Rick Bourdon, a Red Angus breeder currently involved in teaching and research at CSU, has designed this series (continued from last month's Journal) to help breeders understand and use available performance information.

A Series

Beef Cattle Breeding

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(Editor's notes appear in italics and refer specifically to American Angus Assn. procedures.)

Part Seven

Sire Evaluation II: Problems with Field Data Sire Evaluation

National sire evaluation programs offer the most objective means of comparing sires across herds, and yet such programs are not without problems. Field data, unlike data from carefully controlled experiments, are subject to various biases that are difficult to account for. Academic animal breeders have known this for a long time, and have put a great deal of effort into devising statistical techniques or models that do a better job of analyzing troublesome data. In the past few years, much progress has been made, relatively good models are now being used by breed associations, and even better models are in the offing.

In order to appreciate sire evaluation procedures, one should first be aware of the difficulties in sire evaluation, and then understand how the model copes or fails to cope with them. In this article, I will discuss nine major sire evaluation problems. In the following two articles, I will describe sire evaluation models in light of their abilities to overcome these problems.

1. Making valid comparisons among sires.

Ideally, we would like to compare all sires in head-on competition. This would mean that each sire would have enough calves spread among enough contemporary groups so that his calves could be directly compared with calves from every other sire. Clearly, such a situation is impossible with field data. While some widely used A.I. sires have calves in many contemporary groups and therefore have competed against many other bulls, most sires have only been used in a few herds at most and have competed against only a few other bulls. Some sires, those whose calves comprise entire contemporary groups, have never competed at all. The more isolated a sire is (i.e., the fewer bulls against which he has been matched), the more difficult it becomes to make valid comparisons.

2. Accounting for level of competition among sires.

Sires can rank differently depending on the breeding values of the bulls against which they have been compared. Suppose sire A is average in breeding value for yearling weight. Suppose also that sires B, C and D are far below average and sires E, F and G are far above average for yearling weight. If only within-herd ratios are considered and A happens to have calves in the same contemporary groups with calves by B, C and D, but not by E, F or G, A will appear to be superior in breeding value for yearling weight. Conversely, if A competes against E, F and G, but not against B, C or D, he will appear inferior. When a sire has been used extensively in many herds and contemporary groups, we can expect that the biases caused by different levels of competing sires will tend to balance out. This cannot be said, however, for sires with limited exposure, i.e. sires never competing with another sire that can be used to link or "tie" data to information from other herds.

NOTE: Because of widespread A.I. use, the vast majority of Angus herds can be directly or indirectly compared today.

3. Random mating.

Sires are typically described in sire summaries by expected progeny differences or EPDs for various traits. An EPD is defined as the expected performance of a sire's calves if that sire is mated to a **random** sample of cows. If a sire has, in fact, been mated in a

non-random fashion, his estimated EPDs may be biased. If, for example, a bull is mated to only the highest producing cows in a herd, the weaning weights of his calves are sure to reflect the superior producing ability of their dams, and the sire's EPD for weaning weight will be biased upward.

NOTE: Beginning with the 1984 Angus Sire Evaluation, dam effect was considered to account for such bias and EPDs were adjusted accordingly. Such bias will also be adjusted for in maternal EPDs, which will replace MBVs in the 1985 Angus Sire Evaluation.

The bias caused by non-random mating can be significant in some cases and negligible in others. Many times breeders will match sires and dams according to pedigree or to physical characteristics only marginally related to measured performance traits. In these instances, little bias will normally result from the non-random nature of the matings. A more serious situation occurs, however, with popular A.I. sires which command expensive semen or certificate fees. In an effort to produce the best calves possible for their money, breeders will often mate these bulls to cows with histories of high production.

