Genetic Evaluations of Sheep in Canada

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1 Introduction

Since 2010, sheep records in Canada have been maintained in a database system accessible by the Centre d'expertise en Production Ovine du Quèbec (CEPOQ) and the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA). The implementation of a database system has cut down on the frequency and types of errors that occur with data collection. For instance, animal data can only be entered if the genetic parent information is already in the database. Only records that meet age, weight, and date restrictions are allowed into the database, otherwise the records are rejected until someone intervenes and makes the appropriate error corrections.

Prior to the establishment of the database, genetic evaluations of sheep for growth traits were calculated for a number of years at the

Centre for Genetic Improvement of Livestock (CGIL). Once a year the data (all records) were obtained from CEPOQ and OMAFRA, editted, and analyzed. Different people were involved in the analyses over the years, and the edits were often handled differently each time, resulting in different data being utilized in the evaluations. Consistency of results was difficult to maintain.

The database has forced a consistency of data recording upon producers, which has led to stable genetic evaluations over time. The database has allowed the development of an automated genetic evaluation system that can be run any time desired. Currently, evaluations for growth and reproduction traits are run every weekend. Producers can access the new results from their farm computers. For producers with keen interest, the genetic evaluations are utilized more effectively than they were in the past. There are over 1.3 million growth records on lambs in the database going back to 1986.

In 2014, test day records on dairy sheep were included into the database. Eight flocks with milking ewes and a total of 19,000 test day records have been accumulated. An automated genetic evaluation system for dairy sheep is being developed for 2015.

To date, there has been no usage of genomics in sheep in Canada. Many sheep producers do not have the financial resources to have genotypes taken on their sheep. There are discussions about the possibility of collecting conformation scores on dairy sheep, but at this moment no records have been entered into the database for these traits.

This document describes the genetic evaluation models and basic information for growth traits, reproduction traits, and dairy production traits, as of 2015. The people involved have been Delma Kennedy (OMAFRA), and Amélie St-Pierre, Mélanie Larochelle, and Johanne Cameron from CEPOQ. The original CGIL participants have been Dr Jim Wilton, Dr Jane Tosh, Dr Gord Vandervoort, and Valentina Palucci. Dr Cheryl Quinton has recently been involved in developing new economic indexes for selecting ewes and rams. CEPOQ personnel have been extremely dedicated to the collection of good data and overseeing its usage.

2 Growth Trait System

2.1 Breeds and breed groups

There are over 60 different breeds of sheep represented in Canada. The primary breed in the early years was Suffolk, but today the Rideau and Dorset breeds are more numerous. Many of the breeds are represented in only one or two flocks, and thus, their numbers are not sufficient to warrant separate consideration. In addition there are breed crosses of every description possible, and collectively these comprise the majority of sheep in the database.

The view taken, in Canada, is that of a national sheep program where all breeds and animals should be evaluated, if possible. Given that flocks often include more than one breed, the decision was made to collectively evaluate all animals simultaneously, as though they were just one breed.

Table 1
Definition of Breed Groups

Group	Description
1	Arcott-Rideau
2	Dorset
3	Suffolk
4	Polypay
5	Arcott-Canadian
6	Hampshire
7	North Country Cheviot
8	Romanov
9	Unknown Crosses
10	Small-sized Meat breeds
11	Medium-sized Meat breeds
12	Large-sized Meat breeds
13	Prolific/Dairy breeds
14	Wool/Dual purpose breeds
15	Primitive breeds

Breed groups were formed to identify sheep with similar characteristics in terms of size or function. Breed groups are assigned to animals as data are extracted from the database and are not stored explicitly in the database itself. Thus, the group definitions can be altered easily from time to time, if necessary, by altering a routine that determines group membership.

If an animal has unknown parents, then phantom parents are assigned based on the breed group of the animal and the generation number of the animal (which depends when it was born and number generations of subsequent offspring), during the processing of pedigrees.

The genetic evaluation programs totally ignore heterosis because it is impossible to measure for every possible cross that exists in the database, and secondly because the effects of heterosis in sheep are likely small for most traits. If heterosis exists, its effects go into the residual terms of the models, because only additive genetic effects are estimated.

2.2 Traits

Six traits are currently evaluated for growth production.

2.2.1 Survival

Survival is a categorical trait with 5 categories, where 5 is an animal that has made it to weaning age, and 1 is an animal that died shortly after birth. The other numbers (2, 3, and 4) are different lengths of survival, but died before weaning. The survival categories correspond to codes that are put into the database by producers. Code 5A is category 1; code 5B is category 2; code 5C is category 3; code 5D is category 4; and no code means the animal was weaned which is category 5.

2.2.2 Birthweight

If birthweight is not reported, a value of 4 kg is used to calculate adjusted 50-d weights. Birthweights are affected by number of lambs born, breed, age of ewe, ram, sex of lamb, and environmental factors. Only birthweights between 1.2 kg to 8.0 kg are considered valid. Birthweights outside this range are set to missing for genetic evaluation purposes, but remain in the database as recorded.

2.2.3 50-day Weight

Weights are taken around 50 days of age. Actual weights should be taken between 28 and 80 days of age. If outside this age range, then the weight is declared missing. If age is okay, then the weight itself must be between 2.5 kg and 40.0 kg, otherwise it is missing. Growth from birth to 50 days is assumed to be linear, and weights are adjusted to 50 days of age by extrapolation, either up or down.

2.2.4 Gain from 50 to 100 Days

Producers provide 100 day weights, which should be taken between 70 to 135 days of age, and should be from 7.0 kg to 65.0 kg. Linear growth is assumed between 50 and 100 days, and the gain during that period is calculated. Although gain is the trait that is analyzed, EPDs for 100-d weights are provided by adding the EPD for 50-d weight to the EPD for gain.

2.2.5 Ultrasound Traits

Loin area and fat thickness are taken by ultrasound measurements. Only a few producers pay to have these traits recorded. Ideally, these should be measured around 100 days of age. Lambs are weighed at the time of taking ultrasound measurements at about 100 days (70-135 day range allowed). Loin and fat thicknesses (in mm) are adjusted for the weight of the animal rather than the age, at the time of measurement. This adjustment is calculated during the solving of the genetic evaluation equations. Loin measures are required to be between 4 and 44 mm, and fat measures are to be between 0.57 to 14.9 mm.

All traits are assumed to be affected by direct genetic effects and by maternal genetic effects, although the latter may be minor for gain, loin and fat thickness.

Tables 2a and 2b give the means and standard deviations of the traits for lambs by breed groups.

Table 2a
Means and standard deviations of growth traits. See Table 1 for breed group definitions.

Breed Group	item	Surv.	BW kg	50-d WT kg	Gain kg	Loin mm	Fat mm
1	N	196776	113147	134509	108675	4652	4652
	Mean	3.90	3.72	17.08	15.65	23.94	3.59
	SD	1.79	0.96	4.36	5.22	3.59	1.26
2	N	176693	103076	143974	110037	2503	2503
	Mean	4.42	4.52	18.74	13.88	26.67	4.30
	SD	1.41	1.08	4.74	5.12	3.94	1.82
3	N	161914	52805	130272	88831	6394	6394
	Mean	4.35	4.81	20.29	16.16	27.03	4.06
	SD	1.47	1.22	5.27	6.28	4.31	1.61
4	N	59409	46635	44874	34683	64	64
	Mean	4.20	4.14	17.10	13.53	24.84	3.77
	SD	1.60	0.98	4.53	4.57	3.59	1.28
5	N	17476	12185	13232	11005	921	921
	Mean	4.17	5.08	20.03	12.06	24.50	4.16
	SD	1.62	1.16	5.61	5.33	3.93	1.71
6	N	19248	9861	15214	11907	2743	2743
	Mean	4.36	4.67	19.91	15.69	26.67	4.06
	SD	1.47	1.21	5.40	5.89	4.03	1.57
7	N	13509	5812	10626	9055	270	270
	Mean	4.33	4.82	17.51	13.74	23.50	3.38
	SD	1.49	1.16	4.50	5.37	4.46	1.09
8	N	86527	62619	59723	49695	134	134
	Mean	4.16	2.97	14.52	13.44	22.95	2.54
	SD	1.63	0.82	4.13	4.48	2.73	1.00

Table 2b

Means and standard deviations of growth traits. See Table 1 for breed group definitions.

