Trends in beef cattle performance record collection and genetic evaluation systems in the United States

R.L. Weaber

University of Missouri, S134A ASRC, Columbia, Missouri, United States of America

Abstract

Beef production remains the single largest segment of American agricultural production and is a geographically dispersed production system with many independent players in each industry segment. Economic signals for changes in genetic merit or product attributes are often not clearly communicated in pricing systems. Seed stock and commercial producers have effectively utilized performance record collection schemes over the past 40 years to make remarkable changes in the genetic merit of beef cattle. Over time, the suite of traits included in genetic evaluation systems continues to evolve and now includes measures of growth, carcass merit, reproduction, survival and temperament among others. Work continues to develop efficient multiple trait selection systems via industry-wide or firm-level customized indexes. Participation in performance record collection systems by seed stock breeders in the US is at unprecedented levels as breeders seek to discover unique genetic combinations among their cattle. Development of effective molecular genetics assays that describe significant portions of additive genetic variation for a number of beef production traits remains a priority for research and development efforts in the US. Industry and academic leaders continue work to realize convergence of molecular and traditional quantitative genetic evaluation systems for efficient delivery of genetic predictions for use in selection by beef cattle breeders. Economic constraints continue to affect both academic and breed focused institutions motivating the privatization of genetic evaluation services in the US. Undoubtedly, selection at the seed stock and commercial levels by US beef producers will continue to adopt new technologies and methods that enhance the value and improve the nutritional benefits of US beef while simultaneously improving animal health and well-being, minimizing environmental impacts and meeting the dietary needs of a hungry world.

Keywords: beef cattle, performance records, genetic evaluation.

1.0 Introduction

Beef cattle production represents the largest single segment of American agriculture. In 2007, there were 96.3 million cattle in the United States including 32.8 million beef cows. Producers of beef cattle were responsible for more than $61 billion in added value to the U. S. economy, as measured by their contribution to the national output. Approximately 765,000 farms or ranches in the United States report raising beef cattle as an economic activity (USDA, 2009a).

2.0 US beef industry structure

The beef industry in the US spans nearly every geographic region. The wide range in environments requires a wide variety of production systems and breed utilization. The geographic dispersion of beef cows, principally in areas where grazing is the preferred land use as the acreage is not suitable for crop production, is in stark contrast with the cattle feeding segment of the industry. Cattle feeding, in confinement facilities, is concentrated in the high plains states (Nebraska, Kansas, Colorado, Oklahoma and Texas) near feed sources. Weather in these states is much more favourable for cattle feeding. Not surprisingly, a majority of the US beef packing capacity is located in this region. Seed-stock production closely mirrors the commercial cow-calf inventory. The US beef industry remains fractured in both capital ownership and structure. Little vertical integration has occurred in the US beef industry due to the large capital costs to enter the business regardless of point of entry. These barriers are enhanced by significant price risks that exist between segments of the beef industry. Beef industry segments are principally defined at market interfaces as illustrated in Figure 1 below.

Since the mid-1990s, value based purchasing systems that price fed cattle at packing level on an individual basis based on carcass merit have been expanding. Now more than 50% of fed cattle are marketed on individual merit based pricing systems (USDA, 2009b; USDA 2009c) with the balance being sold in groups with an average price paid for each animal in the pen. Value base marketing systems have been a vehicle for communicating value in the beef marketing chain. However, unless an individual producer retains some ownership interest in the animal until harvested, it is very difficult to obtain meaningful information on carcass merit. A variety of marketing alliances exist in the US that assist commercial cow-calf producers in managing and marketing their calves through the feeding segment to harvest. Relatively few producers take advantage of this vertical integration system due to price risks associated with feeding cattle. Several systems in the US work to 'informationally' integrate the beef industry by communicating carcass merit data back to cow-calf producers that were responsible for the mating decisions and rearing of the resulting calf. Even less data is returned to seedstock producers regarding the performance of progeny of herd sires they may have bred.

