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A survey of Oregon sheep producers conducted as part of this research, indicated that lambing losses by sheepgrowers in winter rainfall areas of Oregon currently average 16 percent. The majority of the lambs born in these areas are born in pastures without the benefit of shelter. The utilization of portable pasture shelters with wooden slat floors by lambing ewes was evaluated. The study measured occupancy rates of two shelters under free choice, winter rainfall pasture conditions. Occupancy (sheltering) rates were determined from the number of ewes or lambs in a shelter, and were measured through the use of time lapse photography. The averages of daily maximum sheltering percentages for ewes and lambs were 31.2 and 50.7 percent, respectively. At least one ewe lambed by choice in a shelter on the slatted floor. The use of portable pasture shelters with slatted

floors could reduce the lamb losses experienced by winter rainfall pasture lambing operations.

A Slatted Floor Portable Shelter for Lambing in Winter Rainfall Pastures

by

Martin Theodore Nicholson

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Typed by Karen Bland for Martin Theodore Nicholson

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I. INTRODUCTION

A majority of the lambs born in the winter rainfall areas of Oregon are born without the benefit of shelter. Winter rainfall areas were defined for the purposes of this study as those areas west of the Cascade mountain range which typically receive most precipitation as rain. Climatological records show this definition generally holds true for elevations west of the Cascades below approximately 305 m (1000 ft) (Bates, 1981). While most of the areas so defined receive some snow, it typically does not last more than one or two days (Bates, 1981).

Oregon's sheep industry represents an important segment of the state's agricultural production. The Oregon State University (OSU) Extension Service ranked approximately 80 of Oregon's leading agricultural commodities in 1979, each valued at one million dollars or more. Sheep and lambs ranked 14th with gross farm sales of $19,480,000. In addition, the value of wool production for the state was expected to be 3.1 million dollars for a total worth in 1979 of slightly under 22.6 million dollars. The expected gross farm sales, not considering the value of wool production, was expected to rise to 23.9 million dollars in 1980 (OSU Extension Service, 1980).

Sheep operations in western Oregon winter rainfall areas vary from large rolling range pastures in inland Douglas and Josephine counties and in the coastal counties of Coos and Curry, to the ryegrass and other flatland grass pastures of the Willamette Valley. A large portion of the sheep raised in the Willamette Valley are grazed on rented ryegrass pastures. This is beneficial to ryegrass farmers as the grazing action of sheep helps increase yields. The use of winter feed is beneficial to the sheepgrower.

Sheep population estimates for Oregon in 1979 totalled 460,000 head including 260,000 breeding ewes and 110,000 sheep and lambs on feed. The current outlook for the state's sheep industry is good, and is emphasized by the increasing number of breeding ewes in the last few years from 247,000 head in 1977 to the 260,000 head in 1979 (OSU Extension Service, 1980). The distribution of the state's sheep population in 1960 showed that the 18 westernmost counties held 52 percent of the then 910,000 head. The same area in 1978 held 72 percent of the then 410,000 head. Although over that time the total number of sheep in the state decreased, western Oregon currently holds a higher percentage of the total sheep population than it has in the past (OSU Extension Service, 1980). Consequently, lamb deaths and problems at lambing time in the winter rainfall areas affect more of the total sheep population of Oregon today than in the past.

The survival of newborn lambs is critical to the success of any sheep operation and is of great concern to sheepgrowers lambing in pastures during winter rainfall conditions. A survey conducted as part of this research indicated that the current losses of newborn lambs for winter rainfall sheep operations in Oregon average approximately 16 percent. Purvis _et al_. (1979) conducted a study of newborn lamb losses during the spring lambing season in England. The lambs were born in shelter but were transferred to pastures two to three days following their birth. The highest lamb losses occurred at birth and during the first day of the lamb's life. More losses were experienced once the lambs were transferred to pasture. The amount of thermal stress experienced by pastured lambs was measured prior to lamb deaths from exposure. High thermal stress accounted for 70 percent (14 of 20) of the losses due to chilling during one year of the two year study. The authors suggested that even "quite moderate" weather conditions may pose a serious risk to newborn lambs.

Lambing time in western Oregon and other winter rainfall areas typically peaks in and coincides with the adverse wet conditions of January and February. Most lambing operations in winter rainfall areas are one of three types: pasture, shed, or a combination of pasture and shed (shelter). Pasture lambing conditions offer no shelter to the ewes or lambs other than what minimal protection is naturally available. Shed lambing systems provide complete shelter for the ewes and lambs up to perhaps a week following birth. A combination of shed and pasture may or may not provide shelter at lambing, however, lambs are often individually penned (jugged) with the ewes for a varied time following birth. Jugging lambs born in pastures requires around the clock attendance to the lambing flock to fully take advantage of the procedure.

Most operators are concerned with the conditions in which their ewes lamb, but not all operators are willing or able to extend the required capital, management and additional labor necessary to shed lamb their ewes. The reluctance of ryegrass pasture owners to allow sheepgrowers renting their pasture to erect structures is a deterrent to pasture shelters. Foot rot and other disease problems associated with dirt floor shelters that soon turn muddy, are common in areas with high rainfall and heavy clay soil conditions. As a result, a majority of lambs in winter rainfall areas are born without the benefit of shelter.

While the numbers for lamb losses are highly dependent upon the level of management and the overall quality of operation, shelters made available to ewes lambing in pasture operations could help reduce early lamb losses. Shelters are needed at low cost and management for those operators who lamb their ewes in pastures. A free choice lambing shed, if used by the ewes, could reduce lamb losses by providing shelter for the lamb birth at a minimum of management for the operator, and provide substantial economic benefits. Lamb prices in 1979 for fat market lambs were approximately $0.63 per pound (OSU Extension Service, 1980). Some lambs do not make it to the fat lamb market, and for a wide variety of health and mothering problems are orphaned (bummed) and sold at a young age. These bummer lambs typically sell for 10 to 15 dollars dependent upon age and physical condition. A lamb death at birth could be reasoned to represent the loss of a bummer lamb, or 10 to 15 dollars. However, the loss associated with the death of a bummer lamb or the death of a newborn lamb in the pasture, is not generally taken by sheepgrowers as a 10 to 15 dollar loss. Rather, it is taken as approximately a 60 dollar loss; the gross income from a fat market lamb.

This project and resulting thesis were initiated to determine the feasibility of portable pasture shelters with wooden slat floors that could be used to reduce pasture lambing losses. The acceptance by sheep of the shelters was measured by recording occupancy rates of gestating and lambing ewes and newborn lambs under free choice, pasture conditions. This study was not intended to aid those operators who already provide the intense labor and management to shed lamb or jug lambs following their birth in the field.

The following specific objectives were established for this study.

1) Survey the current sheep operations and lambing conditions throughout the winter rainfall areas in Oregon. Assess operation sizes and types, facilities currently in use and current lambing losses experienced by winter rainfall operators.
2) Design and build a winter rainfall lambing shelter, suitable for use by operators that currently pasture lamb their ewes and presently do not provide shelter for the lambs at birth.
3) Determine if insulation in a free choice lambing shelter alters the environment enough to increase utilization by ewes and/or lambs.
4) Measure the acceptance of the shelter by lambing ewes and subsequently by both ewes and newborn lambs.
5) Propose recommendations for the design and further research of practical winter rainfall lambing shelters.

II. LITERATURE REVIEW

The advantages of shelter for both lambs and ewes have been reported in several studies. Most research investigating the sheltering habits of sheep and the benefits of shelter to sheep has been done in England or Australia. The effects of natural forms of shelter such as grasses, trees, windbreak structures of grass hedges or man-made windbreaks, are those most often studied. Voluntary movement by animals to some form of shelter to lessen the effects of adverse weather has long been observed by man. The desire to shelter from adverse weather is common to farm animals, and the provision of animal shelters has long been utilized to increase their productivity. Troon (1966) reported that "old timers" in Scotland used circular stone walled shelters (stells) to shelter sheep during snowy winter conditions. Each stell was approximately 9.1 m (30 ft) in diameter with 1.8 m (5 ft) high walls and a 0.9 m (3 ft) door opening.

Munro (1962) found during a 1960 study in Scotland that the sheltering habits of sheep depend largely upon wind velocity exceeding 38.6 $km \cdot hr^{-1}$ (24 $mi \cdot hr^{-1}$). No correlation was reported between sheltering and rainfall or relative humidity, however sheltering increased greatly as temperatures dropped below freezing. The study did not involve lambing ewes. Only mature sheep seeking what natural windbreaks and shelter they could find were involved.

Miller (1968) explored the effects of shelter provided by windbreak panels set in a pasture during a three year study in England. Four corrugated iron panels 1.2 m (4 ft) high and 2.4 m (8 ft) long were set in a cross, perpendicular to each other, and joined in the center. Sheltering was measured by the proximity of the sheep to the panels. Twenty ewes with lambs were assigned to each plot and shelter. Weather was comparable to that of the winter rainfall conditions in western Oregon with a mean temperature of 8.3 to 10.0°C (47 to 50°F), wind speed of 9.7 to 12.9 $km \cdot hr^{-1}$ (6 to 8 $mi \cdot hr^{-1}$), however rainfall was less at an average of approximately 7.6 cm (3 in) per year. Miller stated that lambs were particularly sensitive to wetting and sought shelter more frequently than ewes during rainy periods. The available shelter provided only minimal protection from wetting and the shelter primarily could only have helped to reduce chilling from windy conditions. The conclusions presented in Miller's paper were:

1) Lambs sought shelter particularly in rain and were sensitive to high wind speed and low temperature.
2) Ewes were indifferent to rain and stayed in the open even though the lambs sheltered. They occasionally used the shelters for shade during sunny weather.

3) Because of sheltering differences, ewes were less associated with their lambs during rainy weather.
4) No particular weight gain advantage of sheltered lambs over unsheltered lambs was seen with the study. However, lambs with shelter during one year gained weight more slowly than those without, possibly due to less time with the ewe.

Other studies have noted the lambing behavior of ewes in relation to available shelter. A behavioral study in Australia by Alexander, Lynch and Mottershead (1979), related lambing and lambing sites to shelter locations. Shelter was provided by *Phalaris* (grass) hedges and by black plastic windbreaks at various spacings. Merino ewes were stocked at 35 sheep per hectare (14.2 sheep per acre) in paddocks (lots) 80 by 50 m (263 by 164 ft) for shelter spacings of 20 m (66 ft). Similar stocking rates were used in lots 320 by 25 m (1050 by 82 ft) with shelter spacings of 240 m (787 ft). Comparisons were also made between shorn and unshorn ewes and their lambing locations relative to the shelter provided. The authors found that shorn ewes sought shelter for lambing at a higher rate than unshorn ewes, although both sought shelter. The authors noted that perhaps half the ewes tended to isolate themselves while lambing. As in other studies, lambs made more use of the shelters than ewes. Comparisons of the results obtained in Alexander's *et al.* (1979) study were made with the results that would be expected if all the lambing sites were uniformly distributed. With grass hedges 240 m (787 ft) apart in paddocks 320 by 25 m (1050 by 82 ft), 3.75 percent of the lambing sites would be expected to be in sheltered areas. Similarly, 20 m (66 ft) shelter spacings in an 80 by 50 m (263 by 164 ft) lot provided an expected uniform sheltering of 30 percent. Results obtained by the authors for the 240 m (787 ft) hedge spacing showed that for shorn ewes, 30.6 percent lambed in sheltered areas for the births during the day and 44.4 percent lambed in shelter at night. Unshorn ewes sheltered somewhat less at 15.6 and 17.2 percent, respectively. Comparisons were also made between ewes with lambs and ewes without lambs, shorn and unshorn ewes, and day and night. The night time sheltering value for shorn ewes without lambs was highest at 67.6 percent. Shorn ewes with lambs at night sheltered less at 58.3 percent. Respective results for day time values were 28.6 and 27.9 percent. Unshorn ewes had much lower percentages with night values of 2.6 percent without lambs, and 5.2 percent with lambs. Day values were 1.0 and 3.0 percent, respectively.