Breed Group	item	Surv.	BW kg	50-d WT kg	Gain kg	Loin mm	Fat mm
9	N	340325	119059	270807	143211	407	407
	Mean	4.31	4.07	17.13	11.64	22.40	3.83
	SD	1.51	1.07	4.58	4.99	4.78	1.48
10	N	6613	5044	5363	4316	71	71
	Mean	4.42	3.91	15.99	11.37	25.55	3.43
	SD	1.41	0.88	3.89	4.18	3.19	1.49
11	N	144957	84921	113015	74105	1959	1959
	Mean	4.26	4.25	18.11	13.65	25.12	3.72
	SD	1.56	1.06	4.69	5.31	4.41	1.62
12	N	22820	10506	18451	14132	1494	1494
	Mean	4.35	4.52	19.31	15.73	27.16	4.41
	SD	1.47	1.11	4.89	5.78	3.90	1.63
13	N	39837	27102	26036	18091	39	39
	Mean	3.69	3.61	16.89	12.34	23.03	3.18
	SD	1.88	1.02	4.91	5.18	5.14	1.34
14	N	26389	6992	21932	16289	294	294
	Mean	4.44	4.53	18.38	12.72	20.47	3.16
	SD	1.38	1.08	5.01	5.18	3.98	1.31
15	N	3127	2114	2407	1987	977	977
	Mean	4.20	3.77	15.79	9.02	20.30	2.47
	SD	1.60	0.86	3.60	3.69	3.46	0.81

2.3 Three Dams

2.3.1 Genetic Dam

Every lamb can have up to three (3) different dams that have influenced their growth. The first dam is the genetic dam of the lamb. This is the female that has provided one half of the animal's DNA. This is the female parent used in the formation of the additive genetic relationships among animals.

2.3.2 Birth Dam

The birth dam carries the embryo and gives birth to the lamb(s). In most cases the birth dam is the same animal as the genetic dam. However, for producers that use embryo transfer (ET), then birth dam may be an unrelated female, possibly one that will produce more milk and a better maternal environment.

2.3.3 Raise Dam

The raise dam rears the lamb from birth to weaning age. The raise dam may be the same as the genetic dam or may be the same as the birth dam, OR may be a foster dam. In some cases, the raise dam may be a bottle. All bottle-fed lambs had a raise dam identification of 'bottle'.

2.3.4 Modelling

Biologically, the birth dam has an influence on survival and birthweight. The raise dam has an influence on 50-d weights, gain, loin, and fat thickness. The genetic dam has an influence on all six traits through the relationship matrix.

In the past, genetic evaluations assumed that the three dams were all the same individual, and equal to the genetic dam. The new models reported here, allow for the three different dams. The database has allowed this distinction to be made. The number of lambs with more than one dam influencing their records is around 43,000 out of 1.3 million lambs.

Similarly, litter effects are associated with either the birth dam or the raise dam. Age of dam effects are assigned according to birth dams or raise dams, also. If the raise dam was a bottle fed lamb, then the age of that dam was 2400 days, or very mature.

2.4 Models

A multiple trait (6 traits) system has been created in which the model for each trait is different between traits. Table 3 contains a list of the factors and a check indicates which factors are included for each trait.

Table 3
Models for Multi-Trait System for Growth.

Factors	Fixed or Random	Survival	Birth Weight	Adjusted 50-d Wt.	Gain 50-100d	Loin Thick.	Fat Thick.
Year-Month of lambing	F	√	√	√	√	√	√
Age 'birth' dam-sex	F	√	√				
Age 'raise' dam-sex-lambs born	F			√	√	√	√
Covariate weight at US	F					√	√
Flock-year Management group	R	√	√	√	√	√	√
Litter of birth dam	R	√	√				
Litter of raise dam	R			√	√	√	√
Maternal PE birth dams	R	√	√				
Maternal PE raise dams	R			√	√	√	√
Mat. Genetic birth dams	R	√	√				
Mat. Genetic raise dams	R			√	√	√	√
Direct Genetic	R	√	√	√	√	√	√

Variances and covariances among the traits for the various random factors in the model were estimated by Bayesian methods using Gibbs sampling applied to all of the data. Six thousand samples were generated, and averages of the last 5100 samples are shown in Table 4. Covariance matrices should always be checked to ensure that each is positive definite (within the correct parameter space).

Because of the complexity of the new models, including direct by maternal genetic covariances within traits and between traits was not feasible, and thus, were assumed to be zero. Maternal genetic effects are relatively small, expecially for traits occuring after 50 days of age, and therefore, covariances with direct genetic effects were expected to be small as well. Survival and birthweight may be most affected by these assumptions. Usually the direct-maternal covariances are estimated to be negative when many scientists and producers expect the covariances to be positive. Assuming the covariances are zero may be a suitable compromise.

Table 4

(Co)variances For Random Factors in Model

Row	Col	Residual	Mat PE	FYM	Litters	Direct	Mat. Genetic
1	1	1.160	0.015	0.798	0.423	0.062	0.017
1	2	0.027	0.016	0.047	0.118	0.003	0.018
1	3	0.050	0.007	0.642	0.009	0.010	0.076
1	4	0.002	0.005	0.211	-0.006	0.008	0.017
1	5	0.023	0.000	-0.003	-0.014	0.004	0.001
1	6	0.007	0.000	0.098	0.003	0.002	-0.001
2	2	0.183	0.030	0.182	0.335	0.200	0.139
2	3	0.034	0.002	0.156	0.060	0.538	0.521
2	4	-0.004	0.011	-0.041	0.014	0.446	0.135
2	5	0.005	-0.002	-0.062	0.037	0.177	0.002
2	6	0.000	-0.012	0.000	0.017	0.070	0.002
3	3	6.952	1.505	7.478	2.703	3.262	3.294
3	4	-0.012	0.028	1.842	0.242	2.494	0.931
3	5	0.154	0.113	0.308	0.035	1.041	-0.004
3	6	0.015	0.017	0.379	-0.040	0.432	0.121
4	4	6.454	0.544	11.342	0.190	6.585	0.495
4	5	0.149	0.055	1.186	0.001	1653	0.007
4	6	0.033	0.000	0.497	0.001	0.618	0.045
5	5	3.432	0.110	1.159	0.583	8.308	0.082
5	6	0.033	0.006	0.042	0.042	0.769	0.010
6	6	0.152	0.093	0.558	0.222	0.864	0.230

Table 5

Heritabilities of Growth Traits.

Trait	h^2
Survival	.025
Birthweight	.187
Adjusted 50d Wt	.129
Gain	.257
Loin Thick.	.608
Fat Thick.	.408

2.5 Expression of Proofs

The solutions as they occur from solving the mixed model equations are known as Estimated Breeding Values (EBV) and are comparable across breeds. Even so, the EBV are most useful within a flock for making breeding decisions. The EBV are expressed relative to a genetic base group. The genetic base is all lambs born in 2010. Producers prefer to look at Expected Progeny Differences (EPD) rather than EBV. An EPD is one half the value of an EBV. Gain is converted to 100-d weight by adding the gain EPD to the adjusted 50-d weight EPD.

Percentiles are calculated on a within breed group basis so that producers know where an animal stands relative to the population. Accuracies or reliabilities are also approximated using a selection index approach on a trait by trait basis and incorporate five pieces of information. They are 1) animal's own record; 2) animal's progeny, if any; 3) sire's progeny; 4) dam's records; and 5) dam's progeny.

