Neonatal Lamb Mortality in the Gisborne Area

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HEAVY losses of lambs at or within seven days of birth have long been recognised in the Gisborne area. There are, however, no accurate figures on the extent or nature of these losses although it is known that in New Zealand abortion and neonatal mortality in lambs are associated with a variety of infections including Brucellosis, Vibriosis, Listerellosis and Type 2 abortion, (McFarlane et al (1952), Hartley et al (1954 a-b), Jebson et al (1954) and Buddle and Boyes (1954). Further known causes of ante-parturient, parturient and immediate post-parturient deaths in lambs are prolapse of the vagina, severe nutritional stresses in late pregnancy, e.g. pregnancy toxaemia or hyperketonaemia, Vitamin D deficiency and calcium deficiency. In addition, milk fever, dystokia, pulpy kidney, navel infection, starvation, exposure and congenital abnormalities are known causes of death. Little work of a nature similar to that described here has been reported in the literature. Moule (1954), conducted a survey of neonatal mortality in Queensland of 2211 merino ewes which bore 2467 lambs. Most of his analyses are based on field observations and no analysis of post mortem examination results is given. There are a number of references in the literature to the neonatal mortality rate and possible causes of lamb death in individual lambs and flocks (for reference see Moule (1954) and Pugh (1954). Although a wider range of death causes than mentioned above are indicated, the papers are not particularly relevant to the work described here.

The objects of the work described in this paper are, in the Gisborne area:—

(1) To determine the lamb neonatal mortality rate.
(2) To determine the stage and nature of death in neonatal mortalities in lambs.
(3) To compare the neonatal lamb losses in mixed age hill country breeding flocks and fat lamb flocks.

DEFINITIONS:

Neonatal Mortality: All lamb deaths occurring before, during, or within seven days of parturition.

Stage of Death Classes:—

Ante-parturient Death: Lambs in this class are characterised by autolysis of kidneys and liver, the disappearance of a visible capillary system and blood lysis. One or more of the following features are usually present—generalised subcutaneous bloodstained oedematous fluid, excess fluid (often bloodstained) in thorax and abdomen and mummification. A thrombus in or clotted blood around the umbilical arteries, localised oedema, aerated lungs and the presence of muscle tone are never seen in this class.

Parturient Death: Lambs in this class are characterised by the presence of some positive sign of viability at the commencement of or during parturition. The common signs are localised oedema of the head, limbs or perineum and tail, lung aeration, a visible capillary system with no evidence of haemolysis in a part or whole of the body and good to moderate muscle tone. Lambs in this class show no thrombus in nor clotted blood around the umbilical artery but may show autolysis of abdominal viscera, loss of visible capillary system in part of the body, generalised subcutaneous oedema and excess fluid in thorax and abdomen.

Post-Parturient Death: Lambs in this class are characterised by a thrombus in or coagulated blood around the ends of the umbilical artery, good to moderate muscle tone, the presence of a visible capillary system with no blood haemolysis in all parts of the body. In addition, lungs may be aerated on non-aerated; the lamb may have failed to walk or have walked and failed to have fed or have fed. Autolysis of abdominal viscera is not commonly seen even four or five days post mortem. Lambs lying in the sun and dead for several days may show organ autolysis and capillary breakdown but usually retain muscle tone and always show the thrombus in or a blood clot around the umblilical arteries.

Nature of Death Classes: (Tentative aetiological classification):—

Dystokia: Lambs in this class are characterised by signs of a difficult or prolonged birth process or of injuries received during birth. The common findings are localised oedema of the head, limbs, perineum or tail. Liver rupture or stripping of Glisson's capsule with abdominal haemorrhage is common. Death may be parturient or post-parturient. The lamb shows no other obvious probable causes of death.

Intra-uterine Infection: Lambs in this class are characterised by one or more of the following features—anteparturient death with gross subcutaneous bloodstained oedema, fibrinous peritonitis, pleuritis or pericarditis and the presence of plaque formation on the sole or walls of the hooves or accessory digits, the superficial epithelial layers of which become slightly raised, pure white or creamy in colour, definitely harder than the surrounding tissues and, on occasion, calcified. Plaque formation may be a very small local lesion or may involve the complete walls and soles of all feet. Deaths in this class may be ante-parturient, parturient or post-parturient. For the purposes of analysis, all lambs showing plaque formation were classed together because of the ease of recognition of the lesion and the high incidence of this lesion, i.e. 11.7% of all lambs examined, 14.4% of hill country lambs, 6.8% of all fat lambs, 3.7% of aged ewe fat lambs and 9.4% of mixed age ewe fat lambs.

Navel Infection: Lambs in this class are characterised by gangrene of the ventral abdomen or acute or sub-acute inflammatory changes in the double layer of the peritoneum passing as a membrane from the urinary bladder around each umbilical artery. In addition, in the latter case there is usually a localised or diffuse acute or sub-acute serous fibrinous or suppurative peritonitis. Liver abcesses, pleurisy or pericarditis are occasionally present.

Enterotoxaemia: Lambs in this class are characterised by one or more of the following signs—fibrinous or serofibrinous pericarditis, a renal cortex giving a positive "water-test,' (i.e. the typical sea anemone appearance when held under a gentle but continuous flow of water from a tap), the presence of a considerable amount of food in the intestines which shows in the duodenum, jejunum and the proximal ileum, a series of absorption waves with the lymphatic capillaries of the intestinal wall and mesentery full of chyle.

