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Across-Breed EPD Tables For The Year 2016 Adjusted To Breed Differences For Birth Year Of 2014

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ACROSS-BREED EPD TABLES FOR THE YEAR 2016 ADJUSTED TO BREED DIFFERENCES FOR BIRTH YEAR OF 2014

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Summary

Factors to adjust the expected progeny differences (EPD) of each of 18 breeds to the base of Angus EPD are reported in the column labeled 6 of Tables 1-8 for birth weight, weaning weight, yearling weight, maternal milk, marbling score, ribeye area, fat thickness, and carcass weight, respectively. An EPD is adjusted to the Angus base by adding the corresponding across-breed adjustment factor in column 6 to the EPD. It is critical that this adjustment be applied only to Spring 2016 EPD. Older or newer EPD may be computed on different bases and, therefore, could produce misleading results. When the base of a breed changes from year to year, its adjustment factor (Column 6) changes in the opposite direction and by about the same amount.

Breed differences change over time as breeds put selection emphasis on different traits and their genetic trends differ accordingly. Therefore, it is necessary to qualify the point in time at which breed differences are represented. Column 5 of Tables 1-8 contains estimates of the differences between the averages of calves from sires of each breed born in year 2014. Any differences (relative to their breed means) in the samples of sires representing those breeds at the U.S. Meat Animal Research Center (USMARC) are adjusted out of these breed difference estimates and the across-breed adjustment factors. The breed difference estimates are reported as progeny differences, e.g., they represent the expected difference in progeny performance of calves sired by average bulls (born in 2014) of two different breeds and out of dams of a third, unrelated breed. In other words, they represent half the differences that would be expected between purebreds of the two breeds.

Introduction

This report is the year 2016 update of estimates of sire breed means from data of the Germplasm Evaluation (GPE) project at USMARC adjusted to a year 2014 basis using EPD from the most recent national cattle evaluations. The 2014 basis year is chosen because yearling records for weight and carcass traits should have been accounted for in EPDs for progeny born in 2014 in the Spring 2016 EPD national genetic evaluations. Factors to adjust Spring 2016 EPD of 18 breeds to a common base were calculated and are reported in Tables 1-3 for birth weight (BWT), weaning weight (WWT), and yearling weight (YWT) and in Table 4 for the maternal milk (MILK) component of maternal weaning weight (MWWT). Tables 5-8 summarize the factors for marbling score (MAR), ribeye area (REA), fat thickness (FAT), and carcass weight (CWT).

The across-breed table adjustments apply **only** to EPD for most recent (spring, 2016) national cattle evaluations. Serious errors can occur if the table adjustments are used with earlier or later EPD which may have been calculated with a different within-breed base.

The following describes the changes that have occurred since the update released in 2015 (Kuehn and Thallman, 2015):

New samplings of sires in the USMARC GPE program continued to increase progeny records for all of the breeds. The GPE program has entered a new phase in which more progeny are produced from breeds with higher numbers of registrations. Breeds with large increases in progeny numbers as a percentage of total progeny included South Devon and Tarentaise (especially for yearling weight, carcass traits, and maternal milk) and Santa Gertrudis and Chiangus (especially for maternal milk). However, all of the breeds continue to produce progeny in the project and sires continue to be sampled on a continuous basis for each of the 18 breeds in the across-breed EPD program. These additional progeny improve the accuracy of breed differences estimated at USMARC (column 3 in Tables 1-8) particularly for breeds with less data in previous GPE cycles (e.g., South Devon, Tarentaise, Santa Gertrudis, Chiangus).

Materials and Methods

All calculations were as outlined in the 2010 BIF Guidelines. The basic steps were given by Notter and Cundiff (1991) with refinements by Núñez-Dominguez et al. (1993), Cundiff (1993, 1994), Barkhouse et al. (1994, 1995), Van Vleck and Cundiff (1997–2006), Kuehn et al. (2007-2011), and Kuehn and Thallman (2012-2015). Estimates of variance components, regression coefficients, and breed effects were obtained using the MTDFREML package (Boldman et al., 1995). All breed solutions are reported as differences from Angus. The table values of adjustment factors to add to within-breed EPD are relative to Angus.

Models for Analysis of USMARC Records

An animal model with breed effects represented as genetic groups was fitted to the GPE data set (Arnold et al., 1992; Westell et al., 1988). In the analysis, all AI sires (sires used via artificial insemination) were assigned a genetic group according to their breed of origin. Due to lack of pedigree and different selection histories, dams mated to the AI sires and natural service bulls mated to F_1 females were also assigned to separate genetic groups (i.e., Hereford dams were assigned to different genetic groups than Hereford AI sires). Cows from Hereford selection lines (Koch et al., 1994) were used in Cycle IV of GPE and assigned into their own genetic groups. Through Cycle VIII, most dams were from Hereford, Angus, or MARCIII (1/4 Angus, 1/4 Hereford, 1/4 Pinzgauer, 1/4 Red Poll) composite lines. In order to be considered in the analysis, sires had to have an EPD for the trait of interest. All AI sires were considered unrelated for the analysis in order to adjust resulting genetic group effects by the average EPD of the sires.

Fixed effects in the models for BWT, WWT (205-d), and YWT (365-d) included breed (fit as genetic groups) and maternal breed (WWT only), year and season of birth by GPE cycle by age of dam (2, 3, 4, 5-9, >10 yr) combination by any treatment combination where applicable, sex (heifer, bull, steer; steers were combined with bulls for BWT), a covariate for heterosis, and a covariate for day of year at birth of calf. Models for WWT also included a fixed covariate for maternal heterosis. Random effects included animal and residual error except for the analysis of WWT which also included a random maternal genetic effect and a random permanent environmental effect.

For the carcass traits (MAR, REA, FAT, and CWT), breed (fit as genetic groups), sex (heifer, steer) and slaughter date by any treatment combination where applicable were included in the model as fixed effects. Fixed covariates included slaughter age and heterosis. Random effects were animal and residual error. To be included, breeds had to report carcass EPD on a carcass (vs. ultrasound) basis using age-adjusted endpoints, as suggested in the 2010 BIF Guidelines.

The covariates for heterosis were calculated as the expected breed heterozygosity for each animal based on the percentage of each breed of that animal's parents. In other words, it is the probability that, at any location in the genome, the animal's two alleles originated from two different breeds. Heterosis is assumed to be proportional to breed heterozygosity. For the purpose of heterosis calculation, AI and dam breeds were assumed to be the same breed and Red Angus was assumed the same breed as Angus. For purposes of heterosis calculation, composite breeds were considered according to nominal breed composition. For example, Brangus (3/8 Brahman, 5/8 Angus) · Angus is expected to have 3/8 as much heterosis as Brangus · Hereford.

Variance components were estimated with a derivative-free REML algorithm with genetic group solutions obtained at convergence. Differences between resulting genetic group solutions for AI sire breeds were divided by two to represent the USMARC breed of sire effects in Tables 1-8. Resulting breed differences were adjusted to current breed EPD levels by accounting for the average EPD of the AI sires of progeny/grandprogeny, etc. with records. Average AI sire EPD were calculated as a weighted average AI sire EPD from the most recent within breed genetic evaluation. The weighting factor was the sum of relationship coefficients between an individual sire and all progeny with performance data for the trait of interest relative to all other sires in that breed.

For all traits, regression coefficients of progeny performance on EPD of sire for each trait were calculated using an animal model with EPD sires excluded from the pedigree. Genetic groups were assigned in place of sires in their progeny pedigree records. Each sire EPD was 'dropped' down the pedigree and reduced by ½ depending on the number of generations each calf was removed from an EPD sire. In addition to regression coefficients for the EPDs of AI sires, models included the same fixed effects described previously. Pooled regression coefficients, and regression coefficients by sire breed were obtained. These regression coefficients are monitored as accuracy checks and for possible genetic by environment interactions. In addition, the regression coefficients by sire breed may reflect differences in genetic trends for different breeds. The pooled regression coefficients were used as described in the next section to adjust for differences in management at USMARC as compared to seedstock production (e.g., YWT of males at USMARC are primarily on a slaughter steer basis, while in seedstock field data they are primarily on a breeding bull basis). For carcass traits, MAR, REA, FAT, and CWT, regressions were considered too variable and too far removed from 1.00. Therefore, the regressions were assumed to be 1.00 until more data is added to reduce the impact of sampling errors on prediction of these regressions. However, the resulting regressions are still summarized.

Records from the USMARC GPE Project are not used in calculation of within-breed EPD by the breed associations. This is critical to maintain the integrity of the regression coefficient. If USMARC records were included in the EPD calculations, the regressions would be biased upward.

Adjustment of USMARC Solutions

The calculations of across-breed adjustment factors rely on breed solutions from analysis of records at USMARC and on averages of within-breed EPD from the breed associations. The basic calculations for all traits are as follows:

USMARC breed of sire solution (1/2 breed solution) for breed i (USMARC (i)) converted to an industry scale (divided by b) and adjusted for genetic trend (as if breed average bulls born in the base year had been used rather than the bulls actually sampled):

M_i = USMARC (i)/b + [$EPD(i)_{YY}$ - $EPD(i)_{USMARC}$].