Just as an EPD or breeding value of a sire can be biased if he is mated non-randomly, his maternal breeding value (MBV or maternal EBV) can be biased if his daughters are mated non-randomly. The most common occurrence is when heifers are mated to bulls chosen specifically for calving ease. Usually, such "heifer bulls" will be below average in breeding value for growth, so that their calves will average below the mean for weaning weight. This causes the MBV for the sire of the first-calf heifers to be biased downward. His MBV will gradually recover as his daughters get older and are mated to more competitive bulls.

NOTE: This problem is alleviated when breeders report first-calf heifers' calves as a separate contemporary group (suggested if that group numbers at least 10 at weaning).

4. Culling for poor performance.

It is not uncommon for a breeder to develop a negative opinion of a sire based on that sire's progeny performance at weaning, only to find that the same sire's progeny rank high for yearling weight. The apparent paradox is commonly the result of culling at weaning. If the breeder normally culls about 20 percent of his poorest performing calves at weaning, but culls 70 percent

of the progeny of a particular sire, the remaining 30 percent of that sire's calves constitute a select group and are not representative of the sire at all. The bias caused by different culling rates for different sire groups is especially acute for yearling traits, but can also be significant for weaning traits if poor performing bull calves are steered or if data are reported only for calves that are to be registered.

A similar bias can occur in a sire's maternal breeding value estimate if his daughters are culled on production. In this case, older bulls are favored because their worst daughters have been weeded out and their best daughters continue to produce.

5. Genetic trend.

If a breed has undergone selection for a trait over time, it can be expected that breeding values for the trait have been changing from generation to generation. This genetic trend has little effect on estimates which are based on data recorded in a short period of time, but when many years' data are involved, a bias can occur. It is unrealistic, for example, to expect that a ratio of 110 for yearling weight recorded in 1960 means the same thing as a 110 ratio today. Genetic trend makes it difficult to compare sires being used now with those used in the past.

NOTE: Angus Sire Evaluation does account for genetic trend, so sires of all ages are directly comparable.

6. Progeny information only.

Sire evaluation programs (traditional ones, anyway) are, by definition, progeny tests. They estimate a sire's breeding value using what must ultimately be considered the best criteria—the records of his offspring. Progeny tests have the disadvantage, however, of requiring much time to complete. A bull will be 3 years old before yearling information is available on his first calves, 4½ years old before weaning information is available on calves out of his daughters, and perhaps even older by the time he has calves in many herds.

Because of the time factor, bulls which have been accurately evaluated (and subsequently promoted) tend to be fairly old. If these older sires are used at the expense of younger, worthier sires, the overall rate of genetic change in a breed will be slowed. Using the older, proven bulls results in high **selection accuracy** (the old bulls are known genetic quantities), but in slower **generation turnover.** Progeny testing, therefore, trades time for accuracy.

7. Separating the growth component from maternal breeding value.

As I pointed out in the article on estimated breeding values (February issue, page 40), maternal breeding values or MBVs are not "clean" estimates of milking ability or mothering ability. Because they are calculated from weaning weights, MBVs contain a component for animal growth. Some breeders do not consider this a problem since a sire's MBV does indeed estimate the capacity of his daughters to wean heavy calves, and weaning weights are of primary concern. Others would like to know whether the daughters of a bull with a high MBV are exceptionally good milkers, or simply pass on superior genes for growth.

NOTE: Beginning with the 1985 Angus Sire Evaluation, the growth factor will be separated from progeny weaning weights. Thus, maternal EPDs will more accurately reflect the milking ability of a sire's daughters. This will also eliminate some of the bias caused by first-calf heifers being mated to lower-growth sires or "heifer bulls."

8. Reranking of sires in different environments.

National sire evaluation programs are, by definition, national in scope;

Table 1. Selection Index Models and BLUP.