The value of shelter to the lambs and ewes was noted, with shelter expected to reduce lamb deaths and other inclement weather lambing problems such as disease, pneumonia or weakening of the lambs. The authors noted a tendency for the ewes to lamb in isolation more frequently in the smaller paddocks. They also noted many ewes appeared to lamb readily in the presence of other sheep. "The provision of ample shelter near any preferred lambing areas in large paddocks could lead to many lambs being born in shelter and hence to a reduction in mortality of lambs born during inclement weather" (Alexander, Lynch and Mottershead, 1979).

Lynch and Alexander (1977) reported that lamb mortality within three days of birth in unsheltered paddocks was approximately twice that in sheltered paddocks. Again, shelter was provided by grass windbreaks approximately 0.9 m (3 ft) high. Hedges were spaced 20 and 40 m (66 and 131 ft) apart in lots 50 by 80 m (164 by 263 ft), and were spaced 80 m (263 ft) apart in lots that were 50 by 160 m (164 by 525 ft). Sheep in any lot could at no time be more than one hedge spacing from shelter. Temperatures ranged during the 16 day study from -3 to 15°C (26.6 to 59.0°F). Six sunny days, five rainy days with the remaining five having rain showers were recorded. Wind velocities were usually below 10 $km \cdot hr^{-1}$ (6.2 $mi \cdot hr^{-1}$) although five days had winds of 15 $km \cdot hr^{-1}$ (9.3 $mi \cdot hr^{-1}$) for several hours. Sheep positions were plotted every two hours with sheltering defined and recorded as sheep being within 6 m (20 ft) of the leeward side of a grass hedge. Results showed that for night time values, approximately 35 percent of unshorn ewes with lambs sheltered, while 21 percent of those without lambs sheltered. Shorn ewes sheltered at higher rates, 83 percent for ewes with lambs and 84 percent for those without lambs. Lynch and Alexander (1977) noted that the ewes tended to congregate in one area of the paddocks regardless of wind direction and the location of shelter. Therefore, the strategic location of shelters within a paddock was considered important.

Alexander and Lynch (1976) conducted another study which compared lambing locations with shelter locations. Shelter was again provided by grass (a Phalaris hybrid) hedges spaced 20 m (66 ft) apart, 1.3 to 1.5 m (4 to 5 ft) tall. The weather over the 14 day study was comparable to other reported studies by the same authors at that location. The percentages of shorn and fleeced ewes which lambed within 2 m (7 ft) of a shelter strip were recorded as 50 and 40 percent, respectively. The authors reported that chances for lamb survival are often increased if the ewe is sheared approximately one week prior to lambing. They stated this was possibly due to the increased use of the shelter by the ewe, and as a result, an increase in the number of lambs born in shelter. Shearing may also have provided a reduction in the ewe's physical difficulty in lambing. A quieting effect, possibly due to the clearer vision provided by shearing, was also noted on sheared ewes. The quieting effect was reported to aid lamb survival.

Egan, Thompson and McIntyre (1976) studied overgrown grass as shelter for lambing ewes from 1971 to 1974. A paddock was allowed to overgrow with a reportedly unpalatable grass, Phalaris tuberosa, with ewes confined to lamb in the grasses. Deaths of twin lambs from birth to 48 hours old were reduced by 50 percent through the use of such overgrown grasses. Single lambs did not show such a marked effect. The authors stated that cold, wet and windy conditions are responsible for most lamb deaths during the wet winters of Australia.

Egan, McLaughlin, Thompson and McIntyre (1972) conducted a study in Australia in which ewes were confined to sheltered paddocks. Shelter was provided by grass hedges completely surrounding the paddock. Deaths between birth and 48 hours old of single lambs were reduced from 10 percent (of 153) of unsheltered to 6 percent (of 128) of sheltered lambs.

Other studies have also investigated the lambing habits of ewes. It is usually agreed that ewes tend to isolate themselves from the rest of the flock while lambing, although it has been observed that some ewes are indifferent to flock location. Sharafeldin (1976) noted that ewes tended to lamb in the less disturbed and less lighted areas in a study done with half shaded lambing yards. Hersher, Richmond and Moore (1963) reported that domestic ewes are likely to seek shelter indoors while lambing and also to isolate from the rest of the flock.

Bray and Wodzicka-Tomaszewska (1974) found that Merino ewes, when lambed in lot conditions, tended to isolate themselves from the rest of the ewes. Births were most common in the corners of the yards, and were least common in the yard centers. The authors confined 100 ewes in two adjacent 40 m^2 (421 ft^2) lots. The stocking rate was equivalent to 0.8 m^2 (9 ft^2) per ewe and was somewhat less than the 2.3 to 3.7 m^2 (25 to 40 ft^2) per ewe recommended by the Midwest Plan Service (MWPS) for ewes on dry lots (MWPS-3, 1974).

Studies have also explored the benefits of shelter to lambs and ewes. Rench, Ross, McFate and Krieg (1966) stated that sheltered lambs had cleaner fleeces, higher dressing percentages, lighter pelts and made faster gains than unsheltered lambs. Lynch and Marshall (1969) found with varied stocking rates that sheltered sheep performed better than unsheltered sheep. Watson, et al. (1968) also found care and shelter beneficial to lambing ewes through a reduction in lamb losses.

Winfield, Brown and Lucas (1969) observed sheltering behavior at lambing on 800 Welsh Mountain ewes over a three year period. Shelterbelts, trees and other natural shelter were available to ewes confined to a lambing area of five paddocks totalling 32 ha (70 ac); 210 to 300 m (689 to 984 ft) above sea level. The author found that ewes progressively sought more shelter as wind velocity and cooling increased.

A plastic roofed lambing shelter was built and tested during the winter lambing months of January through March, in a study related to conditions in the Pacific Northwest. Torell, Kelly, Bard and Weir (1948) stated that losses of range born lambs in the north coast areas of California can be as high as 90 percent during severe rainstorms. The authors built an experimental polyethylene plastic shelter at the Hopland Field Station in central California which was field tested during the 1957 lambing season during which 48.3 cm (19 in) of rain fell. Fewer lamb deaths were experienced that year than during any of the seven years previous. Ewes and lambs were confined to shelters for two or more days following birth. The design proved adequate for the wind and rain experienced, however, no snow fell and no recommendation was made about the effect of snow loads. The study included data on temperature and radiant heat loads under both black and translucent polyethylene film. Condensation was experienced under the polyethylene and evaporated more slowly under the translucent than black film. Construction guides and building suggestions were included.

Sheepgrowers often do not review current literature to obtain technical information to aid their farmstead planning. The information found in research publications and journals is not usually in an easy form for sheepgrowers to readily use, and the reviewing process is often time consuming. They look to the state's Extension Service to provide bulletins, technical handouts and other information. Popular articles in magazines, farm and agricultural journals and advice from other sheep owner/operators supplement the information available.

The California Agricultural Experiment Station Extension Service provides two leaflets on sheep shelters. Leaflet 118 by Cleaver, Torell and Parks (1959) provides technical advice on building a plastic roofed range shelter. Framed with 10.2 by 10.2 cm (4 by 4 in) posts and 5.1 by 10.2 cm (2 by 4 in) rafters, the shelter requires approximately 31 man hours plus three tractor hours to erect and complete. It is recommended for sheltering lamb feeding facilities, hay or both animals and feed, and can be adapted to other larger animals as well.

A second leaflet numbered 186 by Torell, Rainoldi, Neubauer and Parks (1966) recommends an arch roof plywood covered shelter built in portable sections. Two arches built with 2.5 by 7.6 cm (1 by 3 in) framing are covered with two 1.2 by 2.4 m (4 by 8 ft) plywood sheets to form a shelter that can rest either on the ground or on posts. Sections can be placed side by side to form shelter as long as desired. A 1.2 m (4 ft) long section was recommended for six ewes, allowing 0.7 m^2 (8 ft^2) per ewe. If used as a creep feeder, it was recommended that each section be used for 24 lambs, allowing 0.2 m^2 (2 ft^2) per lamb. Blueprints and construction guides were included.

Neither of the California Extension leaflets discussed the results of any field trials of the shelters. What reaction sheep had to the shelters is not known.

The Midwest Plan Service (MWPS) provides technical information on sheep facility layouts, buildings and equipment in the MWPS-3 Sheep Handbook (MWPS-3, 1974). A portable shed roofed building is included for use as a pasture shelter. It has no floor and is constructed of 10.2 by 10.2 cm (4 by 4 in) and 5.1 by 10.2 cm (2 by 4 in) lumber with plywood sheathing. No discussion is included regarding any experiments involving sheep and buildings of this design.

Other building designs are available from both the OSU Extension Service and the United States Department of Agriculture (USDA). They are not, however, designed specifically for use as portable pasture shelters, and would require considerable modification to be appropriately adapted to such use.

III. SURVEY ANALYSIS

A survey was sent with the Oregon Sheepgrowers Association (OSGA) newsletter to members throughout the state of Oregon, parts of southern Washington and northern California, to obtain information from sheepgrowers about types of lambing systems currently in use as well as the lamb losses associated with those systems. The survey consisted of a business reply postcard stapled to the newsletter with an explanation of the survey objectives. The postcard used to conduct the survey is presented in Appendix A. Conclusions about the method of operation and level of lambing losses experienced by area sheepgrowers were developed from a return of 19 percent (97) of the 500 survey cards sent.

For analysis, operation sizes were grouped as follows:

Category	Number of Sheep	Cards Returned
I	0 - 50	17
II	50 - 100	22
III	100 - 200	20
IV	200 - 500	17
V	>500	17
	Total	93*

*Total excludes four cards which provided insufficient information for analysis.

The information was analyzed for each size category and is summarized in Table 1.

Table 1. Survey results (all areas).

Category	Operation Size (#/sheep)	Total Cards Returned	Number of Responses			Average Number of Lambs Born	Percent Lambs Lost
			Shed	Pasture	Combina-tion		
I	0 - 50	17	8	2	6	42	12
II	50 - 100	22	5	7	10	86	13
III	100 - 200	20	5	4	11	142	14
IV	200 - 500	17	3	6	8	336	16
V	>500	17	7	3	6	1536	14
Totals		93*	28	22	41		
Percent of Total			31%	24%	45%		

*Numbers may not agree in all columns due to missing information on some cards.

Overall reported lamb loss was 15 percent of lambs born. Specific causes for lamb deaths were not defined except in cases where the reply volunteered information about a specific number of deaths related to coyotes. In cases where coyote losses were mentioned or quantified, those losses were not included in the calculations for percent lamb loss. This was infrequent, as only 7 of the 93 replies indicated coyotes were a factor in the reported lamb deaths.