Breed Table Factor (A_i) to add to the EPD for a bull of breed i:

$A_i = (M_i - M_x) - (EPD(i)_{YY} - EPD(x)_{YY})$.

where,

USMARC(i) is solution for effect of sire breed i from analysis of USMARC data,

$EPD(i)_{YY}$ is the average within-breed 2016 EPD for breed i for animals born in the base year (YY, which is two years before the update; e.g., YY = 2014 for the 2016 update),

$EPD(i)_{USMARC}$ is the weighted (by total relationship of descendants with records at USMARC) average of 2016 EPD of bulls of breed i having descendants with records at USMARC,

b is the pooled coefficient of regression of progeny performance at USMARC on EPD of sire (for 2016: 1.17, 0.81, 0.96, and 1.08 BWT, WWT, YWT, and MILK, respectively;

1.00 was applied to MAR, REA, FAT, and CWT data),

i denotes sire breed i, and

x denotes the base breed, which is Angus in this report.

Results

Heterosis

Heterosis was included in the statistical model as a covariate for all traits. Maternal heterosis was also fit as a covariate in the analysis of weaning weight. Resulting estimates were 1.73 lb, 14.91 lb, 24.39 lb, -0.05 marbling score units (i.e. 4.00 = Sl^{00}, 5.00 = Sm^{00}), 0.26 in^2, 0.035 in, and 31.25 lb in for BWT, WWT, YWT, MAR, REA, FAT, and CWT respectively. These estimates are interpreted as the amount by which the performance of an F_1 is expected to exceed that of its parental breeds. The estimate of maternal heterosis for WWT was 8.64 lb.

Across-breed adjustment factors

Tables 1, 2, and 3 (for BWT, WWT, and YWT) summarize the data from, and results of, USMARC analyses to estimate breed of sire differences on a 2014 birth year basis. The column labeled 6 of each table corresponds to the Across-breed EPD Adjustment Factor for that trait. Table 4 summarizes the analysis of MILK. Tables 5, 6, 7, and 8 summarize data from the carcass traits (MAR, REA, FAT, and CWT). Because of the accuracy of sire carcass EPDs and the greatest percentage of data being added to carcass traits, sire effects and adjustment factors are more likely to change for carcass traits in the future.

Column 5 of each table represents the best estimates of sire breed differences for calves born in 2014 on an industry scale. These breed difference estimates are reported as progeny differences, e.g., they represent the expected difference in progeny performance of calves sired by average bulls (born in 2014) of two different breeds and out of dams of a third, unrelated breed. Thus, they represent half the difference expected between purebreds of the respective breeds.

In each table, breed of sire differences were added to the raw mean of Angus-sired progeny born 2011 through 2015 at USMARC (Column 4) to make these differences more interpretable to producers on scales they are accustomed to.

Figures 1-4 illustrate the relative genetic trends of most of the breeds involved (if they submitted trends) adjusted to a constant base using the adjustment factors in column 6 of Tables 1-8. These figures demonstrate the effect of selection over time on breed differences; breeders within each breed apply variable levels of selection toward each trait resulting in reranking of breeds for each trait over time. These figures and Column 5 of Tables 1-8 can be used to identify breeds with potential for complementarity in mating programs.

Across-breed EPD Adjustment Factor Example

Adjustment factors can be applied to compare the genetic potential of sires from different breeds. Suppose the EPD for yearling weight for a Gelbvieh bull is +98.0 (which is above the birth year 2014 average of 96.8 for Gelbvieh) and for a Simmental bull is +89.0 (which is below the birth year 2014 average of 92.5 for Simmental). The across-breed adjustment factors in the last column of Table 3 are -29.3 for Gelbvieh and -12.1 for Simmental. Then the adjusted EPD for the Gelbvieh bull is 98.0 + (-29.3) = 68.7 and for the Simmental bull is 89.0 + (-12.1) = 76.9. The expected yearling weight difference when both are mated to another breed of cow, e.g., Hereford, would be 68.7 – 76.9 = -8.2 lb. The differences in true breeding value between two bulls with similar within-breed EPDs are primarily due to differences in the genetic base from which those within-breed EPDs are deviated.

Birth Weight

The range in estimated breed of sire differences relative to Angus for BWT (Table 1, column 5) ranged from -0.1 lb for Red Angus to 7.2 lb for Charolais and 10.8 lb for Brahman. Red Angus had the lowest estimated sire effect for birth weight (Table 1, column 5). The relatively heavy birth weights of Brahman-sired progeny would be expected to be offset by favorable maternal effects reducing birth weight if progeny were from Brahman or Brahman cross dams which would be an important consideration in crossbreeding programs involving Brahman cross females. Changes in breed of sire effects were small and less than 1.0 lb for all breeds relative to last year's update (Kuehn and Thallman, 2015).

Weaning Weight

All of the 17 breed differences (Table 2, column 5) were within 6 lb of the values reported by Kuehn and Thallman. (2015). Otherwise, changes in breed effects for all 18 breeds seem to be stabilizing since continuous sampling started in 2007, with most minor year-to-year changes coming from selection progress in Angus (increases in the mean EPD each year).

Yearling Weight

Breed of sire effects for yearling weight were also similar to Kuehn and Thallman (2015) in general. Angus continued to have the greatest rate of genetic change for yearling weight (+3 lb since last year), causing most breed of sire differences relative to Angus to decrease at least slightly.

Maternal Milk

Changes to the maternal milk breed of sire differences (Table 4, column 5) were generally small. All changes were less than 4 lb difference from those reported in 2015. However, the breed solution estimates (Table 4, column 3) are expected to change the most in future updates as GPE heifers from each of the 18 breeds being continuously sampled are developed and bred. Females from newly sampled South Devon or Tarentaise sires have continued to add progeny in this update; difference from Angus changed very little in these breeds. We would expect their solutions to change the most in future reports.

Marbling, Ribeye Area, Fat Thickness and Carcass Weight

Most changes to breed of sire differences were minor for each of these carcass traits. Salers had a decreased breed average in 2015, likely due to a processing error—this error seems to have been corrected this year. The breed mean for marbling in Limousin seemed to increase (+0.06) relative to the average of the bulls in GPE (-0.9) resulting in a change in their breed difference since 2015. Generally changes for other carcass traits were minor.

Accuracies and Variance Components

Table 9 summarizes the average Beef Improvement Federation (BIF) accuracy for bulls with progeny at USMARC weighted appropriately by average relationship to animals with phenotypic records. The sires sampled recently in the GPE program have generally been higher accuracy sires, so the average accuracies should continue to increase over the next several years.

Table 10 reports the estimates of variance components from the animal models that were used to obtain breed of sire and breed of MGS solutions. Heritability estimates for BWT, WWT, YWT, and MILK were 0.55, 0.17, 0.43, and 0.15, respectively. Heritability estimates for MAR, REA, FAT, and CWT were 0.53, 0.47, 0.42, and 0.52 respectively.

Regression Coefficients

Table 11 updates the coefficients of regression of records of USMARC progeny on sire EPD for BWT, WWT, and YWT which have theoretical expected values of 1.00. The standard errors of the specific breed regression coefficients are large relative to the regression coefficients. Large differences from the theoretical regressions, however, may indicate problems with genetic evaluations, identification, or sampling. The pooled (overall) regression coefficients of 1.17 for BWT, 0.81 for WWT, and 0.96 for YWT were used to adjust breed of sire solutions to the base year of 2014. These regression coefficients are reasonably close to expected values of 1.0. Deviations from 1.00 are believed to be due to scaling differences between performance of progeny in the USMARC herd and of progeny in herds contributing to the national genetic evaluations of the 18 breeds. Breed differences calculated from the USMARC data are divided by these regression coefficients to put them on an industry scale. A regression greater than one suggests that variation at USMARC is greater than the industry average, while a regression less than one suggests that variation at USMARC is less than the industry average. Reasons for differences in scale can be rationalized. For instance, cattle at USMARC, especially steers and market heifers, are fed at higher energy rations than some seedstock animals in the industry. Also, in several recent years, calves have been weaned earlier than 205 d at USMARC, likely reducing the variation in weaning weight of USMARC calves relative to the industry.

The coefficients of regression for MILK are also shown in Table 11. Several sire (MGS) breeds have regression coefficients considerably different from the theoretical expected value of 1.00 for MILK. Standard errors, however, for the regression coefficients by breed are large except for Angus and Hereford. The pooled regression coefficient of 1.08 for MILK is reasonably close to the expected regression coefficient of 1.00.

Regression coefficients derived from regression of USMARC steer progeny records on sire EPD for MAR, REA, FAT, and CWT are shown in Table 12. Each of these coefficients has a theoretical expected value of 1.00. Compared to growth trait regression coefficients, the standard errors even on the pooled estimates are higher, though they have decreased from the previous year. The MAR regressions were the most variable, possibly because the primary source of marbling variation in many of the breeds is ultrasound-estimated intramuscular fat which generally exhibits a lower level of variation. While REA, FAT, and CWT are both close to the theoretical estimate of 1.00, we continued to use the theoretical estimate of 1.00 to derive breed of sire differences and EPD adjustment factors. Pooled regression estimates for these three traits may be used in future updates.