Characteristic	Association's BLUP Model	Selection Index Method*	Selection Index With Reference Sires
1. Produces valid comparisons among sires.	good	poor	good***
2. Accounts for level of competition among sires.	good	poor	good
3. Accounts for non-random mating.	good	poor	poor
4. Accounts for culling for poor performance.	poor	poor	poor
5. Accounts for genetic trend.	good	poor	fair
6. Uses all available information.	fair	poor	poor
7. Separates the growth component from maternal breeding value.	poor**	poor	poor
8. Accounts for reranking of sires in different environments.	poor	poor	poor
9. Accounts for bad data.	fair	poor	poor

*Similar to calculations used in AHIR EBVs.
**Will be improved in the 1985 Angus Sire Evaluation.
***Only sires competing against reference sires qualify.

sires from all over the country are evaluated together without regard to the regions in which their calves were born or to the levels of management under which their calves were raised. Is this legitimate? Can we assume that a high ranking sire used in the Midwest and Northern Plains will rank equally high in the subtropical areas of Florida and southern Texas? Studies of this subject are inconclusive. Some have reported a reranking of sires or genotype by environment interaction in some traits. Other studies have failed to find such interactions important. If future studies prove conclusively that sires do rank differently for certain traits in different environments, we may see the evaluation of sires on a within-region or within-management level basis.

9. Accuracy of data.

All performance data contain some measurement error; scales are not perfectly reliable, and animals vary considerably in fill at weighing time. These kinds of errors are expected, however, and valid comparisons are still possible. Errors that result from laxity or willful misrepresentation on the part of breeders are another matter. The Association's entire performance program is based on breeder integrity, and accurate records are the only means to true improvement. Every breeder should remember that an inaccurate or false record is more damaging than **no** record at all. If there is no record, no information should be reported (i.e. birth weights should not be "estimated" or "eye-balled," nor should any other information). If there are special circumstances (i.e. a calf is sick or calves are fed separately in preparation for a show, etc.), then differences should be accounted for by separating contemporary groups. Sire Evaluation and AHIR can account for such situations and still make valid comparisons, but only if data is accurately reported.

The concept of accuracy

Accuracy has been described previously in this series as a number which statistically represents the adequacy of information used to estimate breeding values and EPDs. It is essentially a function of the amount of information available. However, accuracy does not describe completely the reliability of an estimate. If an estimated breeding value or EPD is biased by any of the causes listed above, and if the statistical method used to calculate the EBV or EPD does not account for the bias, then the associated accuracy value may be misleading.

NOTE: Current Angus Sire Evaluation procedures account for much of the bias discussed, as well as considering the numbers and distribution of progeny. Accuracy figures may not be perfect, but they are directly comparable and fairly "accurate" in the general sense of the word.

Part Eight

Sire Evaluation III: The Selection Index Method and BLUP

In the last article in this series, I discussed a number of the more important problems with field data sire evaluation. In this article, I would like to describe two currently used statistical techniques or **sire evaluation models** in light of their abilities to cope with these problems.

The following is a list of characteristics we would like an ideal sire evaluation model to have:

1. Produces valid comparisons among sires.
2. Accounts for level of competition among sires.
3. Accounts for non-random mating.
4. Accounts for culling for poor performance.
5. Accounts for genetic trend.
6. Uses all available information.
7. Separates the growth component from maternal breeding value.
8. Accounts for reranking of sires in different environments.
9. Accounts for bad data.

If any of these attributes seem unfamiliar, you may want to review the previous article. In fact, you may want to keep it handy as you read on.

NOTE: The BLUP model is used in the Angus Sire Evaluation. The following discussion of selection index methods (forerunners to BLUP) is presented as background information.

The selection index method

The selection index method is the simplest and most traditional sire evaluation technique. (It should not be confused with the "selection index," a related term which refers to a weighting scheme used in selection for more than one trait.) In its original form, the selection index method is almost identical to the method used to calculate the estimated breeding values (EBVs) that appear on performance pedigrees, a difference being that in sire evaluation only progeny data are used.

The selection index method uses ratios instead of actual measures and produces a ratio as a result. For any given trait, the performance ratios of a sire's calves are averaged over all contemporary groups. This average is then *regressed* toward 100 depending on the number of records involved. The resulting value is the sire's ratio for expected progeny difference or EPD ratio.