All EPDs and auxilliary information are loaded into the database after each run. The results are accessible by all producers, for their flock only, and general results for the population.

2.6 Trends

Genetic trends can be plotted after each run. The results appear in the following six figures, one for each trait.

Figure 1

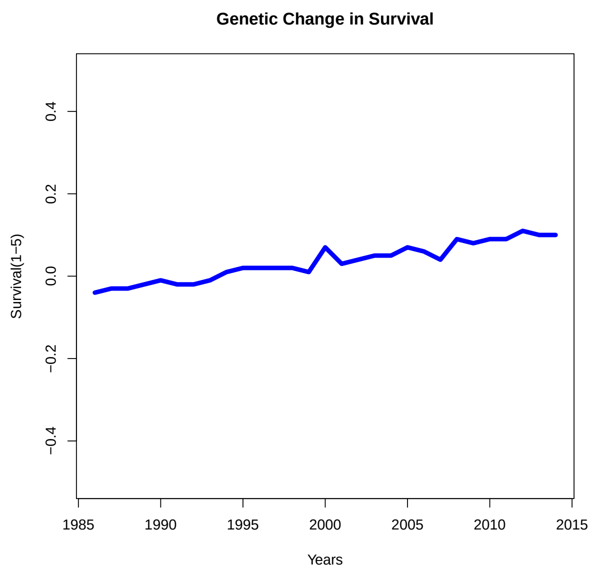


Figure 2

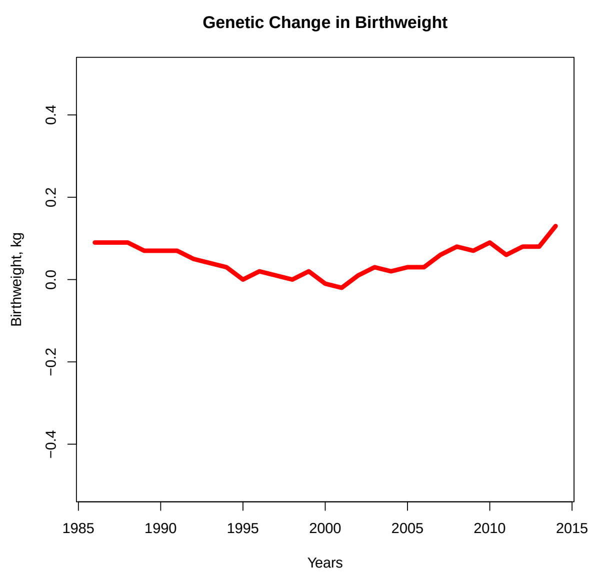


Figure 3

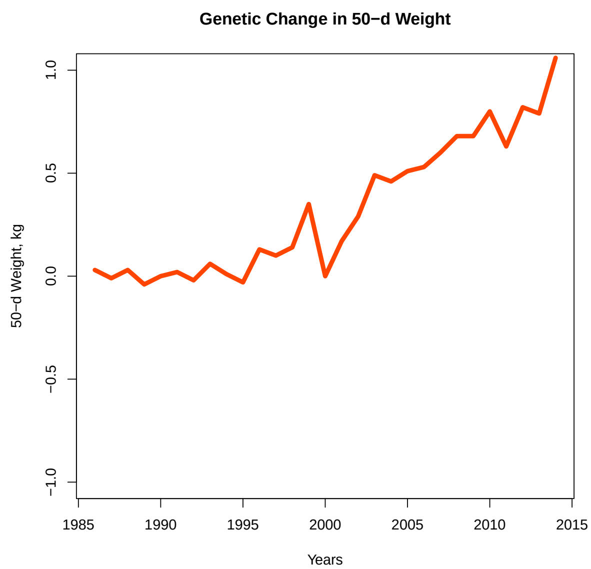


Figure 4

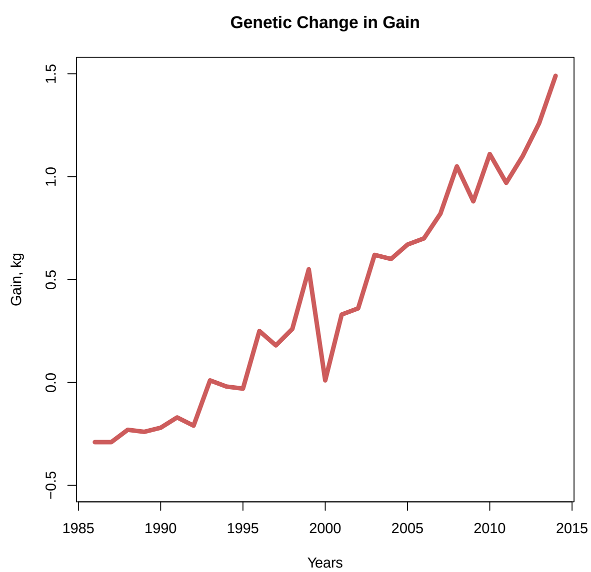


Figure 5

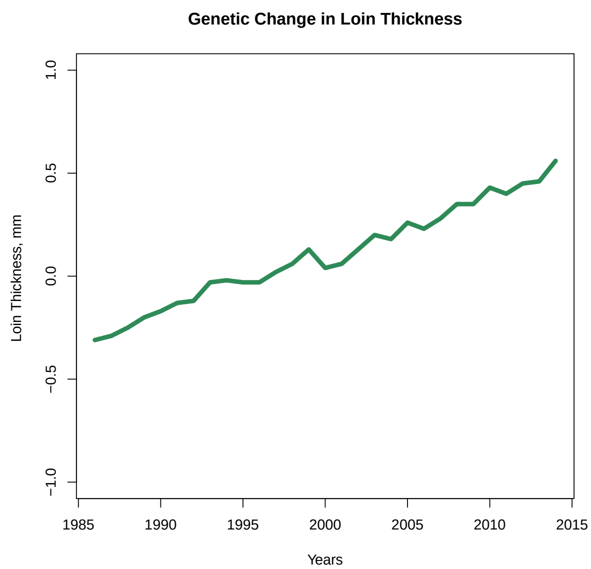
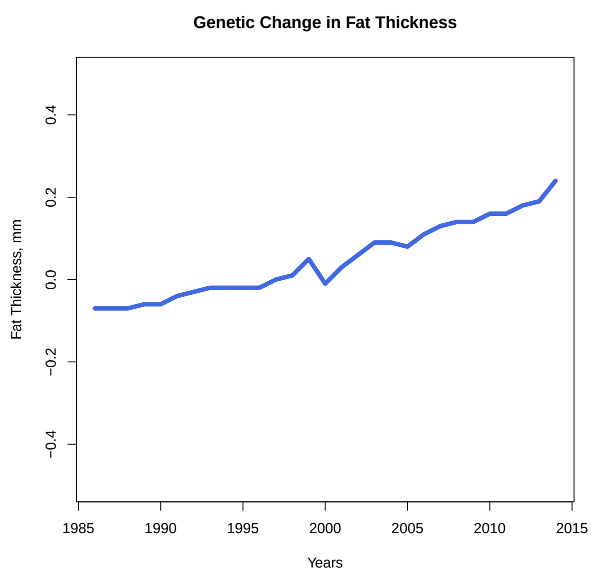


Figure 6



2.7 References

Lewis, R. M. , Emmans, G. C., Dingwall, W. S., Simm, G. 2002. A description of the growth of sheep and its genetic analysis. Animal Science 74:51-62.

Lewis, R. M. , Brotherstone, S. 2002. A genetic evaluation of growth in sheep using random regression techniques. Animal Science 74:63-70.