Prediction Error Variance of Across-Breed EPD

Prediction error variances were not included in the report due to a larger number of tables included with the addition of carcass traits. These tables were last reported in Kuehn et al. (2007; available online at http://www.beefimprovement.org/content/uploads/2013/07/BIF-Proceedings5.pdf). An updated set of tables is available on request (Larry.Kuehn@ars.usda.gov).

Implications

Bulls of different breeds can be compared on a common EPD scale by adding the appropriate across-breed adjustment factor to EPD produced in the most recent genetic evaluations for each of the 18 breeds. The across-breed EPD are most useful to commercial producers purchasing bulls of two or more breeds to use in systematic crossbreeding programs. Uniformity in across-breed EPD should be emphasized for rotational crossing. Divergence in across-breed EPD for direct weaning weight and yearling weight should be emphasized in selection of bulls for terminal crossing. Divergence favoring lighter birth weight may be helpful in selection of bulls for use on first calf heifers. Accuracy of across-breed EPD depends primarily upon the accuracy of the within-breed EPD of individual bulls being compared.

Table 1. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – BIRTH WEIGHT (lb)

	Number		Ave. Base EPD		Breed Soln	BY 2014	BY 2014	Factor to
			Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2014	Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	196	2278	1.3	1.6	0.0	86.3	0.0	0.0
Hereford	183	2565	3.3	2.4	3.6	90.6	4.3	2.3
Red Angus	69	815	-1.3	-1.6	-0.8	86.2	-0.1	2.5
Shorthorn	59	603	2.4	2.7	6.8	92.1	5.8	4.7
South Devon	29	240	2.3	2.0	4.3	90.6	4.3	3.3
Beefmaster	58	565	0.6	1.3	5.1	90.3	4.0	4.7
Brahman	60	716	1.8	0.7	11.1	97.1	10.8	10.3
Brangus	59	564	1.2	0.9	3.2	89.6	3.2	3.3
Santa Gertrudis	29	334	0.2	0.6	5.5	90.9	4.6	5.7
Braunvieh	36	492	2.7	4.2	5.4	89.7	3.3	1.9
Charolais	124	1277	0.5	0.2	7.8	93.5	7.2	8.0
Chiangus	30	357	2.3	2.1	4.3	90.5	4.2	3.2
Gelbvieh	90	1159	0.5	2.1	3.9	88.3	2.0	2.8
Limousin	86	1242	1.3	1.5	2.6	88.6	2.3	2.3
Maine Anjou	51	583	1.6	2.2	5.7	90.9	4.5	4.2
Salers	58	517	1.8	2.4	3.1	88.6	2.3	1.8
Simmental	110	1320	1.9	3.1	5.5	90.1	3.8	3.2
Tarentaise	17	291	1.3	2.1	4.6	89.7	3.4	3.4

Calculations:

(4) = (3) / b + [(1) – (2)] + (Recent Raw Angus Mean: 86.6 lb) with b = 1.17

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 2. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – WEANING WEIGHT (lb)

	Number		Ave. Base EPD		Breed Soln	BY 2014	BY 2014	Factor to
			Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2014	Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	196	2106	51.0	28.2	0.0	570.7	0.0	0.0
Hereford	181	2373	48.2	29.6	-5.2	560.1	-10.6	-7.8
Red Angus	69	781	57.0	52.5	-5.7	545.4	-25.4	-31.4
Shorthorn	59	569	55.0	56.5	-6.8	538.1	-32.6	-36.6
South Devon	29	219	43.6	28.4	-9.1	552.0	-18.8	-11.4
Beefmaster	58	532	23.0	23.9	11.0	560.6	-10.1	17.9
Brahman	58	621	16.0	7.5	19.8	580.8	10.1	45.1
Brangus	59	534	24.4	21.3	4.1	556.1	-14.6	12.0
Santa Gertrudis	29	315	3.8	6.5	11.8	559.8	-10.9	36.3
Braunvieh	36	457	44.4	45.5	-6.7	538.6	-32.1	-25.5
Charolais	123	1163	26.7	15.2	17.5	581.0	10.3	34.6
Chiangus	30	320	43.3	46.5	-7.1	536.0	-34.7	-27.0
Gelbvieh	90	1087	65.6	59.1	6.8	562.8	-8.0	-22.6
Limousin	86	1142	62.7	45.6	-0.7	564.2	-6.5	-18.2
Maine Anjou	51	541	47.2	46.0	-10.3	536.5	-34.3	-30.5
Salers	58	491	41.0	34.8	-0.6	553.4	-17.3	-7.3
Simmental	109	1209	63.4	57.1	15.8	573.7	3.0	-9.4
Tarentaise	17	282	17.5	-0.5	-2.9	562.4	-8.4	25.1

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 548.0 lb) with b = 0.81

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 3. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – YEARLING WEIGHT (lb)

Breed	Number AI Sires	Number Direct Progeny	Ave. Base EPD Breed 2014 (1)	Ave. Base EPD USMARC Bulls (2)	Breed Soln at USMARC (vs Ang) (3)	BY 2014 Sire Breed Average (4)	BY 2014 Sire Breed Difference[a] (5)	Factor to adjust EPD To Angus (6)
Angus	162	1834	91.0	50.3	0.0	1057.4	0.0	0.0
Hereford	158	2170	78.2	48.9	-28.8	1016.1	-41.4	-28.6
Red Angus	57	706	88.0	74.9	-9.7	1019.8	-37.6	-34.6
Shorthorn	59	515	66.0	64.3	-3.2	1015.1	-42.3	-17.3
South Devon	28	193	81.7	56.6	-20.0	1021.0	-36.4	-27.1
Beefmaster	56	425	45.0	45.4	-4.2	1011.9	-45.5	0.5
Brahman	56	564	25.6	13.2	-29.3	998.6	-58.8	6.6
Brangus	57	433	46.3	39.1	-7.0	1016.7	-40.7	4.0
Santa Gertrudis	24	291	5.2	9.9	2.4	1014.6	-42.8	43.0
Braunvieh	33	441	68.0	70.9	-28.2	984.4	-73.0	-50.0
Charolais	111	1061	48.7	29.9	19.2	1055.5	-1.9	40.4
Chiangus	26	287	63.1	66.0	-23.9	989.0	-68.4	-40.5
Gelbvieh	82	1020	96.8	77.9	-1.7	1033.9	-23.5	-29.3
Limousin	76	1052	92.3	60.9	-29.5	1017.4	-40.0	-41.3
Maine Anjou	51	506	62.6	61.8	-26.1	990.3	-67.1	-38.7
Salers	52	466	78.3	67.0	-8.7	1019.0	-38.4	-25.7
Simmental	88	1052	92.5	83.5	20.2	1046.8	-10.6	-12.1
Tarentaise	17	254	30.8	2.7	-40.3	1002.8	-54.6	5.6

Calculations:
(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 1016.7 lb) with b = 0.96
(5) = (4) – (4, Angus)
(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 4. Breed of maternal grandsire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – MILK (lb)

Breed	AI Sires	Number Direct Gpr	Direct Progeny	Ave. Base EPD Breed 2014 (1)	Ave. Base EPD USMARC Bulls (2)	Breed Soln at USMARC (vs Ang) (3)	BY 2014 Sire Breed Average (4)	BY 2014 Sire Breed Difference[a] (5)	Factor to adjust EPD To Angus (6)
Angus	143	3162	751	23.0	15.3	0.0	555.7	0.0	0.0
Hereford	137	3812	932	20.3	10.9	-23.4	535.7	-20.0	-17.3
Red Angus	48	1029	275	20.0	16.0	4.3	555.9	0.3	3.3
Shorthorn	49	528	189	18.0	20.3	9.9	554.8	-0.9	4.1
South Devon	24	378	90	25.1	20.2	9.5	561.7	6.0	3.9
Beefmaster	46	443	138	9.0	9.2	-0.2	547.6	-8.1	5.9
Brahman	56	865	252	5.6	7.1	16.9	562.1	6.4	23.8
Brangus	46	414	125	9.5	6.4	-2.8	548.5	-7.2	6.3
Santa Gertrudis	21	279	112	0.5	-1.6	0.1	550.2	-5.5	17.0
Braunvieh	30	729	187	34.6	34.2	19.5	566.5	10.8	-0.8
Charolais	97	1775	452	8.7	5.9	-1.3	549.6	-6.1	8.2
Chiangus	24	268	112	15.3	14.6	-2.6	546.3	-9.4	-1.7
Gelbvieh	74	1688	408	26.8	29.7	18.0	561.8	6.1	2.3
Limousin	64	1933	438	26.8	25.2	-4.1	545.7	-9.9	-13.7
Maine Anjou	43	740	201	19.1	19.3	-2.4	545.5	-10.1	-6.2
Salers	47	626	201	19.9	19.2	10.5	557.6	2.8	5.9
Simmental	78	1901	454	21.6	25.6	16.0	558.7	3.0	4.4
Tarentaise	14	374	100	0.7	4.0	14.0	557.6	1.9	24.2

