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Larry Benyshek
University of Georgia

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COMPUTATIONS ASSOCIATED WITH NATIONAL BEEF CATTLE EVALUATION PROGRAMS

LARRY BENYSHEK

THE UNIVERSITY OF GEORGIA
ATHENS

In 1971-72 the first U.S. National Sire Summary was published by a beef cattle breed association. At that time the idea of extending beef performance records into a national progeny testing program was indeed revolutionary. Until 1972, truly accurate comparisons of bulls could only be made within a herd-year-season contemporary group. The first and subsequent National Sire Summaries compared bulls across herds and/or generations.

In the years following the first sire summary publications, most researchers working in the area of national genetic evaluation had contended National Sire Evaluation (NSE) was a means to an end rather than the ultimate in a genetic improvement program. Three major problems existed with NSE from the industry’s point of view. First, bulls had to produce progeny before entering the program which resulted in published evaluations of old bulls. Older bulls were usually available only through AI which made them impractical for use in much of the commercial industry. Furthermore, the purebred industry tends to seek young bulls rather than old bulls in an attempt to reduce the generation interval and make faster genetic change. Thus, while the evaluations in National Sire Summaries were and still are very accurate, both the purebred and commercial industry struggled in the late 70’s and early 80’s with how to effectively use the published results. A second problem with NSE was breeders, particularly purebred breeders, contended some bulls in NSE were being mated to superior cows causing a serious bias in the evaluation of those bulls. Fortunately, research has shown this second problem was more perception than reality. The third problem was NSE programs did not use the individual’s own performance record in the analysis. This third problem was not serious for bulls with a substantial number of progeny; however, for a young bull with only a few progeny it meant neglecting a very important piece of performance information. Another deficiency of NSE was that it provided genetic values on males only, thus the females which provide half the genes in the population were ignored. The application of the "Animal Model" in 1984-85 provided evaluations essentially free of the problems associated with National Sire Evaluation and allowed the industry to move to the next phase of genetic improvement now referred to as National Cattle Evaluation.

Today National Cattle Evaluation (NCE) programs are available in all the major beef breeds and have several distinct advantages over NSE programs:

1) NCE provides a genetic value for an individual which incorporates any combination of progeny, pedigree (sire and dam) and individual record information. Thus, the individual’s own record, if available, is incorporated into the analysis. The genetic values from NCE programs

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are in the form of "expected progeny differences" (EPDs) which are the same as sire EPDs from NSE programs.

2) The procedure adjusts for the superiority or inferiority of the mates of the individual. This reduces, if not totally eliminates bias, introduced by specific matings for both sires and dams.

3) The program provides maternal genetic values for those traits which are maternally influenced such as weaning weight.

4) The procedure accounts for genetic change over time in a breed, providing more precise comparisons of individuals from different generations.

5) National Cattle Evaluation computes genetic values for all animals in the breed, i.e. for sires and dams plus young animals (male and female nonparents) which have not yet produced progeny.

It is of major importance that breeders realize that the genetic values (EPDs) for young animals (nonparents) and for dams are comparable across herds and/or generations.

The following brief example will provide some insight into the usefulness of the EPD. Expected Progeny Differences are plus or minus values in units of original measurement (e.g. weaning weight in pounds). The EPDs are used to make comparisons among bulls from which the breeder wishes to make a selection. The comparisons are made one pair of bulls at a time. For example, compare two bulls, A and B, where bull A has a weaning weight EPD of +20 pounds and bull B has a weaning weight EPD of +5 pounds. The EPDs for these two bulls tell the producer if he were to select both bulls for his breeding program and mate them to a large number of comparable cows he could expect a 15 pound difference between the average weaning weights of the calves from the two bulls. Thus, if weaning weight is important in the producer's program, selection of bull A is obvious. The EPDs provide the producer a means of predicting differences between any two bulls without having to breed the bulls in his program. The difference between EPDs for bull A and B (20 - 5 = 15 pounds) is the difference a producer would expect in his own herd. In breeds which have NCE programs, there are thousands of bulls evaluated and it is possible although perhaps not practical to make this pairwise comparison for all of them. Expected progeny differences provide a prediction of future performance of progeny from an individual based on information currently available.