A majority of replies indicated that lambing took place in pasture or in a combination of pasture and shed. The replies that indicated such outdoor lambing numbered 63, or 69 percent of the total replies that responded to that question. The average lamb losses for pasture, and combination of pasture and shed replies combined, was 19 percent, which was higher than the overall average of 15 percent.

Shed lambing was found most frequently in either the small or the large operations. Of those reporting shed lambing, category I had the highest percentage of shed lambing, 8 of 16 replies or 50 percent. Category V also was high with 7 of 17 replies or 41 percent. All other categories had lower shed lambing; 23, 25 and 18 percent for categories II, III and IV, respectively.

The responses from areas receiving winter rainfall were analyzed separately because this study was particularly interested in operators experiencing winter rainfall conditions at lambing. The number of cards returned from winter rainfall areas totalled 59 of 93, or 63 percent of the total replies evaluated. The data for winter rainfall areas only are presented in Table 2.

A majority of the replies from winter rainfall areas only indicated that currently, lambing takes place without shelter. Pasture lambing was indicated by 30 percent of the operators; a combination of pasture and shed by 47 percent. Therefore, 77 percent of operators lambing in winter rainfall areas have all or part of their lambs born outside shelter in winter weather conditions. Lamb losses averaged 15 percent for these operators, and was slightly less than the overall winter rainfall lamb loss of 16 percent.

Table 2. Survey results (responses from winter rainfall areas only).

Category	Operation Size (#/sheep)	Total Cards Returned	Number of Responses			Average Number of Lambs Born	Percent Lambs Lost
			Shed	Pasture	Combination		
I	0 - 50	7	2	2	6	48	8
II	50 - 100	15	3	6	6	85	13
III	100 - 200	14	4	2	8	145	15
IV	200 - 500	12	2	5	5	320	14
V	>500	11	2	2	6	1385	17
Totals		59	13	17	27		
Percent of Total*			23%	30%	47%		

*Based on 57 replies, two of the 59 did not provide the information requested.

IV. MATERIALS AND METHODS

Design Considerations

The design of a successful portable free choice lambing shelter must often be a compromise that will satisfy both the ewe and sheepgrower. The shelter should be acceptable to ewes as a lambing area, and must also fit easily into the sheepgrower's overall management scheme. The shelter should provide protection from wind and rain and thus create a draft-free, dry lambing area.

As noted in the introduction, many ryegrass farmers object to establishing permanent shelters or facilities in their grass seed fields. A portable shelter provides an alternative that should be attractive to both sheepgrowers and ryegrass farmers. Portable shelters can be moved out of the fields when the sheep are removed, and the problems permanent facilities cause during the remainder of the growing season and harvest eliminated. The location of a portable shelter can be changed from year to year or even several times throughout one season which helps minimize grass or crop damage.

Buildings without floors are susceptible to extreme mud conditions in most winter rainfall areas in the Pacific Northwest. Muddy shelters increase problems such as foot rot and parasites associated with animals walking and lying in mud and manure. Slatted floors can successfully solve these problems and provide a dry lambing area.

No references were found which indicated that any floor systems had previously been used in pasture shelters of this type. Therefore, no previous experience with the free choice acceptance based upon floor type was available. Wooden slats, expanded metal flooring and concrete slats have been successfully used in many sheep operations and are included in the recommendations made by the Midwest Plan Service for lambs and ewes in intensive production (MWPS-3, 1974). Through conversations with area sheep-growers, it was learned that sheep often appear to be afraid of and are hesitant to walk on expanded metal flooring when first introduced to it. While sheep perform well on expanded metal flooring under forced confinement conditions (MWPS-3, 1974), it is not known what effect it would have on occupancy of a free choice pasture shelter. Concrete slats require special handling and because of their weight would create specific design problems for a portable shelter. Therefore, wooden slats were chosen as the best alternative for flooring in a portable shelter. They are easily made from readily available lumber and should be accepted by ewes and lambs under free choice pasture conditions.

Shelter Construction

Two shed roofed buildings, each 2.4 by 4.9 m (8 by 16 ft), were designed and constructed for use as test facilities. The shelters were designed to be easily moved, avoid mud problems and provide a draft-free, dry lambing area for ewes. The shelters were similar to a portable shelter recommended by the Midwest Plan Service (MWPS-3, 1974) for pasture sheltering of sheep. However, important modifications were incorporated in the test shelters to adjust the building size and avoid the mudding problems associated with shelters without floors. A pictorial illustration of the entire structure and slat detail are shown in Figure 1.

Each shed roof sloped from the 2.1 m (7 ft) high building opening to the 1.5 m (5 ft) high back wall. The height of the building opening and roof slope were exaggerated to accommodate the camera used to record occupancy in the shelters. The camera had to be placed at an angle relative to the building front that required a minimum 2.1 m (7 ft) high opening to obtain a complete view of the floor. The corner posts were made of 10.2 by 10.2 cm (4 by 4 in) lumber; 5.1 by 10.2 cm (2 by 4 in) studs spaced 1.2 m (4 ft) on center framed the walls and 5.1 by 10.2 cm (2 by 4 in) rafters spaced 21.0 cm (24 in) on center completed the structural framing. The walls and roof underlayment were C-C exterior plywood, 9.5 mm (3/8 in) thick. The roof

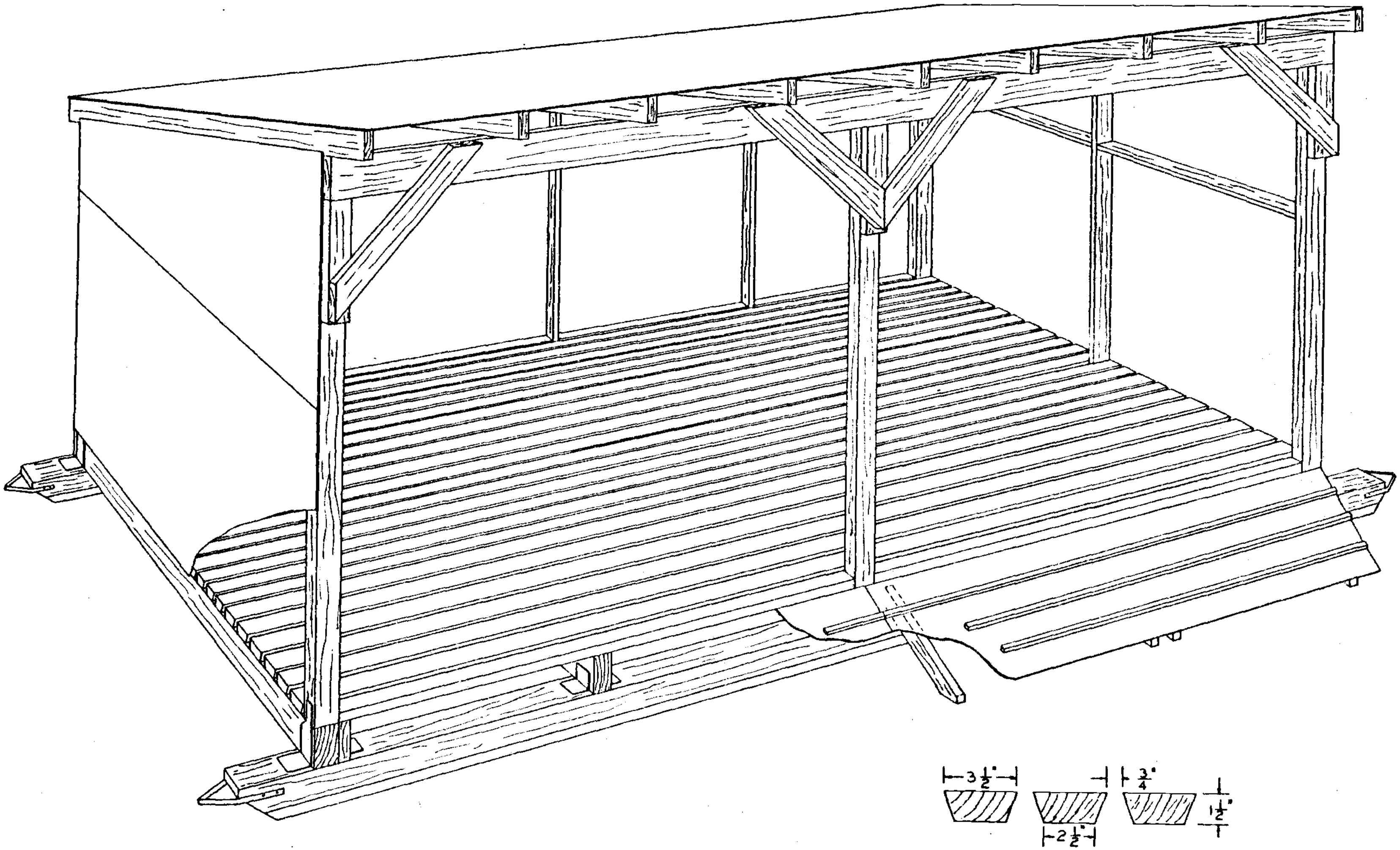

Figure 1. Slat detail and pictorial illustration of shelter.

sheathing was covered with 90 pound felt rolled asphalt roofing.

The slatted floor consisted of 5.1 by 10.2 cm (2 by 4 in) beveled slats oriented parallel to the building opening. Five 10.2 by 15.2 cm (4 by 6 in) floor joists supported the slats and were spaced 1.2 m (4 ft) on center. The floor joists were supported by 10.2 by 15.2 cm (4 by 6 in) skids made of laminated 5.1 by 15.2 cm (2 by 6 in) and 10.2 by 15.2 cm (4 by 6 in) members. Iron brackets were attached to the ends of each skid to facilitate easy movement of the building.

Floor slats and joists were designed to meet specifications recommended by the MWPS (MWPS-1, 1980; MWPS-3, 1974). Recommended design loads for joists and slats were 244.1 kg per m^2 (50 lb per ft^2) and 178.6 kg per lineal meter (120 lb per lineal foot), respectively. The recommended slat spacing of 1.9 cm (3/4 in) for floors supporting both ewes and lambs was also used (MWPS-3, 1974). Standard beam loading equations were used to design the slats, joists and rafters. As the design equations and calculations are basic to engineering science, they are not presented in this paper. The Midwest Plan Service (MWPS-1, 1980) provides a complete review of the design procedures. Entrance ramps were made from 5.1 by 10.2 cm (2 by 4 in) framing and 9.5 mm (3/8 in) C-C exterior plywood to facilitate easy access to the shelters by both ewes and lambs.

Both shelters were constructed by the author in the OSU Agricultural Engineering shop. The skids were first treated with a wood preservative and then laid out square on the floor. The floor joists were fastened to the skids with metal fasteners, and the wall framing erected. The slatted floor was installed next with two 16 penny galvanized nails per slat per joist. The sheathing was then nailed to the wall framing. The shelter was then moved outside due to overhead space and shop door limitations for installation of the rafters and roof sheathing. The addition of the rolled asphalt roofing and entrance ramps completed the construction.