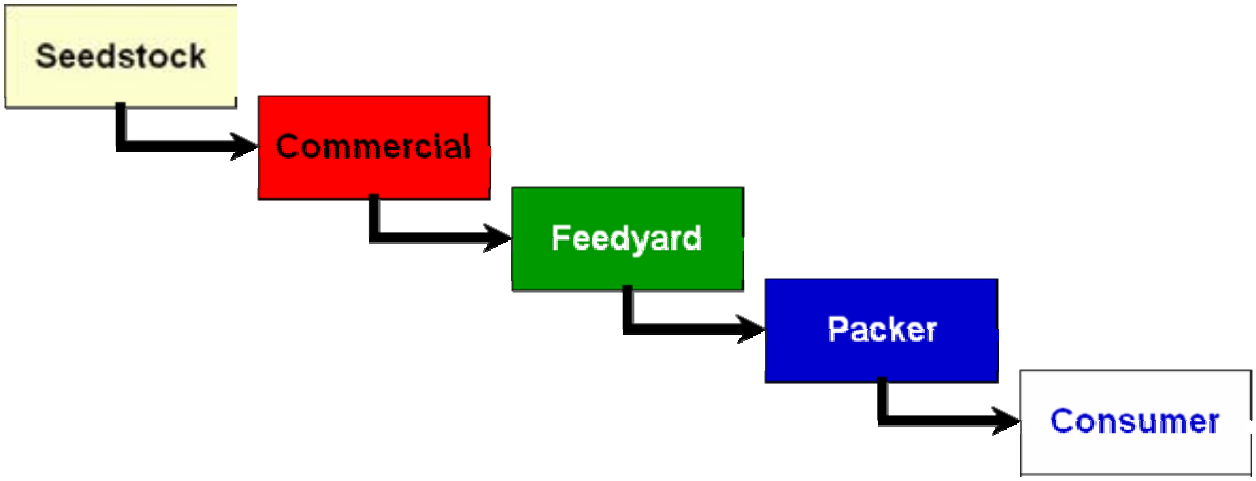

Figure 1. Illustration of germplasm and animal flow is the segmented US beef industry.

The lack of clear market signals between segments of beef industry, especially between the commercial cow-calf producer and feed yard, has resulted in a great deal of heterogeneity in the animals marketed for beef production in the US. Selection decisions at the cow-calf and seed stock levels are then driven by perceived needs of customers. The genetic trends of various breed expected progeny differences (EPD) values for reported traits provide a glimpse into the selection being practiced in these breeds. EPD provide a relative measure of genetic merit for individuals within a pedigree structure and are computed using information from performance records. Figures 2 and 3 illustrate the phenotypic and genetic trends for birth weight (BW) and yearling weight (YW), respectively, for Angus bulls in the US. Regression analysis (data not shown) reveals that changes in BW and YW EPDs explain large portions of the variation (95% and 96%, respectively) in observed BW and YW in Angus bulls. The utility of EPD as a selection tool for genetic change is unparalleled and the technology had been widely adopted across the seed stock and commercial cow-calf sectors. Figures 4-7 illustrate the genetic trends in eight major US beef breeds. The genetic trends illustrate that, generally, seed stock producers have selected to moderate BW, while dramatically improving weaning weight (WW), YW and Milk performance. It is clear that seed stock producers from these breeds are utilizing EPD to change the relative merit of progeny produced in their breeding herds. The changes in merit in these traits are made in response to the purchase demands of commercial cow-calf producers.

