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Survival of twin lambs is increased with shrub belts

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Abstract. Perinatal lamb mortality is a major source of reproductive loss, particularly for twins. A study was conducted to determine whether provision of shelter in the form of shrub belts (a 'maternity ward') could increase survival of twin lambs compared with hedgerows, and whether hedgerows improve survival of single lambs compared with unsheltered paddocks. Measurements were recorded for Merino × Poll Dorset cross twin lambs born in hedgerows (phalaris or hessian) or shrub belts and single lambs born in hedgerows or unsheltered paddocks over the years 2007–2009. Records for 382 single and 726 twin lambs were used. The survival of single lambs was not increased ($P = 0.06$) by hedgerow shelter. The survival of twin lambs in shrubs was 10% higher ($P < 0.05$) than that in hessian hedgerow shelter in 2008–2009 (0.77 cf. 0.70), associated with a reduction in deaths from starvation and/or mismothering and/or exposure. The hessian shelter was associated with an increased ($P < 0.05$) growth rate to weaning of single lambs, but the growth rates of twin lambs were lower ($P < 0.05$) in shrub than in hessian shelter. In 2010, a second study of 178 twin Merino × Poll Dorset cross lambs found that survival of lambs born alive was not improved by shrubs compared with unsheltered paddocks (0.80 *versus* 0.77; $P > 0.05$). It is concluded that shrub belts which forced twin-bearing ewes to lamb in a sheltered environment reduced perinatal mortality in one of three datasets, but was not repeated. The shrubs take time to establish, and the benefit will be small if weather is mild during lambing.

Additional keywords: lamb survival, reproduction.

Introduction

Perinatal lamb mortality is a major source of reproductive wastage, with an average of 20% of lambs born dying under Australian conditions (Plant *et al*. 1976; Haughey 1981). This represents a large economic loss and may be perceived as a significant animal welfare issue. It also reduces selection pressure and the rate of genetic improvement. Given that the mortality of twin-born lambs can be 1.5–3 times that of single-born lambs (Kelly 1992), the economic incentive to increase reproductive rates by increasing the number of twins born is likely to also increase the rate of lamb mortality unless intervening management is effective. There is, therefore, a need for improved management systems for lambing ewes.

Most deaths occur within 3 days of birth (Dennis 1974), and the starvation and/or mismothering and/or exposure (SME) complex and dystocia (difficult parturition) are usually the main causes of lamb deaths (Haughey 1981). These main causes can be associated because lambs that survive a difficult birth are at increased risk of dying from SME. The evidence suggests that lambs experiencing difficult births will be more susceptible to exposure (Alexander *et al*. 1980; Haughey 1980) and this can be attributed, at least partially, to their slower progress to stand and suck (Dwyer 2008). While single-born lambs are at increased risk of dystocia due to their larger size, multiple-born lambs are more likely to die from SME, due to lower birthweights and an increased complexity of behavioural interactions between siblings and the ewe (Hight and Jury 1970; Stevens *et al*. 1982). With twin-born lambs, the difference in weight between siblings has a larger effect on survival to weaning than has each individual's birthweight (Schreurs *et al*. 2010). Providing a more favourable environment is therefore a means of improving survival, particularly of multiple-born lambs.

Lambs are at risk from hypothermia and death when heat loss exceeds metabolic heat production. Heat loss is increased by low temperatures when the skin is wet – either through rainfall or with amniotic fluids following birth, and by wind (Alexander 1974). Maximum heat production can be maintained only for several hours, and is ~1100 $kJ/m^2.h$ (Alexander 1962). By reducing wind speed, shelter has the capacity to reduce the wind chill, the temperature equivalent in still air, and therefore heat loss from lambs. Lambs are most susceptible to adverse weather during the first 24 h after birth, and reducing wind speed to 8 km/h or less in the first 6 h after birth has been shown to reduce the mortality rate of lambs up to 72 h after birth from 33.9% to 5.4% in Merino and 29.7% to 13.3% in Corriedale lambs (Obst and Ellis 1977).

In adverse weather conditions, the mortality rate can be as high as 90% of lambs born (Obst and Day 1968). Merinos are

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more susceptible than other breeds (Sykes *et al*. 1976) and new-born lambs are most susceptible (Alexander 1964). Provision of shelter has reduced mortality rates by up to 50% (McLaughlin *et al*. 1970; Egan *et al*. 1972, 1976; Lynch and Alexander 1976; Alexander *et al*. 1980). It is more effective in twins than singles and in windy than in cold or wet weather (Pollard 2006). However, in more severe weather, the benefit to twins may be reduced (Watson *et al*. 1968; Alexander *et al*. 1980; Nowak 1996).

Shearing during pregnancy has the potential to increase lamb survival by increasing lamb birthweight. However, Kenyon *et al*. (2003) concluded that a benefit is likely to result only if lamb birthweights without shearing are suboptimal, and the ewe has the body condition or adequate feed to respond. Shearing during late pregnancy may also affect the behaviour of ewes during lambing, potentially influencing lamb survival. Ewes do not necessarily seek shelter at the time of parturition (Alexander *et al*. 1979; Stevens *et al*. 1981) and while shearing within 4 weeks of lambing may increase the use of shelter by ewes (Lynch and Alexander 1980), it may increase the mortality of lambs if cold and wet weather occurs (Alexander *et al*. 1980), by causing ewes to desert lambs to seek shelter (Obst and Ellis 1977). Shearing close to lambing also increases the risk of metabolic disease such as pregnancy toxaemia (Miller 1991) and is unlikely to suit the management schedules of many producers. Whether ewes are shorn pre-lambing or not, to be most effective, shelter needs to be designed so that ewes have no choice but to lamb in a sheltered position.

Cypress hedges (Egan *et al*. 1972), trees (Obst and Day 1968; Obst and Ellis 1977), grass hedgerows (Egan *et al*. 1976; Lynch and Alexander 1976; Alexander *et al*. 1979, 1980) and a range of artificial shelters have been tested (Pollard 2006). A survey in Western Australia (Elliott *et al*. 2011) showed that producers are aware that shelter in the form of existing bushland or standing crop can potentially increase lamb survival, and are receptive to new strategies providing they have relevance to commercial conditions. To be relevant for extensive systems, the design needs to minimise labour requirements and disturbance to lambing ewes. The lambing paddock should also have ample pasture and proximity to water to maximise the time spent by the ewe at the birth-site and to facilitate ewe-lamb bonding (Nowak 1996).

The optimal design for shelter in extensive lambing systems has not been established. In particular, to our knowledge, shrubs have not been used in a design to shelter the whole paddock where the ewes range freely – a 'maternity ward'. The aim of the present experiment was to evaluate whether the use of shrubs would provide superior protection to hedgerows of phalaris and increase survival of twin lambs, and whether hedgerow shelter would increase survival of single lambs, compared with an unsheltered paddock. A second experiment evaluated whether survival of twins was increased by shrubs compared with an unsheltered paddock.

Materials and methods

Two experiments were conducted with the approval of the Charles Sturt University Animal Ethics committee (project approvals 05/085; 07/150, 09/011 and 10/063). Experiment 1 was conducted on a property near Tarcutta, south-east of Wagga Wagga, NSW (35°12′S, 147°31′E), between 2007 and 2009, and Experiment 2 was conducted in 2010.

Experiment 1

The experiment was a randomised factorial experiment, with three replicates of the following four treatments: single-bearing ewes in an unsheltered paddock; single-bearing ewes with phalaris (2007) or hessian (2008–2009) shelter; twin-bearing ewes with phalaris (2007) or hessian (2008–2009) shelter; and twin-bearing ewes with *Acacia* spp. shrub belts. The phalaris was replaced with hessian because drought conditions meant that the phalaris did not regenerate and would not have provided adequate shelter. The grazing area, excluding the shelter itself, was adjusted for a 30% higher energy requirement at term in pregnant ewes with twin than with single fetuses (SCA 1990) so that paddock sizes for ewes bearing single or twin lambs were 1 and 1.3 ha, respectively. The same number of single- or twin-bearing ewes was placed on each plot: 19 or 20 in 2007, and 23 and 20 in 2008 and 2009, respectively. The number of ewes differed among plots in 2007 due to uneven numbers being available; all plots had 20 ewes except Replicates 1 and 3 of twins in shrubs and Replicate 1 of twins in hedgerows.