One building was insulated with 2.5 cm (1 in) thick rigid styrofoam insulation in the walls and ceiling. Recommended insulation values intended specifically for cold sheep housing in the conditions of the Willamette Valley were not available. Typically such recommendations are based on outside relative humidity and inside and outside temperatures. The inside and outside temperature difference was not expected to be large due to the large open front and free choice occupancy of the shelters. The insulative value recommended to prevent condensation in cold sheep housing for an inside temperature of -17.8°C (0°F), an inside and outside temperature difference of 2.8°C (5°F) and relative humidity at 95 percent is 0.550 $m^2 \cdot K \cdot W^{-1}$ (3.40 $hr \cdot ft^2 \cdot °F \cdot Btu^{-1}$)(MWPS-3, 1974). The resistance value to heat transfer of the insulation used exceeded the recommended value, and was 0.953 $m^2 \cdot K \cdot W^{-1}$ (5.41 $hr \cdot ft^2 \cdot {}^{\circ}F \cdot Btu^{-1}$) (AMSPEC, 1975). The insulation was considered adequate to determine inside environment changes as measured by temperature and relative humidity.

Cost of building materials was approximately $525 for each building. An additional expense for insulation of approximately $140 was added to one shelter. Useful building life was estimated to be ten years. A complete economic analysis of shelter expense and return on investment depends upon knowing the effectiveness of the shelter in saving lambs. However, with the value of a lost lamb (as noted in the introduction) taken as $60, and disregarding labor costs, the equivalent values of the insulated and uninsulated shelters would be eleven and nine lambs, respectively. This indicates that if the shelters were to pay for themselves during their estimated useful life of ten years, the insulated and uninsulated shelters would need to save an average of 1.1 and 0.9 lambs per year, respectively.

Experiment Layout

The shelters were transported by tractor and trailor to two pastures, approximately 3.2 ha (8 ac) each. The pastures were located on the OSU campus between the Swine Center and the Veterinary Medicine Animal Isolation Laboratory

(VMAIL). Shelters were located within each pasture to take advantage of high ground, where bedding areas were expected to be, and oriented away from the prevailing wind directions. No animals were in either pasture when the shelters were placed. The buildings were leveled by jacking them up and blocking underneath the skids on the low sides. Plywood skirts were used to prevent lambs from crawling underneath the slatted floors from the downhill side. The skirting also reduced the effects of wind blowing under the structure and up through the slatted floor which helped to reduce drafts.

Boxes were built to protect the time lapse observation cameras from the weather and were erected 3.6 m (12 ft) high on posts 3.0 m (10 ft) directly in front of each shelter. Wires anchored the post from each front roof corner and a steel post set as an anchor into the field.

Power cord was strung on existing fences and additional steel fence posts to provide 110 volt power to charge the electronic flashes. Low voltage 18 gauge wire was also strung between the buildings to allow operation of the timer that simultaneously activated both cameras.

Data Observations

Occupancy data were obtained through the use of cameras equipped with electronic flashes. Two 35 mm single lens reflex (SLR) cameras equipped with 28 mm wide angle lenses were mounted in boxes in front of each building. Electronic flashes were provided to illuminate the structures at night. Automatic winders powered by six volt batteries advanced the film and prepared the cameras for the next exposure. A long interval pulse timer provided contact closure which set off the autowinder. Time lapse photography has previously been used to monitor animal occupancy of structures. Young, Hellickson, Reeves and Owens (1972) successfully used time lapse photography to record the preference and use of different types of free stalls by dairy calves.

The cameras provided a view of the floor area of the shelter from above. The numbers of lambs and ewes in each picture were recorded as the number of sheep sheltering at that time. Color slides were exposed on the hour, day and night, for the duration of the study. Three 24 exposure rolls and three 36 exposure rolls provided film for one week. This involved changing film six times per week in each camera. The film was developed uncut and analyzed as a film strip representing either 24 or 36 hours. This prevented changing the sequence of individual slides; each representing a specific hour.

Temperature and relative humidity data were obtained by installing one 7-day recording hygrothermograph in each building and one outside as a control. This arrangement provided data from which environment differences due to the shelter could be determined. Any difference between the insulated and uninsulated building could also be determined. The hygrothermographs were calibrated prior to installation and weekly throughout the study with a sling psychrometer and a dial test thermometer to insure accuracy.

General daily weather conditions such as rain, excessive wind or clear skies were also recorded on a daily basis, however no discrete measurements of rain or wind were recorded.

Animals

Fifty ewes of mixed breeds were obtained from Don Gnos, a local sheepgrower. Ewes were approximately one to two weeks from lambing and had been sheared around the vaginal area and down the back legs (tagged) in preparation of lambing. They were transported to OSU by truck and released into the pastures containing the shelters on February 19, 1980. The pastures provided sufficient feed for the ewes and lambs throughout the study. Although supplemental feed was provided, very little was consumed. Twenty-five ewes were pastured with each shelter, and remained in the same pasture throughout the study.

Care for the ewes and lambs during the study was provided jointly by the author and VMAIL personnel on the OSU campus. Ewes and lambs were observed twice daily, morning and evening. The ewes and lambs were counted, health problems were noted and ewes with birthing problems were given assistance at those times. Several ewes and lambs were doctored for foot rot at various times throughout the study. The lambs were eartagged for identification and their birth dates were recorded daily.

V. RESULTS

Weather

Weather data were recorded to determine if insulation in one building would alter the inside environment, and hence increase sheltering.

A comparison of measured meteorological data to the historical averages for those data showed the weather during the study was typical of that experienced during most Corvallis area winters. The historical averages of the daily maximum and minimum temperatures and mean hourly wind speeds were obtained from information compiled by the Agricultural Experiment Station at Oregon State University (OSU, 1981). The data were recorded at the OSU Hyslop agricultural farm located approximately 10 km (6 mi) from the study site. The average daily maximum temperatures for OSU in February and March are 9.7°C (49.5°F) and 12.2°C (54.0°F), respectively. Average daily minimum temperatures for OSU in February and March are 1.5°C (34.7°F) and 2.7°C (36.8°F), respectively. The mean hourly wind speed for both February and March is 6.4 $km \cdot hr^{-1}$ (4 $mi \cdot hr^{-1}$). The historical averages for temperature are based on 30 years of record, while the wind speed averages are based on 14 years of record (OSU, 1980). Rainfall data during the study were obtained from National

Oceanic and Atmospheric Administration (NOAA) records (NOAA, 1980); Oregon State University (Bates, 1981) provided wind velocity data. The total precipitation during the study was taken from daily precipitation records for the OSU Hyslop agriculture farm. The total number of rainy days during the study was 26, with a maximum daily amount of 2.82 cm (1.11 in) of rain falling on March 14. The total precipitation for the study was 13.3 cm (5.2 in)(NOAA, 1980). The mean hourly wind speed during the study was 4.7 $km \cdot hr^{-1}$ (2.9 $mi \cdot hr^{-1}$), and was obtained from hourly wind run data taken at Hyslop farm (Bates, 1981). Weather conditions recorded by the author were temperature, relative humidity and general sky conditions. Five of the ten non-rainy days were cloudless sunny days. The daily maximum temperature occurred near 2:00 pm Pacific Standard Time (PST), and averaged 10.6°C (51°F). The minimum temperature averaged 2.2°C (36°F) and occurred between 6:00 and 8:00 am PST. Average maximum and minimum relative humidities were 96 and 71 percent, respectively.

Daily maximum and minimum values were averaged over the study for each location. Table 3 lists the calculated means for each location of both temperature and relative humidity. The averages over all locations of each location mean were also calculated and included in Table 3.

The means were compared statistically through an analysis of variance hypothesis of equal means, between locations

Table 3. Temperature and relative humidity means.

Location	Temperature, °C				Relative Humidity, Percent			
	Maximum		Minimum		Maximum		Minimum	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
Uninsulated	10.0	0.6	2.8	0.6	97	1.0	71	2.0
Insulated	10.6	0.6	2.8	0.6	95	1.0	72	2.0
Control	10.0	0.6	1.7	0.6	97	<1.0	68	2.0
Mean of all locations	10.6	0.6	2.2	0.6	96	<1.0	71	1.0

of the uninsulated shelter, the insulated shelter and control. The results of the statistical analysis showed that although small differences existed between means of different categories, no differences were significant at the one percent level chosen for the test. Therefore, no difference could be established between the inside environment of the insulated building and the other locations. The effect of the insulation was negated by the circulation of outside air through the shelter. Consequently, no correlation could be made between the temperature or relative humidity data and shelter preference because no difference in environment between locations was detected.

The analysis of variance is included in Appendix B, and the appropriate analysis of variance tables are presented in Appendix B1. Appendix C contains the raw temperature and relative humidity data.

Lambing

The number of lambs born during the study totalled 69. One set of triplets and one pair of twins were born premature. Four of the premature lambs were born dead and the fifth died within 24 hours following parturation. Two other lambs were born deformed and later died within 24 hours. One lamb died due to exposure during its first night. Two lambs were bummed due to poor condition caused by weather and/or mismothering. The number of remaining lambs in the pasture at the conclusion of the study was 59, or 85.5 percent (59 of 69) of the total birth rate.

The total number of healthy lambs born during the study was 62, if the premature and deformed lambs are disregarded. The total number of lamb deaths from exposure and/or mismothering was three if it is assumed that the two bummed lambs would have died from the same causes. Therefore, the percentage loss from exposure and/or mismothering was 4.8 percent (3 of 62) of the lambs born, disregarding the other deaths.

Most births took place in the pasture. However, one birth positively took place inside the uninsulated shelter on March 7. A ewe gave birth to one lamb inside the shelter but unfortunately was frightened out by VMAIL personnel during the daily inspection. The ewe then gave birth to a second lamb adjacent to the shelter. No births were recorded by the cameras used to monitor the occupancy of the buildings. One ewe and newborn lamb were discovered in the insulated shelter on the morning of March 12. While it is not positive that the lamb was born in the shelter, the lamb and the ewe sheltered on the night the lamb was born. They were in the shelter as was the placenta from the ewe. No pictures of that shelter were available for that particular night due to an equipment malfunction. Other cases of blood and parts of placenta and afterbirth were noted at times in each shelter and indicated that ewes sometimes sheltered soon after lambing. The afterbirth is usually expelled by ewes within two to three hours after lambing (Klinger, 1981).

All other ewes lambed at various locations throughout the pastures. Many lambed near the rest of the ewes at night, where most were bedded down. Specific locations within the pastures of each lamb birth were not recorded.

Occupancy of the Shelters

The ewes were introduced into the pastures February 19, 1980, and were expected to start lambing one to two weeks following that date. Although one lamb was born that night, the majority of lambing took place between February 28 and March 15. The sheep remained in the pastures and were observed for 36 days.

A break-in period was expected while the ewes became accustomed to the shelters and familiar with their surroundings. However, after five days, the break-in period could have overlapped with the projected lambing schedule since no ewes had yet sheltered. Therefore, a block of salt was placed into each building on the sixth day for the remainder of the study. Before the introduction of salt, the sheep did not realize the shelter was a dry area and suitable for avoiding rain and wind. Ewes began to shelter sporadically at first after the sixth day, and by the 18th day were more accustomed to both the shelter and the pasture.

Analysis of the data began with the 18th day and continued through the end of the study. The first 17 days were not analyzed due to the infrequent and sporadic sheltering by both ewes and lambs. The photographic data verify that ewes and lambs were using the shelters for bedding purposes during the night by the 18th day.

Two distinct sheltering periods existed for the days of the study analyzed. Sheltering during the night hours was common, while sheltering during the daylight hours was intermittent. Consequently, the data were divided into 2 twelve-hour periods (7 pm through 6 am, and 7 am through 6 pm).

