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Beef Cattle National Genetic Evaluation Programs

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Introduction and Brief History

Selection alters the frequency of genes in a population (breed) affecting a particular characteristic. Population genetic change is difficult for breeders to understand because they deal with individuals when making selection decisions and in their merchandising programs. Nevertheless, breeds (populations) which practice intense selection for characteristics of economic importance to the cattle industry will change genetically and eventually be the successful populations because they will leave the most progeny in the next generation. The genetic improvement of a population (breed) cannot overlook the individual because the individual, if selected, is the vehicle containing the genes which are to be passed on to the next generation. Bull selection is central to directed changes in gene frequency of any defined beef cattle population because of the low reproductive rate in beef females. Sophisticated genetic prediction techniques have been developed to help U.S. beef cattle producers make sound selection decisions.

In 1971-72, the American Simmental Association published the first U.S. National Beef Sire Summary. Only a few far-ranging thinkers understood what the publication of this document really meant to the beef industry. Bulls were now compared across herds and/or generations. Beef cattle breeding had entered the twentieth century!

Proliferation and implementation of technology in the area of beef sire evaluation has been fantastic. Dr. C.R. Henderson (1973) presented an invited paper at the 1972 American Society of Animal Science meetings which formalized his mixed model procedures providing best linear unbiased predictions (BLUP) of breeding values.

Increased use of artificial insemination in beef cattle has provided a data structure which lends itself to rather sophisticated models. Increased sophistication of mathematical models used in National Sire Evaluation (NSE) has paralleled improvements in computer hardware. Introduction of large-scale scientific "super" computers has certainly opened the door to applications of models not thought possible only a few years ago.

National Sire Evaluation procedures first used a rather basic model including contemporary group effects, sire effects and residual (random error). The sire effects become the "Expected Progeny Differences" (EPDs) when the model is applied. The model required that sires and contemporary groups be "connected", that is at least some sires must be used over more than one contemporary group thereby forming "ties" between sires across contemporary groups. Each contemporary group had to have at least two sires represented.

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1Presented at the Beef Seedstock Symposium, South Dakota State University, Brookings, December 13-14, 1991.
The model assumed sires had been mated to comparable sets of cows (cows randomly allotted to sires) and that progeny were treated similarly within contemporary group. The model assumed genetic trend was nonexistent or relatively unimportant in the population. These were essentially safe assumptions in the early 1970's for analyses of field data from the newly imported Continental breeds. In the first analyses of the U.S. domestic British breeds, the programs were designed to meet these assumptions. Analysis procedures of the early 1970's approximated true mixed model procedures.

In the decade from 1975 to 1985, many changes took place in sire evaluation technology. Mathematical models used in the analyses began to account for more and more of the factors which could possibly bias EPDs. The inverse of Wright's Numerator Relationship matrix which enhances accuracy of genetic prediction became a part of sire evaluation procedures. The relationship matrix provided the means to incorporate pedigree information in the analysis procedure and a method to account for genetic trend. Use of the A-inverse, as it is now referred to, certainly was a major breakthrough in NSE because pedigree breeding now began to take on real meaning.

Even with improvements in models, breeders and researchers alike continued to question the effect of non-random or specific mating of dams to sires on sire evaluation results. At the same time (late 70's and early 80's), computer hardware was improving at a phenomenal rate. By 1984, it seemed feasible to include a dam effect in the basic model for sire evaluation. In 1984, model dependency on difficult to verify assumptions was becoming less of a problem in sire evaluation. Incorporation of dams into the model along with the A-inverse provided breeders the most accurate prediction of breeding values to date.

Another problem which continued to burden breeders and researchers was the older age at which bulls were entering national sire summaries. Scientists were concerned because the generation interval increases with the age of the parents in a population and this may result in reduced genetic change per year. Breeders like to use young bulls; therefore, they were making selection decisions based on information other than that contained in sire summaries.

Most researchers have contended that National Sire Evaluation was a means to an end rather than the ultimate in genetic improvement of performance characteristics. It was generally recognized that unless NSE was somehow merged with on-farm and ranch testing programs, genetic progress would be slow particularly in the commercial industry.