A flock of 400 medium to large-framed (55 kg fleece-free liveweight) 3–9-year-old Merino ewes of Centre Plus bloodline was used. In 2009, ewes with constitutional faults were culled and replaced with 242 3–5-year-old ewes of Bundilla bloodline, such that the flock then comprised 435 ewes. The ewes were mated in February 2007 and 2008 and March 2009. In 2007, oestrous cycles were synchronised using an intravaginal controlled internal release device (EAZI-BREED CIDR; 0.3 g progesterone, Pharmacia and UpJohn Pty Ltd, Rydalmere, NSW, Australia) inserted for 12 days; in 2008, one injection of 1 mL prostaglandin (Estrumate, 250 mg/mL cloprostenol, Schering-Plough Animal Health, Baulkham Hills, NSW, Australia) was used because the ewes had recently been synchronised in a separate experiment; in 2009, oestrous cycles were synchronised using two injections of prostaglandin. At the time of CIDR removal or prostaglandin injections, ewes were also injected with 500 IU (in 2007) or 400 IU (in 2008) pregnant mare serum gonadotrophin [Pregnecol, Bioniche Animal Health (A/Asia) Pty Ltd, Armidale, NSW, Australia], except in 2009 when ewes were fed 500 g/day lupin grain for 7 days prior. Composite (based on Poll Dorset × White Suffolk) rams were introduced on the day of CIDR removal or prostaglandin injection, and remained with ewes for 30 days. The number of rams joined was 23 (5.8%), 17 (4.1%) and 20 (4.6%) in 2007–2009, respectively. A commercial operator used ultrasound to determine fetal number and age at ~45 days after ram removal.

The ewes were shorn 5–9 weeks before lambing commenced in each year. Prior to lambing, single- and twin-bearing ewes were randomly allocated to treatment groups according to bloodline, body condition, liveweight and fetal age. The ewes were side-branded with their unique number, weighed, condition-scored and placed in plots (2 July, 20 June, 31 July in 2007–2009, respectively) within 1 week before lambing. They remained in the paddocks for 41–46 days after the first birth, after which they were weighed and grazed as one flock. The ewes were weighed and condition scored, without fasting, at approximately monthly intervals using a scale of 0 (emaciated) to 5 (obese) (Jefferies 1961). They were supplementary-fed when necessary to target a body condition score of 3 at joining and lambing. When necessary, ewes in low condition were separated after weaning and fed a higher rate to regain condition. In 2008, the ewes were supplementary-fed oat grain at a rate of 1 kg/ewe per day in the last 2 weeks before lamb marking, due to the low quantity of pasture. The condition of ewes when placed on plots differed ($P < 0.05$) among years, but was moderate in all years at 2.9, 2.8 and 2.7 in 2007–2009, respectively, although twin-bearing ewes were 0.1 condition score leaner ($P < 0.05$) than single-bearing ewes. The mean liveweight of ewes differed among years ($P < 0.05$) and was 68, 65 and 72 kg in 2007–2009, respectively, with twin-bearing ewes 3–4 kg heavier ($P < 0.05$) than single-bearing ewes.

During lambing, the ewes were inspected daily. Ewes were assisted to deliver lambs only when obviously in difficulty. In all years, lambs were identified to ewes at birth to confirm single or twin birth type, tagged, and birthweight was recorded. Dead lambs were recorded and underwent a post-mortem examination (McFarlane 1965) to attribute cause of death, with lambs that had not breathed fully being classified as 'born dead'. Lambs were again weighed at marking, approximately 4 weeks after the start of lambing, and at weaning 14–16 weeks after the start of lambing.

Experiment 2

An experiment was conducted at the same site in 2010. The experiment was of a randomised block design, with three replicates of the following two treatments: twin-bearing ewes in unsheltered paddocks, and twin-bearing ewes in shrub belts.

A flock of 200 ewes was naturally mated to six Composite (based on Poll Dorset × White Suffolk) rams for 28 days from 29 January 2010. Ultrasound was used to determine fetal number and age at 56 days after ram removal. Prior to lambing, 103 twin-bearing and eight triplet-bearing ewes were randomly allocated to treatment groups according to body condition, liveweight and fetal age. The ewes were side-branded, weighed and placed in plots on 23 June, within 1 week of lambing. Measurements during lambing were similar to those in 2007–2009 in Experiment 1. The ewes remained in the paddocks until the end of lambing, then were weighed at lamb marking on 4 August and grazed as one flock until weaning on 24 September, 13 weeks after the start of lambing. The lambs were weighed at marking and weaning. Due to the low quantities of pasture, ewes were fed lupin grain every second day at 0.5 kg/ewe per day from 26 June, and 1.0 kg/ewe per day from 8 July, until removed from the lambing paddocks.

Shelter design

All shelters were placed perpendicular to the expected prevailing winds (SW), as well as along the northern, western and southern sides of all sheltered paddocks. Shrubs were planted in an E-shaped design in relevant paddocks, with shrub belts 10 m wide and located 50 m apart and fenced to prevent grazing, with a single 3-m-wide access walkway through the central shrub belt

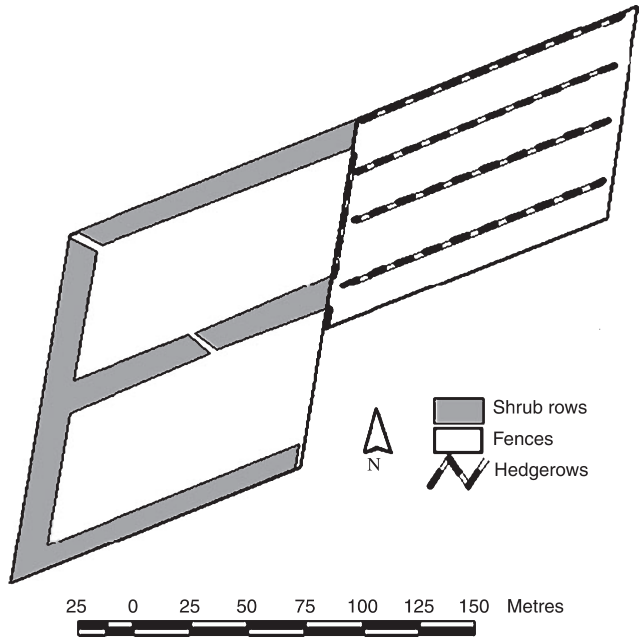

Fig. 1. Layout of shrub belt and hedgerow shelter.

(Fig. 1). The distance between shelter rows was based on 20 times the height of the shelter, using a predicted shrub height at maturity of 2.5 m. The shrubs were planted in 2005, with some replanting in 2006 and 2007 to replace dead plants. In each belt, three rows of shrubs were planted, with the central row being taller-growing species (*A. ideophila*, *A. salacina*, *A.saligna*) and the two outer rows being shorter species (*A. bucksifolia*, *A. cultiformis*, *A. decora*, *A. ideophila*).

Phalaris hedgerows were 1 m wide and 20 m apart (Fig. 1) and were achieved by allowing rank growth of an established pasture and then slashing to leave rows in 2006, which carried through to 2007. Drought conditions meant that the phalaris plants did not produce seed-heads in spring 2007, and, if retained, would not have provided shelter in 2008. Hessian rows were erected for 2008 and 2009 instead, strung on plain wires 1 m high held by fence posts. The internal hessian rows had 2–3-m gaps placed every 25–30 m, with a 6-m gap at the eastern end of each row to facilitate sheep movement. Both phalaris hedgerows and hessian rows are referred to as hedgerows in the present paper for brevity.