Ewe and lamb occupancies were averaged over the 12 hour period from 7 pm through 6 am each night. The numbers of ewes and lambs in each picture were counted and recorded for that hour. The average number of ewes or lambs sheltering was taken as the total number counted divided by the number of hours (pictures). The maximum number of ewes or lambs sheltering was also recorded. The maximum number of animals that occurred in any one picture over a 24 hour period from 12 pm to 12 pm was recorded as the maximum number of animals that sheltered during the night.

The average and maximum numbers of ewes and lambs that sheltered were then expressed as a percentage of the number of respective animals available in each pasture. The number of ewes remained nearly constant from day to day, however the number of lambs increased as more lambs were born. Appendix D lists the numbers of lambs and ewes available for shelter in each pasture on each day of the study.

The average number and maximum number of ewes sheltering for each 7 pm through 6 am period are expressed as a percentage of the available sheep that could have sheltered, and are presented in Figures 2 and 3, respectively. The same data for lambs are presented in Figures 4 and 5. Appendices E through H contain additional tabulated data, and list the occupancy rates of each shelter for both ewes and lambs.

The averages over the study of the daily sheltering data presented in Figures 2 through 5 are presented in Table 4. Columns 1 and 2 in Table 4 present the averages over the study of the daily average and daily maximum sheltering percentages for ewes and lambs.

No difference in the inside environment was detected by measured data, therefore as was noted earlier, no explanation could be made about the differences in sheltering percentages between the insulated and uninsulated shelters. An average sheltering percentage that reflects the reaction of ewes and lambs to slatted floor shelters should include both shelters. The combined averages for the shelters is shown in column 3.

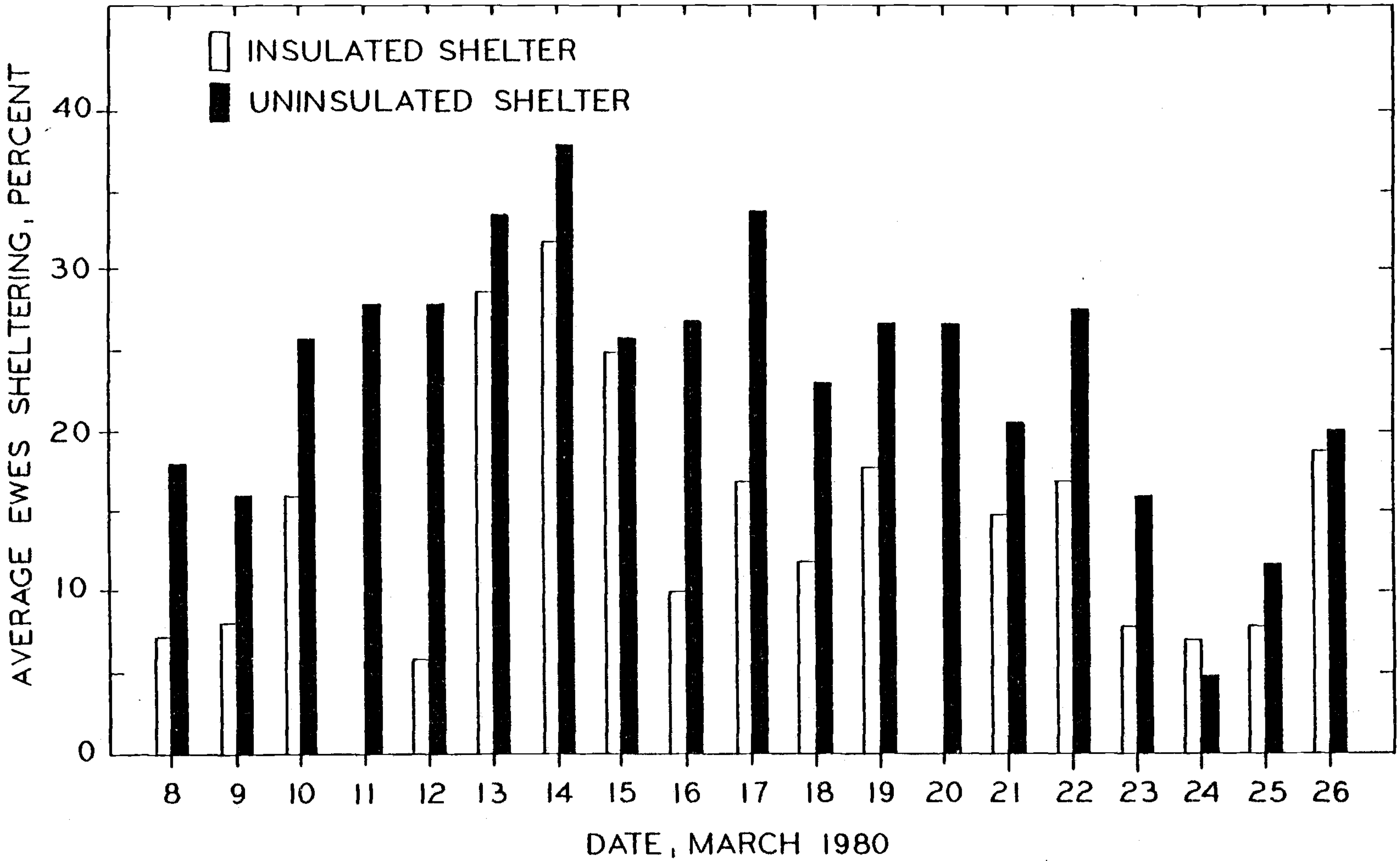

Figure 2. Average number of ewes that sheltered each night, expressed as a percentage of the total number of ewes in the pasture. (Insulated shelter data not available for March 11 and 20.)

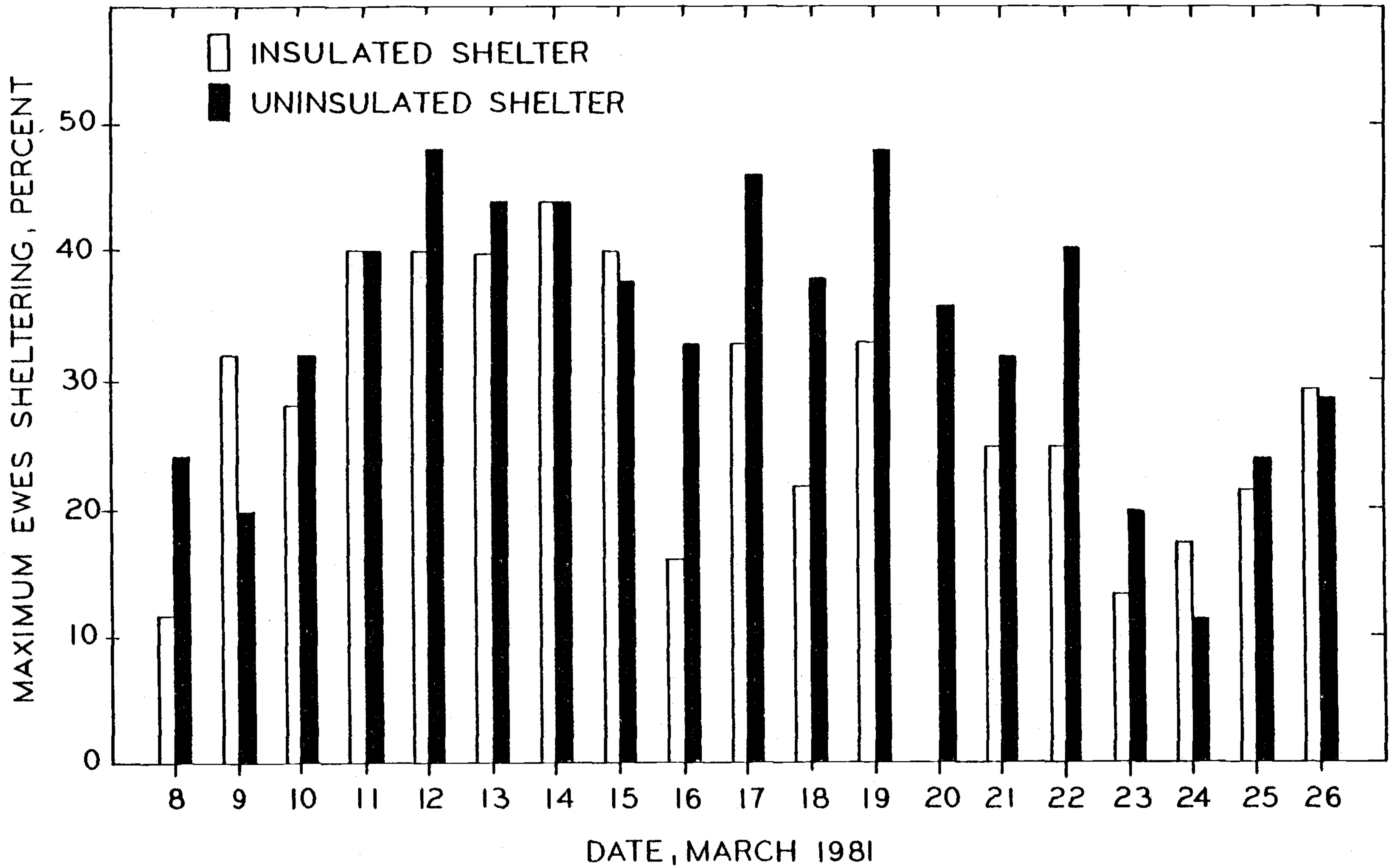

Figure 3. Maximum number of ewes that sheltered during a 24 hour period, expressed as a percentage of the total number of ewes in the pasture. (Insulated shelter data not available for March 20.)