C.R. Henderson and R.L. Quaas (1975) discussed methods for best linear unbiased prediction of breeding values utilizing records on large numbers of relatives, as well as the individual's own record. The mathematical model termed the "animal model" by Cornell researchers R.L. Quaas and E.J. Pollak (1980) was less dependent on hard-to-verify assumptions and it incorporated the sire's own record into the analysis. It also provided genetic values on dams and young animals not yet producing progeny. The procedure adjusted for merit of mates of the individual reducing substantially, if not totally eliminating effects of non-random (specific) mating. Finally, the procedure provided simultaneous breeding values (or EPDs) for direct growth and maternal ability for those traits which are maternally influenced.
The "animal model" along with the data structure the purebred beef industry had established by ten years of AI and NSE seemed to provide the ultimate in genetic prediction techniques for beef cattle--across herd and/or generation evaluations of all individuals (male and female) in the breed. However, the complexity of the model resulted in a computational nightmare. Quaas and Pollak (1980) proposed an equivalent model called the reduced animal model. The reduced animal model was less of a computational nightmare but also seemed beyond computing strategy and hardware of the time.

Application of the reduced animal model was encouraged by the availability of large scale scientific computers and experience gained in developing computing strategy for more sophisticated models in 1983-84. In late 1984, the model was applied to large beef cattle populations and the technology has now been generally adopted by all the major beef breeds in the United States.

The technology in prediction of genetic values is rapidly being accepted across the beef cattle industry, because now the commercial industry can share directly and much earlier in the purebred industry genetic progress. Young bulls not yet producing progeny (nonparents) now have genetic values (EPDs) comparable across herds and/or generations just as the older progeny tested sires have had for years in NSE. In 1985, the U.S. purebred cattle industry moved from National Sire Evaluation to National Cattle Evaluation.

Evidence that Genetic Predictions Can Impact Breeding Programs

Procedures used in making genetic predictions have been developed on a sound theoretical basis. Genetic theory has always been difficult to directly substantiate and has relied many times on indirect proof. Research efforts must be enhanced to continue challenging the theory and assumptions on which national beef cattle genetic improvement programs are based.

Perhaps the first place to look for evidence that sire evaluation is influencing breeding programs is the genetic trend in breeds which have been using such programs. Figures 1 and 2 plot the genetic trend for yearling weight (YWT), weaning weight (WWT), birth weight (BWT) and milking ability as pounds of weaned calf (MAT) in the Angus and Horned Hereford breeds. The graphs represent the average breeding value for animals born in a particular year.

It is encouraging that the trends for weaning and yearling weight are positive. The WWT trends for 1970-90 are 2.4 and 2.2 lb/year for Angus and Hereford, respectively. The YWT trends for Angus and Hereford are 4.0 and 3.4 lb/year. The trends are probably not significantly different between these breeds.

The number of bulls evaluated through National Sire Evaluation became significant in the late 70's for the two breeds. The rate of genetic change for weaning and yearling weight from 1977 to 1990 is more than double the rate for the period 1970 to 1978. The magnitude of the effect of NSE on these breeds is difficult to quantitate; however, there has been increased interest in performance and along with that interest has come greater use of outstanding sire summary bulls in both breeds.
Milking ability has changed in the Hereford breed over the years; however, the Angus breed has made little change in this trait. This difference between the breeds probably results from the fact that Hereford breeders have been more conscientious of milking ability since that breed is generally thought to produce less milk than the Angus breed. Both breeds now have access to milking ability EPDs through their National Cattle Evaluation (NCE) programs so that genetic change can be made rapidly for that trait.

Birth weight has changed in both breeds. This change is a correlated response to selection for growth and frame. It is impossible to determine the practical significance of these birth weight changes. It is safe to say that birth weight extremes are a problem for the industry because of their effect on calving ease. In general, birth weight effects on calving ease are most important in heifers. A majority of calving difficulty problems could be eliminated by selection of easier calving bulls to use on heifers. Information is available through the NCE programs to help identify bulls which produce calves with smaller birth weights.

In the spring breeding season of 1977, a project was initiated at the Northwest Georgia Branch Experiment Station (NWBS), Calhoun, Georgia to determine the magnitude of genetic change for single trait (yearling weight) selection. The selection practiced in this herd was through NSE, that is bulls used in the selection line were the top yearling weight EPD bulls from the American Hereford Association Sire Evaluation program. A control line was maintained to quanitate environmental changes in the project. Genetic trends for several traits of economic importance were obtained by regressing differences between the selection line and the control line on years. Most of the genetic change was due to sire selection since little selection was practiced on the heifer replacements going into the selection line. Differences between the selection and control line are shown in Table 1. Observation of the yearling weight differences in Table 1 show a linear increase from 30 lb in 1978 to 95 lb in 1983. This represents genetic change of 14 lb per year. This is more than double the trend shown in the industry during that same time period. Obviously, part of the difference between industry change and genetic change in this research project is due to the single trait selection practiced. Single trait selection is seldom the situation in a beef breeding program; however, the project does show that rapid genetic change can be made in a beef cattle herd.