Exposure: Lambs in this class are characterised by normal hydration of subcutaneous tissues and abdominal and thoracic viscera. The liver is of normal size and is friable; the small intestines show local or diffuse flaccid dilatation with obvious mucous contents; meconium has not been voided; the perirenal and epi- and pericardial fat shows little or no absorption; the lambs show signs of having walked only a short distance.

Starvation: Lambs in this class are characterised by a generalised dehydration; the liver is small and less friable than normal; the small intestines are contracted and empty; meconium has been voided; the perirenal and epi- and pericardial fat shows advanced or complete absorption; the lamb shows signs or having walked moderately well or well.

In describing exposure and starvation the classical or extreme types have been given. In the course of the survey two additional classes were found necessary because signs of both exposure and starvation were found in the one animal. Thus 687 cases showed signs of exposure alone, starvation alone or distinct signs of both starvation plus exposure. These were divided up as shown in Table 1.

TABLE 1.

An Analysis of Starvation and Exposure Classes.

	Uncomplicated	Complicated Starvation and/or Exposure	Total
Exposure ..	145	126	271
Starvation ..	352	57	409
TOTAL..	497	183	680

145 lambs died of exposure and 126 of exposure complicated by starvation. 352 lambs died of starvation and 57 of starvation complicated by exposure.

Miscellaneous: This group contains many lambs for which the cause of death was known, e.g., hernia, intussusception, volvulus, congenital abnormalities, etc., In no instance does any group included under "miscellaneous" appear to be of sufficient importance to justify including as a separate entity.

MATERIAL AND METHODS:

Lamb Neonatal Death Rate: The counting of all lambs born dead or dying within seven days is impossible on hill country and no direct estimate of neonatal mortality rate seems possible. At castration and docking of lambs a small proportion of farmers can give sufficiently accurate counts of (1) ewe losses from mating to docking and castration, (2) ewes failing to conceive or resorbing or aborting the foetus at an early stage of pregnancy (barren ewes), (3) ewes which have lambed and subsequently lost all lambs born, (4) ewes bringing a live lamb or lambs to marking and (5) the number of foster mothers in group 4. As (3) above gives a minimal estimate of lambs lost, farmers in the area were invited to submit figures of the above and other items for analysis. Table 2 shows the nature and the amount of material received

TABLE 2.—The Nature and Numbers of Ewes Losing All Lambs Born.

	No. of Years	No. of Farmers	No. of Observations	Ewes to Ram	Ewes losing lambs No.	Ewes losing lambs %
Data available from individual property for	1	10	10	18,753	1,973	10.5
	2	2	4	5,071	463	9.1
	3	2	6	7,235	833	11.5
	4	2	8	8,873	1,435	16.2
	5	9	45	60,295	6,768	11.2
TOTAL:		25	73	100,327	11,472	11.4
MEAN/FLOCK:			2.92	1,374.34	157.15	11.4
RANGE:				266/7747		5.2–22.6

Twenty-five farmers submitted figures suitable for analysis and, of those, ten submitted data for one year, two for two years, two for three years, two for four years and nine for five years—a total of seventy-three observations on 100,327 ewes, of which 11,472 lost all their lambs between birth and marking . Twenty-two of the properties were hill country mixed age ewe flocks. One was a mixed age ewe fat lamb flock, one an aged ewe (five years and over) fat lamb flock and two were Romney stud flocks. The mean number of sheep per flock was 1374.34 and the range was 266-7747.

TABLE 3.—The Distribution and Numbers of Lambs Examined Between the Various Types of Farming.

Nature of Property	PROPERTIES No.	% of total	Lambs per property	LAMBS No.	% of total
Hill country properties from which over 28 lambs were submitted	20	22.7	53.5	1,070	48.4
Hill country properties from which less than 28 lambs were submitted	47	53.4	7.85	369	16.7
TOTAL HILL COUNTRY PROPERTIES SUBMISSION	67	76.1	21.48	1,439	65.0
Fat lamb properties with aged ewes submitting more than 28 lambs	5	5.7	87.4	437	19.8
Fat lamb properties with mixed age ewes submitting more than 28 lambs	3	3.4	53.33	160	7.2
Fat lamb properties with aged ewes submitting less than 28 lambs	13	14.8	13.54	176	8.0
TOTAL FAT LAMB SUBMISSIONS	21	23.9	36.95	776	35.0
TOTAL SUBMISSIONS	88	100.0	25.14	2,212	100.0

Collection: The 2,212 lambs examined and analysed were collected during July, August and September, 1954, from Cook and Waikohu Counties. These counties are substantially difficult hill country and support large cattle and sheep-breeding industries. There is a small area of rich, flat country with associated fat lamb industry.

The lambs were collected from six different areas within the two counties. From five of the areas collection was made once a week on the same day and from one of the areas there was a daily collection. Table 3 sets out the number of submitters, the range in number of lambs submitted and the types of property whence they came.