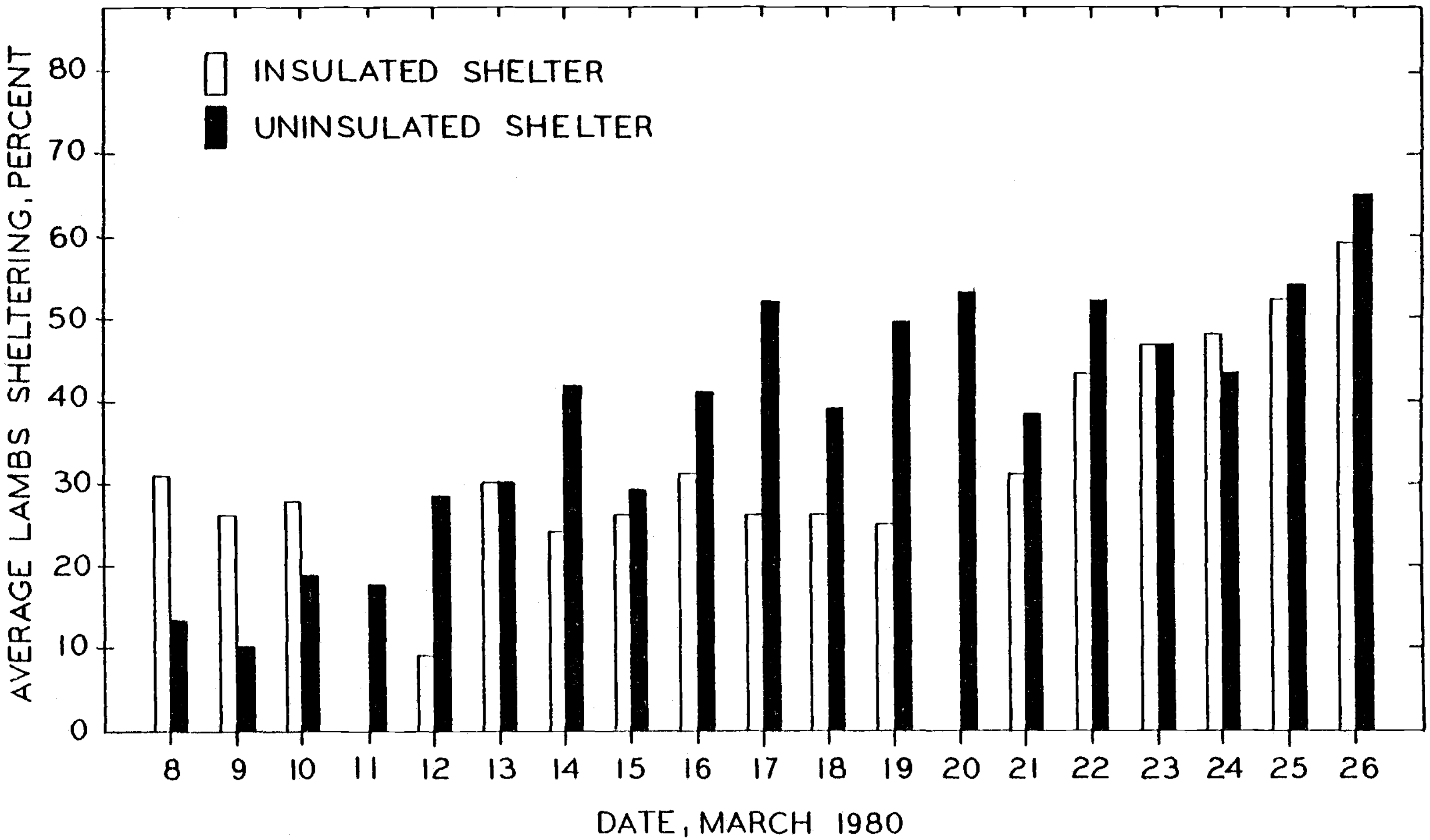

Figure 4. Average number of lambs that sheltered each night, expressed as a percentage of the total number of lambs in the pasture. (Insulated shelter data not available for March 11 and 20.)

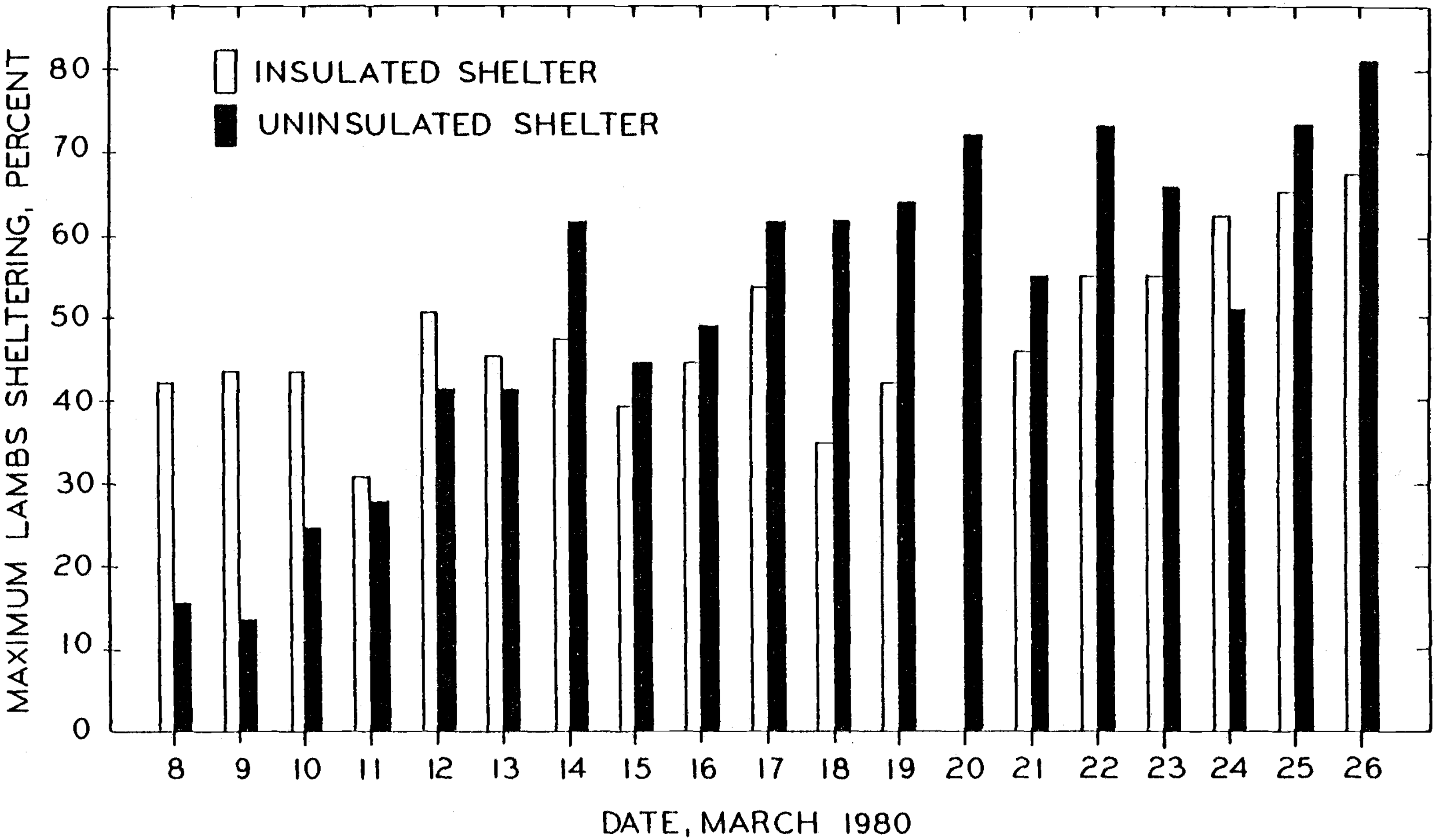

Figure 5. Maximum number of lambs that sheltered during a 24 hour period, expressed as a percentage of the total number of lambs in the pasture. (Insulated shelter data not available for March 20.)

Table 4. Daily values of sheltering data averaged over the study.

	Ewe sheltering as a percentage of total ewes (%)			Lamb sheltering as a percentage of total lambs (%)		
	I[1]	U[2]	B[3]	I[1]	U[2]	B[3]
Daily average	14.9	23.9	19.6	32.8	38.0	35.5
Daily maximum	28.3	34.0	31.2	49.1	52.3	50.7

[1] Insulated

[2] Uninsulated

[3] Both shelters; the average of the data used in columns 1 and 2. (Values in column 3 reflect averages of the data and may not be the averages of the numbers in columns 1 and 2 due to differences in sample size.)

To summarize, these values indicated that on the average, 19.6 percent of the available ewes and 35.5 percent of the available lambs sheltered each night throughout the study. The average maximum percentage of ewes and lambs that sheltered at some time during the night was 31.2 and 50.7 percent, respectively.

VI. DISCUSSION

Partial funding for this project was requested from the Oregon Sheep Commission, which rejected the proposal. The decision not to fund this project was in part influenced by the opinions of several sheepgrowers in the state of Oregon who believed that ewes would not, by free choice, seek and enter a shelter such as those used in this study. They were further convinced that ewes would not lamb in such a shelter.

This study has shown, however, that by free choice, ewes will lamb and seek protection in slatted floor buildings, and that lambs will also utilize the same shelters. These results could benefit both large and small sheep operations. Slatted floor shelters could be used in large sheep operations where the owner/operator physically cannot or chooses not to inspect the flock each day during lambing. The smaller sized operations of perhaps 25 to 50 ewes owned by someone whose primary source of income may not be from sheep, could also benefit. Slatted floor shelters could provide a dry, draft-free lambing facility for the ewes while the owner is away from the flock. The use of shelters of this type by operators who currently do not supply intense labor and management to their lambing flocks would not increase the labor involved with their present system. The shelters could provide the advantages of increased lamb survival, dry, disease-free lambing areas and the chance for increased profit from the lamb flock at a low cost. The cost of each shelter, approximately $525, translates into a required payback approximately equal to saving just one lamb per year over the estimated building life of ten years. Additional research can hopefully provide a more exact prediction of the savings expected from the utilization of slatted floor pasture shelters.

Results of the mail survey indicate that a majority of lambs born in winter rainfall areas are not provided shelter at birth. Some operators jug the lambs shortly after birth for a period of 24 to 48 hours; however, the birth itself is without shelter. In those situations where the operator does not wish to or cannot provide the management, labor and facilities required to jug lambs soon after birth, lambs may only have available what natural shelter they can find. Shelter in grass seed fields may be minimal or even nonexistent. The losses, as reported by the survey data, are expected to be very sensitive to the competence and dedication of the individual owner/operator. Personal observations revealed an extremely wide range of management schemes, facilities and equipment used in sheep operations. Many smaller operations relied on using barns and other buildings not specifically designed for sheep handling. Older barns adapted to jugging and caring for newborn lambs and expectant ewes were often used.

Information generated by the survey makes possible general statements regarding lambing management and lamb losses in winter rainfall areas. The reported percent losses of lambs for pasture, and combination of pasture and shed, were slightly less than the overall reported losses for all winter rainfall area sheepgrowers. Shed lambing allows better record keeping than large pasture lambing operations. Operators of large pasture operations may or may not be able to exactly determine birth and death rates experienced in the pastures because all lamb deaths may not be discovered. The numbers for pasture operations could therefore include generalized percentages rather than percentages based on exact births and deaths.

The results obtained from this study and those in the literature may not be directly comparable. Most studies reviewed used shelters of either natural hedge or man-made windbreaks. The effort required of a ewe to shelter by standing next to a windbreak is different from that required to step up onto a slatted floor in a building. The ewe must leave the pasture and step onto an artificial surface. The distinct difference could cause differences in sheltering rates. Also, the proximity of the sheep to the shelter varied from study to study. In those studies where hedges were used and spaced a distance of 29 m (77 ft), the chance of sheep sheltering was much greater than it would have been if a building was used for shelter.

The furthest sheep could be from shelter in this study was approximately 366 m (1200 ft). Stocking rates were also much higher in other studies than they would be under pasture conditions. The study by Alexander, Lynch and Mottershead (1979) is an example of ewes sheltering to lamb. Unshorn ewes in that study sheltered very little, one to five percent. However, lambing in shelter was much higher, 15.6 and 17.2 percent for day and night values, respectively. The results showed a clear tendency for unshorn ewes to purposely seek shelter while lambing. They will seek shelter to lamb even when, as that study showed, the weather is not severe enough to cause the ewe to seek shelter for herself. So while the literature provided an assessment of the fact that 1) sheep seek shelter under wet winter conditions, and 2) they seek shelter in which to lamb, not much was revealed about what a ewe would do with a building as a free choice pasture shelter. Specifically, nothing was found regarding slatted floor free choice buildings. Free choice movement by ewes to slatted floor shelters has not previously been reported, and the results of this study show promise for slatted floor shelters for pasture operations.