Pasture and shrub measurements

Pasture composition was estimated using the Botanal method (Mannetje and Haydock 1963) and biomass was visually estimated (Campbell and Arnold 1973) in 60 quadrats per plot when ewes entered and were removed from lambing paddocks. Calibration quadrats were cut at ground level with an electric handpiece. The quantity of dead pasture was not estimated in 2007 and 2009 when the quantity of live pasture was large, because it was matted beneath the live material and could not be accurately assessed. Samples for herbage quality were taken using the 'toe-cut' method (Cayley and Bird 1996) when ewes entered plots in 2007 and 2008, and when ewes were removed from plots in 2008 only. Quality samples were sent for testing, using near-infrared spectroscopy (NIR) (FEEDTEST, Department of Primary Industries, Hamilton, Victoria) for crude protein (CP), neutral detergent fibre (NDF), dry matter digestibility (DMD) and digestibility of organic matter (DOMD). Metabolisable energy (ME) was calculated.

For the phalaris hedgerows in 2007, 30 quadrats (1 m^2) per paddock were randomly selected and the average height per quadrat of both the seed head and vegetative growth was measured. The height of the heads in phalaris hedgerows was 73 cm. The height to the top of clumps, the top of the vegetative leaf, was 29 cm.

The height of the shrubs was measured in five quadrats of shrubs per paddock, each 10 m^2, in each year around the time of lambing. The height of shrubs was 60, 127, 151 and 208 cm in 2007–2010, respectively.

Weather

Due to technical failure of a weather station located on the experimental site, data was used from a weather station (Vantage Pro2, Davis Instruments, Hayward, CA, USA) located 4 km east of the trial area, 1.5 m above ground level, which recorded temperature, wind speed and direction, rainfall and wind chill. During the lambing period, the station logged readings hourly. In addition, in 2007, 2008 and 2010, wind speed and temperature loggers (Tiny Tags, Hastings Data Loggers, Port Macquarie, NSW, Australia) were placed 30 cm above the ground level in each of the paddocks for the lambing period, recording measurements every 10 min. In the shelter treatments, they were placed an equal distance from two shelter rows, or in the centre of unsheltered paddocks. In 2009, the loggers were placed only in Replicate 1 because they were being used in a separate study. In addition to the hourly wind chill, which was calculated by the weather station using the formula of Osczevski (1995), which shows the temperature equivalent without wind (°C), a daily chill index showing heat loss (kj/m^2.h) was calculated for both the weather station and the plot logger readings using the formula of Donnelly *et al*. (1997). Data from the day the first lamb was born until lamb marking were used in the analyses.

Relatively mild weather conditions were experienced during lambing in all years (Fig. 2), in comparison to long-term weather data for Tarcutta (1943–2006) (from GrassGro, Donnelly *et al*. 1997), the nearest meteorological station (Table 1). From measurements 1.5 m above the ground level, the chill index was above 1000 kj/m^2.h on 10–15 days (22–37% of days) during the lambing period in 2007–2010, well below the long-term average for these periods. Only 2 or 3 days of rainfall of 5 mm or more occurred in 2007–2009, but 7 days (21% of days) of rainfall occurred in 2010. The number of days with minimum temperatures below 0°C was higher in 2007 than in later years, but mean maximum daily temperatures were similar to the long-term average. Maximum daily wind speeds were above 8 km/h on 24–30 days (59–68% of days) in all years except 2010, when it occurred only on 14 days (40% of days). The wind came from the south-west to north-west quadrat 40% of the time. The other dominant wind direction was from the north-east to east (26%, range 20– 29%). However, the direction of highest daily wind speed was highly variable, most commonly (10–15% of days) coming from the west, west-south-west, or the north.

Statistical analyses

Experiment 1

Data were analysed using GENSTAT, 12th edition (Payne *et al*. 2009). For 2007–2009, records from 743 ewes and 1108 lambs were used. Data from ewes and lambs with the incorrect birth class (scanning error) were excluded. Lambs tagged at birth but not present at marking were assumed to have died, and were categorised in the 'unknown' cause of death class. The effect of shelter on survival and cause of death data were analysed with binomial generalised linear mixed modelling using contrasts, with year and contrasts and their interaction as the fixed effect and replicate as the random effect. Lamb tag was used as the random effect to analyse cause of death in 2008 and 2009. Interactions were removed from the model when not significant. The contrast between single- and twin-born lambs in hessian shelter was analysed separately, as the degrees of freedom allowed only three contrasts to be fitted in the model. Survival data were analysed for both time periods 2007–2009 and 2008–2009 separately, because after 2007, hessian replaced the phalaris hedgerows and the shrubs had reached an established height. The effect of weather on lamb survival was analysed using weather condition by treatment as the fixed and replicate as the random effect, by using weather data from the unsheltered plot. Ewe liveweight and body condition, lamb weights and growth rates were analysed using residual maximum likelihood (REML). Weather data within plots at 30-cm height for 2007 and 2008 were analysed using REML, with treatment × year as the fixed effect and year, replicate and day of lambing as the random effect. For REML analyses, differences among the means were compared using twice the standard error of differences. Pasture quantity, composition and quality data were analysed by ANOVA. The quantity of pasture was transformed by square root when appropriate before analysis.

Experiment 2

Data from 114 ewes and 178 twin-born lambs were used. Methods similar to those in Experiment 1 were used, except contrasts were not used to examine survival data. Treatment was used as the fixed effect and replicate as the random effect.

Results

Experiment 1

Lamb survival

The survival of twin lambs was lower ($P < 0.05$) than that of singles for lambs born alive in the same shelter type (hedgerows) in both 2007–2009 and 2008–2009. The survival of twin lambs born alive was higher ($P < 0.05$) in shrubs (80%) than with hedgerows (75%) in 2008–2009, if the contrasts single unsheltered versus twin shrub and single unsheltered versus single hedgerow were already fitted in the model (Table 2). The survival of single lambs was not improved ($P = 0.06$) by shelter in either set of years, although there tended to be a trend for the survival of lambs born alive to be increased in 2008–2009 (Table 2).

Of total births, the survival of twins was similar ($P > 0.05$) to that of single lambs when born in the same shelter type for 2007–2009, but was lower ($P < 0.05$) for 2008–2009. Of total