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 548.0 lb) with b = 1.08

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 5. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – MARBLING (marbling score units[a])

	Number		Ave. Base EPD		Breed Soln	BY 2014	BY 2014	Factor to
			Breed	USMARC	at USMARC	Sire Breed	Sire Breed	adjust EPD
	AI	Direct	2014	Bulls	(vs Ang)	Average	Difference[b]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	145	831	0.59	0.23	0.00	5.88	0.00	0.00
Hereford	154	1015	0.09	0.02	-0.52	5.07	-0.81	-0.31
Red Angus	53	268	0.45	0.48	-0.02	5.47	-0.41	-0.27
Shorthorn	57	267	0.05	0.03	-0.34	5.20	-0.68	-0.14
South Devon	23	70	0.40	-0.06	-0.37	5.61	-0.27	-0.08
Brahman	55	235	0.00	-0.01	-1.02	4.51	-1.37	-0.78
Santa Gertrudis	24	139	-0.01	-0.02	-0.79	4.73	-1.14	-0.54
Braunvieh	32	206	0.56	0.50	-0.43	5.14	-0.73	-0.70
Charolais	66	329	0.04	-0.02	-0.58	5.00	-0.88	-0.33
Chiangus	26	133	0.10	0.14	-0.43	5.05	-0.83	-0.34
Gelbvieh	81	452	0.09	-0.24	-0.74	5.10	-0.77	-0.27
Limousin	69	424	-0.01	-0.26	-0.92	4.85	-1.03	-0.43
Maine Anjou	51	253	0.05	0.03	-0.77	4.77	-1.11	-0.57
Salers	48	230	0.20	-0.37	-0.69	5.40	-0.48	-0.09
Simmental	86	490	0.14	-0.01	-0.58	5.09	-0.79	-0.34

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 5.52) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]4.00 = Sl^{00}, 5.00 = Sm^{00}

[b]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 6. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – RIBEYE AREA (in^2)

Breed	Number AI Sires	Number Direct Progeny	Ave. Base EPD Breed 2014 (1)	Ave. Base EPD USMARC Bulls (2)	Breed Soln at USMARC (vs Ang) (3)	BY 2014 Sire Breed Average (4)	BY 2014 Sire Breed Difference[a] (5)	Factor to adjust EPD To Angus (6)
Angus	145	832	0.53	0.11	0.00	13.57	0.00	0.00
Hereford	154	1015	0.31	-0.02	-0.20	13.28	-0.29	-0.07
Red Angus	53	268	0.13	-0.07	-0.17	13.19	-0.39	0.01
Shorthorn	57	267	-0.06	-0.09	0.17	13.35	-0.22	0.37
South Devon	23	70	0.23	0.21	0.39	13.56	-0.01	0.29
Brahman	55	240	0.01	0.05	-0.10	13.01	-0.57	-0.05
Santa Gertrudis	24	140	0.04	0.02	-0.17	13.00	-0.58	-0.09
Braunvieh	32	206	0.35	0.33	1.01	14.17	0.60	0.78
Charolais	66	332	0.32	0.16	1.07	14.38	0.80	1.01
Chiangus	26	134	0.32	0.18	0.41	13.70	0.13	0.34
Gelbvieh	81	454	0.45	0.37	1.01	14.24	0.67	0.75
Limousin	69	425	0.48	0.39	1.30	14.54	0.96	1.01
Maine Anjou	51	253	0.21	0.20	1.07	14.22	0.65	0.97
Salers	48	231	0.02	0.02	0.85	14.00	0.43	0.94
Simmental	86	491	0.79	0.56	0.95	14.33	0.75	0.49

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 13.15 in^2) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 7. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – FAT THICKNESS (in)

	Number		Ave. Base EPD		Breed Soln at USMARC	BY 2014 Sire Breed	BY 2014 Sire Breed	Factor to adjust EPD
	AI	Direct	Breed 2014	USMARC Bulls	(vs Ang)	Average	Difference[a]	To Angus
Breed	Sires	Progeny	(1)	(2)	(3)	(4)	(5)	(6)
Angus	145	832	0.017	0.003	0.000	0.677	0.000	0.000
Hereford	154	1014	0.003	-0.003	-0.062	0.607	-0.070	-0.056
Red Angus	52	266	-0.007	-0.010	-0.029	0.637	-0.040	-0.016
Shorthorn	57	267	-0.033	-0.029	-0.136	0.522	-0.155	-0.105
South Devon	23	70	0.010	0.008	-0.127	0.537	-0.140	-0.133
Brahman	55	240	0.000	-0.002	-0.149	0.515	-0.162	-0.145
Santa Gertrudis	24	140	0.002	0.003	-0.080	0.582	-0.095	-0.080
Braunvieh	32	205	-0.090	-0.091	-0.186	0.478	-0.199	-0.092
Charolais	66	331	0.005	0.006	-0.205	0.457	-0.220	-0.208
Chiangus	26	133	-0.060	-0.024	-0.120	0.507	-0.170	-0.093
Limousin	69	424	-0.040	-0.069	-0.203	0.488	-0.189	-0.132
Maine Anjou	51	253	-0.041	-0.032	-0.221	0.433	-0.245	-0.187
Salers	48	231	0.000	-0.007	-0.205	0.464	-0.213	-0.196
Simmental	86	491	-0.056	-0.053	-0.185	0.475	-0.202	-0.129

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 0. 663 in) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

[a]The breed difference estimates represent half the differences that would be expected between purebreds of the two breeds.

Table 8. Breed of sire solutions from USMARC, mean breed and USMARC EPD used to adjust for genetic trend to the year 2014 base and factors to adjust within breed EPD to an Angus equivalent – CARCASS WEIGHT (lb)

Breed	Number		Ave. Base EPD		Breed Soln at USMARC (vs Ang) (3)	BY 2014 Sire Breed Average (4)	BY 2014 Sire Breed Difference[a] (5)	Factor to adjust EPD To Angus (6)
	AI Sires	Direct Progeny	Breed 2014 (1)	USMARC Bulls (2)				
Angus	145	832	33.0	14.3	0.0	913.7	0.0	0.0
Hereford	154	1015	61.0	42.9	-30.5	882.7	-31.0	-59.0
Red Angus	53	268	20.0	12.4	-11.0	891.7	-22.0	-9.0
Shorthorn	57	267	11.6	11.1	-10.4	885.2	-28.5	-7.1
South Devon	23	70	28.3	15.3	-23.9	884.2	-29.5	-24.8
Brahman	55	241	1.4	0.4	-41.7	854.4	-59.4	-27.8
Santa Gertrudis	24	140	3.3	5.7	-6.4	886.2	-27.5	2.2
Charolais	66	332	16.8	10.7	9.3	910.5	-3.2	13.0
Chiangus	26	134	10.9	11.4	-21.1	873.5	-40.2	-18.1
Gelbvieh	81	454	27.6	18.4	-10.9	893.4	-20.4	-15.0
Limousin	69	425	26.3	6.6	-19.7	895.1	-18.7	-12.0
Maine Anjou	51	253	9.0	10.2	-20.0	873.8	-39.9	-15.9
Salers	48	232	20.5	15.5	-22.3	877.8	-36.0	-23.5
Simmental	86	491	27.6	22.3	12.3	912.8	-1.0	4.4

Calculations:

(4) = (3) / b + [(1) – (2)] + (Raw Angus Mean: 895.1 lb) with b = 1.00

(5) = (4) – (4, Angus)

(6) = (5) – (5, Angus) – [(1) – (1, Angus)]

Table 9. Mean weighted[a] accuracies for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), maternal weaning weight (MWWT), milk (MILK), marbling (MAR), ribeye area (REA), fat thickness (FAT), and carcass weight (CWT) for bulls used at USMARC

Breed	BWT	WWT	YWT	MILK	MAR	REA	FAT	CWT
Angus	0.82	0.80	0.75	0.75	0.55	0.55	0.53	0.53
Hereford	0.68	0.65	0.64	0.61	0.32	0.44	0.35	0.56
Red Angus	0.92	0.92	0.92	0.89	0.72	0.70	0.70	0.60
Shorthorn	0.82	0.81	0.80	0.80	0.46	0.45	0.46	0.57
South Devon	0.46	0.49	0.44	0.50	0.07	0.09	0.10	0.33
Beefmaster	0.88	0.90	0.80	0.68				
Brahman	0.53	0.51	0.45	0.34	0.11	0.14	0.10	0.28
Brangus	0.89	0.83	0.73	0.73				0.70
Santa Gertrudis	0.73	0.69	0.58	0.56	0.42	0.49	0.51	0.46
Braunvieh	0.63	0.56	0.32	0.50	0.11	0.18	0.09	0.18
Charolais	0.82	0.76	0.69	0.70	0.47	0.50	0.44	0.45
Chiangus	0.82	0.79	0.79	0.75	0.25	0.22	0.34	0.57
Gelbvieh	0.85	0.84	0.84	0.82	0.63	0.58		0.56
Limousin	0.94	0.93	0.93	0.92	0.66	0.65	0.66	0.61
Maine Anjou	0.79	0.78	0.77	0.77	0.26	0.25	0.29	0.55
Salers	0.82	0.82	0.76	0.79	0.28	0.31	0.36	0.61
Simmental	0.94	0.94	0.94	0.93	0.72	0.71	0.71	0.60
Tarentaise	0.92	0.91	0.90	0.88				

[a]Weighted by relationship to phenotyped animals at USMARC for BWT, WWT, YWT, MAR, REA, FAT, and CWT and by relationship to daughters with phenotyped progeny MILK.