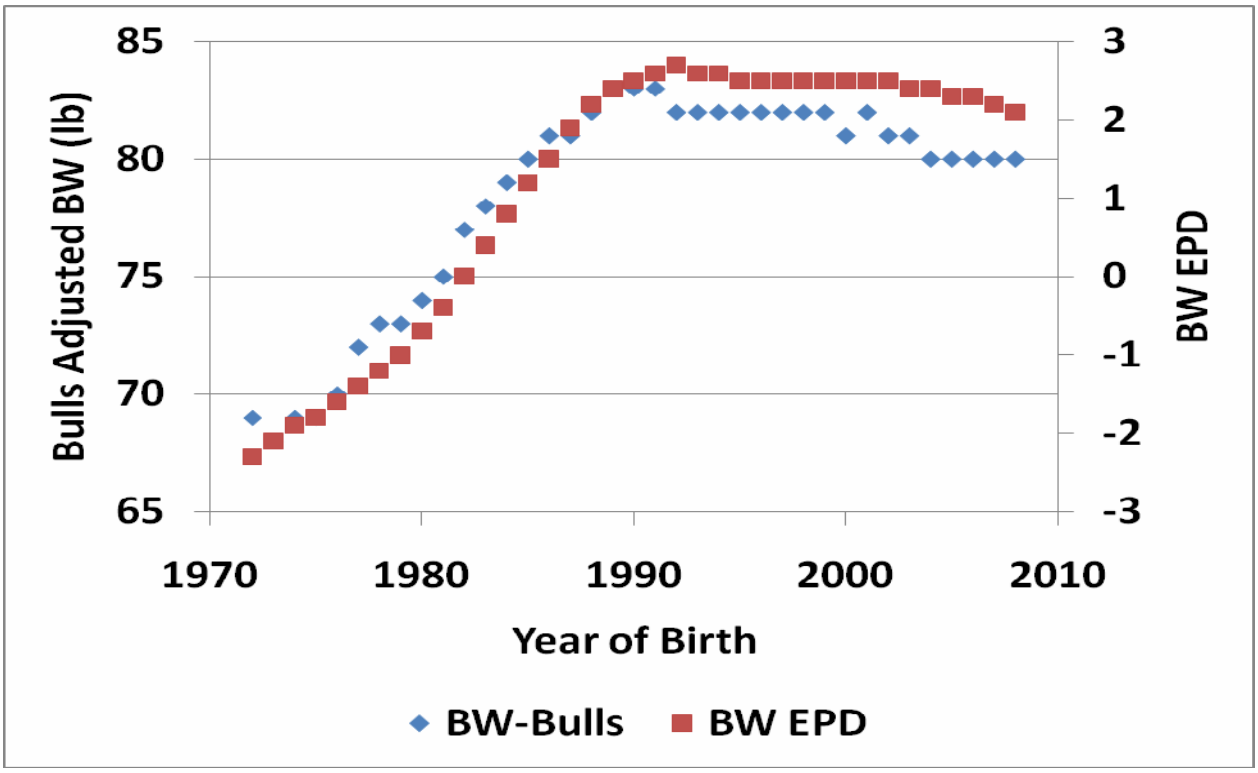

Figure 2. Angus bull birth weight phenotypic and genetic trends. (adapted from Am. Angus Assn., 2010a).