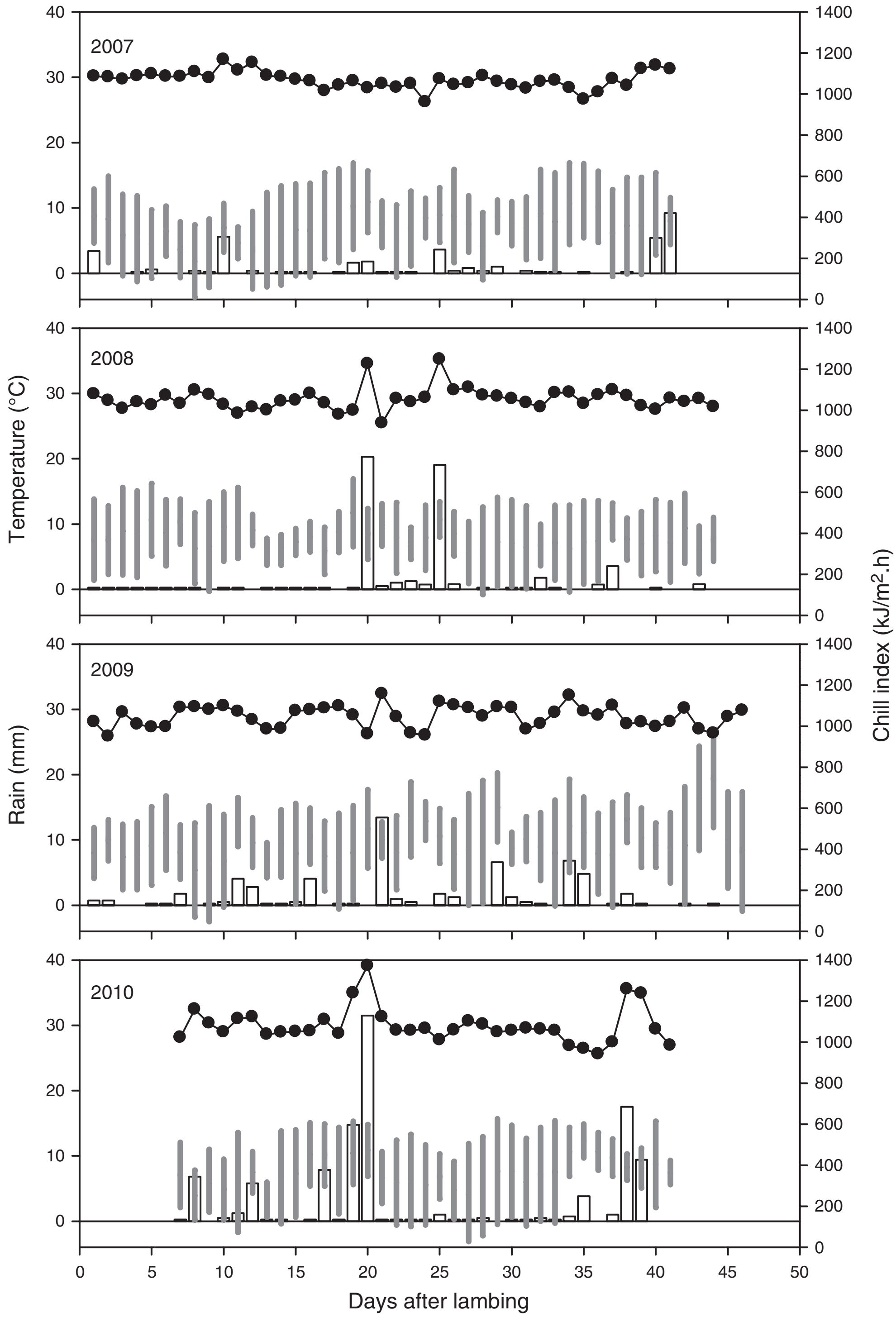

Fig. 2. Mean daily chill index (kj/m^2.h) (circles), maximum and minimum temperature (°C) (vertical bars) and rainfall (mm) (columns) recorded at 1.5 m above ground level during the lambing periods in 2007–2010.

births, the survival of twins born in shrubs (77%) was higher ($P < 0.05$) than that of twins born in hedgerows (70%) for 2008–2009, but for other comparisons survival was higher only if contrasts single unsheltered versus twin shrub and single unsheltered versus single hedgerow were already fitted in the model. The survival of single lambs was not increased ($P > 0.05$) by shelter.

For 2007–2009, the proportion of lambs born alive that survived was reduced ($P < 0.05$) by 7% when winds of 8 km/h or more occurred within the first 3 days of birth (Table 3). There

Table 1. Percentage of days with adverse weather in 2007–2010, compared with the long-term average (in parentheses) for Tarcutta (1943–2006)

Parameter	2007	2008	2009	2010
Month of lambing	July	July	August	July
Days chill index >1000 kj/m^2.h (%)	35 (48)	25 (48)	28 (39)	23 (48)
Days rainfall >5 mm (%)	5 (15)	6 (15)	6 (15)	23 (15)
Days minimum temperature <0°C (%)	40 (29)	8 (29)	13 (16)	32 (29)
Mean maximum temperature (°C)	12.7 (12.9)	12.7 (12.9)	14.5 (14.8)	12.6 (12.9)

was no ($P > 0.05$) interaction between the degree of wind and the treatment group. Rain of 5 mm or more or a chill index of 1000 kj/m^2.h or more within 3 days of birth did not reduce ($P > 0.05$) survival of lambs compared with drier days or days with a lower chill index (Table 3), and there was no interaction ($P > 0.05$) with treatment.

The main causes of lamb death were SME and dystocia, comprising 43% and 35% of dead lambs, respectively. The proportion of SME deaths of lambs born alive for twins was twice (2007–2009) or three times (2008–2009) ($P < 0.05$) that for single lambs born in the same shelter type (hedgerows). For live births, shrubs reduced ($P < 0.05$) the SME deaths of twin-born lambs compared with hedgerow shelter in 2007–2009 from 16% to 14% (Table 2) only if the contrasts single unsheltered versus twin shrub and single unsheltered versus single hedgerow were already fitted in the model. For live births, the provision of shrubs did not reduce ($P < 0.05$) SME deaths of twins to levels similar to those of non-sheltered singles. Hessian shelter reduced ($P < 0.05$) SME deaths of single lambs born alive compared with unsheltered paddocks in 2008–2009 from 8% to 6% of deaths. The proportion of lamb deaths that were attributed to SME was similar among years ($P > 0.05$).

Deaths from dystocia, as a proportion of total births, were higher ($P < 0.05$) in 2007 than in 2008 or 2009. They were higher ($P < 0.05$) in singles than in twins such that under the same type of shelter, deaths in singles were 21%, 12%, and 8% and for twins 8%, 6% and 8% of lambs born in 2007–2009, respectively. Shelter did not influence ($P > 0.05$) the level of dystocia (Table 2). As a proportion of dead lambs, the level of dystocia was similar ($P > 0.05$) among years but was higher ($P < 0.05$) in singles (55%) than in twins (25%). The proportion of deaths attributed to dystocia was reduced ($P < 0.05$) in the 2007–2009 dataset for sheltered compared with unsheltered single lambs due to differences ($P < 0.05$) in the proportion dying from SME. Shrub shelter reduced ($P < 0.05$) the proportion of deaths from dystocia in twins in both sets of years, but only when other contrasts were fitted in the model first.

Age of lamb at death

Most lambs that died (83%) did so within 3 days of birth. The majority (95%) of the dystocia deaths occurred on the day of birth, while most (89%) deaths from SME occurred during the first 4 days. All deaths from primary predation (3% of all deaths) also occurred during the first 5 days after birth. Of the deaths from other causes, 41% occurred after 5 days of age and up to marking with the majority (80%) of these later deaths due to infection (4% of all deaths).

Lamb weights

The mean birthweight of lambs differed ($P < 0.05$) among years and was 6.0 ± 0.06, 5.3 ± 0.06 and 5.9 ± 0.06 kg in 2007, 2008 and 2009, respectively. Single lambs at 6.4 ± 0.06 kg were heavier ($P < 0.05$) than twins (5.1 ± 0.05 kg), and shelter type did not influence birthweight. Single lambs that died from SME were 0.7 kg lighter ($P < 0.05$) than

Table 2. Mean proportion of single (S) and twin (T) lambs surviving and lambs dying from starvation/mismothering/exposure (SME) and dystocia in 2007–2009 and 2008–2009 in different shelters, and the significance of the difference between the treatments

*$P < 0.05$. s.e.m. = 0.01–0.04, except for the proportion dystocia of deaths, where s.e.m. = 0.04–0.1

Parameter	Proportion				Signficance of the difference between treatments		
	S no shelter	S hedgerow	T hedgerow	T shrub	T shrub versus T hedgerow	S no shelter versus T shrub	S no shelter versus S hedgerow
2007–2009							
Survival of total births	0.76	0.76	0.70	0.74			
Survival of live births	0.88	0.87	0.76	0.78	*	*	
SME of total births	0.07	0.06	0.15	0.13	*	*	
SME of live births	0.08	0.07	0.16	0.14	*	*	
Dystocia of total births	0.14	0.13	0.07	0.07	*	*	
Dystocia of deaths	0.59	0.57	0.26	0.24	*	*	*
2008–2009							
Survival of total births	0.75	0.80	0.70	0.77	*		
Survival of live births	0.86	0.88	0.75	0.80	*	*	
SME of total births	0.07	0.05	0.16	0.12	*	*	*
SME of live births	0.08	0.06	0.18	0.12	*	*	*
Dystocia of total births	0.13	0.10	0.04	0.07		*	
Dystocia of deaths	0.53	0.50	0.20	0.23	*	*	

