoggets in pregnancy (Kenyon *et al.* 2006d). Shearing was found to increase the birthweight of single lambs, but not twins born to ewe hoggets. Mid-pregnancy shearing did not however influence lamb liveweight at weaning or survival to weaning.

Hogget lamb mortality

Traditionally, the mortality of lambs born to hoggets has been considered to be higher than those born to mature ewes (Kenyon and Corner-Thomas 2022). However, few studies have actually compared this. Morris *et al.* (2000) and Annett and Carson (2006) examined survival of lambs born to first parity two-tooths and observed it to be lower than that of lambs born to multiparous mature ewes. In a comparison study, Mulvaney (2011) bred and lambed mature ewes and ewe hoggets in one group and found no difference in single lamb survival, although they were lighter at birth and at weaning. The findings of Mulvaney *et al.* (2013) and Ridler *et al.* (2015, 2017), which do not directly compare the two groups, also suggest higher loss rates in lambs born to hoggets.

Across numerous studies, mortality rates of lambs born to hoggets have been reported to be in the range of 12 to 60% (McCall & Hight 1981; McMillan 1983; McMillan & Kitney 1983; Stevens & McIntyre 1999; Stevens 2001; Morris *et al.* 2005; Kenyon *et al.* 2008b; Mulvaney *et al.* 2008; Mulvaney *et al.* 2010b; Schreurs *et al.* 2010). These levels of losses tend to be greater than those reported for singles and twin lambs born to mature ewes (Hight & Jury 1970; Dalton *et al.* 1980; Knight *et al.* 1988; Thompson *et al.* 2004; Everett-Hincks & Dodds 2008; Morel *et al.* 2009).

McMillan (1983) reported that dystocia was the single largest cause of death to day 3 of age, in lambs born to hoggets, accounting for about 12 lambs per 100 lambs born, while starvation/exposure caused almost 3 deaths per 100 lambs born. Young *et al.* (2010) also reported that dystocia was the major death risk for lambs born to hoggets, although starvation/exposure was also a significant killer. Stevens (2001) reported farmer diagnoses of cause of death and stated that, for singles, 53% of deaths were due to dystocia and 10% due to starvation/exposure. In twins, the numbers were 12% for dystocia and 41% for starvation/exposure. Kenyon *et al.* (2004b), from a survey, reported that farmers indicated that 7% of their hoggets needed assistance during the lambing period and 4% needed to be mothered up to their lambs.

Ridler *et al.* (2022) reported that the greatest cause of death of lambs born to hoggets was due to still births, followed by starvation exposure, and then dystocia, with low birthweights and multiple litters being risk factors. Griffiths *et al.* (2016) reported low liveweight gains in pregnancy were also a risk factor. Ridler *et al.* (2022) also noted that ewe hogget deaths were a significant factor in total lamb deaths.

In mature ewes, the optimum birthweight range has been reported somewhere between 4.5 to 6.5kg (Hight & Jury 1970; Dalton *et al.* 1980; Knight *et al.* 1988; Thompson *et al.* 2004; Everett-Hincks & Dodds 2008; Morel *et al.* 2009). McMillan (1983) reported that birthweight of lambs born to hoggets was an important factor in lamb deaths, with an optimum range of 3.3-4.1kg. Birthweights of single lambs born to hoggets are known to be less than those born to mature ewes (Mulvaney 2011). Schreurs *et al.* (2010b) modelled the effect of lamb birthweight on the survival of lambs born to hoggets and their results suggested birthweight has a positive relationship with survival until at least 5.0kg.

Opinion is divided on whether a high level of shepherding and lambing assistance is required with ewe hoggets. Based on survey results, Stevens (2001a, 2001b) recommended intensive shepherding. Kenyon *et al.* (2004b), from a survey, reported no effect of frequency of supervision during lambing, although, they did report separating single and twin-bearing hoggets in lactation improved the lambing percentage. However, as indicated, Ridler *et al.* (2022) reported that ewe hogget death was a significant cause of overall lamb deaths, therefore some form of monitoring over the lambing period is warranted.

Level of feeding in lactation

There has been a lack of research examining the effect of feeding level in lactation on the performance of the hogget and her offspring, and more research is required. Kenyon *et al.* (2004b) found, in a survey, that separating single- and twin-bearing hoggets in lactation improved the lambing percentage, which might suggest an advantage of improved nutrition for the twin bearing/lactating ewe hogget. However pasture mass and/or height at set stocking had no influence on lambing percentage. In mature ewes, it has been reported that ewe intake is unrestricted when pasture covers/mass are above 1000 – 1200kgDM/ha and that under these conditions lamb performance to weaning is not restricted (Morris *et al.* 1993, 1994; Morris and Kenyon 2004). Therefore, it might be expected that the same pasture cover/mass minima be used for ewe hoggets. Studies have shown that both herb/clover mixes and pure swards of lucerne are viable options in lactation to improve the weaning weights of lambs born to hoggets and the weight of the hogget herself at weaning (Corner-Thomas *et al.* 2014b, 2018).