A total of 88 farmers submitted 2212 lambs, with an average of 25.1 lambs per property. Of these, 67 hill country farmers submitted 1439 lambs with an average of 21.5 per property. Twenty hill country farmers each submitted more than 28 lambs—a total of 1070 lambs with an average of 53.5 lambs per property. The remaining forty-seven hill country farmers each submitted less than 28 lambs—a total of 369 lambs with a property average of 7.8 lambs. Twenty-one fat lamb farmers submitted 776 lambs, a per property average of 36.9. Five properties were aged ewe fat lamb farms submitting more than 28 lambs: the total was 437 lambs with an average of 87.4 lambs per property. Three properties were mixed age ewe fat lamb farms, each submitting more than 28 lambs for a total of 160—an average of 53.3 lambs per property. The balance of thirteen miscellaneous fat lamb farmers submitted 176 lambs for an average of 13.5 lambs per property. 76.1% of the farmers and 65% of the lambs were from hill country farms and the balance were from fat lamb farms.

Submitters on the once-a-week collection route were asked to submit all lambs dying on the property for the two days prior to collection or to collect all lambs dying in one or two mobs of ewes for two days prior to collection.

All submitters on the daily-collection route were asked to submit all lambs dying on the property or all lambs dying in one or two mobs of ewes. Owners were given tie-on labels and the following information was requested for each lamb:—age of ewe, single or twin lambs, assisted birth and the presence of prolapse of vagina in the ewe.

Post Mortem Examination: Each lamb was submitted to a routine post mortem examination in which the feet, skin, wool, subcutaneous tissues, joints, ribs, thyroids, thoracic and abdominal viscera were examined. The following information was recorded for each lamb:—the Ischio-frontal length of each lamb was measured to the nearest half inch by placing the nose and frontal region of the face along a horizontal bracket projecting from a vertical support and allowing the lamb to hang with the occipital region and vertebral column in contact with the vertical support. The length was read by placing the index finger in contact with the tuber ischii, horizontally against an inch scale on the vertical support. The weight to the nearest tenth of a lb., the date of submission, the sex and all information submitted by the owner were recorded as were foot maturity, whether death was ante-parturient, parturient or post-parturient, whether the lamb had breathed, walked or obtained food, the nature of death, the week of lambing in which the lamb was born, the weather of the day on which the lamb was collected and the nature of the farm from which the lamb was sent.

Analysis: Each post mortem was recorded on a tape-recorder, typed and punched on to 9in x 8in cards with 166 marginal holes. The information listed took up 72 holes; the remaining 96 were used to quantitate certain of the above data and to describe other interesting and relevant information.

The various classes for analysis were sorted on needles. All counting was done by weighing the cards, of which there were 33 to the lb. In no case did the estimate obtained by weighing differ from an

TABLE 4.—Type of Farming Versus Stage of Death Class Analysis.

			CLASS 150			CLASS 151				
			HILL COUNTRY			FAT LAMBS				
CLASS.	Tentative Nature of Deaths.	Number % Range %	A. Properties with Individual Analysis.	B. Misc. Properties Grouped.	C. TOTAL.	A. Aged Ewe Individual Analysis.	B. Mixed Age Ewe Individual Analysis.	C. Misc. Properties Grouped.	D. TOTAL.	GRAND TOTAL.
40	Ante-Partum Death	No.	75	24	99	11	16	9	36	135
		%	7.0	6.5	6.9	2.5	10.0	5.1	4.7	6.1
		Range %	2-18	—	2-18	2-6	2-25	—	2-25	2-25
43	Parturient Death	No.	454	119	573	90	39	33	162	735
		%	42.4	32.2	39.8	20.6	24.4	18.7	21.0	33.2
		Range %	14.67	—	14-67	14-27	14-34	—	14-34	14-67
45) 46)	Post Parturient Not Walked	No.	128	63	191	63	28	19	110	301
		%	12.0	17.1	13.3	14.4	17.5	10.8	14.2	13.6
		Range %	3-33	—	3-33	11-22	11-35	—	11-35	3-35
47	Post Parturient Walked No Food	No.	242	88	330	185	46	73	304	634
		%	22.6	23.8	22.9	42.3	28.7	41.5	39.3	28.7
		Range %	6-59	—	6-59	27-48	10-45	—	10-48	6-59
48	Post Parturient Walked. Food Present	No.	171	75	246	88	31	42	161	407
		%	16.0	20.3	17.1	20.1	19.4	23.9	20.8	18.4
		Range %	5-30	—	5-30	11-32	8-27	—	8-32	5-32
	Total:		1,070	369	1,439	437	160	176	773	2,212
	% of Class Total		74.4	25.6	100.0	56.5	20.7	22.8	100.0	—
	% of Grand Total		48.4	16.7	65.0	19.8	7.2	8.0	34.9	100.0

TABLE 5.—Type of Farming Versus Nature of Death Class Analysis.