3 Reproduction Traits

After the growth traits were evaluated, the need to focus on ewe productivity or reproduction became more urgent. The strategy was to separate first parity animals from second and later parity animals, because there is usually a major difference between first and later parities. For first parity dairy cows, the age at first calving was important and had a heritability of .14. Thus, age at first lambing was thought to have a similar role in sheep, but the heritability estimate has been only .035.

Another trait in dairy cattle reproduction was the interval between calvings with a slightly lower heritability at .05. In sheep the interval between lambings has a heritability of only .014. The more crucial trait in sheep is the number of lambs born, and here the heritabilities have been .092 for first parity ewes and .079 for later parity ewes. In dairy cattle, nearly all births are singles, but in sheep it is more important to have two or more lambs because meat is the primary product.

Initially, number of lambs weaned was evaluated. However, because the three different types of dams were not distinguished, ewes were getting credit for lambs that they did not actually wean, and the ewes that did raise the lambs and successfully wean them were not credited at all.

Thus, the genetic variability in this trait was low due to an inconsistency in measurements. With the identification of the three types of dams (genetic, birth, and raise) it has been possible to assign credit more fairly to the appropriate ewes.

Another change has been to use a composite trait called total weaning weight (TWW), or the sum of the adjusted 50-d weights of lambs that were weaned. This includes number of lambs weaned, but also how well the 'raise' dam contributed to the lambs weaning weight. Estimates of heritability of this trait have been .20 in the literature (Snowder, 2008), but in Canadian sheep has only been about .04. With TWW the genetic model needs to account for the proportion of male and female progeny because there is a sex difference in weaning weights to consider.

A six-trait system was therefore developed with three traits for parity 1 and three traits for later parities. Age at first lambing, number born at first lambing, and TWW at first lambing were three traits for first parity animals, and interval between lambings, number born, and TWW were for second and later parities.

Table 6a

Means and standard deviations of reproductive traits. See Table 1 for breed group definitions.

		First Lambings			Later Lambings		
Breed Group	item	Age at first	No Born	Total WW	Lamb. Interval	No. Born	Total WW
1	N	7127	7120	7127	16518	63628	63706
	Mean	368.8	1.88	26.06	346.6	2.38	33.48
	SD	19.7	0.71	11.12	27.3	0.95	14.77
2	N	3337	3336	3337	25031	101183	101288
	Mean	371.3	1.15	20.32	351.0	1.54	26.70
	SD	16.6	0.37	7.57	25.7	0.59	11.53
3	N	4772	4770	4772	33245	83869	83949
	Mean	370.8	1.30	22.99	357.0	1.67	30.98
	SD	13.6	0.47	9.97	22.3	0.62	13.81
4	N	1689	1689	1689	4824	27666	27707
	Mean	372.0	1.45	21.74	341.6	1.83	27.15
	SD	21.9	0.53	9.88	27.0	0.68	12.37
5	N	289	289	289	1634	8783	8802
	Mean	374.9	1.39	24.58	350.5	1.67	29.92
	SD	17.2	0.52	9.29	25.7	0.63	13.75
6	N	164	162	164	4506	11150	11161
	Mean	374.6	1.21	20.56	357.6	1.54	27.56
	SD	20.4	0.42	9.98	23.2	0.58	12.59
7	N	174	173	174	3599	7297	7305
	Mean	370.1	1.14	16.92	360.3	1.61	25.72
	SD	13.4	0.35	8.10	19.5	0.59	11.75
8	N	1405	1402	1405	4126	27485	27543
	Mean	369.0	2.21	22.43	339.6	2.74	30.47
	SD	29.2	0.78	11.55	26.8	0.95	15.49

Table 6b
Means and standard deviations of reproductive traits. See Table 1 for breed group definitions.

		First Lambings			Later Lambings		
Breed Group	item	Age at first	No Born	Total WW	Lamb. Interval	No. Born	Total WW
9	N	15447	15422	15447	39512	168183	168638
	Mean	366.4	1.28	19.63	355.2	1.65	26.24
	SD	13.4	0.49	8.52	23.0	0.65	11.42
10	N	175	175	175	1469	3899	3903
	Mean	373.6	1.23	18.31	355.5	1.47	21.75
	SD	14.7	0.49	7.98	22.8	0.57	10.04
11	N	5881	5834	5881	18783	65884	66131
	Mean	369.8	1.36	21.58	354.4	1.81	29.68
	SD	17.8	0.53	9.38	23.6	0.71	12.74
12	N	777	775	777	5582	11717	11782
	Mean	375.9	1.26	22.59	357.2	1.63	28.80
	SD	16.5	0.47	7.82	21.9	0.63	13.42
13	N	1675	1672	1675	3756	12262	12315
	Mean	370.5	1.64	23.35	356.3	2.27	32.40
	SD	16.5	0.66	9.82	23.9	0.91	14.26
14	N	508	508	508	6144	14810	14817
	Mean	370.1	1.18	19.67	360.0	1.58	27.05
	SD	12.3	0.39	8.38	21.2	0.58	11.95
15	N	77	77	77	812	1543	1544
	Mean	376.1	1.13	16.04	363.1	1.65	24.17
	SD	14.0	0.34	5.79	18.1	0.55	9.07

3.1 Data Preparation

Age at first lambing, intervals between lambings, and number born at each lambing were obtained by processing the data by birth dam. Determining the number of lambs raised and total weaning weights of lambs weaned were obtained by processing the data by raise dams. Bottle raised lambs were skipped. A total of 654,088 lambings were utilized.

3.1.1 Age Groups

Age groups were not needed for first parity ewes because of the trait age at first lambing. Age groups were created for second parities as follows.

Table 7
Age Groups

Group	Ages	Number of lambings
1	Parity 1, All ages	43,497
2	less than 507 d	39,926
3	507 to 647 d	25,623
4	648 to 789 d	97,952
5	790 d plus	447,090

3.1.2 Year-Seasons

Season 1 included Dec, Jan, Feb, Mar, Apr, and May, and season 2 were the other months. Year of lambing was subdivided to give a total of 174 year-season subclasses.

Year-seasons were subdivided further by flock ID to give 25,831 flock-year-season subclasses, which was a random factor in the genetic evaluation model.

3.1.3 Males to Females

Total weaning weights are influenced by the number of males and females that are weaned. Male lambs are 1 to 1.5 kg heavier than female lambs at weaning. Attempting to account for number of males and females in the model results in accounting for the number of lambs weaned, which is not desired. Therefore, a pre-adjustment of weaning weights for sex of the lamb and breed of the lamb was incorporated. Phenotypic means for male and female lambs were computed from the data. The means for males and females by breed group are shown below.

Table 8
Mean Adjusted 50-d Weights by Breed Group and Sex

Group	Breed	Males		Females	
		Number	Mean	Number	Mean
1	Arcott-Rideau	57,926	17.6	58,059	16.5
2	Dorset	56,038	19.4	60,514	18.2
3	Suffolk	55,631	21.1	57,781	19.9
4	Polypay	18,307	17.6	20,392	16.5
5	Arcott-Canadian	4,401	20.0	4,664	18.9
6	Hampshire	6,921	20.6	7,245	19.5
7	North Country Cheviot	4,514	18.2	4,849	17.0
8	Romanov	15,617	14.8	17,854	13.2
9	Unknown Crosses	105,916	17.9	109,623	16.9
10	Small Meat	2,280	16.3	2,426	15.3
11	Medium Meat	125,356	18.1	138,941	16.8
12	Large Meat	13,832	19.8	14,413	18.8
13	Prolific/Dairy	12,818	17.8	13,414	16.7
14	Wool/Dual	8,923	18.9	9,544	17.7
15	Primitive	1,101	16.4	1,136	15.1

The differences, Male average minus Female average, were added to all female adjusted 50-d weights, so that all 50-d weights were expressed on a male basis for each breed.