Timing of weaning

Pregnancy and lactation can impact on the liveweight of the ewe hogget which can affect two-tooth weight (Kenyon *et al.* 2008d). Negative effects of hogget breeding on two-tooth liveweight and subsequent breeding performance are major concerns for farmers (Kenyon *et al.* 2004a). Weaning lambs born to hoggets relatively early allows more time for the hogget to gain liveweight and potentially be heavier at two-tooth breeding. Weaning lambs born to mature ewes at 8 weeks of age has been reported to have no detrimental effects on lamb growth rates (Rattray *et al.* 1976; Smeaton *et al.* 1979;

Earl *et al.* 1990), while having positive effects on ewe liveweight (Corbett & Furnival 1976; Smeaton *et al.* 1979). Mulvaney *et al.* (2009) reported that weaning at 10 weeks of age had no impact on lamb growth post weaning and a small positive effect on liveweight gain of the hogget. However, Mulvaney *et al.* (2011) reported weaning at 9, 11 or 13 weeks had no impact on the weight of the hogget or her lambs. If lambs are to be weaned early, they need to be weaned onto high quality legume-based swards that do not limit intake.

Longer-term impacts of hogget breeding

Effect of hogget lambing on subsequent production

An often-stated concern of breeding ewe hoggets is that it will have negative effects on the young ewes' future liveweight and reproductive performance (Kenyon *et al.* 2014b, Kenyon and Corner-Thomas 2022). Studies have shown that breeding ewe hoggets can slightly reduce two-tooth ewe breeding liveweight (Keane 1974, Tyrrell 1976; Baker *et al.* 1981, McMillan & McDonald 1983; Kenyon *et al.* 2008d). However, any effect on liveweight has either had only a minor negative effect (Kenyon *et al.* 2008d), no effect (Suiter & Croker, 1970; Moore *et al.* 1983; Akcapinar *et al.* 2005) or even a positive effect (McCall & Hight 1981; Craig 1982; McMillan & McDonald 1983; Moore & Miller 1983) on two-tooth reproductive performance and the survival of their lambs. It is also important to note that any reduction in liveweight, as a two-tooth has been generally found to disappear by the weaning of their second set of lambs (Kenyon *et al.* 2014b), although in one study it was not until weaning of their third set (Thomson *et al.* 2021).

Hogget fleece weight can be reduced by hogget lambing, although there is no flow on effect on the next year's production (Tyrrell 1976; Baker *et al.* 1981; McCall & Hight 1981).

Kenyon *et al.* (2011) reported there were no effects of ewe hogget breeding on breeding performance or number of foetuses per ewe presented for breeding in ewes aged 3 to 5 years of age. When the number of foetuses per ewe at two-tooth breeding was combined with years 3 to 5, there was still no effect of hogget breeding on ewe reproductive performance post hogget breeding (Kenyon *et al.* 2008d). This result complements previous work which showed that ewe pregnancy rates and number of lambs born per ewe as they aged from 2 to 6years did not differ (Cannon & Bath 1969; Baker *et al.* 1978; Ponzoni *et al.* 1979; Morel *et al.* 2010). Flay *et al.* (2021) reported that there was no influence of pregnancy, or successfully rearing a lamb, on the risk of a hogget being culled or being identified as dead or missing. They did, however, find that higher body condition at hogget and two-tooth breeding was associated with reduced ewe wastage in that production year. Thomson *et al.* (2021) found that hogget losses during the lambing period resulted in fewer ewes in later years, in comparison to those bred for the first time as two-tooths.

When hogget performance was added to lifetime data, reproductive performance from 8 months to 5 years of age was found to increase (Kenyon *et al.* 2011; Thomson *et al.* 2021). This indicates that the relative success of hogget breeding on lifetime performance is very much dependent on the performance achieved as a hogget. Although no data was given in the survey, Stevens (2001) stated that lifetime performance was generally better in ewes mated as hoggets than those that were not mated. Hogget breeding has been reported to have no effect on apparent ewe wastage (Ponzoni *et al.* 1979; Baker *et al.* 1981; Kenyon *et al.* 2011).

Although it is well established that heavier breeding liveweights have a positive influence on hogget reproductive performance, few studies have examined if liveweight as a hogget affects lifetime success. Haslin *et al.* (2022b) reported that heavier weights at hogget breeding had no influence on reproductive performance as a two-tooth or three-year-old ewe. Although, over three years, heavier hoggets at breeding weaned more lambs, due to the influence on their first year's performance (Haslin *et al.* 2021b). In contrast, the efficiency of heavier hoggets (kg lamb weaned per kg of ewe hogget put to the ram) did not differ (Haslin *et al.* 2021, 2022a).