			CLASS 150 HILL COUNTRY			CLASS 151 FAT LAMBS				
CLASS.	Tentative Nature of Deaths.	Number % Range %	A. Properties with Individual Analysis.	B. Misc. Properties Grouped.	C. TOTAL.	A. Aged Ewe Individual Analysis.	B. Mixed Age Ewe Individual Analysis.	C. Misc. Properties Grouped.	D. TOTAL.	GRAND TOTAL.
49	Dystokia	No.	312	75	387	89	34	25	148	535
		%	29.2	20.3	26.9	20.4	21.2	14.2	19.1	24.2
		Range %	3-50	—	3-50	11-24	11-23	—	11-24	3-50
50	Intra-uterine Infection	No.	112	30	142	19	16	13	48	190
		%	10.5	8.1	9.9	4.3	10.0	7.4	6.2	8.6
		Range %	0-23	—	0-23	0-13	2-25	—	0-13	0-23
51	Intra-uterine Infection+ Plaque Formation	No.	149	64	213	16	15	14	45	258
		%	13.9	17.3	14.8	3.7	9.4	7.9	5.8	11.7
		Range %	3-31	—	3-31	0-12	5-28	—	0-28	0-31
53	Navel Infection	No.	74	30	104	32	8	17	57	161
		%	6.9	8.1	7.2	7.3	5.0	9.7	7.4	7.3
		Range %	0-15	—	0-15	5-11	3-7	—	3-11	0-12
54	Entero-toxaemia	No.	38	10	48	8	1	8	17	65
		%	3.5	2.7	3.3	1.8	0.6	4.5	2.2	2.9
		Range %	0-13	—	0-13	1-4	0-2	—	0-2	0-13
56	Exposure	No.	60	26	86	128	23	35	186	272
		%	5.6	7.0	6.0	29.3	14.4	19.9	24.1	12.3
		Range %	0-17	—	0-17	11-39	3-29	—	3-39	0-39
57	Starvation	No.	164	74	238	101	34	36	171	409
		%	15.3	20.0	16.5	23.1	21.2	20.4	22.1	18.5
		Range %	2-41	—	2-41	13-39	5-31	—	5-39	2-41
61	Miscellaneous + No Assignable Cause	No.	161	60	221	44	29	28	101	322
		%	15.0	16.3	15.4	10.1	18.1	15.9	13.1	14.6
		Range %	0-35	—	0-35	2-19	16-25	—	2-25	0-35
	Total:		1070	369	1439	437	160	176	773	2212
	% Class Total:		74.4	25.6	100.0	56.5	20.7	22.8	100.0	100.0
	% Grand Total:		48.4	16.7	65.0	19.8	7.2	8.0	34.9	100.0

actual count by more than one per cent. Differences in numbers in the same class in the various tables are due to this method of assessment. No attempt has been made to adjust estimates. All data were recorded with a view to subsequent analysis by normal contingency methods although other analytical methods are applicable to a limited number of the collected information.

RESULTS:

Lamb Neonatal Mortality Rate: Table 2 sets out the findings from 72 observations of 25 farmers. The mean percentage of ewes losing all lambs born is 11.4. The mean percentage of ewes losing all lambs born is 11.4. The between-property range is from 5.2% to 22.6%. The lowest loss was in the flock of a stud breeder with a breeding flock of 280 ewes and the highest in a small crossbred flock of 266 ewes on first class flat and easy hill country.

The Stage and Nature of Death of Lamb Neonatal Mortalities:

(1) **Stage of Death:** (Table 4).

6.1% of the 2212 lambs died before the commencement of parturition, 33.2% died during parturition, 13.6% were post-parturient deaths in lambs which had failed to walk, 28.7% were post-parturient deaths in lambs that had walked and failed to obtain food and the balance of 18.4% were post-parturient deaths in lambs which had walked and obtained food. The total post-parturient deaths totalled 60.7% although the survival of the post-parturient group failing to walk (13.6%) was so short that they might be more satisfactorily classed as parturient deaths.

(2) **Nature of Death:** (Table 5).

Based on the definitions given earlier, it was possible to group the lambs in tentative "cause of death" classes as follows:—24.2% of the 2212 lambs were classed as having died from dystokia, 8.59% from intra-uterine infection without plaque formation and 11.7% from intra-uterine infection with plaque formation, i.e., a total of 20.2% for intra-uterine infection. Navel infection was responsible for 7.3% and enterotoxaemia 2.9%, i.e., a total of 10.2% for post-natal infection. 12.3% of the lambs examined died from exposure and 18.5% from starvation, i.e., a total of 30.8% for the non-infective post-natal death group. Miscellaneous identified and unidentified "causes" of death amounted to 14.6% of the total.

A Comparison of Neonatal Lamb Losses in Hill Country Breeding Flocks and Fat Lamb Flocks:—

The method of comparison was by simple contingency analysis—type of farming classes vs. stage and nature of death classes. The following comparisons were made:—

(1) Total lamb deaths from hill country flocks vs. total lamb deaths from fat lamb farms (total hill lambs versus total fat lambs).

(2) Lamb deaths in individually analysed hill country flocks from which were submitted 28 or more lambs vs. lamb deaths from the grouped hill country properties from which were submitted less than 28 lambs individual hill lambs vs. grouped hill country properties (individual hill lambs vs. grouped hill lambs).

(3) Lamb deaths in individually analysed hill country flocks vs. lamb deaths in mixed age ewe fat lamb farms from which were submitted more than 28 lambs (individual hill lambs vs. mixed age fat lambs).

(4) Lamb deaths in individually analysed hill country flocks vs. lamb deaths in aged ewe fat lamb farms, from which were submitted more than 28 lambs (individual hill lambs vs. aged fat lambs).

The Results of a Comparison of the Stages and Nature of Death Between Types of Farming by Contingency Analysis.