If a lamb was indicated to have been weaned, but there was no adjusted 50-d weight in the record, then the Male average in the table above was used.

The phenotypic relationships between number weaned and total weaning weight are shown in the next table by breed group.

Table 9
Number weaned and total weaning weight by breed groups.

	First Lambings			Later Lambings		
Breed Group	No. Weaned	Total WW	Corr.	No. Weaned	Total WW	Corr.
1	1.6	26.7	.79	2.0	34.4	.77
2	1.1	21.2	.64	1.4	27.9	.78
3	1.2	24.1	.74	1.5	32.2	.79
4	1.3	23.1	.75	1.6	28.3	.77
5	1.3	25.5	.78	1.5	31.1	.77
6	1.1	22.3	.70	1.4	29.0	.75
7	1.1	18.3	.71	1.5	27.3	.79
8	1.8	23.7	.75	2.2	32.4	.70
9	1.2	20.7	.70	1.5	27.2	.78
10	1.2	18.8	.79	1.4	22.9	.81
11	1.3	22.4	.75	1.6	30.5	.78
12	1.2	23.1	.70	1.5	29.8	.82
13	1.4	23.7	.75	1.9	32.9	.77
14	1.1	20.6	.67	1.5	28.0	.77
15	1.1	16.7	.67	1.5	24.9	.79

3.1.4 Animal PE and Genetic Effects

Animals, in this model, are ewes having litters and raising lambs to weaning. Ewes can have more than one lambing in these data, thus the need for permanent environmental (PE) effects.

Animal additive genetic effects include all animals that were in the growth analyses. So the same pedigree files were used as for the growth traits. Hence there were many animals which are male, and many younger female animals which have not yet had their own litters. Thus, all animals are evaluated as are evaluated for growth.

3.2 Parameters

Covariance matrices were estimated from all data by Bayesian methods using Gibbs Sampling. The traits are numbered as 1)Age at first lambing; 2)number born in first lambing; 3) total weaning weight in first lambing; 4) interval between lambings; 5)number born in second and later lambings; 6) total weaning weight of later lambings.

Table 10
Covariance Matrices for FYS, PE effects, Genetic effects, and Residual effects

Row	Col	FYS	APE	ADD	RES
1	1	202.77	0.00	11.78	122.67
1	2	0.12	0.00	0.01	0.09
1	3	6.89	0.00	0.04	0.28
1	4	77.06	0.00	-0.09	0.00
1	5	0.01	0.00	-0.01	0.00
1	6	-1.73	0.00	0.04	0.00
2	2	0.03	0.00	0.02	0.20
2	3	0.41	0.00	0.02	1.07
2	4	-0.11	0.00	0.02	0.00
2	5	0.02	0.00	0.01	0.00
2	6	0.32	0.00	0.06	0.00
3	3	33.33	0.00	3.15	44.60
3	4	6.01	0.00	0.22	0.00
3	5	0.37	0.00	0.03	0.00
3	6	31.63	0.00	1.01	0.00
4	4	259.19	2.34	8.08	296.64
4	5	0.12	0.03	0.00	0.24
4	6	4.92	0.63	0.69	-0.52
5	5	0.04	0.01	0.03	0.35
5	6	0.60	0.09	0.20	2.35
6	6	43.25	2.77	5.18	92.64