Can hogget breeding be used to accelerate genetic gain?

Hogget breeding and lambing offers an additional means of accelerating genetic gain. This can occur by reducing the generation interval (Schick, 2001). Further potential gains could be made by using a ram hogget with the ewe hoggets. Terrill (1982) calculated the increase in the reproductive rate of sheep averaged 0.5% per annum from 1940 to 1981. Terrill (1982) suggested progress of 2-5% per annum was possible by adopting a number of procedures, including mating of ewe hoggets. Although farmers acknowledge hogget breeding can increase genetic gain very few actually keep replacements born to ewe hoggets (Kenyon *et al.* 2004b).

How does achieving puberty as a hogget affect potential future performance?

A number of studies have shown there is a positive relationship between achieving puberty or the incidence of oestrus (heat) as a hogget and future reproductive performance and lamb production, irrespective of whether ewes were bred as a hoggets or not. Two-tooth fertility of Romney ewes is known to be genetically correlated with hogget oestrus (Ch'ang & Rae 1972), which itself is under genetic control (Ch'ang & Rae 1970). In their review, McMillan & Moore (1983) distinguish between "passively" and "actively" capitalising on hogget oestrus (heat) activity. They suggested farmers can capitalise on hogget oestrous activity "passively" by using hogget oestrus (heat) as an early index of subsequent lamb production, or "actively" by breeding hoggets at 8 – 9 months of age. Wall *et al.* (2018) found greater ewe lifetime economic performance in ewes bred for the first time as two-tooths, but that had achieved puberty as a hogget, compared to those which had not. This supports the notion of selecting replacements from those ewes that achieved puberty as a hogget in systems where hoggets are not bred. It has been found that there are effects of hogget oestrus on two-tooth reproduction over and above any liveweight effect, although, the effect tends to diminish as the ewe gets older (Hulet *et al.* 1969; Hight & Jury 1976; Moore *et al.* 1978; Moore & Hockey, 1982; Moore & Smeaton 1980). Thus, hoggets which display hogget oestrus (heat) produce more lambs as an adult ewe because (i) they are heavier, and (ii) because they have more lambs at a given liveweight. In addition, the daughters of these ewes which display oestrus as a hogget may have a higher genetic potential for lamb production. Hogget oestrus also appears to influence subsequent two-tooth milk production, but this is likely a reflection of the hogget liveweight advantage (Knight *et al.* 1995).

Should hoggets that fail to breed be culled?

Baker *et al.* (1981) found that ewes that did not lamb as a hogget tended to wean fewer lambs as a two-tooth. Similarly, Moore *et al.* (1983) reported that ewes that did not become pregnant as a hogget were less likely to get pregnant and wean a lamb as a two-tooth.

Kenyon *et al.* (2011) reported that the lifetime performance of ewes which failed to breed as a hogget did not differ from those which were not presented for breeding as a hogget. Baker *et al.* (1978) reported no difference in reproductive performance between ewes that did not lamb as a hogget and those that successfully lambed. Kenyon *et al.* (2011) however, reported that those that did lamb as a hogget had greater lifetime (8 months to 5 years) performance than those which failed to breed as a hogget. In support of this, Fogarty *et al.* (2007) reported that ewes which successfully reared a lamb as a hogget subsequently reared more lambs to weaning in their second and third lambings than those that did not. Baker *et al.* (1981) reported that ewes that did not lamb as a hogget weaned fewer lambs during their next three years than those that did lamb as a hogget. Combined, these studies indicate that another potential advantage of hogget breeding is that those that fail to breed at 8-9 months, but are of suitable liveweight, are likely to be less productive in future years (Kenyon *et al.* 2008d) and may not be suitable replacements.

Potential intergenerational effects of hogget breeding

Craig (1982) examined the records of 27,181 ewe hoggets that were mated from 1973 to 1980 in the Waihora Group Breeding Scheme concluded that the progeny of hoggets were severely handicapped and suggested they were less suitable to be retained in the breeding flock. Loureiro *et al.* (2010) reported that foetuses from ewe hoggets tended to be lighter than those from mature ewes. In support of this, Mulvaney (2011) reported offspring born to ewe hoggets were lighter at birth and to weaning than those born to mature ewes. Further, Loureiro *et al.* (2011) reported that offspring born to ewe hoggets were lighter to at least one year of age. However, reproductive performance at 18 months did not differ (Loureiro *et al.* 2010, Loureiro *et al.* 2012) from those born to mature ewes. In addition, their lactational performance did not differ. There was also no difference in any productive parameters at three years of age and, over their lifetime, there was no difference in total weight of lambs weaned (Pettigrew *et al.* 2019). There is sparse New Zealand data on lifetime effects of being born to a hogget compared to a mature ewe, when both classes of ewe have been bred together with the same rams.