It is important that breeders realize what information EPDs do not provide. For example, selecting a bull with a +20 pound EPD does not guarantee that the breeder's herd average will be increased by 20 pounds. This would be true if the herd average was the same as the overall breed average. If the herd is above breed average one would expect less than 20 pounds increase; however, if the herd was below breed average a greater than 20 pound increase could be expected. A second important note is that the NCE results cannot be used to compare breeds, that is, the EPDs are to be used only for within breed comparisons.

Traits available for comparison vary from breed to breed. Traits evaluated are birth weight, weaning weight, milking ability expressed as pounds of weaned calf, yearling weight, hip height, scrotal circumference and calving ease. Other traits such as carcass traits will be added in the near future.
Best linear unbiased prediction procedures (BLUP) used in National Cattle Evaluation programs are complex, to say the least. Let us now examine how factors such as the contemporary group influence the computation of an individual's expected progeny difference (EPD).

First, an example of a contemporary group effect. Remember the definition of a contemporary group is a set of animals of the same sex and similar age which have had equal opportunity to perform (same management, pasture, year, etc.). As an example, suppose we have two contemporary groups (these could be herds also) which have the same two sires, say A and B, represented. Each sire produces ten bull calves in each contemporary group. The performance of each sire’s progeny in each group is summarized in the following table:

<table>
<thead>
<tr>
<th>Sires</th>
<th>Contemporary groups (herds)</th>
<th>Average across herds</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>500*</td>
<td>550*</td>
</tr>
<tr>
<td>B</td>
<td>400*</td>
<td>450*</td>
</tr>
</tbody>
</table>

*Average of 10 calves by each sire in each contemporary group.

The averages by sire across contemporary groups gives one the difference in progeny performance for the two bulls A (525) and B (425) with bull A’s progeny having a 100 pound advantage (sire differences). The averages by group across sires quantitates the difference between contemporary groups. As you can see there is a 50 pound advantage for group 2. This is the contemporary group effect. If one assumes the females are similar for both groups then the 50 pound advantage for group 2 must come from some environmental source. Whatever the cause of differences between contemporary groups is of little concern; however, these differences may bias the evaluation of animals in those contemporary groups. Therefore, analysis procedures used in NCE adjust for these contemporary group differences which result in genetic evaluations (EPDs) computed as though all the cattle were raised in one giant contemporary group. If the contemporary groups were for some reason improperly identified, say for example, 5 of bull B’s progeny in group 2 were in a different pasture, the estimate of the contemporary group effect could be wrong and perhaps bias the sire evaluations.

In order to understand the computation of an individual's weaning EPDs for growth let us examine several of the factors involved. First, remember all that is available to us for the identification of superior genetics are the records on individual animals. All of the analytical procedures are designed to separate the environmental and genetic factors affecting an individual's record thus providing a prediction of the individual's genetic worth. Thus as one thinks
about factors affecting the EPD of an individual we are actually considering the genetic and environmental effects on the record of the individual.

The first factor to consider is the genetic makeup of the individual which is referred to as its breeding value (EPD = 1/2 Breeding Value). Obviously, this is the factor of most concern because it is directly related to the EPD of the individual. Another factor which comes to mind immediately with respect to a weaning record is the milking ability of the individual’s dam. The milking ability of the individual’s dam can be represented by her milk breeding value (2 times her milk EPD). Milking ability EPDs or breeding values are expressed as pounds of weaned calf (not pounds of milk). The milk breeding value of the dam represents her genetic potential for milking ability. A cow may have tremendous genetic potential for milking ability but may never exhibit that ability due to environmental effects (e.g. suppose a high milking cow contracts mastitis). Thus, a third factor affecting an individual’s weaning record might be any permanent environmental effect decreasing or increasing the milking ability of the individual’s dam. The final factor which was discussed above is the contemporary group effect. These four factors explain much of the variability in weaning weight records; however, not all of the variation is explained by these factors thus there is a fifth factor which we will simply refer to as unknown or error.