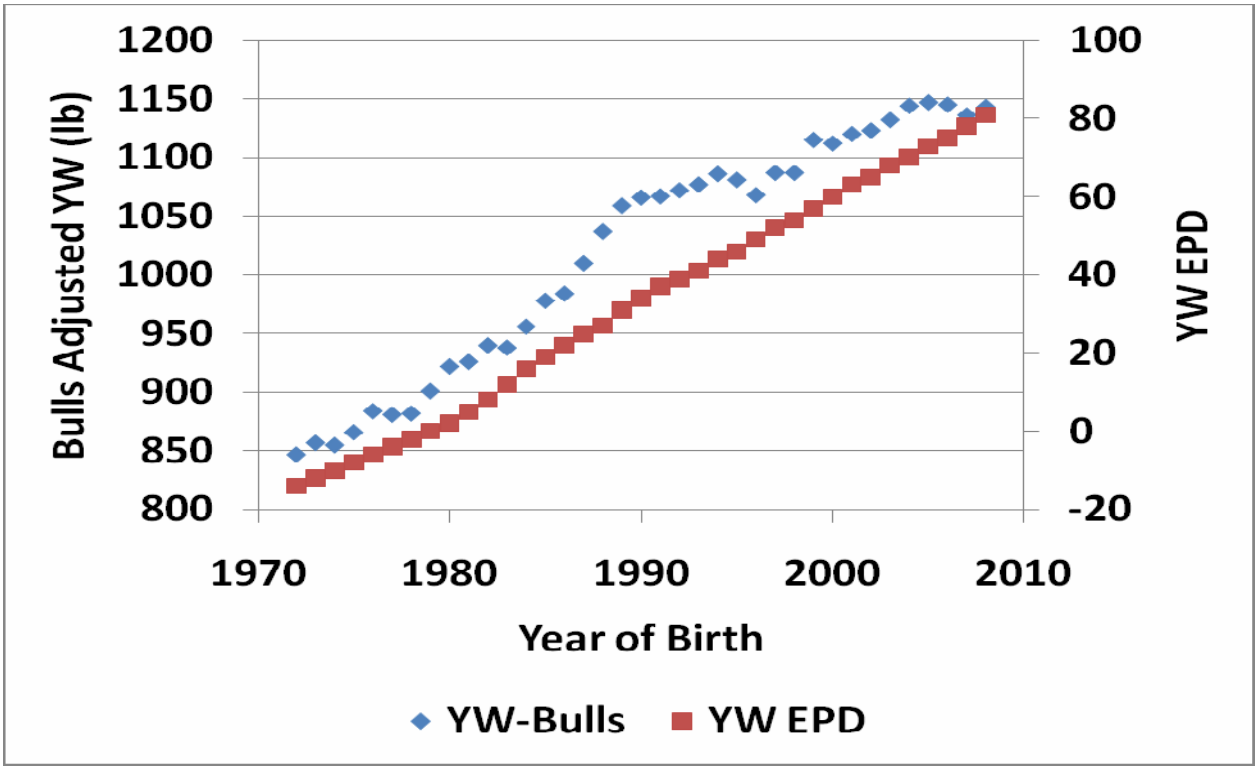

Figure 3. Angus bull yearling weight phenotypic and genetic trends. (adapted from Am. Angus Assn., 2010a).