The first 17 days of data for this study were not analyzed due to the infrequent sheltering that took place. A period of time during which sheltering would be low was expected until the ewes became familiar with their surroundings. The ewes quickly became used to the flash units on the data cameras. Flashes were set off on the hour, 24 hours a day. Ewes standing next to the shelter on the first three or four days were startled and moved off a short distance when the flash was set off. The flash exposure and noise of the autowinder that advanced the film had no noticeable effect on the sheep after approximately one week. After three weeks, ewes and lambs would often remain in the shelter while the film was changed in the cameras.

The results of this study were likely affected by transporting the pregnant ewes close to their lambing date. The ewes were expected to lamb beginning approximately two weeks after the beginning of the study. However, one ewe lambed the very first night, and two more lambs were born during the first week. The rates of sheltering and lambing in shelter would likely have been higher had the sheep been accustomed to and using the shelters for a longer period of time prior to lambing.

The period of adjustment to the pastures and shelters was shortened by the use of salt. During the first two or three days following the introduction of salt, the ewes which were sheltering during the day were primarily in the shelters to lick salt. The ewes soon learned, however, that the shelters were dry and provided protection from the wind. The data clearly showed that after approximately the 17th day, occupation at night by the sheep was primarily for bedding purposes. Many lambs and ewes spent a large part of the night bedded in one location in the shelter. Distinction between individual sheep was not made, however, and exact sheltering times for individual sheep were not determined. The wooden slat floors of the buildings were often wet after a night of occupancy by ewes and lambs that entered with wet coats. The floors when wet were slightly slippery, and ewes and lambs would lose footing when frightened into attempting to run. Excessive slipping was not observed if normal activity was not disrupted. The slatted floors were always quite clean and manure was readily worked through the slat openings by the action of the sheep. No manure build up was experienced in either shelter.

No attempt was made to statistically distinguish between the difference in sheltering between the two shelters, due to the analysis of the temperature or relative humidity data. The environment in either shelter, as measured by these data, was not significantly different from the other. Therefore the effect of the insulation was considered to be negligible. This does not indicate that insulation should not be used for all shelters. Conditions experienced in other types of livestock housing often require insulation to avoid condensation on the inside shelter surfaces.

The sheltering rates of the uninsulated building for ewes and for lambs were higher than those for the insulated shelter. This was true for all categories of average and maximum ewes sheltering, and average and maximum lambs sheltering. The author's opinion is that factors unique to each pasture and the particular shelter location within each pasture, related to the bedding area used by the ewes, were the causes for these differences. The bedding area of the sheep in the pasture of the uninsulated shelter varied from 20 to 60 m (22 to 66 yards) away from the shelter front. The area the sheep used to bed down in the pasture of the insulated building was somewhat further away at 50 to 90 m (55 to 98 yards). Bedding location also seemed to vary more from night to night in the pasture of the insulated building. The emphasis noted by Lynch and Alexander (1977) previously, is therefore reiterated. Shelter location plays an important part in the use and occupation of shelter. The shelters in this study were placed prior to the introduction of sheep to the pastures. Better results most likely would have been obtained by placing shelters in pastures in which the sheep had already defined their bedding locations.

Figures 2 through 5 illustrate that lambs in both shelters tended to shelter at a higher rate than the ewes. The sheltering percentages of the lambs increased throughout the study while ewe sheltering rates were more varied and tended to decrease towards the end of the study. This correlates with observations made in the field that as the number of lambs sheltering in a shelter at any particular time increased, the number of ewes in the shelter tended to decrease.

Lamb sheltering increased towards the end of the study even though few lambs were being born during that period. The increases shown in Figures 4 and 5 do not reflect increased sheltering due to more lambs being available for shelter. They express the percentages of the available lambs for shelter, and therefore reflect not more lambs, but a higher percentage of total lambs that were sheltering. The highest sheltering rate for lambs occurred on the last night of the study. The average shelterings of lambs for the insulated and uninsulated shelters on that night were 58.6 and 64.2 percent, respectively. The maximum numbers of lambs sheltering on the same night, expressed as a percentage of those available, were 68.8 (22 of 32) and 81.5 (22 of 27) percent for the insulated and uninsulated shelters, respectively. Figures 4 and 5 show that the rate of increase in the sheltering percentages for lambs had not peaked by the end of the study.

VII. SUMMARY AND CONCLUSIONS

Summary

The success of every ewe-lamb operation is largely dependent upon the survival of newborn lambs. Lambs born in pastures that experience winter rainfall may receive essentially no care other than what is given by the ewe, and no shelter other than what often the minimal protection available natural shelter provides. The use of shelters in pasture lambing operations of this type could increase the chances of survival for newborn lambs. A review of literature has shown that shelter is beneficial to newborn and young lambs, and that ewes will seek out shelter in which to lamb. The literature has not evaluated, however, the free choice movement of sheep to buildings as was reported in this study. The results of this project provide an additional alternative to pasture shelters, different from what has previously been established. Slatted floor portable shelters have additional advantages over natural shelter and buildings without floors, such as a mud-free building interior, a dry, draft-free lambing area and an ease in building movement which allows flexibility for a wide variety of operations. Not all sheep growers choose to, or are able to shed lamb their ewes. The survey conducted as part of this study indicated that a majority of the lambs born in winter rainfall areas are born outdoors with little or no shelter at the time of birth. The reluctance of grass seed pasture owners to allow buildings to be erected in their pastures, and the mud and associated disease problems associated with non-floor shelters are common deterrents to pasture shelters.

Two shelters were built and field tested to determine the reaction of lambing ewes under free-choice pasture conditions. The design incorporated slatted floors to eliminate muddy conditions inside the shelters. The shelters were portable to make them more acceptable to both sheepgrowers and grass seed farmers by minimizing the disruption of the grass seed operation. The effect of insulation on the inside shelter environment was determined by insulating one shelter. The results showed that overall, ewes and lambs sheltered at night for bedding purposes at averages of 19.6 and 35.5 percent, respectively. The average maximum percentages of sheltering for ewes and lambs were 31.2 and 50.7 percent, respectively. Due to the openness and free choice occupancy of the shelters, any beneficial effects the insulation may have provided was negated by the exchange of shelter air with the outside environment.

Lambing season for many sheepgrowers does not take place year around. With few changes, the shelters as designed could easily be adapted to other uses in the off-season. The slatted floors provide a dry environment sheltered from wind, and the ease in shelter movement provides flexibility in shelter placement. The installation of a creep gate across the shelter front (which would allow only lambs to pass through) and a feeder along the back wall, would allow the shelter to be used as a creep feeder. The slatted floors would particularly lend the shelters to this type of use because of their size and the cleanliness a slatted floor provides. The shelters have a floor area of 11.9 m^2 (128 ft^2) and would provide creep feeder space for 64 to 85 lambs at the 0.14 to 0.19 m^2 (1.5 to 2.0 ft^2) recommended by the MWPS (MWPS-3, 1974).

Lambs could be confined to the shelter during a finishing period when they are fattened prior to market. The available floor area would provide enough space for approximately 25 to 30 feeder lambs at the 0.37 to 0.46 m^2 (4 to 5 ft^2) per feeder lamb on slatted floor confinement recommended by the MWPS (MWPS-3, 1974).

The shelter could also easily be used as a small jugging facility for newborn lambs or for lambs with particular health problems. Sick or weak lambs or ewes could also be confined to the shelter during periods in which they received medication or special care.

Other particuar uses would be determined by each sheepgrower's individual needs and management schemes.

Conclusions

Specific conclusions drawn from this research, survey and literature review are:

1. A majority of the lambs born in winter rainfall areas are born outdoors with little or no shelter at the time of birth.
2. Losses of newborn lambs by winter rainfall sheep-growers are approximately 16 percent of the lambs born.
3. Available literature indicates that shelter is beneficial to ewes and newborn lambs.
4. Slatted floor portable shelters are acceptable to lambing ewes. Ewes seeking out a place in which to lamb will lamb by free choice and shelter with newborn lambs on wooden slat floors. One ewe positively lambed in shelter while another was discovered with a newborn lamb in shelter the morning after the lamb's birth.
5. Ewes and lambs utilized slatted floor free choice portable shelters at night for bedding purposes. Ewes and lambs sheltered on the average 19.6 and 35.5 percent, respectively. The average of the maximum percentage of ewes and lambs that sheltered each night were 31.2 and 50.7 percent, respectively.
6. The strategic location of pasture shelters near

known bedding areas may increase ewe and lamb sheltering.

7. Lambs sheltered to avoid sudden weather changes, in particular intense rain periods, whether or not the ewe sheltered. The sheltering percentage of lambs changed from 11.5 (3 of 26) to 53.9 (14 of 26) percent within 15 minutes after the beginning of one rainstorm.

VIII. RECOMMENDATIONS FOR ADDITIONAL RESEARCH

The acceptance by ewes and lambs of portable pasture shelters with wooden slat floors has been verified by this study. While the feasibility of the shelters has been shown, further research is necessary before definite conclusions can be made regarding their economic benefits.

The economic considerations and return on investment of the shelters are dependent upon several factors. Research is needed to determine specific lamb survival rates for ewes lambing with and without pasture free choice shelter over a period of time long enough to establish a statistically sound data base. The weight gain and performance of each individual lamb as well as the lambing location for each ewe from year to year should also be analyzed.

Studies conducted with lambing ewes and free choice pasture shelters would benefit from the use of pastures in which ewes have previously defined bedding and lambing areas. The shelters could then be strategically located.

Recommended values for floor space allotment per lambing ewe are needed for pasture lambing shelters. The optimum moving schedule of portable pasture shelters to minimize pasture damage is also needed.

A specific recommendation for change in the design of the shelters used in this study is roof height. The roof height should be reduced to 1.2 m (4 ft) for the shelter front, and 1.1 m (3.5 ft) for the shelter back wall. This change would result in a lower shelter cost through a reduction in building materials needed. A reduction in drafts and air circulation in and out of the shelter may also be realized, which could create a warmer inside environment and hence increase ewe and lamb sheltering. However, this change would increase the difficulty of an operator entering the shelter to care for animals or perform shelter maintenance or inspection due to the low roof height. The roof height and slope used in this study were extended to accomodate the camera used to record sheep occupancy. The camera angle relative to the building front required a minimum 2.1 m (7 ft) high opening to obtain a complete view of the floor.

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APPENDICES

APPENDIX A. Survey post card.

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY CARD
FIRST CLASS PERMIT NO. 1 CORVALLIS, OR 97331

POSTAGE WILL BE PAID BY ADDRESSEE

Martin Nicholson
Agricultural Engineering Dept.
Gilmore Hall
Oregon State University
Corvallis, OR 97331

Mr. Nicholson - Here are figures on our sheep operation.

	Winter 77-78	Winter 78-79
Total number of sheep	______	______
number of ewes	______	______
number of feeders	______	______
lambs born	______	______
lambs lost	______	______

We lamb in shed ______, pasture ______, combination ______,

Other ________________________________

Name ______________________

Address ______________________

____

APPENDIX B. Temperature and relative humidity statistical analysis

The purpose of the statistical analysis of the temperature and relative humidity data was to determine if significant differences existed between the means for each location. Differences between means would allow comparisons of shelter preference and environment differences. The analysis required four tests: one each for maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity. A complete review of the analysis of variance test for the hypothesis of equal means was presented in Dixon and Massey (1969). The test determines if there is a significant difference between the variance between category means, and the variance of the overall mean. The assumption of equal means between categories is rejected if the difference in variances is significant.