Table 10. Estimates of variance components (lb^2) for birth weight (BWT), weaning weight (WWT), yearling weight (YWT), and maternal weaning weight (MWWT) and for marbling (MAR; marbling score $units^2$), ribeye area (REA; in^4), fat thickness (FAT; in^2), and carcass weight (CWT; lb) from mixed model analyses of USMARC data

Analysis	BWT	WWT[a]	YWT
Animal within breed (18 breeds)	69.19	489.50	3552.36
Maternal genetic within breed (18 breeds)		445.59	
Maternal permanent environment		706.81	
Residual	57.23	1306.33	4634.15

Carcass Direct	MAR	REA	FAT	CWT
Animal within breed (13-16 breeds)	0.288	0.670	0.0105	2382.21
Residual	0.258	0.764	0.0144	2170.34

[a]Direct maternal covariance for weaning weight was -44.17 lb^2

Table 11. Pooled and within-breed regression coefficients (lb/lb) for weights at birth (BWT), 205 days (WWT), and 365 days (YWT) of F_1 progeny and for calf weights (205 d) of F_1 dams (MILK) on sire expected progeny difference and by sire breed

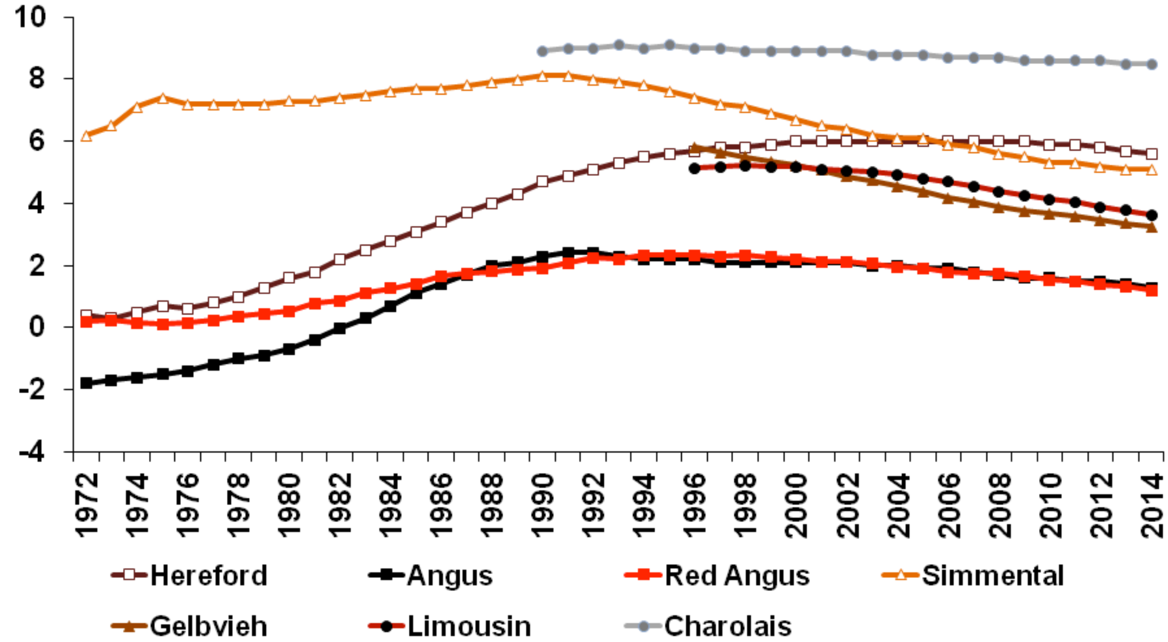
	BWT	WWT	YWT	MILK
Pooled	1.17 ± 0.03	0.81 ± 0.03	0.96 ± 0.04	1.08 ± 0.06
Sire breed				
Angus	1.13 ± 0.09	0.88 ± 0.06	1.12 ± 0.07	1.06 ± 0.15
Hereford	1.18 ± 0.07	0.70 ± 0.05	0.98 ± 0.06	1.07 ± 0.14
Red Angus	1.00 ± 0.13	0.70 ± 0.13	0.62 ± 0.15	1.18 ± 0.25
Shorthorn	0.74 ± 0.18	0.51 ± 0.14	0.40 ± 0.17	0.63 ± 0.41
South Devon	-0.01 ± 0.39	0.97 ± 0.26	0.56 ± 0.30	1.22 ± 0.95
Beefmaster	1.91 ± 0.27	0.76 ± 0.20	0.77 ± 0.32	8.24 ± 1.68
Brahman	1.88 ± 0.21	1.13 ± 0.17	1.31 ± 0.21	0.66 ± 0.60
Brangus	1.49 ± 0.22	0.80 ± 0.19	0.88 ± 0.17	0.82 ± 0.55
Santa Gertrudis	3.16 ± 0.64	1.20 ± 0.23	1.16 ± 0.28	0.25 ± 1.00
Braunvieh	0.79 ± 0.27	0.66 ± 0.28	0.32 ± 0.25	1.67 ± 0.62
Charolais	1.09 ± 0.12	0.93 ± 0.10	0.87 ± 0.11	0.96 ± 0.21
Chiangus	1.30 ± 0.25	0.28 ± 0.22	0.47 ± 0.26	0.34 ± 0.42
Gelbvieh	1.11 ± 0.13	0.87 ± 0.10	1.16 ± 0.12	0.86 ± 0.23
Limousin	1.08 ± 0.12	0.79 ± 0.07	0.86 ± 0.08	1.35 ± 0.21
Maine Anjou	1.47 ± 0.16	0.90 ± 0.18	0.80 ± 0.23	1.86 ± 0.38
Salers	1.31 ± 0.22	0.82 ± 0.24	0.64 ± 0.23	1.67 ± 0.35
Simmental	1.15 ± 0.13	1.40 ± 0.12	1.31 ± 0.12	0.86 ± 0.28
Tarentaise	1.21 ± 0.49	1.01 ± 0.21	1.39 ± 0.32	1.25 ± 0.80

Table 12. Pooled and within-breed regression coefficients marbling (MAR; score/score), ribeye area (REA; in^2/in^2), fat thickness (FAT; in/in), and carcass weight (CWT; lb) of F_1 progeny on sire expected progeny difference and by sire breed

	MAR	REA	FAT	CWT
Pooled	0.53 ± 0.04	0.81 ± 0.05	0.91 ± 0.08	0.97 ± 0.06
Sire breed				
Angus	0.78 ± 0.07	0.70 ± 0.12	0.98 ± 0.13	0.94 ± 0.10
Hereford	0.73 ± 0.13	0.62 ± 0.12	1.01 ± 0.16	1.05 ± 0.11
Red Angus	1.07 ± 0.15	1.12 ± 0.19	1.03 ± 0.34	1.08 ± 0.22
Shorthorn	1.30 ± 0.25	0.75 ± 0.38	1.34 ± 0.47	0.50 ± 0.28
South Devon	-0.05 ± 0.19	2.06 ± 2.36	3.10 ± 2.38	-1.02 ± 0.86
Brahman	1.70 ± 0.89	1.16 ± 0.33	0.97 ± 0.55	0.51 ± 0.23
Santa Gertrudis	1.01 ± 0.64	0.77 ± 0.47	1.70 ± 0.82	1.21 ± 0.46
Braunvieh	-0.02 ± 0.50	0.58 ± 0.28	-1.93 ± 3.37	0.36 ± 0.39
Charolais	1.03 ± 0.18	0.86 ± 0.16	1.32 ± 0.34	0.88 ± 0.26
Chiangus	0.70 ± 0.19	0.37 ± 0.45	0.67 ± 0.37	0.62 ± 0.42
Gelbvieh	1.15 ± 0.17	1.29 ± 0.16		1.49 ± 0.18
Limousin	1.08 ± 0.25	0.82 ± 0.13	1.07 ± 0.28	0.85 ± 0.13
Maine Anjou	-0.43 ± 0.48	-0.61 ± 0.49	-0.54 ± 0.50	1.36 ± 0.31
Salers	0.04 ± 0.06	1.35 ± 0.52	0.79 ± 0.51	0.74 ± 0.43
Simmental	0.94 ± 0.15	0.70 ± 0.14	0.19 ± 0.28	1.55 ± 0.20

Figure 1. Relative genetic trends for birth weight (lb) of the seven most highly used beef breeds (1a) and all breeds that submitted 2016 trends (1b) adjusted for birth year 2014 using the 2016 across-breed EPD adjustment factors.

1a.



1b.