Table 3. The effect of maximum daily wind (km/h), rain (mm) and maximum daily chill index (kj/m^2.h) within 3 days of birth on survival of lambs born alive in 2007–2009

Means followed by the same letter within a row (a, b) or within a column (x, y) are not significantly different (P = 0.05). s.e.m. = 0.03–0.04

Variable	Survival proportion				
	Singles no shelter	Singles hedgerow	Twins hedgerow	Twins shrubs	Total
Wind speed <8 km/h	0.90b	0.91b	0.79a	0.85ab	0.87y
Wind speed ≥8 km/h	0.86b	0.86b	0.74a	0.75ab	0.81x
Rain <5 mm	0.87b	0.86b	0.77a	0.79ab	0.82
Rain ≥5 mm	0.89b	0.91b	0.74a	0.77a	0.84
Chill index <1000 kj/m^2.h	0.87b	0.86ab	0.78a	0.78a	0.82
Chill index ≥1000 kj/m^2.h	0.88b	0.90b	0.73a	0.79a	0.84

those that survived (5.7 ± 0.23 cv. 6.4 ± 0.05 kg); there was no difference between twins. Single lambs that died from dystocia were 0.6 kg heavier (P < 0.05) than those that survived (7.0 ± 0.17 cv. 6.4 ± 0.05 kg), while the difference (P < 0.05) for twins was 0.3 kg (5.4 ± 0.16 cf. 5.1 ± 0.04 kg).

The marking and weaning weights of lambs varied with year and treatment and their interaction was significant (P < 0.05). The marking (Fig. 3) and weaning weight of twin-born lambs was always lighter (P < 0.05) than that of singles. Shelter type did not influence weights in twins, but in both 2008 and 2009, single lambs in hessian shelter were ~2 ± 0.5 kg heavier (P < 0.05) than unsheltered lambs at marking and up to 4 ± 0.7 kg heavier (P < 0.05) at weaning. Weaning weights are not presented.

Similar trends were evident in lamb growth rates. Growth to marking was up to 48 g/day higher (P < 0.05) in single lambs with hessian shelter in 2008–2009, and up to 31 g/day higher (P < 0.05) to weaning. The growth to marking for twins was 34 g/day less (P < 0.05) and growth to weaning 17 g/day less (P < 0.05) for twins in shrub than for those in hessian shelter in 2009.

Differences in the number of twin-born lambs surviving to be raised as singles affected mean lamb weights. When only twin-born lambs raised as twins were included in the analysis, marking and weaning weights and growth rates to weaning were similar (P > 0.05) between twins in the different shelter types. However, there was an interaction (P < 0.05) between year and treatment for growth rate to marking. In 2007 and 2008, the shrubs were not associated with lower lamb growth rates than were hedgerows, but in 2009 twins in hessian hedgerows grew more quickly (P < 0.05) (303 cf. 274 g/day).

Ewe liveweight and condition score

The post-lambing condition of ewes differed (P < 0.05) among years, being 2.8 ± 0.03, 2.5 ± 0.02 and 2.6 ± 0.03 in 2007–2009, respectively, and while the condition of twin-bearing ewes was 0.2 ± 0.03 score lower (P < 0.05) than that of singles in 2007 and 2009, in 2008 singles with no shelter were similar (P > 0.05) in condition to twin-bearing ewes (Fig. 4). In 2008, the condition of ewes declined by 0.3 ± 0.02 score during the 49 days between pre- and post-lambing

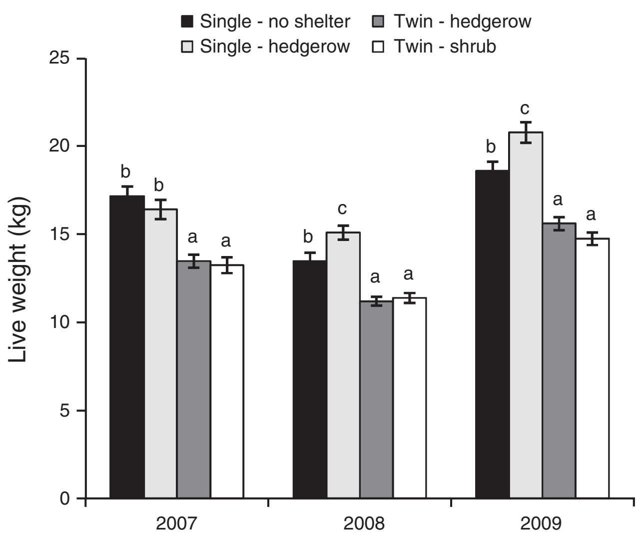

Fig. 3. Mean weight (kg) of lambs at marking in 2007–2009. The same letter within a year indicates that the means are not significantly different (at P = 0.05).

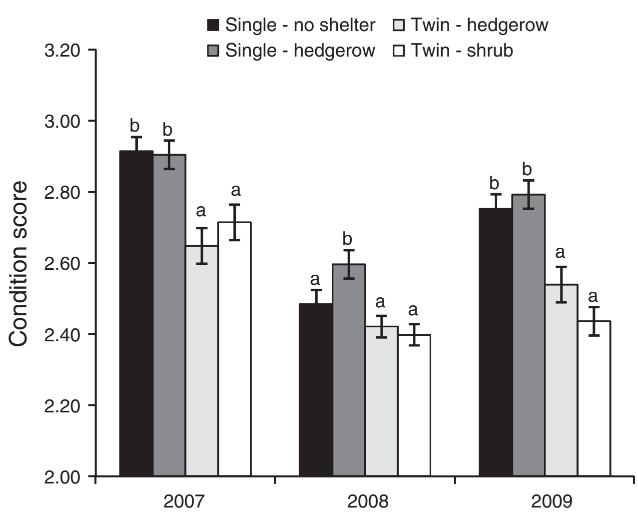

Fig. 4. Mean condition score of ewes post-lambing in 2007–2009. The same letter within a year indicates that the means are not significantly different (at P = 0.05).

measurements, but this decline was similar ($P > 0.05$) in all treatments. The post-lambing liveweight of ewes differed ($P < 0.05$) among years, being 66 ± 0.62, 52 ± 0.50 and 59 ± 0.48 kg, but was similar ($P > 0.05$) among the treatments.

Pastures

There was an interaction ($P < 0.001$) between year and treatment for the quantity of live pasture available at the start and end of the lambing period (Table 4). Unprotected single ewes had more pasture available pre-lambing than did ewes in the other treatments, except in 2008, when there was less pasture than in the sheltered single treatment. However, post-lambing there was not consistently more live pasture available in the unsheltered single treatment. The quantity of live pasture was low in 2008. All treatments had 0.6 t DM/ha dead pasture available pre-lambing in 2008, the only year in which dead pasture was estimated.

Pasture composition

The subclover (*Trifolium subterraneum*), annual grass, phalaris (*Phalaris aquatica*) and broadleaf composition of pastures varied among years pre-lambing, with a higher percentage of clover in 2007 than in 2009, more annual grasses in 2009, and the least phalaris in 2009 ($P < 0.05$). The annual grasses were largely barley grass (*Hordeum leporinum*) and annual ryegrass (*Lolium rigidum*). The interaction between year and treatment was significant ($P < 0.05$) only for percentage phalaris. Pre-lambing unsheltered singles grazed pastures containing a higher ($P < 0.05$) percentage of clover and annual grasses but less phalaris than the other treatments (Fig. 5).