Types of Farming Compared.	Basis of Comparison	
	Stage of Death P =	Nature of Death P =
Combined hill country versus combined fat lambs	less than 0.001	less than 0.001
Individually analysed hill versus grouped hill	less than 0.02	less than 0.02
Individually analysed hill versus mixed age ewe fat lambs	less than 0.001	less than 0.001
Individually analysed hill versus aged ewe fat lamb	less than 0.001	less than 0.001
Mixed age ewe fat lamb versus aged ewe fat lamb	less than 0.001	less than 0.001

(5) Lamb deaths in individually analysed mixed age ewe fat lamb farms vs. lamb deaths in individually analysed aged ewe fat lamb farms (mixed age fat lambs vs. aged fat lambs).

In No. 2 above P = less than 0.02 in both stage and nature of death comparisons. In all the others P = less than 0.001 when comparison is versus stage and versus nature of death classes.

(1) **Total Hill Lambs vs. Total Fat Lambs:—**

Stage of Death: (P = less than 0.001) (Table 4). The main differences between the types of farming lie in the ante-parturient, parturient, and in the post-parturient "walked, no food" death classes.

In the ante-parturient death class, hill lamb deaths were 6.9% and fat lamb deaths were 4.7%.

In the parturient death class hill lamb deaths were 39.8% and fat lamb deaths 21.0%, and finally in the post-parturient walked no food class, hill lambs were 22.9% and fat lambs 39.3%.

Nature of Death: (P = less than 0.001) (Table 5). The main differences between the types of farming in this analysis were in classes:— dystokia, intra-uterine infection without plaque formation, intra-uterine infection with plaque formation, exposure and starvation, i.e., in the dystokia death class the hill lambs were 26.9% and the fat lambs 19.1%.

In the intra-uterine infection without plaque formation death class the hill lambs were 9.9% and fat lambs 6.2%.

In the plaque formation death class hill lambs were 14.8% and fat lambs 5.8%, i.e., for all intra-uterine infection 23.7% for hill country lambs and 12.0% for fat lambs.

In the exposure death class hill lambs were 6.0% and fat lambs 24.1%.

In the starvation death class hill lambs were 16.5% and fat lambs 22.1%.

A comparison of combined exposure and starvation classes, hill lambs versus fat lambs shows 22.5% and 46.2% respectively.

(2) **Individual Hill Lambs versus Grouped Hill Lambs:—**

Stage of Death: (P = less than 0.02) (Table 4). The main differences between the types of farming in this analysis are in the parturient, post-parturient not walked and the post-parturient walked and fed classes. In the parturient death class individual hill lambs were 42.4% compared to 32.2% in grouped hill lambs.

In the post-parturient, not walked death class the individual hill lambs were 12.0% compared to 17.1% in grouped hill lambs. In the post-parturient walked plus food death class individual hill lambs were 16.0% and the grouped hill lambs 20.3%.

Nature of Death: (P = less than 0.02) Table 5). The main difference between individual hill and grouped hill types of farming in this analysis are in the dystokia and starvation death classes. Smaller but important differences are seen in both intra-uterine infection death classes.

In the dystokia death class there were 29.2% in individual hill lambs as compared to 20.3% grouped hill lambs.

In the starvation death class individual hill lambs were 15.3% while grouped hill lambs were 20.0%.

In the intra-uterine infection without plaque formation death class individual hill lambs were 10.5% and grouped hill 8.1% and, finally, in the plaque formation class individual hill lambs were 13.9% compared to 17.3% of the grouped hill lambs. By combining the two intra-uterine infection classes the differences are narrowed, i.e., 24.4% versus 25.5%.

(3) **Individual Hill Lambs versus Mixed Age Fat Lambs:—**

Stage of Death: (P = less than 0.001) (Table 4). Substantial differences between the types of farming in this analysis are to be found in all classes of death.

In the ante-parturient death class hill lambs were 7.0% and fat lambs 10.0%.

In the the parturient death class hill lambs were 42.4% and fat lambs 24.4%.

In the post-parturient not walked death class hill lambs were 12.0%and fat lambs 17.5%.

In the post parturient walked no food death class hill lambs were 22.6% and fat lambs 28.7%.

In the past-parturient walked and food death class hill lambs were 16.0% and and fat lambs 19.4%.

Nature of Death: (P = less than 0.001) (Table 5). Substantial differences between types of farming in this analysis are to be found in the following nature of death classes:—Dystokia, intra-uterine infection with plaque formation, enterotoxaemia, exposure and starvation.

In the dystokia class hill lambs were 29.2% and fat lambs 21.2%. In the plaque formation class hill lambs were 13.9% and fat lambs 9.4%.

In the enterotoxaemia class hill lambs were 3.5% and fat lambs 0.6%. In the exposure class hill lambs were 5.6% and fat lambs 14.4%. In the starvation class hill lambs were 15.3% and fat lambs 21.2%.

(4) **Individual Hill Lambs versus Aged Fat Lambs:—**

Stage of Death: (P = less than 0.001) (Table 4). The major differences between individual hill lambs and aged fat lambs are to be found in all "stage of death" classes.

In the ante-parturient death class there are 7.0% hill lambs and 2.5% fat lambs.