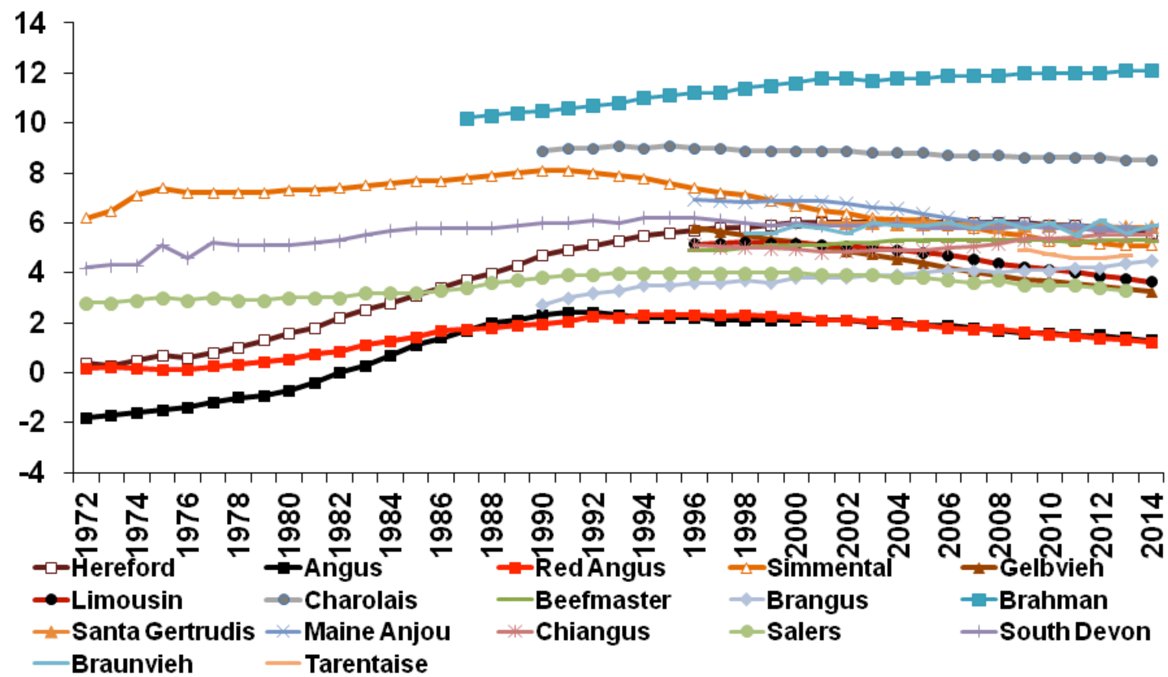
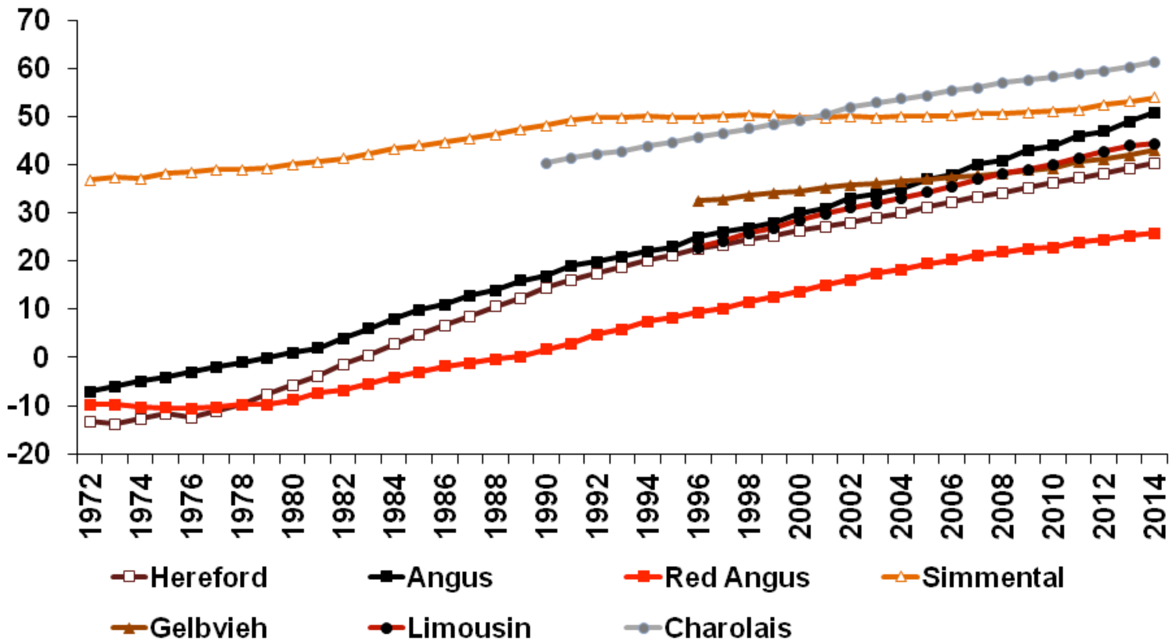


Figure 2. Relative genetic trends for weaning weight (lb) of the seven most highly used beef breeds (2a) and all breeds that submitted 2016 trends (2b) adjusted for birth year 2014 using the 2016 across-breed EPD adjustment factors.

2a.



2b.

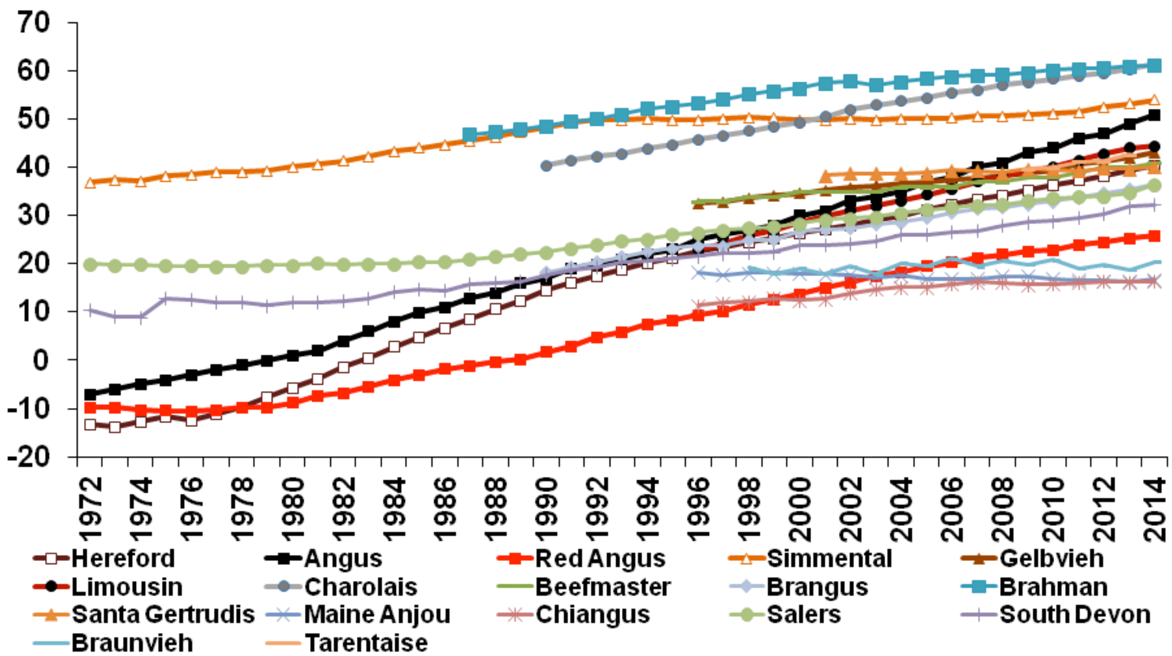
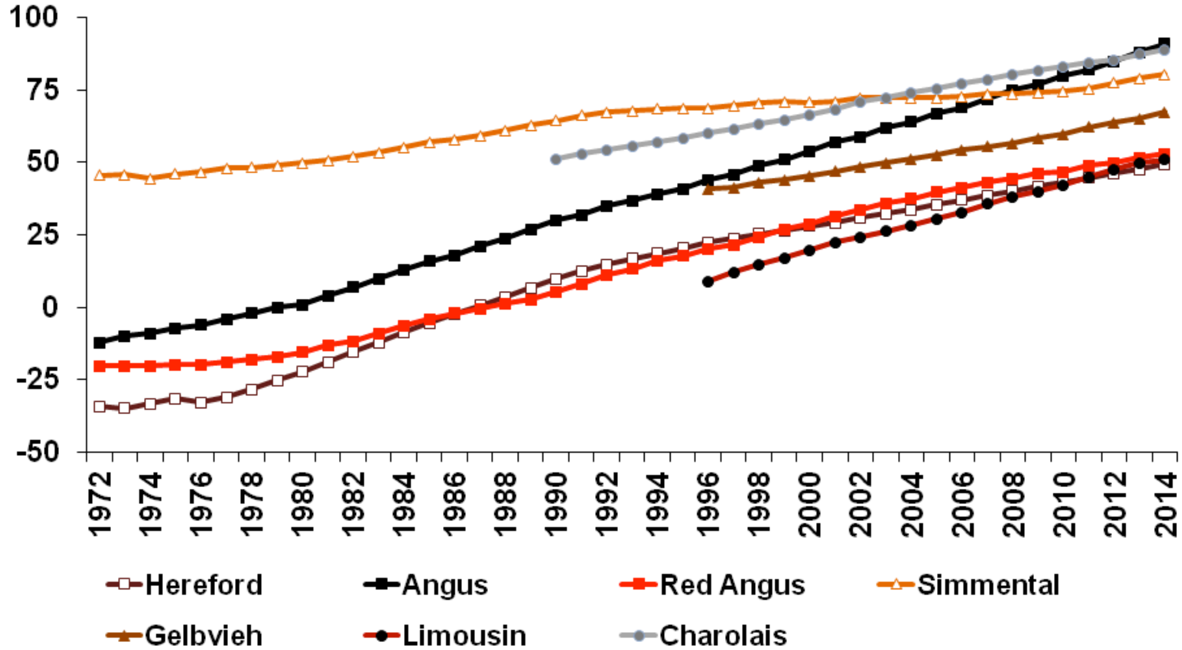


Figure 3. Relative genetic trends for yearling weight (lb) of the seven most highly used beef breeds (3a) and all breeds that submitted 2016 trends (3b) adjusted for birth year 2014 using the 2016 across-breed EPD adjustment factors.