Post-lambing, the percentage of clover and annual grasses was similar ($P > 0.05$) among years, while the percentage of phalaris was lower ($P < 0.05$) in 2009 than in previous years. The interaction between year and treatment was significant ($P < 0.05$) only for percentage phalaris. Post-lambing, unsheltered singles had access to pastures with a higher ($P < 0.05$) clover content than did twins in shrub shelter, had more ($P < 0.05$) grass than those in treatments with hedgerows, and had less ($P < 0.05$) phalaris than those in all other treatments. The pastures in the twin shrub treatment contained a similar ($P > 0.05$) clover content as did the treatments with twins in hedgerows, but more ($P < 0.05$) annual grasses than did both the single and twin hedgerow treatments.

Nutritive value of pastures

In 2007 and 2008, when ewes entered plots, there were no differences ($P > 0.05$) among the treatments in the ME content of live (11.3 MJ ME/kg DM) or dead (4.3 MJ ME/kg DM) pasture or the protein content of dead pasture (9.5%). The protein content was higher in live pasture but was different among the treatments, with the unsheltered singles higher ($P < 0.05$) than other treatments (25.9 cf. 23.2%).

The CP composition (28%) of live pastures at the end of lambing in 2008 was similar ($P > 0.05$) among treatments, but the ME content of these was lower ($P < 0.05$) in twin paddocks than those for singles (8.9 cv. 10.2 MJ ME/kg DM).

Climatic factors

Using data from within-plot loggers in the unsheltered paddock at 30-cm height, lower wind speeds were recorded than at 1.5-m height. Maximum daily wind speeds of 8 km/h or more occurred only on 11, 18 and 9 days during the lambing periods of 2007–2009, respectively, equating to 26%, 41% and 20% of days. Maximum wind speeds above 15 km/h occurred on only 1 day each in 2008 and 2009. A chill index of 1000 kj/m^2.h or greater occurred on only 3, 5 and 2 days during the lambing period from 2007 to 2009, respectively, equating to 7%, 11% and 4% of days.

The mean daily wind speed was similar ($P > 0.05$) in 2007 and 2008. In 2007, it was not influenced by shelter type, while in 2008, hessian in singles paddocks reduced ($P < 0.05$) mean wind speed compared with the unsheltered paddocks, but shrub shelter did not (Table 5). In 2007, the maximum daily wind speed during lambing was lower ($P < 0.05$) in the shrub treatment than in the unsheltered paddocks, but was similar in 2008. In 2007, the maximum daily wind speed in the phalaris hedges was similar ($P > 0.05$) to that in both the shrubs and the unsheltered paddocks. In 2008, hessian hedges in singles paddocks produced a lower ($P < 0.05$) wind speed than did all other treatments, while for the hessian twin paddocks, wind speed was less ($P < 0.05$) than that in unsheltered paddocks but similar ($P > 0.05$) to that in shrub-sheltered paddocks.

There were no differences ($P > 0.05$) among years or treatments for mean or maximum daily wind chill (temperature equivalent without wind). Minimum wind chill was similar ($P > 0.05$) among years. In 2007, the minimum wind chill was higher ($P < 0.05$) in the shrub treatment than in all others, but the effect of shelter type was inconsistent among years. The mean daily chill index (930 kj/m^2.h) (heat loss) was similar ($P > 0.05$) in 2007 and 2008, with no differences among the treatments.

Experiment 2

Sheep

Shrubs did not improve ($P > 0.05$) the survival of lambs or reduce deaths from SME (Table 6). The birthweight of lambs was

Table 4. Mean quantity of live pasture available at the start of the lambing period in 2007–2009

Means within a row within time periods followed by the same letter are not significantly different ($P = 0.05$). s.e.m. = 0.02–0.29

Lambing period	Pre-lambing live pasture (t DM/ha)				Post-lambing live pasture (t DM/ha)			
	Singles no shelter	Singles hedgerow	Twins hedgerow	Twins shrubs	Singles no shelter	Singles hedgerow	Twins hedgerow	Twins shrubs
2007	3.03c	2.52ab	2.44a	2.68b	1.95b	1.64a	1.94b	2.10b
2008	0.44a	0.61b	0.51a	0.50a	0.49a	0.56ab	0.65bc	0.69c
2009	2.41d	1.80b	1.62a	2.11c	3.83c	2.97a	3.54b	3.73bc

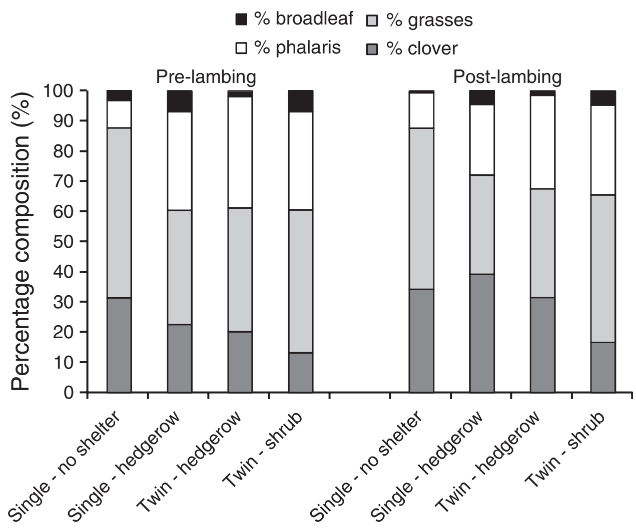

Fig. 5. Mean botanical composition of pastures (%) pre- and post-lambing in 2007–2009.

similar ($P > 0.05$) between shelter types, but marking weights and growth rates were higher ($P < 0.05$) in lambs born in the unsheltered paddock than in the shrub shelter. The lower ($P < 0.05$) growth rates were still evident when lambs raised as singles were excluded from the analysis.

The liveweight and condition score of ewes was similar ($P > 0.05$) pre-lambing (unsheltered 73 ± 0.8 kg; condition 2.7 ± 0.03; shrubs 73 ± 0.9 kg, condition 2.6 ± 0.02). However, ewes in shrub shelter lost condition, such that ewes post-lambing were lighter ($P < 0.05$) (49 ± 0.8 versus 55 ± 0.9 kg) and in poorer ($P < 0.05$) condition (2.4 ± 0.04 versus 2.7 ± 0.05) than those in the unsheltered paddock.

Pastures

The quantity of live pasture was higher ($P < 0.05$) in the shrub (0.9 ± 0.02 t DM/ha) than in the unsheltered paddock (0.7 ± 0.05 t DM/ha) pre-lambing, but both pastures were similar ($P > 0.05$) post-lambing (0.7 t DM/ha). The quantity of dead pasture (0.6 t DM/ha) did not differ ($P > 0.05$) between the treatments at either time. The composition of pastures was similar ($P < 0.05$) between the treatments pre- and post-lambing, and was dominated by grasses (93%) with a small clover and broadleaf content.

Weather

In 2010, shrubs did not influence temperatures or wind chill. However, shrubs reduced ($P < 0.05$) mean daily wind speed at 30-cm height (by 20%, 1.4 versus 1.8 km/h), mean daily maximum wind speed (5.6 versus 6.5 km/h) and the mean chill index (948 versus 959 kj/m^2.h). Mean maximum daily wind speed in unsheltered paddocks exceeded 8 km/h on 32% of days, and exceeded 15 km/h on 5% of days while the chill index exceeded 1000 (kj/m^2.h) on 20% of days. In sheltered paddocks, mean maximum wind speed exceeded 8 km/h on 24% of days and exceeded 15 km/h on 3% of days and the daily chill index exceeded 1000 (kj/m^2.h) on 18% of days.