A hypothesis was first formulated that the means were equal for each category of insulated, uninsulated and control. The level of significance (α) was chosen as $\alpha = 0.01$, or a one percent chance of rejecting the hypothesis if it was true. The test was evaluated with the F statistic, which was equal to the mean square estimator of the variance between means of categories, divided by the mean square estimator of the overall variance within categories. The critical region for rejecting the hypothesis is F larger than

$F_{1-\alpha}(k-1, \Sigma n-k)$, where α is the level of significance of the test, k is the number of categories (three in each test), and Σn is the total number of observations from all categories (101 in each test). The degrees of freedom were k-1 and $\Sigma n-k$ for between category means and the overall mean, respectively. The hypothesis of equal means cannot be accepted if the computed F statistic lies in the critical region. The critical F statistic in each test was $F_{0.99}(2,98)$, and was equal to 4.83 (Dixon and Massey, 1969). Therefore, the critical region was $F>4.83$.

The analysis of variance tables and the respective computed F statistics are presented in Appendix B1. The F statistic was not in the critical region in any test, therefore the hypothesis of equal means was not rejected for each test. Statistically, this indicated that the differences between the computed means of the data for each location were not significant enough to allow comparisons of shelter preference with environment differences.

Appendix B1. Analysis of variance tables.

	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Maximum Temperature				0.18
category means	9.46	2	4.73	
within	2511.77	98	25.63	
Total	2521.23	100		
Minimum Temperature				0.97
category means	60.85	2	30.43	
within	3080.79	98	31.44	
Total	3141.64	100		
Maximum RH				3.31
category means	65.18	2	32.59	
within	963.88	98	9.84	
Total	1029.06	100		
Minimum RH				0.86
category means	221.02	2	110.51	
within	12552.82	98	128.09	
Total	12773.84	100		

APPENDIX C. Temperature and relative humidity data.

		Temperature, °C						Relative Humidity, Percent					
		Maximum			Minimum			Maximum			Minimum		
Day of Study	Date	I[1]	U[2]	C[3]	I	U	C	I	U	C	I	U	C
1	Feb 20	--	--	--	--	--	--	--	--	--	--	--	--
2	21	5.6	6.1	4.4	-3.3	-2.2	-3.3	96	98	100	80	82	82
3	22	7.8	8.3	6.7	0.0	1.1	0.0	98	98	98	82	84	83
4	23	11.1	12.2	11.1	2.2	2.8	0.6	98	98	98	70	70	68
5	24	14.4	15.0	13.3	5.0	6.1	4.4	96	98	97	70	70	70
6	25	8.9	8.3	8.3	6.1	6.7	5.6	98	98	98	96	95	95
7	26	14.4	13.9	13.3	8.3	7.8	7.8	98	98	98	88	88	88
8	27	12.2	11.7	--	8.3	6.1	--	98	98	--	90	88	--
9	28	11.7	11.1	9.4	1.7	3.9	-0.6	96	100	95	68	69	63
10	29	11.7	11.7	11.1	0.6	0.6	-1.7	100	100	100	72	70	69
11	Mar 1	10.6	10.0	10.0	1.7	2.2	1.1	98	100	100	80	80	77
12	2	15.6	15.0	15.6	5.0	5.0	4.4	98	100	98	56	54	53
13	3	13.3	12.8	12.8	6.1	6.1	5.6	93	100	98	80	79	72
14	4	13.3	12.8	13.3	5.6	6.7	5.6	98	100	97	64	63	63
15	5	10.6	10.0	--	3.3	3.3	--	100	100	--	82	79	--
16	6	10.6	10.0	11.1	1.7	2.2	2.2	100	100	98	70	68	66
17	7	12.8	11.1	12.2	2.2	2.2	1.1	98	100	100	72	70	62
18	8	11.1	10.0	11.1	5.6	4.4	4.4	96	100	97	65	67	65
19	9	13.3	12.2	12.8	0.0	0.0	-1.1	96	100	100	66	65	60
20	10	8.9	7.8	7.8	3.9	3.9	3.3	100	100	98	82	87	82
21	11	7.2	6.7	6.7	2.2	1.7	1.7	96	100	97	74	76	70
22	12	5.6	5.6	--	0.6	0.6	--	96	92	--	84	78	--
23	13	6.7	6.7	6.1	2.2	2.8	1.1	92	90	96	80	80	76
24	14	8.3	7.2	7.2	1.1	-1.1	-1.1	95	95	96	56	56	52
25	15	5.6	6.1	4.4	-0.6	1.1	-1.7	96	94	98	80	77	78
26	16	8.9	9.4	8.3	0.0	1.1	-1.7	99	96	98	65	66	64
27	17	7.8	8.3	7.2	2.8	5.0	2.2	91	92	96	77	77	77
28	18	10.0	10.0	8.9	1.1	2.8	1.1	95	95	96	65	66	65
29	19	10.0	10.0	--	3.3	4.4	--	88	92	--	72	75	--
30	20	8.9	5.6	7.2	0.6	1.7	2.2	92	95	98	72	72	70
31	21	11.1	11.7	11.7	1.1	1.7	1.1	96	96	98	72	68	70
32	22	12.2	12.8	12.2	3.3	3.9	2.8	95	94	95	66	65	64
33	23	10.0	11.1	10.0	1.7	2.2	1.7	88	92	90	59	59	60
34	24	12.2	12.8	12.2	-1.1	-0.6	-2.2	88	95	97	48	46	49
35	25	15.0	15.6	15.6	1.1	1.7	0.0	85	95	95	44	45	43
36	26	10.0	10.0	10.0	3.3	4.4	1.1	90	94	94	67	64	65

[1]insulated; [2]uninsulated; [3]control.

APPENDIX D. Ewes and lambs available for shelter.

Day of Study	Date	Insulated ewes	Insulated lambs	Uninsulated ewes	Uninsulated lambs
1	Feb 20	25	0	25	0
2	21	25	1	25	0
3	22	25	2	25	0
4	23	25	2	25	1
5	24	25	2	25	1
6	25	25	2	25	1
7	26	25	2	25	1
8	27	25	3	25	1
9	28	25	3	25	2
10	29	25	3	25	3
11	Mar 1	25	3	25	4
12	2	25	4	25	5
13	3	25	6	25	8
14	4	25	6	25	8
15	5	25	6	25	9
16	6	25	12	25	12
17	7	25	13	25	16
18	8	25	14	25	19
19	9	25	16	25	21
20	10	25	16	25	24
21	11	25	19	25	24
22	12	25	21	25	24
23	13	25	24	25	24
24	14	25	25	25	24
25	15	25	25	24	24
26	16	25	26	24	24
27	17	24	26	24	24
28	18	24	28	24	24
29	19	24	30	25	26
30	20	24	32	25	26
31	21	24	32	25	27
32	22	24	32	25	27
33	23	24	32	25	27
32	24	24	32	25	27
35	25	24	32	25	27
36	26	24	32	25	27

APPENDIX E. Insulated shelter average occupation data.

		Ewes		Lambs	
Day of Study	Date (March)	Average Number	Percent	Average Number	Percent
18	8	1.8	7.2	4.3	30.7
19	9	2.0	8.0	4.1	25.5
20	10	4.0	16.0	4.4	27.6
21	11	--	--	--	--
22	12	1.6	6.3	1.8	8.6
23	13	7.3	29.0	7.2	29.9
24	14	8.0	32.0	6.0	24.0
25	15	6.2	24.7	6.5	26.0
26	16	2.4	9.7	8.1	31.4
27	17	4.0	16.7	6.7	25.6
28	18	2.8	11.7	7.3	25.9
29	19	4.4	18.3	7.5	25.0
30	20	--	--	--	--
31	21	3.6	15.0	9.9	31.0
32	22	4.0	16.7	13.6	42.5
33	23	1.9	7.9	14.7	45.8
34	24	1.7	7.1	15.3	47.9
35	25	1.9	7.8	16.5	51.6
36	26	4.7	19.4	18.6	58.6

APPENDIX F. Uninsulated shelter average occupation data.

		Ewes		Lambs	
Day of Study	Date (March)	Average Number	Percent	Average Number	Percent
18	8	4.4	17.6	2.5	13.3
19	9	4.0	16.0	2.2	10.3
20	10	6.4	25.7	4.6	19.1
21	11	7.0	28.0	4.3	18.1
22	12	6.9	27.7	7.0	29.1
23	13	8.4	33.7	7.3	30.2
24	14	9.6	38.3	10.2	42.4
25	15	6.3	26.3	7.0	29.1
26	16	6.5	27.1	9.0	41.0
27	17	8.2	34.0	12.6	52.4
28	18	5.5	22.9	9.3	38.6
29	19	6.8	27.3	12.8	49.0
30	20	6.8	27.3	13.8	53.2
31	21	5.3	21.0	10.3	38.3
32	22	6.9	27.7	14.0	51.6
33	23	4.1	16.3	12.3	45.7
34	24	1.3	5.0	11.5	42.6
35	25	2.9	11.5	14.5	53.7
36	26	5.0	20.0	17.3	64.2

APPENDIX G. Insulated shelter maximum occupation data.

Day of Study	Date (March)	Ewes			Lambs		
		Max No.	No. Hours[1]	%	Max No.	No. Hours[1]	%
18	8	3	3	12.0	6	4	42.9
19	9	8	1	32.0	7	1	43.8
20	10	7	2	28.0	7	1	43.8
21	11	10	1	40.0	6	1	31.6
22	12	10	1	40.0	11	1	52.4
23	13	10	1	40.0	11	1	45.8
24	14	11	3	44.0	12	1	48.0
25	15	10	2	40.0	10	1	40.0
26	16	4	3	16.0	12	1	46.2
27	17	8	1	33.3	14	1	53.8
28	18	5	1	20.8	10	3	35.7
29	19	8	2	33.3	13	1	43.3
30	20	-	-	--	-	-	--
31	21	6	1	25.0	16	1	46.9
32	22	6	2	25.0	18	1	56.3
33	23	3	5	12.5	18	3	56.3
34	24	4	1	16.7	20	4	62.5
35	25	5	1	20.8	21	1	65.6
36	26	7	2	29.2	22	1	68.8

[1]Total number of hours the maximum number of animals indicated was observed.

APPENDIX H. Uninsulated shelter maximum occupation data.

		Ewes			Lambs		
Day of Study	Date (March)	Max No.	No. Hours[1]	%	Max No.	No. Hours[1]	%
18	8	6	2	24.0	3	7	15.8
19	9	5	2	20.0	3	4	14.3
20	10	8	2	32.0	6	3	25.0
21	11	10	1	40.0	7	1	26.9
22	12	12	2	48.0	10	1	38.5
23	13	11	3	44.0	10	3	38.5
24	14	11	4	44.0	15	1	57.7
25	15	9	1	37.5	11	1	42.3
26	16	8	3	33.3	12	1	46.2
27	17	11	2	45.8	15	2	57.7
28	18	9	1	37.5	15	1	57.7
29	19	12	1	48.0	17	2	65.4
30	20	9	1	36.0	19	1	73.1
31	21	8	1	32.0	15	1	55.6
32	22	10	1	40.0	20	1	74.1
33	23	5	4	20.0	18	1	66.7
34	24	3	3	12.0	14	3	51.9
35	25	6	1	24.0	20	1	74.1
36	26	7	1	28.0	22	1	81.5

[1] Total number of hours the maximum number of animals indicated was observed.