3.3 Trends

Figure 7

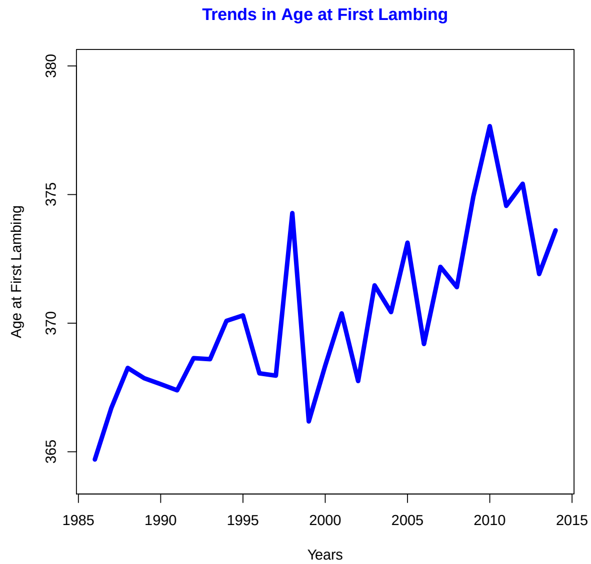


Figure 8

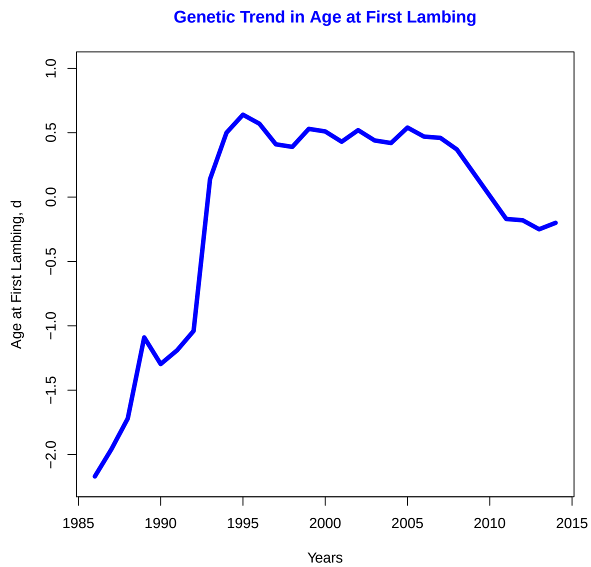


Figure 9

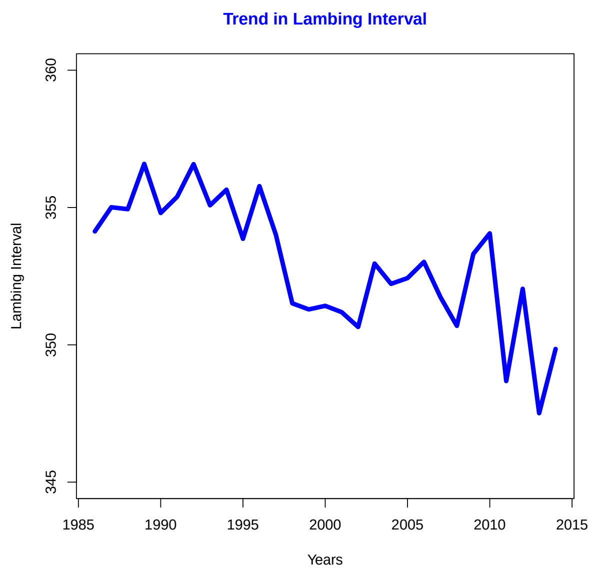


Figure 10

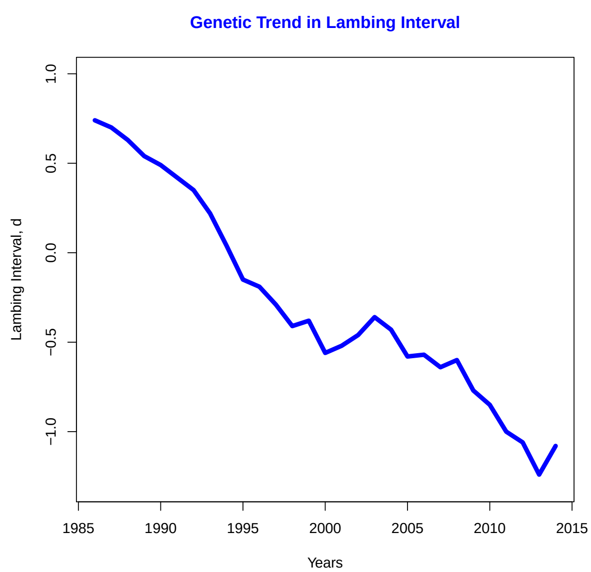


Figure 11

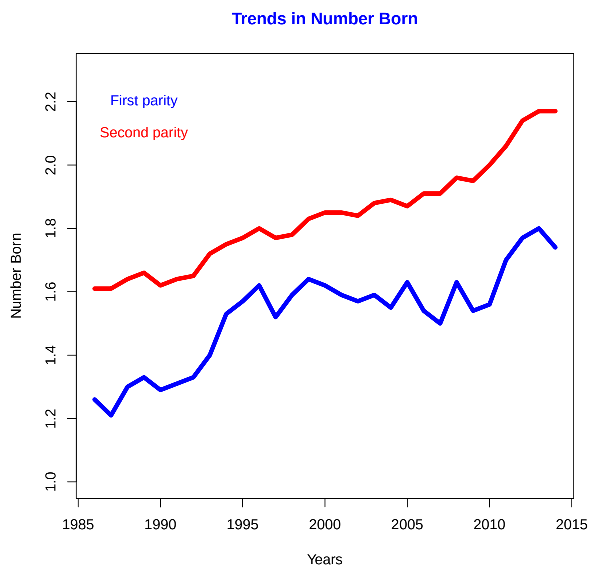


Figure 12

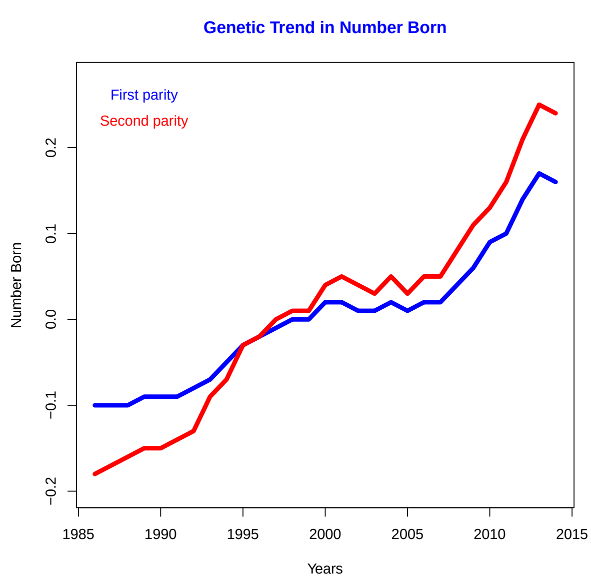


Figure 13

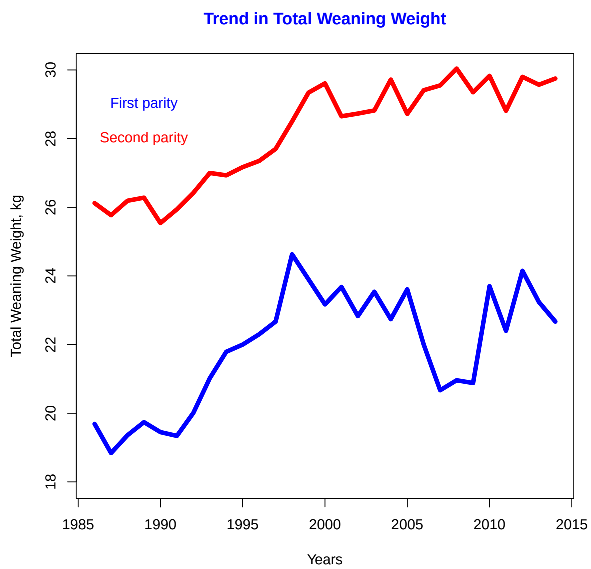
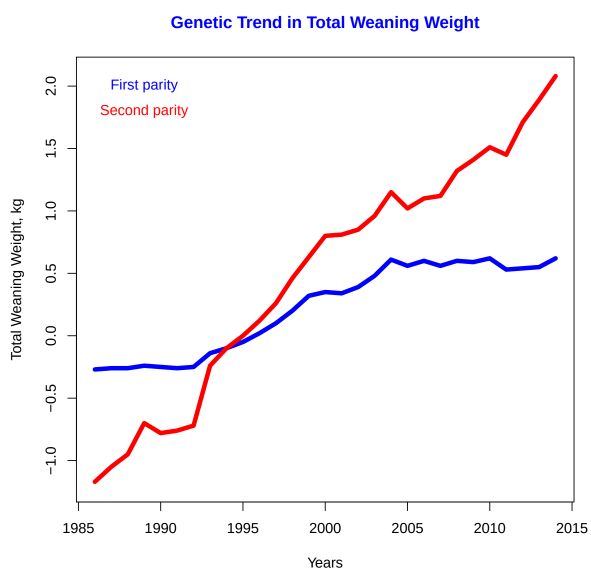


Figure 14



The trends for the reproductive traits seem to be in the right direction both phenotypically and genetically, although the rate of change is very low. Age at first lambing is increasing at .07 days per year genetically. The goal here is to have ewes lamb at a consistent and optimum age, not necessarily at older ages. The interval between lambings, however, has been decreasing at .06 days per year.

The number born per lambing is currently at 1.74 in first parity and 2.17 in second parity. Older ewes tend to have bigger litters. Genetically, the number born has been increasing at .009 per year for first parity, and .01 per year for later parities.

Total weaning weight has been increasing genetically at .03 kg per year for first parity ewes and .12 kg per year for later parity ewes. While positive, these rates are low.

Duguma, G. , Schoeman, S. J., Cloete, S. W. P., Jordaan, G. F. 2002. Genetic and environmental parameters for ewe productivity in Merinos. South African Journal of Animal Science 32(3)154-159.

Snowder, G. D. 2008. Genetic improvement of overall reproductive success in sheep: A review. Asociacion Latinoamericana de Produccion Animal. 16(1):32-40.

4 Dairy Production

4.1 Introduction

The Dairy Sheep project was started and led by CEPOQ. Eight flocks were initially recruited to collect test day records on milk weights, but also components of milk. The flocks were on the Valacta milk recording program in Quebec, but some flocks were able to provide milk records reported to two decimal places, and also had exact start and end milking times for each ewe. Milk samples still needed to be sent to Valacta for component testing.

The goal of the project, in the long term, was to have all of the data entered into the GenOvis database. Thus, in January 2015 the preparation of the existing data for inclusion into the database began.

CEPOQ have been correcting the data and adding lambing information for ewes that were missing.

Afterwards, the genetic evaluation system had to be altered so that it could be run routinely without human intervention, but this is almost an impossible task because the problems with data collection and checking have not been completely ironed out.

Several problems arose with the genetic evaluations, and these were related to having too few records for analyses, and a model that was too complex. Thus, the model was greatly simplified in order to make any genetic evaluations possible. Interactions between important factors had to be ignored, and only main effects were included in the model. As the data become more numerous in future years (more animals, more records, more flocks), then the model should be re-visited.

4.2 Data Extraction

A total of 19,302 test day records were extracted if ewes had a test day record with milk yield or components recorded (from any flock in the database). No limits were put on the actual yields, but this may be necessary in the future. Milk yields above 3 kg at one milking, for example are very rare. There was one record at 7 kg and another at 9 kg, which were obviously errors that were off by a factor of ten.

The earliest test day record was 1996/06/15 and the latest was 2014/11/06. After editing for days in milk between 5 and 220 days, there were 17,886 records. There were 6,427 records having only 1 test per day, 11,597 with AM and PM tests, and 37 with 24 hour milk yields only.

4.2.1 Breeds

There were three main dairy breeds represented in the data. These were East Friesian(EF), Lacaune (CU), and British Milking sheep (BM). Ewes were assigned to one of ten breed groups as shown in the next table.