Observation of the differences in Table 1 between lines for other traits gives an indication of the response of traits correlated with yearling weight to the intense selection for yearling weight. Generally, the correlated responses have been favorable. Birth weight has increased; however, this increase did not affect calving ease as dramatically as expected. Perhaps of some concern was the small change in postweaning average daily gain. Much of the change in yearling weight seems to be coming through weaning weight. This result indicated the need for a multiple trait analysis which more accurately accounts for the effects of selection at weaning on yearling weight (many records are lost between weaning and yearling). The project has not addressed changes in fertility; however, it is encouraging to see only small changes in mature cow calving difficulty and positive changes for scrotal circumference and pelvic size.
Figures 3 through 7 compare the genetic trends in the NWBS experimental herd with the genetic trend in the Horned Hereford breed for several traits. The data for the NWBS herd represented in these graphs includes calf crops through 1989. These calf crops are not included in the data in Table 1 since the selection practiced changed somewhat with the 1983 breeding season. Selection has been continued for yearling weight; however, some attention was given to ease of calving bulls for first calf heifers. The genetic trend for the NWBS herd has been over 7.3 lb per year from 1977 to 1989, whereas the trend for the Hereford breed for that same period was 4.5 lb per year.

Generally, the trend in the NWBS herd had been at least twice that in the Hereford breed until 1985. The use of low birth weight EPD bulls with lower yearling weight EPDs on a large number of heifers appears to have contributed to some decline in the rate of genetic change in the NWBS herd. Basically, this decline in the rate of genetic change from 1984 to 1985 indicates the necessity of maintaining intense selection pressure if rapid genetic improvement is to be accomplished. If calving difficulty becomes a problem as it did in the 1984 calf crop then it is imperative to find bulls with low birth weight EPDs which can also continue changing post-natal growth. It is of interest that calving difficulty was not a problem in the first six calf crops at the NWBS (see Table 1).

In addition to the change in selection pressure, another contribution to the decrease in yearling weight genetic change was that one of the top EPD bulls selected for use in the project produced progeny which did not perform up to expectation. This may have been due to random chance (simple sampling error) or perhaps a sire by environment (herd) interaction. Even with the decline from 1984 to 1985, the NWBS herd is changing much more rapidly than the Hereford breed.

Figure 4 compares the weaning weight trend for the NWBS and the Hereford breed. Again, until 1985 the trend had been over two times as great in the NWBS herd as the Hereford breed. From 1977 to 1989, the NWBS herd changed at a rate of 4.6 lb per year versus 2.9 lb per year for the Hereford breed.

Figure 5 compares the birth weight trends. Selection of lower birth weight EPD bulls did result in a decline in the rate of change for birth weight experienced in the first six calf crops. The NWBS herd has increased birth weight .6 lb per year while the Hereford breed increased only .3 lb/year.

No attention has been given to maternal (milking ability) EPDs in the selection of bulls for the NWBS. Observation of Figure 6 shows what can be expected in maternal ability change if attention is not given to the trait in the selection program. The NWBS milking ability breeding values have been up and down during the study.

Frame size has never been a consideration in the NWBS selection program. Generally, size appears to be increasing at a more rapid rate in the NWBS cattle than in the general Hereford population. This change is due to the relationship between weight and height. Hip height (see Figure 7) has increased at .15 in per year in the NWBS cattle while during the same period the Hereford breed changed .08 in per year.
Scrotal circumference has been shown to be related to male fertility as measured by semen evaluation techniques. Also, some evidence exists suggesting that age of puberty in females is related to the scrotal circumference of their sire. This trait has never been considered in the selection practiced at the NWBS. Figure 8 indicates what has been happening to the trait in the NWBS herd. Changes in scrotal circumference appear to have been generally random.

The NWBS project shows that rapid genetic change can be accomplished with single trait selection. However, caution must be exhibited since efficient beef cattle production requires the consideration of several economic characteristics. Information now available through National Cattle Evaluation programs will provide the necessary genetic values to consider several traits in a selection program. The concept of optimums continues to gather support in the commercial cattle industry. Successful commercial breeders are learning how to sort young bulls on the basis of EPDs from different breeds which can then be put together through crossbreeding to enhance production efficiency.