For example, suppose a particular sire's calves have an average weaning ratio of 103 across all herds, years and contemporary groups. If the total number of calves is high (as it would be for a popular A.I. sire) the sire's EPD ratio will be only slightly less than 103. If the sire has only a few calves, his EPD ratio will be lower—above 100, but only marginally.

The biggest problem with the selection index method is its use of ratios as the sole source of information. Ratios were devised to account for environmental differences among contemporary groups, but the use of ratios assumes that group differences are strictly environmental in origin. Genetic differences among groups are ruled out.

Because of this assumption, the selection index method cannot account for level of competition among sires. The average ratio of a sire's calves will be misleadingly high if competing sires (those which produce calves in the same contemporary groups as the sire in question) were particularly poor, and low if those sires were especially good. With the selection index method, a sire receives no extra credit for tough competition or penalty for weak competition.

By using ratios, the selection index method ignores the existence of genetic trend. An old bull who was an outstanding sire in his day will have high progeny ratios. If the same bull were used today, however, his progeny ratios might only be average. The selection index method makes no adjustments for *when* a sire's calves were born, disregarding the fact that cattle populations change genetically over time.

The selection index approach skirts the issue of valid comparison of sires. There is no record of which bull competed against which other bull. Likewise, there is no record of the cows to which a bull was mated and thus no mechanism to compensate for non-random mating. The method is blind to the fact that calves by some sires may have been culled especially heavily at weaning. These sires will then rank higher than they should for yearling traits.

A major fault of the selection index method is that the degree to which an EPD estimate is regressed depends only on the *number* of progeny and not on the *distribution* of progeny. It matters not, for example, whether the 100 recorded calves of a given sire come from one large contemporary group or

from 20 smaller groups. This creates opportunities for a single breeder to bias sire evaluation results.

If genotype by environment interactions are important, i.e. if sires rank differently in different environments, the inability of the selection index method to consider the distribution of progeny can aggravate the problem. For example, if all of a sire's calves are concentrated in a few contemporary groups within a single environment, the sire will have been evaluated for that environment only, and his EPDs may not be meaningful in other environments.

The selection index method calculates maternal breeding values (MBVs) in the standard way, and therefore fails to separate the growth component from the MBV estimate. And finally, the method uses only a sire's own progeny to predict his EPD, ignoring other sources of information which might be useful.

From this discussion, you probably have the impression that the selection index method of sire evaluation is relatively useless. It lacks the characteristics listed in the beginning of this article as attributes of an ideal sire evaluation model. It is incorrect to say that the method has no value, however. The method is basically sound and contains so many useful statistical properties that it has become the standard by which other models are judged. The practical value of the selection index method will depend on the extent of the biases existing in field data.

Selection index with reference sires

In an attempt to correct some of the selection index method's faults, a version of the method was devised which uses **reference sires.** Reference sires are simply sires which have been used extensively within a breed and whose breeding values are well documented. With this method, a sire can only qualify for sire evaluation if he has calves in the same contemporary groups as calves by at least one reference sire.

Computationally, the reference sire version of the selection index method is a bit complicated. The average ratio of a sire's progeny is computed not by simple averaging over contemporary groups, but by weighting the records from each contemporary group for number of the sire's calves, number of contemporaries and number of reference sire progeny. Once a set of EPDs has been calculated for all sires being compared, those EPDs are used to estimate genetic means for each contemporary group, new ratios are calculated

based on these means, and new EPDs are computed. The process repeats itself over and over until the EPDs no longer change.

The reference sire technique is an improvement over the basic selection index method in two important ways. First, by requiring that a reference sire be represented in each contemporary group, the method ensures valid comparisons among sires. By competing against one or more reference sires, each bull is compared indirectly with every other bull.