Table 11
Breed Groups for Dairy Analyses

Group	Composition	Records
1	75% EF or better	10,669
2	75% CU or better	946
3	75% BM or better	23
4	50% EF × 50% CU	681
5	50% EF × 50% BM	30
6	50% CU × 50% BM	0
7	50-74% EF	2286
8	50-74% CU	934
9	50-74% BM	71
10	All other	1221

Breed groups were used to assign missing parents to phantom parent groups. Thus, if a ewe belonged to group 4, for example, its sire was unknown, and the ewe was from the latest generation, then the unknown sire was replaced by a Group 4 phantom sire belonging to the previous generation. Thus, every ewe with test day records had either a known sire and dam or a phantom sire or dam.

Table 12
Breed Group Averages

Group	Composition	AM Milk	PM Milk	24h Milk
1	75% EF or better	.92	.73	1.54
2	75% CU or better	1.10	.66	1.20
3	75% BM or better	.88	.71	-
4	50% EF × 50% CU	.97	.71	.85
5	50% EF × 50% BM	.75	.56	-
6	50% CU × 50% BM	-	-	-
7	50-74% EF	.82	.56	1.03
8	50-74% CU	.96	.62	1.07
9	50-74% BM	.56	.45	.76
10	All other	.81	.55	.66

Table 13
Breed Group Averages

Group	Composition	Fat %	Prot %	Lact %
1	75% EF or better	5.70	4.86	4.74
2	75% CU or better	5.51	5.04	4.73
3	75% BM or better	5.95	5.27	4.69
4	50% EF × 50% CU	5.88	5.20	4.68
5	50% EF × 50% BM	5.81	5.43	4.75
6	50% CU × 50% BM	-	-	-
7	50-74% EF	5.74	4.97	4.71
8	50-74% CU	5.58	5.01	4.73
9	50-74% BM	4.76	4.89	4.62
10	All other	5.80	4.90	4.71

Table 14
Breed Group Averages

Group	Composition	SCS	MUN	BHB
1	75% EF or better	12.07	22.37	.14
2	75% CU or better	11.47	21.30	.16
3	75% BM or better	11.74	19.03	.21
4	50% EF × 50% CU	11.59	20.81	.14
5	50% EF × 50% BM	12.72	20.39	.14
6	50% CU × 50% BM	-	-	-
7	50-74% EF	11.45	21.75	.12
8	50-74% CU	11.17	22.06	.16
9	50-74% BM	9.87	22.55	.08
10	All other	11.35	21.64	.13

4.2.2 Milking Intervals

For test days with both AM and PM milk yields, the interval between milkings is important. Nine (9) interval groups were formed, as shown below. These are the times (in minutes) from morning milking to evening milking.

Table 15
Milking Intervals

Group	Limits	Records
1	$<$ 465 min	220
2	$>$ 464 min	704
3	$>$ 509 min	3370
4	$>$ 559 min	1377
5	$>$ 589 min	1847
6	$>$ 623 min	1569
7	$>$ 652 min	1749
8	$>$ 675 min	459
9	$1440 - 1441$ min	6766

Below are the effects of milking intervals on AM milk yields over the entire lactation accumulated. The estimates shall become more accurate as data are accumulated.

Table 16
Milking Intervals - Effects on AM yields, kg

Group	Limits	Parity 1	Parity 2
1	$<$ 465 min	+43.09	+60.67
2	$>$ 464 min	+4.73	+38.08
3	$>$ 509 min	+6.95	+29.06
4	$>$ 559 min	+10.62	+29.43
5	$>$ 589 min	+16.02	+13.30
6	$>$ 623 min	+6.46	+21.12
7	$>$ 652 min	+10.38	+9.45
8	$>$ 675 min	+6.89	-9.97
9	$1440 - 1441$ min	-.50	-.33

4.2.3 Age Groups

Age groups were formed within parities as shown below. Parity 1 had 7,447 records, and later parities had 10,614 records.

Table 17
Age Groups

Group	Parity	Age	Records
1	1	$<$ 366 d	666
2	1	$>$ 365 d	2998
3	1	$>$ 440 d	579
4	1	$>$ 472 d	3204
5	2	$<$ 710 d	721
6	2	$>$ 709 d	1588
7	2	$>$ 765 d	8305

The difficulty is assigning parity number to newly enrolled animals, because it is not known if they have lambed previously without lambing dates in the database.

The following tables show estimated differences for each trait due to age. The milk yields are on a complete lactation basis from day 5 to 220 in milk, while the other traits are an average over the lactation (i.e. daily basis). Differences dues to age of the ewe at lambing are small.

Table 18
First Parity - age group differences

Trait	(Age2)-(Age1)	(Age3)-(Age1)	(Age4)-(Age1)
AM milk (220d)	-.86	.87	6.69
PM milk (220d)	.31	1.42	3.99
24h milk (220d)	-1.64	-3.76	-.82
Fat %	.05	.06	.11
Prot %	.04	.03	.03
Lact %	.00	.00	.00
SCS	.03	.11	.12
MUN	-.20	-.10	.10
BHB	.00	.00	.00

Table 19
Second Parity - age group differences

Trait	(Age6)-(Age5)	(Age7)-(Age5)
AM milk (220d)	-.78	2.11
PM milk (220d)	1.79	1.82
24h milk (220d)	-3.90	1.76
Fat %	-.02	.11
Prot %	-.01	.02
Lact %	.00	.00
SCS	.23	.29
MUN	.05	-.08
BHB	.00	.00

4.2.4 Number Born

The number of lambs born to start a lactation has an influence on the amount of milk produced by the ewe. Up to 7 lambs were recorded in the dairy data. However, there were less than 10 such lambings amongst later parity ewes. For first parity dairy ewes, the upper limit was 4 and there were very few of those. Thus, parity one had three groups (1 lamb, 2 lambs, or 3 and more lambs). Later parities had four groups (1 lamb, 2 lambs, 3 lambs, or 4 and more lambs).

Table 20
Number Born

Lambs	Records
1	5170
2	9873
3	2676
4+	342

Below are the estimated effects due to number of lambs born on each trait. There were not enough data in the group with 4 or more lambs born.

Table 21
First Parity - Effects of number of lambs born

Trait	(2)-(1)	(3)-(1)	(4)-(1)
AM milk (220d)	2.92	3.01	-
PM milk (220d)	1.14	1.95	-
24h milk (220d)	-.03	1.16	-
Fat %	.00	.01	-
Prot %	.01	.02	-
Lact %	.00	.00	-
SCS	.06	.11	-
MUN	.11	.22	-
BHB	.00	.00	-

Table 22
Second Parity - Effects of number of lambs born

Trait	(2)-(1)	(3)-(1)	(4)-(1)
AM milk (220d)	3.87	3.92	-
PM milk (220d)	1.55	3.98	-
24h milk (220d)	6.27	7.82	-
Fat %	-.03	-.04	-
Prot %	.01	.02	-
Lact %	.00	.00	-
SCS	.06	.11	-
MUN	.07	.11	-
BHB	.00	.00	-

There seem to be more milk produced by ewes with two lambs over ewes with one lamb, and also a slight increase of ewes with three lambs over ewes with two. There were not enough observations to know if this trend continues with 4 lambs born. In any case, these are small increases.

4.2.5 Seasons

Most lambs were born from December through May, but some were born from June through November although much fewer. Two seasons were used in the model. Season 1 had 16,895 test day records, and season 2 had 1166 records.

Table 23
Effects of seasons (season 2 - season 1)

Trait	Parity 1	Parity 2
AM milk (220d)	1.07	-2.11
PM milk (220d)	.83	6.29
24h milk (220d)	.99	.29
Fat %	-.29	-.36
Prot %	-.10	-.05
Lact %	.04	.03
SCS	.02	-.12
MUN	.48	.57
BHB	.00	.00

Season 2 had very few records and the effects for parity one were greatly different for parity two ewes. This indicates that the season effects are not estimated very accurately.