3a.



3b.

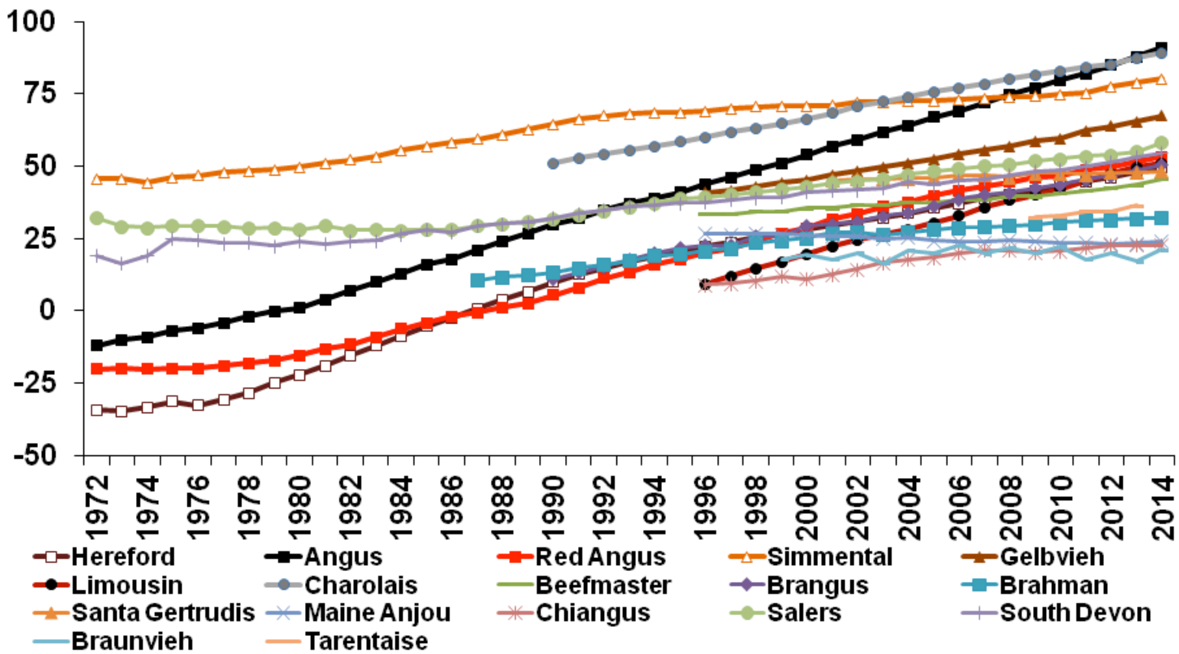
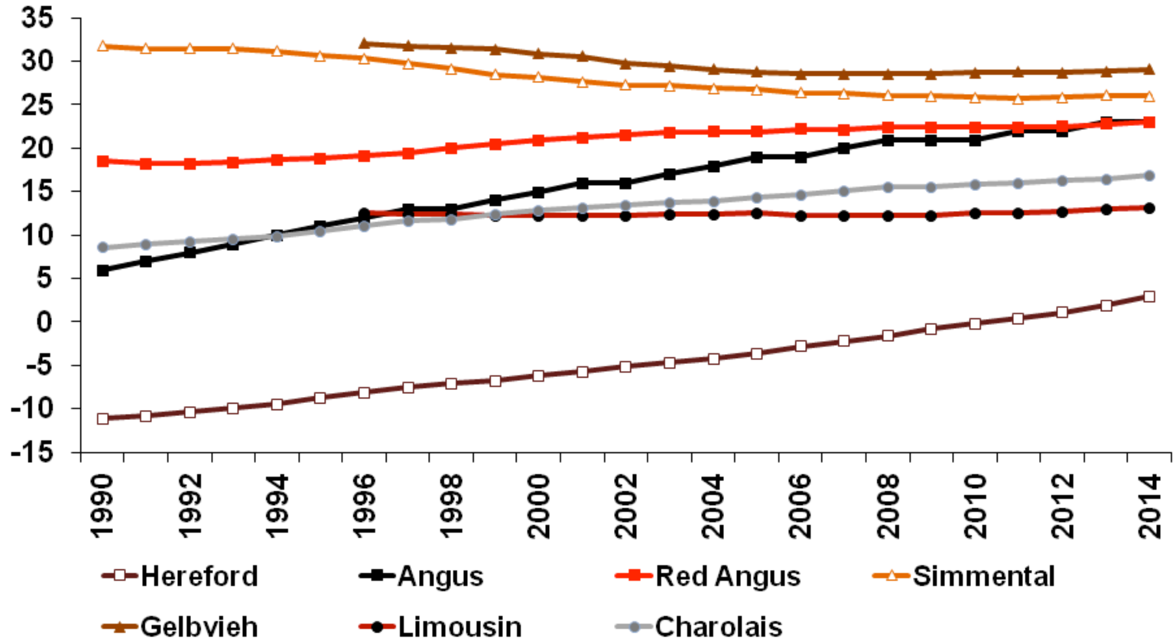
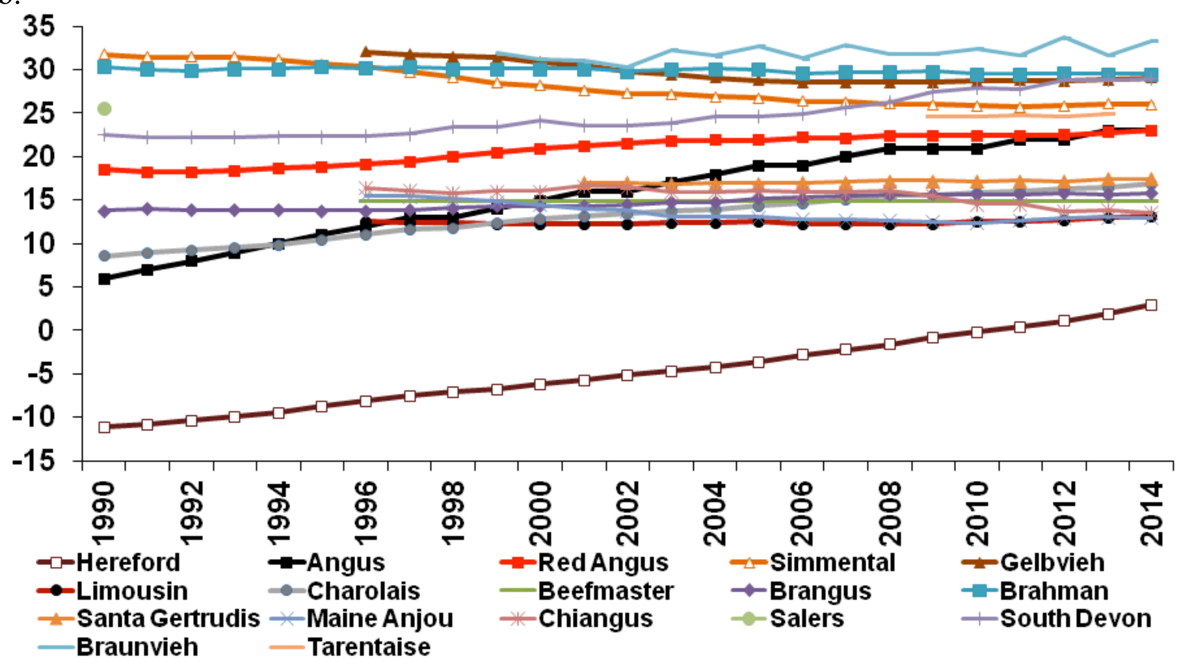


Figure 4. Relative genetic trends for maternal milk (lb) of the seven most highly used beef breeds (4a) and all breeds that submitted 2016 trends (4b) adjusted for birth year 2014 using the 2016 across-breed EPD adjustment factors.

4a.



4b.