In the parturient death class there are 42.4% of the hill lambs and 20.6% of the fat lambs.

In the post-parturient not walked class there are 12.0% of the hill lambs and 14.4% of the fat lambs.

In the post-parturient walked no food class there are 22.6% of the hill lambs and 42.3% of the fat lambs.

In the post-parturient walked plus food class there are 16.0% of the hill lambs and 20.1% of the fat lambs.

Nature of Death: (P = less than 0.001) (Table 5). There are substantial differences between farming types in all "nature of death" classes except navel infection.

In the dystokia class there is 29.2% of the hill lambs and 20.4% of the fat lambs.

In the intra-uterine infection class there is 10.5% of the hill lambs and 4.3% of the fat lambs.

In the plaque formation class there is 13.9% of the hill lambs and 3.7% of the fat lambs.

The difference in combined intra-uterine infection is 24.4% versus 8.0%.

In the enterotoxaemia class there is 3.5% of the hill lambs and 1.8% of the fat lambs.

In the exposure class there is 5.6% of the hill lambs and 29.3 of the fat lambs.

In the starvation class there is 15.3% of the hill lambs and 23.1% of the fat lambs.

(5) Aged Fat Lambs versus Mixed Age Fat Lambs:—

Stage of Death: (P = less than 0.001) (Table 4). The main differences in this comparison are in the ante-parturient and post-parturient walked no food class. Small contributory differences are present in the other classes.

In the ante-parturient death class there is 2.5% of the aged ewe fat lambs and 10.0% of the mixed age ewe fat lambs. In the post-parturient walked no food class there is 42.3% of the aged fat lambs and 28.7% of the mixed age ewe fat lambs.

Nature of Death: (P = less than 0.001) (Table 5). The main differences between types of farming in this comparison are to be found in the the two intra-uterine infection classes and in the exposure class.

In the intra-uterine infection without plaque formation class there are 4.3% of the aged ewe fat lambs and 10.0% of the mixed age ewe fat lambs.

In the plaque formation class there are 3.7% of the aged ewe fat lambs and 9.4% of the mixed age ewe fat lambs.

In the exposure class there are 29.3% of the aged ewe fat lambs and 14.4% of the mixed age ewe fat lambs.

The Between Property and Type of Farming Range of the Stage and Nature of Death Classes:—

One of the most striking features of this analysis is the very wide range in stage and nature of death classes between properties and the smaller but important range between types of farming. Reference to Tables 4 and 5 shows this clearly. Table 4, showing stage of death class, records ranges from 2-25%, 14-67%, 3-35%, 6-59%, 5-32% respectively in ante-parturient, parturient, and post-parturient not walked, post-parturient walked no food and post-parturient walked plus food death classes. Comparison of "total hill lambs" with "total fat lambs" records ranges of 40-21%, 23-39% respectively in ante- parturient and post-parturient walked no food death classes. Table 5, showing nature of death classes, records between-property ranges of from 3-50%, 0-23%, 0-31%, 0-12%, 0-13%, 0-39%, 2-41% and 0-35% respectively in dystokia, intra-uterine without and with plaque formation infection, enterotoxaemia, exposure, starvation and miscellaneous death classes. The between types of farming range, also in Table 5, are not so marked but are nevertheless important. Thus between hill and fat lamb farms there are ranges in nature of death classes of from 27-19%, 10-6%, 15-6%, 6-24% and 17-22% respectively in dystokia, intra-uterine infection without and with plaque formation, exposure and starvation death classes.

DISCUSSION

Consideration of the data presented raises an important issue. Are the samples obtained suitable for analysis? In the case of the lamb neonatal mortality rates accurate direct counts of neonatal lamb losses is to be desired; this, however, is not possible on the average farm in the area. Assessment of the proportion of ewes losing all their lambs in possible. The number of observations (73), and the number of farmers (25), submitting data on ewes losing all their lambs is not high and clearly a larger sample is necessary before representative figures can be given for the area. The use of the proportion of ewes losing all their lambs prior to marking as a minimal neonatal mortality rate is open to criticism. Thus there are losses from the seventh day after birth to docking and castration and these cannot be obtained with any accuracy. On the other hand a proportion of ewes losing all lambs born will have borne twins, some ewes having multiple births will lose one of more lambs although rearing a lamb and the number of ewes losing all lambs will be lowered by the number of foster mothers in the flock with live lambs at marking. The first two of those factors would raise the percentage of lamb

losses above the percentage of ewes losing all their lambs whilst the third would increase the percentage of ewes losing all their lambs. From farmers' estimates and records it would appear that the percentage of ewes losing all their lambs should be increased by up to 50% to approximate the actual lamb losses. The addition of up to 50% to arrive at the actual loss is based solely on data supplied by farmers and a general consideration of the additional lamb losses mentioned above. To obtain more comprehensive data on this and other features it will be necessary to draw up a diary in which the sheep farmer can keep accurate figures each time the flock is handled at a point where accurate counts can be made.

The significance of the data gathered from the collection, post mortem examination and analysis of 2212 lambs from 88 properties is open to still more serious criticism. The limited number of properties submitting more than twenty-eight lambs and the very wide between-property ranges in the "stage" and "nature of death" classes indicates that in some respects the sample is much too restricted and that urgent consideration should be given to sampling methods before the 1955 lambing season. It seems that with such wide ranges, even if the aetiology of the death was clear, it would be difficult to obtain any accurate assessment of the economic importance of individual factors causing loss.