4.2.6 Residual Groups

The lactation period was divided into 5 groups because the variances of yields are not the same throughout the lactation. Yields in the early part of lactation tend to be more variable because yields are higher than towards the end of lactation.

Table 24
Residual Groups

Group	Days	Records
1	5-47	3459
2	48-75	2721
3	76-110	3691
4	111-145	3488
5	146-220	5943

4.3 Model

The same model was assumed for all nine traits. Separate curves were estimated for first and later parities, simultaneously. A random regression test day model was employed with 5 covariates used to describe lactation curves. The fixed factors of the model were Year of Lambing, Age group, Season, Number Born group, and Interval group. The random factors were Flock-year-season groups, animal permanent environmental effects, and animal additive genetic effects.

Ninety parameters were estimated for each animal (and phantom parent), and each level of the fixed and other random factors.

Whenever an animal had both an AM and PM milk yield, then the 24 hour milk yield was declared missing. In the database the 24 hour yield is equal to the sum of the AM and PM yields, thus if you know two of the three, then you automatically know the third one. This dependency caused computational problems in calculating EBVs for ewes. Thus, the need to declare one of the three yields as unknown, and the 24 hour yield was chosen to be set as unknown, when both AM and PM yields were known.

A more complex model would have included interactions among age, season, and number born, and possibly with year of lambing and milking interval groups. However, such grouping would have created too many subclasses having only one test day record, which is not enough to estimate a 5 parameter curve. The simple model is recommended for the next three years until the number of test day records has more than doubled. The simplified model should suffice until that time.

4.4 Accuracies and Percentiles of EBVs

Accuracies and percentile rankings were calculated for each trait using the same selection index approximation as used in the evaluations for growth and reproduction. The factors going into the accuracies are

- The number of test day records on an animal.
- The number of female progeny that also have TD records.
- The sire and number of daughters it has.
- The dam and number of TD records it has.
- The dam and number of daughters it has.

Genetic correlations between traits are not taken into account in the accuracy calculations. Thus, the accuracies are conservative estimates, and deliberately kept lower than they might actually be.

4.4.1 Range and Average of EBVs

There were a total of 3,023 animals in the pedigree information, of which 145 were rams and 1277 were dams of ewes. Only 12 animals were inbred. There were 74 phantom parent groups required for animals with unknown parentage.

Table 25
Information about EBVs

Trait	Minimum	Maximum	Average	SD
Parity 1 Ewes				
Milk Yield, kg	-171	213	-10.8	46.0
Fat Yield, kg	-9.8	13.5	-0.7	2.7
Protein Yield, kg	-8.4	11.2	-0.4	2.3
Lactose Yield, kg	-7.9	10.3	-0.6	2.2
Fat %	-0.85	1.14	-0.01	0.29
Protein %	-0.64	1.04	0.06	0.21
Lactose %	-0.73	0.41	-0.03	0.12
SCS	-1.91	2.64	-0.01	0.46
MUN	-4.65	7.20	-0.20	1.28
BHB	-0.09	0.11	0.00	0.02
Persistency	0.56	0.96	0.82	0.04
Parity 2 and Later				
Milk Yield, kg	-267	333	-17.9	64.4
Fat Yield, kg	-15.8	17.3	-1.3	3.9
Protein Yield, kg	-13.2	15.0	-0.8	3.2
Lactose Yield, kg	-12.4	15.8	-0.9	3.0
Fat %	-1.13	1.41	-0.02	0.36
Protein %	-0.75	1.28	0.08	0.24
Lactose %	-0.68	0.32	-0.02	0.10
SCS	-2.05	2.90	-0.03	0.66
MUN	-6.34	9.97	-0.24	1.49
BHB	-0.08	0.12	-0.01	0.02
Persistency	0.34	0.95	0.72	0.06

Milk, fat, protein, and lactose yields are yields over the entire lactation from day 5 to 220 days. The percentages are the average daily percentage, as for SCS, MUN, and BHB. Persistency is the only trait that does not have a mean close to zero. Note that persistency in parity 1 is better than in parity 2, but parity one ewes usually do not produce as much total milk as older ewes.

Compared to the two previous runs, the extraction of data from the database resulted in fewer records. Thus, some animals that were previously evaluated are no longer evaluated. This could change the evaluations of some animals to which they had been compared previously. The records in this run will always be included in future runs (unless they are corrected or removed from the database for other reasons).

4.4.2 Estimates of Variances

The estimates of the proportion of genetic variances out of the total variance remain high for the dairy traits. Barillet (1994) studied 130,409 ewes from 2,670 rams, and reported heritabilities of .30, .28, and .29 for milk, fat and protein yields for the Lacuaune breed of France. Oravcova (2007) gave values of .15, .10, and .25 for milk, fat, and protein for 2,196 test day records (much less data than here) of Lacaune ewes from Slovakia. Bauer et al. (2012) studied Lacaune and East Friesian ewes in the Czech Republic with a data set of similar size to the Quebec population. They found a heritability for milk yield of .28. The work of Banos et al. (2005) with Chios sheep of Greece was more similar to the current analyses (in terms of models and methods), based on 42,675 test day records from 75 flocks. They utilized records from days 40 to 240 of lactation.

Table 26
Proportions of Total Variation

Trait	Genetic	Perm. Env.	Flock-YS
Parity 1 Ewes			
AM Milk Yield, kg	.597	.207	.195
PM Milk Yield, kg	.594	.206	.199
24h Milk Yield, kg	.510	.228	.261
Fat %	.378	.153	.466
Protein %	.587	.155	.257
Lactose %	.699	.155	.145
SCS	.703	.113	.177
MUN	.425	.130	.443
BHB	.577	.217	.205
Parity 2 and Later			
AM Milk Yield, kg	.678	.160	.161
PM Milk Yield, kg	.681	.157	.162
24h Milk Yield, kg	.608	.173	.218
Fat %	.430	.151	.416
Protein %	.541	.141	.317
Lactose %	.696	.147	.155
SCS	.759	.062	.174
MUN	.487	.093	.417
BHB	.575	.206	.219

These estimates are lower than in previous reports. The estimates are expected to decrease to their true level as the number of test day records and flocks increase. More data means that there are more animals of differing genetic background, so there is a better reflection of the entire genetic pool for dairy production. At the moment only 145 different rams are represented and 1277 dams of ewes, and a good number of these are related to ancestors from Wooldrift Farm in Ontario.

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5 Summary Remarks

The Sheep Web Application and the database upon which it is based have been going for a number of years for growth and reproduction in sheep in Canada. After five years, it was time to update the genetic evaluation systems for growth and reproduction with newer models. In addition, dairy records of milking sheep have been added, and will continue to be collected. The genetic evaluation system for milk traits needed to be described. The changes that have been made should stand for another five to ten years. There are actually fewer programs to run now for each system.

In the future, there may be data on conformation traits of milking ewes, and a genetic evaluation system for these may need to be developed. Artificial insemination (now less than 0.2 % of the lambs born) may grow in usage, and studies should be made at that time about the impact on the reproductive trait evaluations. The models may need to be adjusted, and also the computer programs for genetic evaluation.

To date there has been little interest from sheep producers to apply genomics to sheep improvement, even though genomics programs are in place in other countries for sheep.

Economics should dictate which sheep breeds, if any, are profitable in Canada. The three major breeds are Arcott-Rideau, Dorset, and Suffolk, followed by Romanov and Polypay. However, the main body of sheep are crossbreds of many types and medium sized meat breed crosses. Inbreeding is not really a problem for producers in Canada.

The database system has provided a consistency in data recording for the Canadian sheep industry. The genetic evaluations from these data allow producers to select for superior genetic individuals for growth, reproduction, or dairy production. Indexes have been built to assist producers in their selections, but these have been described elsewhere.