Secondly, despite its use of ratios, the technique deals with genetic differences among groups. Group averages are adjusted for the EPDs of the sires represented in those groups. This, in effect, accounts for the level of competition among sires. Sires which have competed mostly against good sires will be given credit, and sires which have competed mostly against poor sires will be penalized.

An extra benefit of the reference sire method is a reduction in the bias caused by genetic trend. Old and young sires alike must compete against the reference sires. The reference sires provide a standard against which both old and new records are compared.

The disadvantage of the reference sire method is that much of the field data is not used because breeders fail to use reference sires in their programs. The method works best for breeds in which artificial insemination is common and in which a number of A.I. sires have been used extensively.

BLUP
Best Linear Unbiased Prediction

BLUP (pronounced either B-L-U-P or just plain blup) stands for **Best Linear Unbiased Prediction.** The name is full of meaning to statisticians, but is of little consequence to most of us. BLUP is a general statistical technique for genetic evaluation and, as such, constitutes a whole family of statistical models. The particular BLUP model to be discussed here is one which has only recently been applied to beef cattle.

BLUP models are an improvement over the selection index method of sire evaluation for a number of reasons. First, BLUP techniques use actual performance measures, not trait ratios, and do not assume that there are no genetic differences among contemporary groups. BLUP models keep track of which sires were used in which contemporary groups, thereby accounting for level of competition among sires.

BLUP models use what is known as the numerator relationship matrix. This is really a table containing the pedigree relationships of all sires being compared. The use of relationships has the effect of creating genetic ties among herds, years and contemporary groups, enabling the indirect comparison of large numbers of sires. For example, sire A and sire B may not have competed against each other *directly*—i.e. their calves were not in the same contemporary groups. However, if sire A has competed against sons of sire B, then through the relationship connection between B and his sons, sires A and B have competed *indirectly.*

By using relationships, the BLUP model makes use of more information than simply the records of a sire's progeny. A sire's EPD will reflect not only the performance of his own offspring, but also the performance of calves by his sire, his uncles, brothers, sons and so on. A useful byproduct of the numerator relationship matrix is the calculation of inbreeding coefficients for each sire.

In the BLUP model, it is not just the number of calves by a sire which affects the sire's EPD and its accuracy, but also the distribution of those calves among contemporary groups. The model tends to favor having a few calves in many contemporary groups over having a large number of calves in just a few groups. Sires are given credit not for their actual number of progeny, but for **Effective Progeny Number** or **EPN.** A sire with 200 calves spread uniformly over 10 contemporary groups will have a considerably higher EPN than a sire whose 200 calves are all in one or two groups.

BLUP's emphasis on distribution of progeny has some important effects. It reduces the influence of contemporary groups containing many calves by a sire and, proportionately at least, increases the influence of groups containing fewer of the sire's calves. This makes it harder for any one breeder to bias sire evaluation results through non-random mating or preferential treatment.

BLUP provides a means of accounting for genetic trend. A sire's EPDs can be adjusted for the year of his birth or for the generation coefficient of his calves. (The generation coefficient is simply a measure of the number of generations separating an individual from foundation animals.)

Table 1 rates in a subjective way the BLUP model being used today for the characteristics we would want in an ideal sire evaluation model. Selection index methods are compared in the same table. The ratings, no doubt, soon will be outdated. Large scale sire evaluations soon will use BLUP to estimate maternal breeding values; the MBVs that appear on sire summaries for breeds using BLUP models are calculated by a method similar to the selection index. When BLUP is used to calculate maternal EPDs (this year in Angus Sire Evaluation), it may well be successful in sorting out the growth component. Further refinements in BLUP models may be able to account better for non-random mating and culling of poor performing animals.

The next article in this series will deal with another type of BLUP model which has not been used yet for breed-wide sire evaluation. This new model may be as much or more of an improvement over the BLUP sire effects model being used now as that model is over the selection index method.

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NEXT:
Sire Evaluation IV:
The Animal Model