The criticisms offered above appear to be sufficiently important to throw serious doubt on the significance of the differences between the small samples of aged and mixed age ewe fat lamb farming and between hill country farming and the small samples in mixed age, aged ewe and miscellaneous fat lamb farming. The differences between combined hill country farming and combined fat lamb farming or between individual hill country farming and grouped hill country would appear to be satisfactory because the numbers are larger and the differences are those that would have been expected "a priori." Thus the cull-for-age ewe constitutes the highest proportion of the fat lamb flocks and she would be expected to show greater immunity to infections and the fat lambs from aged ewes to show a lower loss from infection acquired "in utero" than the hill country mixed age ewes with presumably highly susceptible two and three-year-old sheep. Similarly, the effects of a severe storm during the peak of fat lambing is reflected in the exposure figures. It is interesting to note that, even when the heavy exposure losses class is removed from the contingency analysis, the significance and the relative proportions of the other causes is not greatly altered.

It is obvious when "nature of death" classes are based on morbid anatomical criteria that some "infective" classes may, in fact, be non-infective, and also that no accurate distinction can be made between infections. This is inevitable and clarification must await more intensive work. Reference to the definitions will show that the criteria adopted for the various classes are, to a very large extent, the generally morbid anatomical criteria of specific or non-specific infections. Two main exceptions can be noted. Plaque formation is included as a criterion of intra-uterine infection, and lambs have been included in the enterotoxaemia class showing only intestinal absorption waves in the absence of more generally accepted fibrinous or sero-fibrinous pericardial sac exudate and/or kidneys reacting to the "water test." Plaque formation occurred in 11.7% of all lambs examined, in 14.8% of hill country lambs and 5.8% of fat lambs. This lesion has been associated with fibrinous or serofibrinous exudates in 17.8% of cases and when the foetal membranes of lambs showing plaque formation have been present (10 cases), they have shown obvious signs of Brucellosis, Type 2 abortion or a gross disease of the foetal membrane, not so far described(in all but one case and in this case only a small part of the membrane was present. From seven positive Brucella foetal membranes, four of the lambs showed plaque formation and from fourteen positive Type 2 abortion foetal membranes four of the lambs

showed plaque formation. A further and common observation is that lambs submitted with attached foetal membranes infected by Brucella showed no recognisable pathological changes. Based on those findings it seems reasonable to assume an association, probably causal between intra-uterine infection and plaque formation.

The grouping of lambs in a tentative enterotoxaemia class in the absence of the more commonly accepted signs is based on the fact that in all cases where one or both the classical signs was present the finding of good quality food in the abomasum, duodenum, jejunum and proximal ileum, with several clear absorption waves, was constant. Those findings in the intestines were not common and are so characteristic that it was thought justifiable to include them in the enterotoxaemia group.

A general point worth stressing is that there appear to be classes of loss of a probable infective nature where the cause has not yet been established. Serum, milk whey and vaginal mucous agglutination, complement fixation or other tests for ready diagnosis of infectious losses would be of great assistance in this class of work. Unfortunately, no such tests are at present available. Until such time as simple diagnostic tests are available for all major infective diseases causing neonatal mortality, the collection and post mortem examination of a satisfactory sample of dead lambs seems necessary to establish the causes, infective and non- infective, of the deaths to develop diagnostic techniques and ultimately to assess the nature and extent of the losses.

Another point is that the wide "between property" and "types of farming" differences in nature of death classes mean that laboratory information based on cultural examinations of restricted and often biased samples of dead, newly born lambs cannot be used for an assessment of the extent of the economic importance of infective losses.

In spite of the criticisms offered above, it seems that no matter what the aetiological significance of the stage and nature of death classes may turn out to be, since they are distinctive morbid anatomical entities and it is on these easily definable classes that the analysis has been based, that significant differences between adequate samples of different classes of lambs are judged by nature of death classes are real. There can be little criticism of the accuracy of the stage of death classes and the highly significant differences between types of farming based on those classes.

If the position as stated above is accepted, several important points can be stated in summary form.

(1) **The Minimal Lamb Neonatal Mortality Rate** based on the proportion of ewes in the flock losing all their lambs and derived from 73 observations on 25 properties is 11.4 lambs for every hundred ewes mated. The range is from 5.2% to 22.6%. The probable neonatal mortality rate is considered to be the minimal rate of ewes losing all lambs plus 50%, that is 15%. This adjustment is considered necessary because (a) a proportion of the ewes losing all their lambs will have had twins, (b) a proportion of the ewes bringing a live lamb to marking will have lost one or more lambs from a multiple birth and (c) a proportion of the ewes bringing a live lamb to marking will be foster mothers.

(2) **The stage and nature of neonatal lamb deaths.** Dystokia, the two classes of intra-uterine infection, exposure and starvation are important classes of lamb loss. If a figure of 15% neonatal mortality is accepted, then these four classes are responsible for the loss of 3.6, 3.0, 1.8, and 2.8 lambs respectively for every hundred ewes mated, i.e., 75.2% of all lamb deaths.