A question of importance to both commercial and purebred cattle breeders is the reliability of genetic values (EPDs) computed for young animals which have not yet produced progeny. A study concerning this question has been conducted at the University of Georgia with Limousin and Hereford for postweaning gain. The study involved 71 Limousin and 138 Hereford bulls, all of which had legitimate individual postweaning records, as well as progeny with records. Expected progeny differences were computed for these bulls using the reduced animal model, first based on their record plus pedigree and secondly based on only their progeny plus pedigree. The 71 Limousin bulls all had between 10 and 30 progeny, whereas the 138 Hereford bulls all had at least 30 progeny. The rank correlations between these two sets of EPDs were found to be .59 and .58 for Limousin and Hereford, respectively. This is in contrast to correlations for within contemporary group ratios for these bulls and their EPDs based on progeny which were .17 and .20 for the Limousin and Hereford, respectively. This does not prove conclusively that nonparent EPDs are the best predictors of breeding worth; however, it does show that selection decisions based on ratios may not retain those bulls which will have high EPDs after they have produced progeny. These correlations point out the necessity of accounting for genetic competition in the contemporary group when comparing across herds. This study suggests that the commercial industry can buy young bulls with more confidence that the values on which they select the bulls will indeed turn into more pounds of product in their herds.

Predicting Calving Ease

Dystocia can be a major problem in beef cattle production, resulting in significant financial losses to the industry. In 1967, Anderson and Bellows reported calf losses at or shortly after birth to be 5-8%, with 50% of these losses directly related to dystocia. These percentages probably have not decreased in recent years. The commercial industry appears quite sensitive to the problem as indicated by the commercial cattlemen's interest in birth weights of yearling bulls.
A disproportionate difference between fetus size and dam size is the major cause of dystocia. Many factors, both genetic and environmental, affect the size of the calf at birth and also the size of the dam. These include sex of calf, length of gestation, breed, heterosis, inbreeding, genotype, age and parity of dam and nutrition of dam. Size of dam has generally not been a good predictor of calving ease because larger dams tend to produce larger calves.

Pelvic size measured as pelvic area is inversely related to the occurrence of dystocia in heifers. Measurement of pelvic size has received more attention in recent years as a possible way to reduce dystocia. Pelvic area (computed as the product of a vertical and horizontal measurement) appears to have a heritability of .53 as reported by Benyshek and Little (1982) in a study involving Simmental cattle. However, that same study indicated the genetic correlation between pelvic size and birth weight to be large (.73). Thus, selection for increased pelvic size could be accomplished; however, without some attention to birth weight the actual decrease in dystocia would be minimal.

Pelvic size could be incorporated into National Cattle Evaluation Programs. This would require large numbers of heifers to be measured in the purebred industry. Pelvic size measurement is not difficult but does require some training. The measurement requires time and labor to collect the data. At present the effect of such selection on dystocia would appear to be minimal, thus it seems impractical for the purebred industry to gather the necessary data. Pelvic size measurements may be useful as a commercial producer management tool in making mating decisions for first calf heifers in conjunction with other available information such as birth weight EPDs.

The effect of calf shape on dystocia is a popular topic of conversation among cattlemen. It seems logical that shape of calf should have some effect on calving ease; however, scientific investigation has given little credibility to the idea. Laster (1974) measured new born calves within 24 hours of birth for shoulder width, hip width, chest depth, wither height and body length. He found these measurements independent of birth weight to have no relationship to dystocia. In two recently published studies (Nugent et al., 1991 and Nugent and Notter, 1991), it was also concluded that selection for calf body shape measurements (head circumference, shoulder width, hip width, heart girth, cannon circumference and length and body length) would not reduce dystocia.

Generally birth weight is considered by most to be the major antagonist to calving ease. Birth weight EPDs are available for all breeds with NCE programs. Scrutinizing the birth weight EPDs of individuals to be mated can lead to acceptable phenotypic birth weights and a reduction in dystocia. Perhaps of most importance is for the industry not to become captivated by single trait selection for growth such as yearling weight EPD. The relationship between postnatal growth and prenatal growth is positive and as shown by the birth weight changes in the Hereford selection project at the Northwest Georgia Branch Station (see figure 5) discussed earlier in this paper.