Discussion

The results showed that a 'maternity ward' environment using shrubs, where ewes were forced to lamb in shelter without management intervention, led to a higher survival of twin lambs than when twins were born in hessian hedgerow shelter. The 10% higher survival and 23% lower mortality rate of total twins born in shrubs in 2008–2009 indicates that shrubs were more effective than hessian. The difference in survival of twins was clearly associated with a reduction in deaths from SME. The difference in mortality is less than the 30–50% reduction in mortality achieved by using phalaris hedgerows compared with unsheltered paddocks previously reported (Egan *et al.* 1976; Lynch and Alexander 1977; Alexander *et al.* 1980) or the 68% (6 versus 19% mortality in singles) reduction in singles achieved by penning ewes against cypress hedges (Egan *et al.* 1972). However, the weather conditions during those studies were colder and wetter than the ones experienced during our study. This probably explains why the provision of phalaris or hessian hedgerows did not improve the survival of single-born lambs in our study.

The lack of improvement in survival in 2010 for twins highlights the relatively small and inconsistent benefit of shelter in mild weather conditions. Although any benefit of shelter to survival could have been masked by suspected differential lupin intake, as discussed later, the weather conditions were such that a response to shelter could be considered unlikely. In a study with Corriedale lambs by Obst and Day (1968), the mortality rate was reported to be increased only with winds >16 km/h in the absence of rain, although rain of 5 mm or more per day in the absence of wind increased mortality. Other studies have also found no benefit of shelter to lamb survival where the mean wind speed was low (Egan *et al.*

Table 5. Mean daily wind speed (km/h), wind chill (°C) and chill index (kj/m^2.h) during the lambing periods in 2007 and 2008
Means within a row and within a year followed by the same letter are not significantly different ($P = 0.05$). s.e.m. = 0.1–0.3 for wind speed and wind chill; 4.5–4.9 for chill index

Parameter	2007				2008			
	Singles no shelter	Singles hedgerow	Twins hedgerow	Twins shrubs	Singles no shelter	Singles hedgerow	Twins hedgerow	Twins shrubs
Wind speed (km/h)	1.1	1.0	1.0	0.9	2.3bc	1.6a	1.9ab	2.2bc
Maximum wind speed (km/h)	5.4b	4.7ab	4.8ab	4.3a	8.5c	6.4a	7.7b	7.9bc
Minimum wind chill (°C)	–0.6a	0.1b	–0.5a	2.3c	1.7ab	2.1b	1.4a	2.0ab
Chill index (kj/m^2.h)	928	919	923	915	946	928	938	942

Table 6. Lamb weights, growth rates and proportion surviving or dying from starvation/mismothering/exposure (SME) in 2010
Means (s.e.m.) within rows followed by the same letter are not significantly different ($P = 0.05$)

Parameter	No shelter	Shrubs
Birthweight (kg)	5.0 (0.11)	4.9 (0.11)
Marking weight (kg)	11.4 (0.30)b	9.6 (0.24)a
Weaning weight (kg)	23.5 (0.40)b	20.5 (0.38)a
Growth to marking (g/day)	243 (7.3)b	169 (7.0)a
Survival of total births	0.69 (0.06)	0.72 (0.06)
Survival of live births	0.77 (0.05)	0.80 (0.04)
SME of total births	0.13 (0.04)	0.14 (0.04)
SME of live births	0.15 (0.04)	0.15 (0.04)

1976) or weather conditions were mild (Pollard and Littlejohn 1999; Pollard 2006). Egan *et al*. (1972) found that the benefit of shelter in their study was solely due to a reduction in deaths during a 5-day period of poor weather.

During our study, there were very few days of rainfall above 5 mm recorded during lambing, and the occurrence of rain is known to dramatically increase mortality rates in a cool environment (Arnold and Morgan 1975; Egan *et al*. 1976). Obst and Day (1968) found that increased wind speed in the absence of rain did not increase Corriedale lamb mortality. In our study, the maximum daily wind speeds at 30-cm height were only above 8 km/h on 20–40% of days during lambing, and at least in 2007 and 2009, the height of the pasture would have provided some shelter to lambs in all plots, further limiting any relative benefit of the shrubs or hessian. This may explain why overall lamb survival was reduced by 7% with winds >8 km/h, but there was no benefit of shelter when compared with less windy conditions. Rainy days did not reduce survival in our study, probably reflecting low numbers of lambs being born on wet days (64 lambs; 6% of lambs born alive). During the years of the study, the weather conditions were milder than the long-term average for this location. Larger responses in survival than those recorded may therefore be likely in closer-to-average years.

Our study used crossbred lambs that are less susceptible to poor weather conditions than Merino lambs (Obst and Day 1968; Donnelly 1984). The size of both the ewes and their lambs could also have reduced the influence of shelter on lamb survival. Smaller lambs are more prone to SME deaths due to their larger surface area relative to body mass because this increases heat loss (Alexander 1974). The mean annual birthweight of lambs in the present study ranged from 5.3 to 6.0 kg, which is much higher than the 3–4.3 kg reported in many previous shelter experiments (Obst and Day 1968; Egan *et al*. 1972, 1976). The optimum range of birthweight for lamb survival differs among breeds (Smith 1977; Holst *et al*. 2002; Everett-Hincks and Dodds 2008). However, lambs larger than the average for the genotype are more likely to experience a difficult birth (Smith 1977) and it is likely that high birthweights explain the high mortality rates of single-born lambs (25% of total births) in our study. The survival of lambs that survive the birth process may still also be affected by a difficult birth because these lambs can be slower to stand and suck (Dwyer 2008), which makes them more susceptible to adverse weather, and are at greater risk of being abandoned by the ewe (Alexander 1960; Hancock *et al*. 1996; Nowak *et al*. 2000).

It is also possible that the lower proportion of SME deaths in twin lambs in shrubs than in hedgerows was associated with a difference in the behaviour of ewes and lambs in the different shelter types. In a separate study within this experiment, where use of contact loggers recorded sheep coming within ~4 m of another sheep, ewes in the hessian shelter had 17% less contact with their twin lambs than ewes in the shrubs (Broster *et al*. 2010). However, it is not clear whether this lower level of contact contributed to reduced survival.

Shelter did not consistently reduce wind speed, wind chill or chill index, even when shrubs had attained a reasonable height (127 cm) in 2008. The low wind speeds observed reduced the potential for shelter to reduce wind speed. Although the shelters were designed to protect lambs against the prevailing winds, the wind also commonly blew from the north-east – in which case the shelter would have provided a minimal barrier. However, because the loggers were placed in the centre of paddocks where they would be least affected by shelter, it is likely that their measurements underestimate any effect of shelter on wind speed. The largest reductions in wind speed occur close to the shelter (Lynch and Alexander 1977; Bird *et al*. 2007), and because ewes and lambs utilise the whole paddock (1 or 1.3 ha), they were likely to obtain a greater benefit than that indicated by the wind measurements. Measurements in 2009 indicated that the maximum wind speed 2.5 m from the shrub belts was 83% of the wind speed in the centre of the shrub paddocks, reducing wind chill by 10% (J. Broster, pers. comm.). The reduction in wind speed is the expected mechanism that caused the reduction in SME deaths and increase in survival of twins we recorded, with our data showing that survival of lambs born alive was reduced with wind ≥8 km/h (Table 3), although we could not show that shelter increased survival in windy conditions.

Differences in the quantity and quality of pasture are unlikely to have influenced differences in lamb survival among the treatments within years for 2007–2009. In 2007 and 2009, the quantity of pasture was sufficient to cause little or no restriction on pasture intake by ewes, and would not be expected to limit the survival of twin lambs (Morris *et al*. 2003; Everett-Hincks *et al*. 2005). In 2008, pasture intake was restricted, evident by the loss in condition of ewes over the lambing period. However, the quantity of pasture was similar between the twin and unsheltered single groups and the differences in the quantity of pasture were small and resulted in similar loss in condition score across all treatment groups. The slightly higher protein content of live pasture in the unsheltered single pastures, although significant, is unlikely to have influenced lamb survival via effects on milk production because protein levels in all pastures were high. The lower energy content of live pasture post-lambing in twin paddocks in 2007 and 2008 did not appear to be associated with higher rates of weight loss in these ewes, so is also unlikely to have influenced survival.