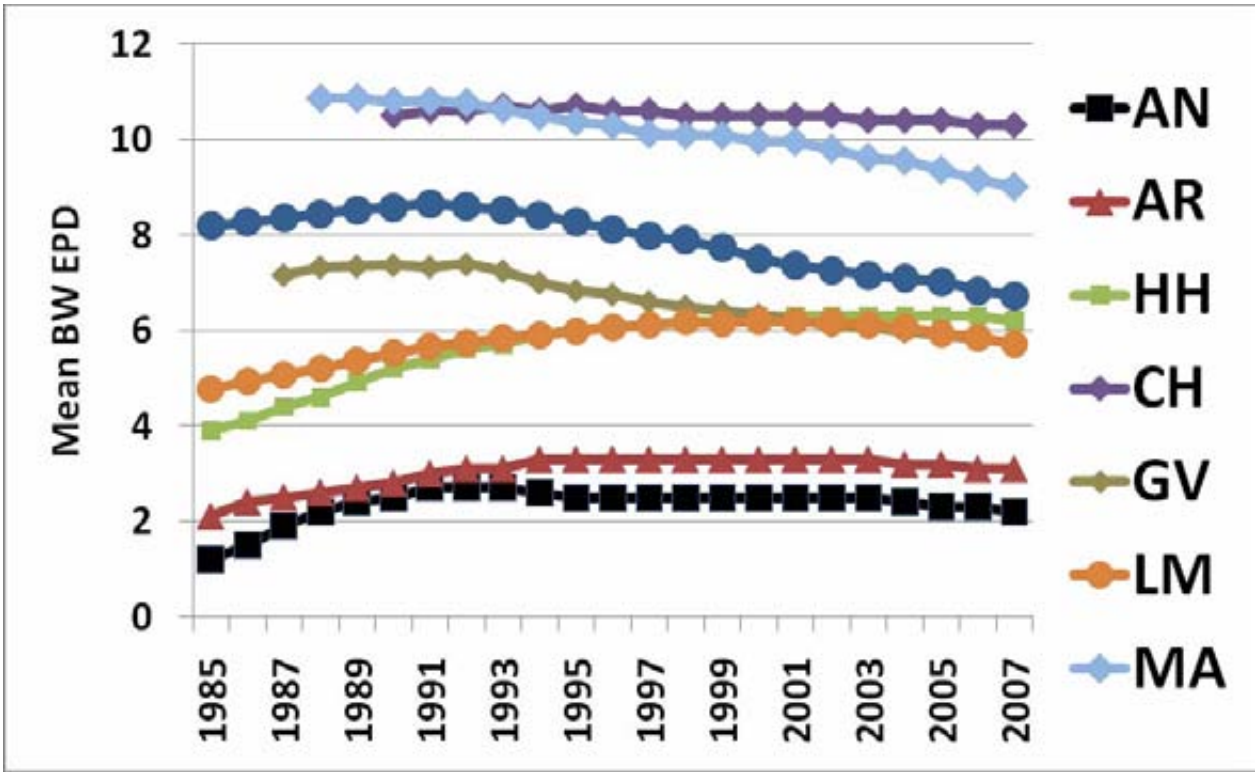

Figure 4. Birth weight EPD genetic trends converted to Angus base using USDA-MARC across breed EPD adjustment factors for eight major US beef breeds where AN=Angus, AR=Red Angus, HH=Hereford, CH=Charolais, GV=Gelbvieh, LM=Limousin, MA=Maine Anjou, SM=Simmental.

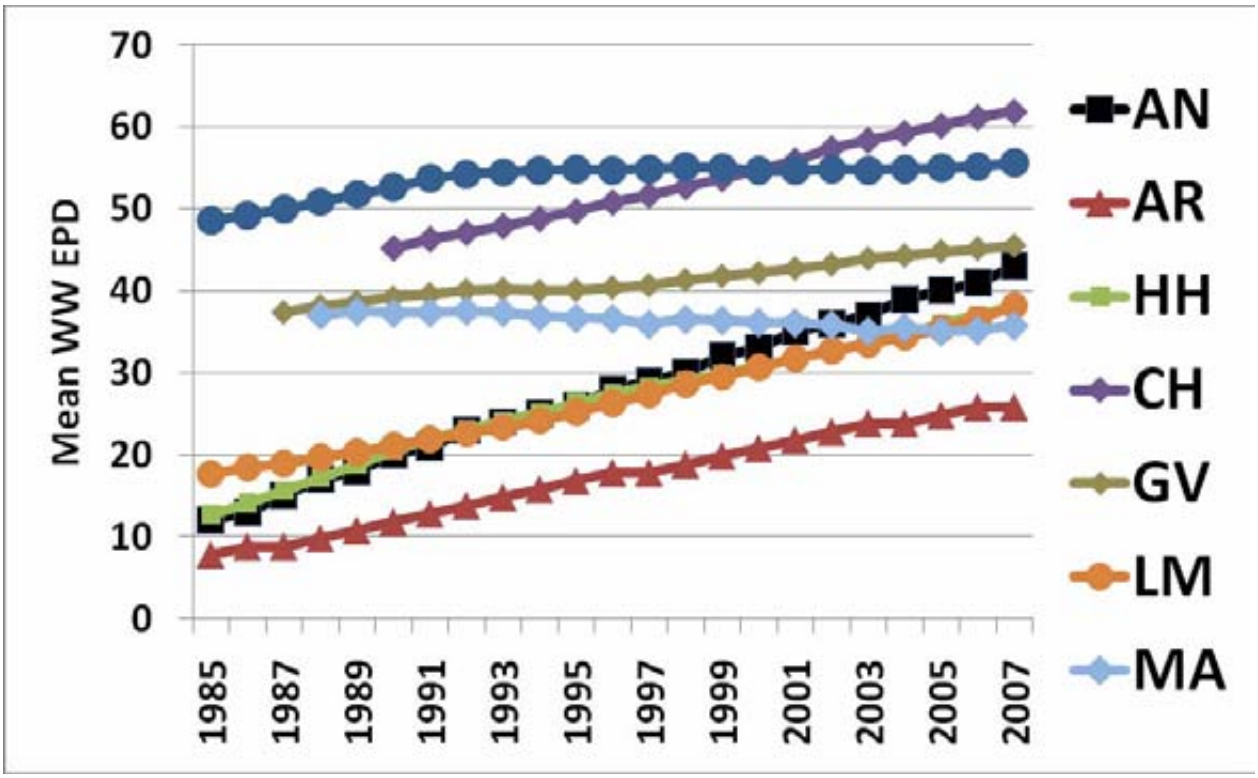

Figure 5. Weaning weight EPD genetic trends converted to Angus base using USDA-MARC across breed EPD adjustment factors for eight major US beef breeds. where AN=Angus, AR=Red Angus, HH=Hereford, CH=Charolais, GV=Gelbvieh, LM=Limousin, MA=Maine Anjou, SM=Simmental.