Birth weight can be moderated by using EPDs. This has been done in the Hereford Selection Project at NWBS. In addition to the NWBS study Arnold et al., 1990 at The University of Georgia has summarized a study concerning the accuracy of birth weight (BWT) and yearling weight (YWT) EPDs. In the four year study,
BWT and YWT EPDs were examined in a high-low birth weight selection study. Angus bulls were selected for either high BWT and high YWT, or low BWT and high YWT. The EPD selection criteria for sires were: high line BWT EPDs ≥ 7 lb and low line BWT EPDs ≤ 3 lb. Sire YWT EPDs for both lines had to exceed 40 lb with an accuracy of .8. The selected sires were randomly mated to Angus cows and resulting progeny data were analyzed for birth weight, weaning weight, postweaning gain and yearling weight. Table 2 shows the least squares means and the average EPDs for sires used in each line. The difference column in Table 2 shows that the difference in average EPDs of the sires used within lines predicted very well the actual line differences observed. This study shows that birth weight can be significantly altered using the EPD concept.

Calving ease EPDs are computed in some NCE programs. Some procedures use a linear model while others use a threshold model (nonlinear). Theoretically the threshold model appears superior, although considerably more difficult to compute. The scientific literature contains little information from breeding studies to indicate the usefulness of calving ease EPDs. Initial information from a Gelbvieh study at The University of Georgia (Bertrand, unpublished) indicates that birth weight is still the dominant factor in a multiple trait analysis involving birth weight and calving ease scores. The multiple trait linear model and threshold model appear to give the same rankings for calving ease in some studies. However, work at Cornell University with Simmental field data (Man Cang Dong, personal communication) found the rank correlation between direct calving ease EPDs from a linear versus threshold model to be .57. The Cornell study found birth weight to have less effect on calving ease EPDs in the multiple trait analysis than in the Georgia study. The genetic association between birth weight and calving ease was considerably larger in the Georgia study.

Generally, birth weight is the culprit in calving difficulty and must be dealt with accordingly, using birth weight EPDs.

Maternal (Milk) Ability EPDs

Maternal ability EPDs (MEPD) probably raise more controversy than any other selection criteria in the beef cattle industry. This resulted because it is a value that could not be easily selected for prior to the application of the animal model. One of the advantages of the animal model is that it addresses weaning weight as a trait of the calf (indicating genes for growth) and as a trait of the cow (indicating genes for milk). This in itself is certainly not controversial since cattlemen have tried to do this in one way or another for years. It is doubtful that many breeders ever bought a potential herd sire without looking at the productivity of the dam producing that sire. Thus, the animal model does mathematically and systematically what breeders have tried to do mentally for some time. The second controversy with MEPDs is that they are subject to more change than other EPDs since the only animals with records are females which have produced and suckled a calf.

The first step in discussing the MEPD is to understand how the value is computed. To obtain this understanding it is necessary to look at a simplified
equation which shows the factors considered in the computations. The following equation computes maternal ability breeding value which is two times MEPD.

\[
\text{MEPD} \times 2 = \text{Regression Coefficient} \times \left[ \begin{array}{c} \text{Cow’s calves’ Contemporary records} \\ \text{weaning group effect - growth environmental} \\ \text{breeding effect of the cow} \\ \text{<summed over all the cow’s calves>} \\
\end{array} \right] + \text{Regression Coefficient} \times \text{Sum of the milk breeding values for relatives of the individual} \\
- \text{Regression Coefficient} \times \frac{1}{2} \text{Sum of the milk breeding values for mates of the individual} \\
+ \text{Adjustment for the relationship between growth and milking ability}
\]

If this equation is for a cow who has raised a calf, the first part of the above equation adjusts the records of her calves to reflect her milk production. First, the contemporary group effect is adjusted out of the record removing any environmental factors which may have influenced the record positively or negatively compared to all other calves’ records in a particular contemporary group. Second, the calves’ growth breeding values are subtracted from the records. This second subtraction removes the effect of the calves’ innate genetic ability to grow leaving the portion of the record reflecting the cow’s milking ability. This is the portion of the record that the cow would influence through her milking ability regardless of the genetics possessed by her calves. Finally, to get the records to more adequately reflect the cow’s genetics for milking ability, the permanent environmental effect is subtracted from the record. The regression coefficient is a weighing factor which adjusts for the heritability of the trait and the relationship between this piece of information (records of her calves) and other possible sources of information (relatives of the cow).