The survival of twins has been increased from 82% to 90% during mild weather conditions through lambing ewes in a forage oat crop, compared with an annual pasture (Oldham *et al*. 2008). However, the sowing of forage crops may be neither possible nor cost-effective in all situations, hence the need to evaluate alternatives. In addition, lambing ewes on cereal crops can lead to metabolic disorders and elevated levels of dystocia and reduce the survival of single-born lambs, with a three-fold increase in the mortality rate of single-born lambs reported (Oldham *et al*. 2008). Insufficient time since sowing for the forage crop to attain a height that provides much shelter may also limit the use of crops as shelter. The lower height of the oats in some studies (Glover *et al*. 2008; Paganoni *et al*. 2008), in addition to mild weather, may explain their lack of effect on lamb survival, in contrast to that of Oldham *et al*. (2008).

In previous studies, shelter has both increased (Alexander and Lynch 1976), had no effect or decreased (Miller 1968) lamb growth rates. The reductions were due to an increase in intestinal parasites. In our study, the growth advantage for single lambs born in hessian shelter compared with unsheltered paddocks in 2008 was probably due to a combination of modified weather and a slightly larger quantity of pasture. GrazFeed simulations (version 4.1.13) (Freer *et al*. 1997) suggested that 20% of the difference in growth could be explained by the modified weather, with the other 80% due to the quantity of pasture. The growth difference in 2009 did not appear to be associated with a different composition, quantity or quality of pasture, and this was supported by GrazFeed simulations. Shelter could be expected to reduce heat loss, leading to more energy reserves being available for growth, and this may explain the growth advantage for single lambs.

It is unlikely that the high body condition of sheltered single-bearing ewes in 2008 contributed to the higher growth rate of their lambs than that of lambs of unsheltered ewes. Body condition of the ewe has little effect on milk production when pasture supply is not limiting (Kenyon *et al*. 2004), but lamb growth rates can still be higher from fatter ewes (Gibb and Treacher 1980). Where ewes are losing condition during lactation, as in our study in 2008, it could be expected that fatter ewes could produce more milk. However, the difference in condition score of 0.1 is unlikely to be sufficient to cause this effect. The growth rate of sheltered single lambs was higher in 2009 when the condition of sheltered and unsheltered ewes was similar, suggesting that the difference in lamb growth was not associated with ewe condition. The 0.1 score higher body condition of sheltered single ewes in 2008 is more likely to be due to a higher quantity of live pasture available at the start of the lambing period, due to pre-experimental grazing, rather than any effect of the shelter treatment.

It is not clear why the response differed in twins where shrubs reduced twin-lamb growth rates in both 2009 in Experiment 1 and in 2010 in Experiment 2. The slower growth of the twins in shrubs in 2009 may have been partially due to the lower clover content in their pasture. Although not measured in 2009, it is also possible that the nutritive quality of the pastures in shrub paddocks may have been lower than that of the pasture in hessian paddocks. Shrub paddocks contained a higher content of annual grasses which may have been more mature and of lower quality than the clover and phalaris pasture elsewhere. In 2009, the ewes lambed in August, rather than July as in previous years when pastures would be at a purely vegetative stage.

The lower growth rate of sheltered twins in 2010 was associated with loss of weight and condition in the ewes. This suggests a nutritional deficit in the shrub paddocks, which was not apparent in the quantity or composition of the pastures. It is possible that differences in pasture growth contributed; however, this was not measured. Alternatively, predictions of ewe intake and growth obtained using GrazFeed suggest that in order to achieve the weight loss recorded, the ewes in shrub shelter would have been consuming no more than half of the lupin grain offered. When the quantity of pasture was higher at the start of lambing they would have been consuming very little. Although refusals were not measured, this is consistent with our observations that refusals were higher in the shrub paddocks, particularly in the first half of the lambing period. The lower lupin intake was probably associated with the initially higher quantity of live pasture in shrub than in unsheltered paddocks, because a higher substitution rate of supplement for pasture occurs with declining levels of pasture (SCA 1990). Small differences in digestibility between the shrub and open paddocks may also have contributed, because an increase in digestibility of live pasture from 70% to 80% reduced the ewe weight loss predicted by GrazFeed (Freer *et al*. 1997) by 100 g/day.

Mobilisation of fat reserves may have elevated the milk production of ewes in shrubs in 2010. However, given the differences in the growth rate of lambs, it appears that any increase in milk production was relatively smaller than that in milk production from unsheltered ewes consuming more lupins. If the faster growth of the unsheltered lambs in 2010 was the result of a higher intake of lupins by their mothers, which then increased milk production, it is also possible that a higher intake of lupins may have given their lambs an advantage in survival. Feeding lupins appears to increase colostrum production even when ewes are grazing 'lush' pasture and are well fed throughout pregnancy (Murphy *et al*. 1996), and increased colostrum is associated with an increase in lamb survival (Banchero *et al*. 2009). However, ewes in low body condition can produce similar levels of colostrum as ewes in high body condition (Banchero 2003), and lupin grain has not consistently increased colostrum production (Banchero *et al*. 2004). The degree and duration to which lupin intake differed between the shrub and unsheltered groups is unknown, so could not be accounted for in the analysis. However, the differences in lamb weights suggest that differential lupin intake occurred. If so, lamb survival in the unsheltered twins may have been elevated, masking any benefit of the shrub treatment to survival in comparison.

The paddocks used in the present study were small relative to extensive commercial sheep production norms. The concept of a 'maternity ward' could be used in larger paddocks with commercial flock sizes, but shelter would need to be placed in rows at appropriate distances apart, such that the whole paddock was sheltered. The effect of this design on ewe and lamb behaviour and survival may differ from that recorded in our study. The area of shelter required on a property could be minimised if pregnancy scanning were used and only twin-bearing ewes were placed in shelter during lambing. A difficulty with minimising the lambing area is that either the quantity of pasture required in the lambing paddock would need to be increased, which might be difficult to achieve when lambing in winter, or there would be an increased risk of needing to supplementary-feed during lambing.

The value of shrub-based maternity wards also needs to be considered against existing land use. Purpose-built shelter may not be economic in mild environments, or if lambing occurs at a time when poor weather is unlikely, because there may be no or only a small increase in lamb survival. However, if shrub rows are already to be planted for other reasons such as reducing groundwater recharge, it is logical, where possible, to plant them in a design which will also benefit lamb survival. Consideration should also be given to using existing forms of shelter which may provide a similar benefit. Although a larger increase in survival of Merino than crossbred lambs could be expected, the higher value of crossbred lambs may mean that shelter is more cost-effective for these enterprises. It can be considered only probable that in more adverse weather conditions, the benefit of shelter to lamb survival would be greater than indicated by our study.

Conclusion

Once established to form a 'maternity ward', shrub belts resulted in fewer deaths of twin lambs from SME and a higher survival of lambs born alive than did hedgerow shelter, but not in all years. There were apparently growth benefits for single-born lambs, but these also did not occur in all years. The absence of any benefit to survival in single-born lambs warrants preferential use of shelter by twin-bearing rather than single-bearing ewes, because of a potentially greater economic benefit. Although the differences in survival were small and were not achieved in all years due to the mild weather experienced, greater differences could be expected in conditions of more wind and rain, particularly if a period of poor weather occurred during peak lambing. It is also likely that a larger benefit would be achieved with breeds such as the Merino that are more susceptible to adverse weather conditions than the crossbreds used in the present study. There is a need to evaluate weather conditions and the potential for shelter to improve lamb survival at specific locations before investment in purpose-built shelter.

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