Literature Cited

Arnold, J. W., J. K. Bertrand, and L. L. Benyshek. 1992. Animal model for genetic evaluation of multibreed data. J. Anim. Sci. 70:3322-3332.

Barkhouse, K. L., L. D. Van Vleck, and L. V. Cundiff. 1994. Breed comparisons for growth and maternal traits adjusted to a 1992 base. Proc. Beef Improvement Federation 26th Research Symposium and Annual Meeting, Des Moines, IA, May, 1994. pp 197-209.

Barkhouse, K. L., L. D. Van Vleck, and L. V. Cundiff. 1995. Mixed model methods to estimate breed comparisons for growth and maternal traits adjusted to a 1993 base. Proc. Beef Improvement Federation 27th Research Symposium and Annual Meeting, Sheridan, WY. May 31-June 3, 1995. pp 218-239.

Boldman, K. G., L. A. Kriese, L. D. Van Vleck, and S. D. Kachman. 1993. *A Manual for Use of MTDFREML* (DRAFT). A set of programs to obtain estimates of variances and covariances. USDA-ARS, Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE. (120 pp).

Cundiff, L. V. 1993. Breed comparisons adjusted to a 1991 basis using current EPD's. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Asheville, NC. May 26-29, 1993. pp 114-123.

Cundiff, L. V. 1994. Procedures for across breed EPD's. Proc. Fourth Genetic Prediction Workshop, Beef Improvement Federation, Kansas City, MO. Jan. 1994.

Koch, R. M., L. V. Cundiff, and K. E. Gregory. 1994. Cumulative selection and genetic change for weaning or yearling weight or for yearling weight plus muscle score in Hereford cattle. J. Anim. Sci. 72:864-885.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2007. Across-breed EPD tables for the year 2007 adjusted to breed differences for birth year of 2005. Proc. Beef Improvement Federation 39th Annual Research Symposium and Annual Meeting, Fort Collins, CO. June 6-9, 2007. pp 74-92.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2008. Across-breed EPD tables for the year 2008 adjusted to breed differences for birth year of 2006. Proc. Beef Improvement Federation 40th Annual Research Symposium and Annual Meeting, Calgary, AB. June 30-July 3, 2008. pp 53-74.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2009. Across-breed EPD tables for the year 2009 adjusted to breed differences for birth year of 2007. Proc. Beef Improvement Federation 41th Annual Research Symposium and Annual Meeting, Sacramento, CA. April 30-May 3, 2009. pp 160-183.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2010. Across-breed EPD tables for the year 2010 adjusted to breed differences for birth year of 2008. Proc. Beef Improvement Federation 42nd Annual Research Symposium and Annual Meeting, Columbia, MO. June 28-July 1, 2010. pp. 71-92.

Kuehn, L. A., L. D. Van Vleck, R. M. Thallman, and L. V. Cundiff. 2011. Across-breed EPD tables for the year 2011 adjusted to breed differences for birth year of 2009. Proc. Beef Improvement Federation 43rd Annual Research Symposium and Annual Meeting, Bozeman, MT. June 1-4, 2011. pp. 92-111.

Kuehn, L. A., and R. M. Thallman. 2012. Across-breed EPD tables for the year 2012 adjusted to breed differences for birth year of 2010. Proc. Beef Improvement Federation 44th Annual Research Symposium and Annual Meeting, Houston, TX. April 18-21, 2012. pp. 152-177.

Kuehn, L. A., and R. M. Thallman. 2013. Across-breed EPD tables for the year 2013 adjusted to breed differences for birth year of 2011. Proc. Beef Improvement Federation 45th Annual Research Symposium and Annual Meeting, Oklahoma City, OK. June 12-15, 2013. pp. 114-141.

Kuehn, L. A., and R. M. Thallman. 2014. Across-breed EPD tables for the year 2014 adjusted to breed differences for birth year of 2012. Proc. Beef Improvement Federation 46th Annual Research Symposium and Annual Meeting, Lincoln, NE. June 18-21, 2014. pp. 134-155.

Kuehn, L. A., and R. M. Thallman. 2015. Across-breed EPD tables for the year 2015 adjusted to breed differences for birth year of 2013. Proc. Beef Improvement Federation 47th Annual Research Symposium and Annual Meeting, Biloxi, MS. June 9-12, 2015. pp. 97-124.

Notter, D. R., and L. V. Cundiff. 1991. Across-breed expected progeny differences: Use of within-breed expected progeny differences to adjust breed evaluations for sire sampling and genetic trend. J. Anim. Sci. 69:4763-4776.

Núñez-Dominguez, R., L. D. Van Vleck, and L. V. Cundiff. 1993. Breed comparisons for growth traits adjusted for within-breed genetic trend using expected progeny differences. J. Anim. Sci. 71:1419-1428.

Van Vleck, L. D. 1994. Prediction error variances for inter-breed EPD's. Proc. Fourth Genetic Predication Workshop, Beef Improvement Federation, Kansas City, MO. Jan. 1994.

Van Vleck, L. D., and L. V. Cundiff. 1994. Prediction error variances for inter-breed genetic evaluations. J. Anim. Sci. 71:1971-1977.

Van Vleck, L. D., and L. V. Cundiff. 1995. Assignment of risk to across-breed EPDs with tables of variances of estimates of breed differences. Proc. Beef Improvement Federation 27th

Research Symposium and Annual Meeting, Sheridan, WY. May 31-June 3, 1995. pp 240-245.

Van Vleck, L. D., and L. V. Cundiff. 1997. Differences in breed of sire differences for weights of male and female calves. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Dickinson, ND. May 14-17, 1997. pp 131-137.

Van Vleck, L. D., and L. V. Cundiff. 1997. The across-breed EPD tables adjusted to a 1995 base. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Dickinson, ND. May 14-17, 1997. pp 102-117.

Van Vleck, L. D., and L. V. Cundiff. 1998. Across-breed EPD tables for 1998 adjusted to a 1996 base. Proc. Beef Improvement Federation Research Symposium and Annual Meeting, Calgary, Alberta, Canada. July 2, 1998. pp 196-212.

Van Vleck, L. D., and L. V. Cundiff. 1998. Influence of breed of dam on across-breed adjustment factors. Midwestern Section ASAS and Midwest Branch ADSA 1998 Meeting, Des Moines, IA. Abstract # 10. p 31.

Van Vleck, L. D., and L. V. Cundiff. 1999. Across-breed EPD tables for 1999 adjusted to a 1997 base. Proc. Beef Improvement Federation 31th Annual Research Symposium and Annual Meeting, Roanoke, VA. June 15-19, 1999. pp 155-171.

Van Vleck, L. D., and L. V. Cundiff. 2000. Across-breed EPD tables for 2000 adjusted to a 1998 base. Proc. Beef Improvement Federation 32th Annual Research Symposium and Annual Meeting, Wichita, KS. July 12-15, 2000. pp 98-116.

Van Vleck, L. D., and L. V. Cundiff. 2001. Across-breed EPD tables for 2001 adjusted to breed differences for birth year 1999. Proc. Beef Improvement Federation 33th Annual Research Symposium and Annual Meeting, San Antonio, TX. July 11-14, 2001. pp 44-63.

Van Vleck, L. D., and L. V. Cundiff. 2002. Across-breed EPD tables for 2002 adjusted to breed differences for birth year of 2000. Proc. Beef Improvement Federation 34th Annual Research Symposium and Annual Meeting, Omaha, NE. July 10-13, 2002. pp 139-159.

Van Vleck, L. D., and L. V. Cundiff. 2003. Across-breed EPD tables for the year 2003 adjusted to breed differences for birth year of 2001. Proc. Beef Improvement Federation 35th Annual Research Symposium and Annual Meeting, Lexington, KY. May 28-31, 2003. pp 55-63.

Van Vleck, L. D., and L. V. Cundiff. 2004. Across-breed EPD tables for the year 2004 adjusted to breed differences for birth year of 2002. Proc. Beef Improvement Federation 36th Annual Research Symposium and Annual Meeting, Sioux Falls, SD. May 25-28, 2004. pp 46-61.

Van Vleck, L. D., and L. V. Cundiff. 2005. Across-breed EPD tables for the year 2005 adjusted to breed differences for birth year of 2003. Proc. Beef Improvement Federation 37th Annual Research Symposium and Annual Meeting, Billings, MT. July 6-9, 2005. pp 126-142.

Van Vleck, L. D., and L. V. Cundiff. 2006. Across-breed EPD tables for the year 2006 adjusted to breed differences for birth year of 2004. Proc. Beef Improvement Federation 39th Annual Research Symposium and Annual Meeting, Choctaw, MS. April 18-21, 2006. Available online at: http://www.beefimprovement.org/content/uploads/2013/07/Across-Breed-EPD-Tables.pdf.

Van Vleck, L. D., L. V. Cundiff, T. L. Wheeler, S. D. Shackelford, and M. Koohmaraie. 2007. Across-breed adjustment factors for expected progeny differences for carcass traits. J. Anim. Sci. 85:1369-1376.

Westell, R. A., R. L. Quaas, and L. D. Van Vleck. 1988. Genetic groups in an animal model. J. Dairy Sci. 71:1310-1318.