Now that the factors affecting the weaning record of an individual have been identified it is possible to develop a mathematical model representing the record in terms of these factors:

\[
\text{Weaning Weight Record} = \text{Contemporary Group Effect} + \text{EPD of the Individual's Sire Breeding Value of the Individual} + \text{EPD of the Individual's Dam Value of the Individual} + \text{Mendelian Sampling Effect of the Individual} + \text{Milk Breeding Value of the Individual's Dam} + \text{Permanent Environmental Effect of the Dam} + \text{Unexplained Factors or Random Error}
\]

Notice in this equation that the individual’s breeding value is represented by the sum of its parental EPDs and a Mendelian sampling effect. The Mendelian sampling effect accounts for the fact that an individual receives 1/2 of his genetic makeup from each parent in a random fashion. The Mendelian sampling effect is the reason that even full-sibs (offspring of the same parents) show considerable differences.

An equation similar to the above is developed for every individual in the breed which has a legitimate weaning record. These equations are solved by iterative techniques providing values for each entry in the equation to the right of the equals sign including the breeding value of the individual. The EPD is given by dividing the breeding value of the individual by two.

Keeping in mind that an individual’s EPD is equal to 1/2 his breeding value, the following gives an individual’s weaning growth breeding value:
Breeding Value = Regression Coefficient \times \left[ \begin{array}{c}
\text{Record of the individual - contemporary group effect - milk breeding value of dam - permanent environmental effect of the dam} \\
+ \text{Sum of breeding values for relatives of the individual (note: this includes sire and dam and/or any progeny of the individual)} \\
- \text{Sum of breeding values for mates of the individual (note: applies when progeny are available)} \\
+ \text{adjustment for the relationship between growth and milk (note: in some breeds assumed to be zero)}
\end{array} \right]

Subtracting the contemporary group effect, milk breeding value of the dam and the permanent environmental effect of the dam adjusts the record for those environmental factors. After these factors are subtracted the portion remaining more adequately reflects the genetic makeup of the individual for growth. The regression coefficients are weighting factors computed according to the relationship between each piece of information contributing to the individual's breeding value thus allowing the combination of information. Note that any combination of the possible information may be used to compute the breeding value. Notice also the procedure will go back in the pedigree to the sire and dam of an individual or forward in the pedigree to any progeny available. Mates of the individual are adjusted for by subtracting 1/2 of the mate's breeding value when progeny records are available. Finally if there is a relationship between milk and growth it can be accounted for in the procedure.

A numerical example will show the importance of each factor in computations of an individual's EPD. The following example is for two young calves (nonparents) which are full-sibs (same sire and dam) and it is data taken from one of the breeds presently being analyzed at the University of Georgia:
As you can see only individual records and parental values enter into the computations since these two animals have not yet produced progeny. In the case of these full-sibs the only differences in the computations are the records and the contemporary group effects. Calf A has a larger weight (645) than calf B (570) but in addition the contemporary group effect (which might be thought of as an adjusted contemporary group average) for calf A (469.96) is smaller than the one for B (486.80). Calves in B’s contemporary group had a 16.84 pound environmental advantage which is given by the difference between the contemporary group effects (486.80 - 469.96). Thus calf B had a somewhat better environment in which to make his record. The effect of this better environment is adjusted out when the contemporary group effect is subtracted from the calf’s record. Calf B did not grow as well as calf A, plus B had a better environment than A therefore the record contribution to the breeding values for the two calves was 20.56 versus 7.44 pounds for A and B, respectively. Notice the pedigree contribution for both calves is larger than either record contribution which may
not always be the case. Obviously, the pedigree contribution to an individual's EPD depends on how large the EPDs (breeding values) are for its parents. Breeders should also note that the 18% difference between performance ratios translates to only a 6.56 pound difference in EPDs for these two calves. Ratios and weights may be misleading with respect to actual genetic transmitting ability. In the case of these two animals selection on weight or ratio would have retained the genetically superior individual. It should be noted as groups become more diverse with unrelated individuals, selection based on EPDs will more often retain the genetically superior individual than either weights or ratios.

The following is a comparison of two sires with progeny. The table contains information for sire A (breeding value = 88.4; EPD = 44.2 lb) and sire B (breeding value = 132.2; EPD = 66.1 lb).