The second part of the equation brings the pedigree of the individual (a cow in this case) into the computations. The procedure moves backwards and forward through the pedigree. It picks up information (breeding values) on the ancestors of the individual particularly the sire and dam. However, if progeny are available it will gather the information (breeding values) on each progeny. The third part adjusts for mates of the individual removing any bias caused by non-random or specific mating. The final entry in the equation adjusts for any genetic relationship between growth and milking ability.

The reliability of the MEPD is many times questioned by breeders, particularly MEPDs for yearling bulls. Correlations between the pedigree MEPDs on young bulls and the MEPDs those same bulls will produce as their daughters come into production is about .45. This is less than the .60 correlation found for early information (record and pedigree) versus later progeny test EPDs for growth traits. Once a young bull produces progeny with records the correlation will improve. MEPDs for sires can have a high degree of accuracy actually at the
same level as other trait EPDs once large numbers of daughters come into production. The problem is simply that a sire's accurate evaluation for maternal ability of his daughters comes later in his life and breeders need to make decisions early for rapid genetic change.

Changes in EPDs from one NCE analysis to the next are of major concern to cattle producers. Table 3 shows the rank correlations over time between maternal EPDs from the semi-annual analyses conducted for the American Hereford Association. As one might expect as the amount of information increases changes occur. Thus, most of the time the correlations for a six month period analysis, May versus December, are very high .98-.99. Generally, the farther apart in time any two analyses the lower the rank correlations, say for example May, 1985 and May, 1990. However, the lowest correlation in the table is .86. The table points out that most bulls do not change but even at a correlation of .98 some significant changes can occur because bulls attain data at different rates, thus sampling variances will be different.

The lower correlations shown in the May 1990 column of Table 3 resulted because the analysis changed from a single trait to a multiple trait analysis and new genetic parameters were incorporated. Also new age of dam and age of calf adjustment procedures were implemented at that time. Most of the time EPD changes for a single individual are the result of more information becoming available; however, the May 1990 column of Table 3 points out that procedure changes are usually the cause of general shifts in EPDs.

Some information is accumulating with respect to MEPDs from actual breeding experiments. Diaz et al., 1991 have researched the relationship between maternal EPDs of Polled Hereford sires and the actual milking ability of their crossbred daughters. Over the range of sire maternal EPDs (-22 to +35 lb) actual milk production increased by 27% of the mean, or by about .5% per pound of maternal EPD.

In general, MEPDs are more variable than growth EPDs; however, they still represent the best method of describing the genetics of milk production and maternal ability in beef cattle. The industry probably tends to over-emphasize MEPDs. The MEPD should be used only to gauge general trends in a breed. If a breeder emphasizes MEPD at the expense of growth EPDs, the results of the breeding program will undoubtedly be disappointing. However, it must also be pointed out that continual use of negative MEPD sires will lead to lower herd MEPDs and ultimately lower herd milk production. A common sense approach is warranted with respect to Maternal Ability EPDs.

Generally, National Cattle Evaluation has been firmly established in the U.S. beef industry. Theoretically the procedures are sound; however, considerable research needs to be done in refinement of the procedures and education of producers for maximum success in the industry. Indications are that programs are working and genetic change is taking place in the cattle industry. The selection practiced in the next few years in a breed may determine whether that breed exists in the U.S. beef industry of the 21st century.
LITERATURE CITED


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Table adapted from Hough et al. (1985)

$^1$Selection line least square mean - control line least square mean.

$^2$Score 1 = no assistance; 2 = minor assistance; 3 = major assistance; 4 = cesarean section; 5 = abnormal presentation.

$^3$Regression of line differences on years.
Figure 1. ANGUS GENETIC TRENDS

Figure 2. HEREFORD GENETIC TRENDS
Figure 3. YEARLING WEIGHT TRENDS
NWBS AND NATIONAL HEREFORD

Figure 4. WEANING WEIGHT DIRECT TRENDS
NWBS AND NATIONAL HEREFORD
Figure 5. BIRTH WEIGHT TRENDS
NWBS AND NATIONAL HEREFORD

Figure 6. WEANING WT MATERNAL TRENDS
NWBS AND NATIONAL HEREFORD
Figure 7. HIP HEIGHT TRENDS
NWBS AND NATIONAL HEREFORD

Figure 8. SCROTAL CIRCUMFERENCE TRENDS
NWBS AND NATIONAL HEREFORD