Kenyon *et al.* (2008e) examined the performance of offspring born to traditional first-lambing two-tooths or second-lambing two-tooths (i.e. those that had been bred successfully as a hogget). They reported no difference in liveweight or reproductive performance of the progeny to two years of age. Pettigrew *et al.* (2021b) recently examined performance of single and twin ewes born to hoggets, compared to twins born to mature ewes. Single and twins born to hoggets remained lighter than twins born to mature ewes although, for those that reached target breeding weights as a hogget, there was no difference in reproductive performance. Two–tooth performance did not differ between the groups. Fewer twins born to hoggets met the minimum pre-breeding target weight, therefore, their overall performance was the lowest. Combined, these results indicate that, if progeny born to hoggets are heavy enough when bred at eight months of age, their reproductive performance does not differ from those born to mature ewes. However, lifetime data is needed to confirm this.

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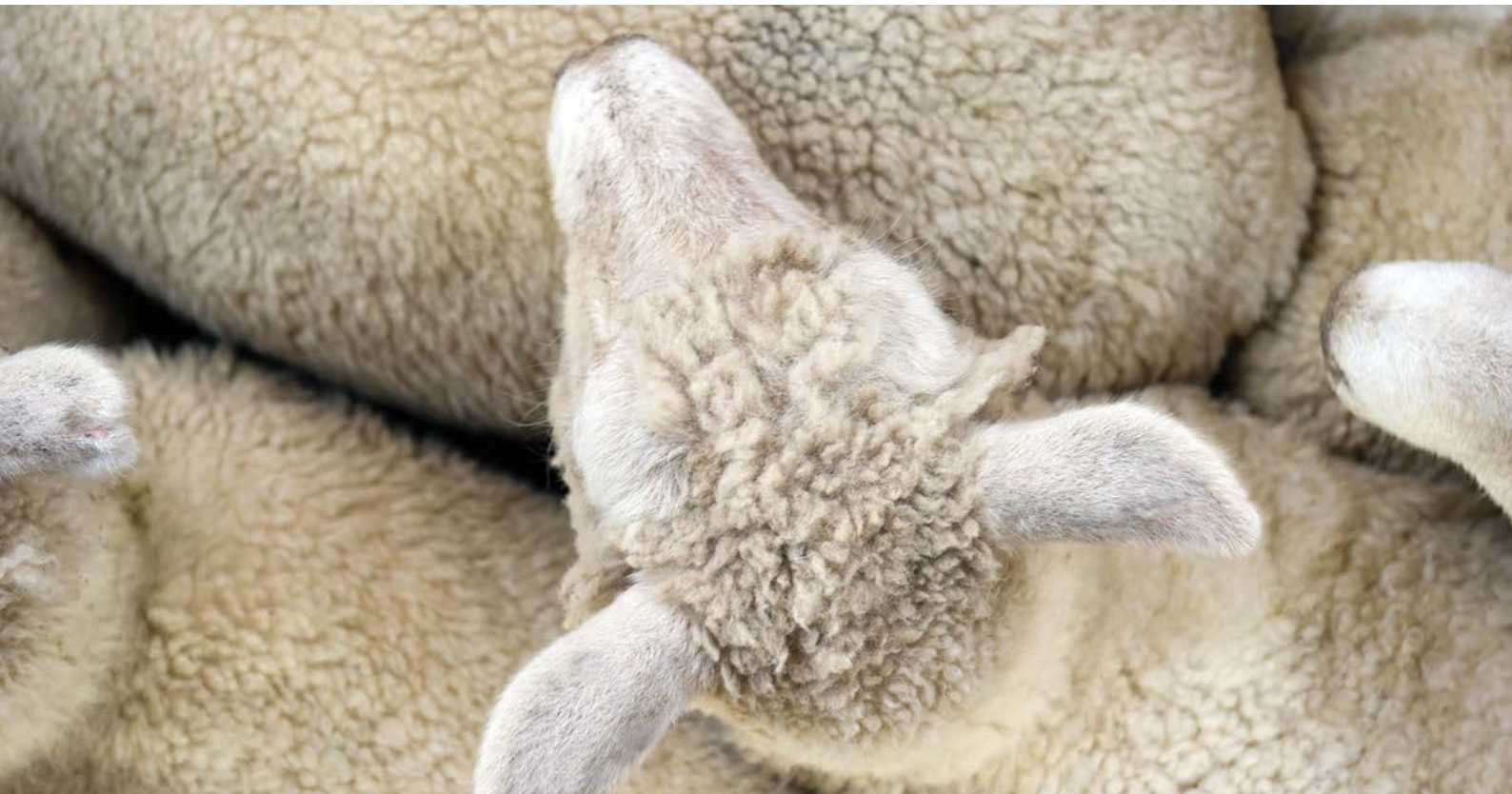

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