<table>
<thead>
<tr>
<th>Individual ID</th>
<th>Average weaning ratios of progeny</th>
<th>Number Weaning Contemporaries</th>
<th>Individual Weaning Performance Pounds (Ratio)</th>
<th>Sire Breeding Value (lb)</th>
<th>Dam Breeding Value (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>408 males 105.0</td>
<td>178(9703)*</td>
<td>703 (124.5)</td>
<td>65.4</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>369 females 103.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>424 males 105.8</td>
<td>71(3547)*</td>
<td>729 (136.5)</td>
<td>150.4</td>
<td>45.8</td>
</tr>
<tr>
<td></td>
<td>403 females 104.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Number of contemporaries in parenthesis raised with progeny of A and B.

Notice the average progeny ratios do not reflect the difference in EPDs for sires A and B. The following will show why these averages are not indicative of the EPDs for the two sires. First, examine the following table which gives the contribution (in pounds) of each available piece of information to the sires' breeding value and subsequent EPD:

<table>
<thead>
<tr>
<th>Sire ID</th>
<th>Sire's own record</th>
<th>Sire's parents</th>
<th>Progeny</th>
<th>Adjustment for mates</th>
<th>Breeding value (lb)*</th>
<th>EPD (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.1103</td>
<td>.2219</td>
<td>94.4230</td>
<td>-6.3611</td>
<td>88.3941</td>
<td>44.2</td>
</tr>
<tr>
<td>B</td>
<td>.1813</td>
<td>.5179</td>
<td>171.0545</td>
<td>-39.5536</td>
<td>132.2000</td>
<td>66.1</td>
</tr>
</tbody>
</table>

*Sum of the previous four columns, EPD = 1/2 Breeding Value.

The EPD for A is given by (.1103 + .2219 + 94.4230 - 6.3611) + 2 = 44.2. The EPD for B is given by (.1813 + .5179 + 171.0545 - 39.5536) + 2 = 66.1. It is readily seen that the major contribution to each sire's EPD comes from their progeny (94.4230 and 171.0545). A sire's own record and his ancestor's account
for a very small part of his EPD when large numbers of progeny are available and particularly when the progeny are far above or far below average.

Note there is a larger adjustment for mates of sire B than sire A (-39.5536 vs -6.3611, respectively). The reason for this is that sire B was mated to cows superior to those of sire A. The average EPD for sire B’s mates was 39.8 lb whereas sire A’s mates averaged 6.4 lb. Even after adjustment for superior mates B still had the larger EPD.

Observation of the table including the adjustment for mates does not yet answer our question as to exactly why B’s EPD is so much larger than A’s. The answer is found in the genetic competition within the contemporary groups in which the progeny of these two sires were raised. Average breeding values for the sires and dams of other progeny in the contemporary groups in which sire A’s progeny were raised are 40.6 and 13.4 lb, respectively. The averages for sires and dams of progeny raised contemporarily with sire B’s progeny are 61.4 and 34.4 lb, respectively. This simply says that the genetic merit (measured as breeding value) of the contemporary groups in which sire B’s progeny were raised was greater than those in which sire A’s progeny were raised. This coupled with the fact that sire B’s progeny averaged 46.1 lb more than their contemporaries while sire A’s progeny averaged only 2.2 lb more than their contemporaries results in the large difference seen in progeny contribution to their EPDs. This genetic competition within contemporary groups is not reflected in performance ratios thus reducing their value as an aid to selection, particularly in comparisons across herds. Clearly, NCE accounts for this and other factors making the EPDs more precise for across herd comparisons.

An accuracy value is computed for each EPD which provides an indication of the reliability of the EPD. Accuracy values range from zero to one with values closer to one indicating greater accuracy or reliability of prediction. Unfortunately, accuracy values are only approximations and may sometimes underestimate or overestimate the true accuracy of the EPD.

Mixed linear models (BLUP) are finding widespread application in the beef cattle industry. The procedures provide a most accurate method for making selection decisions. Today’s cattlemen, both purebred and commercial, who learn to use the genetic information available in a creative breeding program will achieve greater profitability over time. This is because genetic stability will allow for sound management decisions including those decisions affecting, marketing and merchandising.