(3) **A comparison of the neonatal lamb losses in hill and fat lambs.** Attention will be focused on comparisons by nature of death classes

only because although the stage of death classes are satisfactory for analytical purposes, they give little information as to possible causes of death. As mentioned above, two of the analyses appear to be satisfactory, namely total hill lambs vs. total fat lambs and individual hill lambs vs. grouped hill lambs. The three other analyses are subject to criticism because of the limited number of submitters and lambs examined; there are nevertheless some interesting features in these analyses.

In the total hill lambs vs. total fat lamb analysis a main difference lies in dystokia and the two intra-uterine infection classes, in all of which the hill lambs exceeded the fat lambs. Thus the combined total of those three classes is 51.6% and 31.2% respectively. In the exposure and starvation classes the hill lambs are significantly less than fat lambs, i.e., 22.5% and 46.2% respectively.

A reasonable explanation for such differences in the former figures would appear to be the accepted high proportion of difficult births and the high susceptibility to infection of young two, three and four-year-old sheep which make up more than 50% of breeding flocks and which are absent from the usual fat lamb flocks. The reasons for the differences in exposure and starvation classes are less easily suggested. Older ewes are commonly believed to be better mothers and so losses from those causes should be reduced. However, fat lambs tend to be born in the early part of the lambing season when the weather is less reliable and in the 1954 lambing there was a serious flood during the peak of the fat lamb lambing which accounted for a large proportion of deaths. An interesting point, however, is that aged ewe fat lambs, all lambed on flat or very easy country, showed a combined starvation and exposure loss of 52.4% compared to 35.6% of the mixed age ewe fat lambs, all of which came from easy hill country where the lambs were born during the same flood period as the aged ewe fat lambs. The exposure/starvation losses of the mixed age ewe fat lambs exceeded those of the hill country lambs where the lambing had barely begun during the flood. The findings would suggest the serious effect of flood conditions, particularly on flat country where surface water lies and where there is neither high ground nor protection from the elements. The question of whether or not weather is a factor which should be included in analysis such as this or not is difficult to answer. A comparison by stages of death of the total lamb losses 1953 and 1954 showed no significant difference despite the fact that the lambing weather of 1953 was excellent and that of 1954 had a serious flood at the peak of fat lamb lambing and a blizzard at the peak of hill country lambing. The inclusion of three mixed age ewe fat lamb flocks in the total fat lamb figures narrows the difference between the classes under consideration because this class of lamb falls between the aged ewe fat lambs and the hill lambs in most nature of death classes. (Table 5).

The analysis, individual hill lambs vs. grouped hill lambs was carried out to discover if the smaller samples were highly selective. There appears to have been a degree of selection but a comparison of the nature and extent of the differences in this analysis shows them to be very much lower than in any of the other between-farming comparisons.

Although the restricted nature of the samples probably invalidates the other three analyses, there are certain differences which fit the biological pattern which has evolved so far. Thus the greatest difference in the summed dystokia and the two intra-uterine infection classes is between total hill lambs (51.6%) and aged ewe fat lambs (28.3%). In this case the diluting effect of the young ewes in the mixed age ewe fat lambs is removed. Similarly, the summed exposure and starvation classes show the biggest between class differences in those same classes, i.e., 22.5% and 52.4% respectively. Here again the diluting effect of the mixed age ewe fat lambs ex hill country are removed and the full effect of weather, lack of protection and ewe

age differences is seen. The comparisons between individual hill lambs, aged ewe fat lambs and mixed age ewe fat lambs seem to indicate the increase in dystokia and the two intra-uterine infections is related to the fact that over 50% of the mixed age ewe flocks are two, three and four years old while the aged ewes are five years and over.

SUMMARY:

(1) The neonatal death rate in lambs cannot be obtained by direct counting under normal shepherding conditions. An approximate figure obtained by adding 50% to the percentage of ewes put to the ram which lose all the lambs born to them appears to be a suitable working assumption. 11.5% of 100,327 ewes fall into the above category giving a minimal lamb loss percentage. The assessed figure for neonatal lamb mortality is 17.2 lambs for every hundred ewes put to the ram.

(2) **Stage of Death:** 6.1% of the 2212 lambs died before the commencement of parturition, 33.2% died during parturition, 13.6% were post-parturient deaths in lambs which failed to walk, 28.7% were post-parturient deaths in lambs that had walked and failed to obtain food and the balance of 18.4% were post-parturient deaths in lambs which had walked and obtained food.

(3) **Nature of Death:** 24.2%of the 2212 lambs were classed as having died from dystokia, and 20.3% from intra-uterine infection. Navel infection was responsible for 7.3% and enterotoxaemia for 2.9%, i.e., a total of 10.2% for post-natal infections. 12.3% of the lambs examined died from exposure and 18.9% from starvation, i.e., a total of 30.8% for the non-infective post natal death group. Miscellaneous identified and unidentified "causes" of death amounted to 14.6% of the total.

(4) Highly significant differences are apparent between hill country breeding flocks, mixed age ewe and aged ewe fat lamb flocks as judged by the stage and nature of death classes. The main differences are that the mixed age ewe flocks show a higher proportion of ante-parturient and parturient deaths and of intra-uterine infection and dystokia. The aged ewe flocks show a higher proportion of losses in the post-parturient walked no food deaths and in exposure and starvation classes.

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