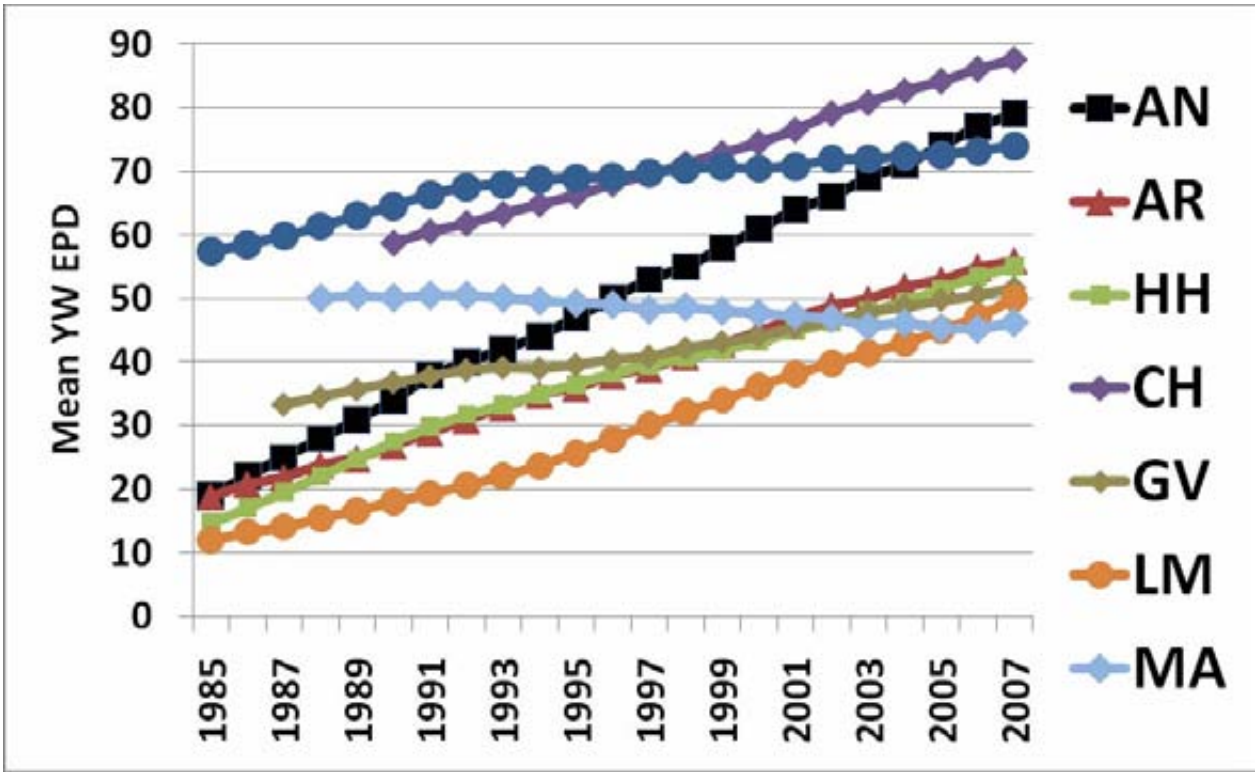

Figure 6. Yearling weight EPD genetic trends converted to Angus base using USDA-MARC across breed EPD adjustment factors for eight major US beef breeds where AN=Angus, AR=Red Angus, HH=Hereford, CH=Charolais, GV=Gelbvieh, LM=Limousin, MA=Maine Anjou, SM=Simmental.

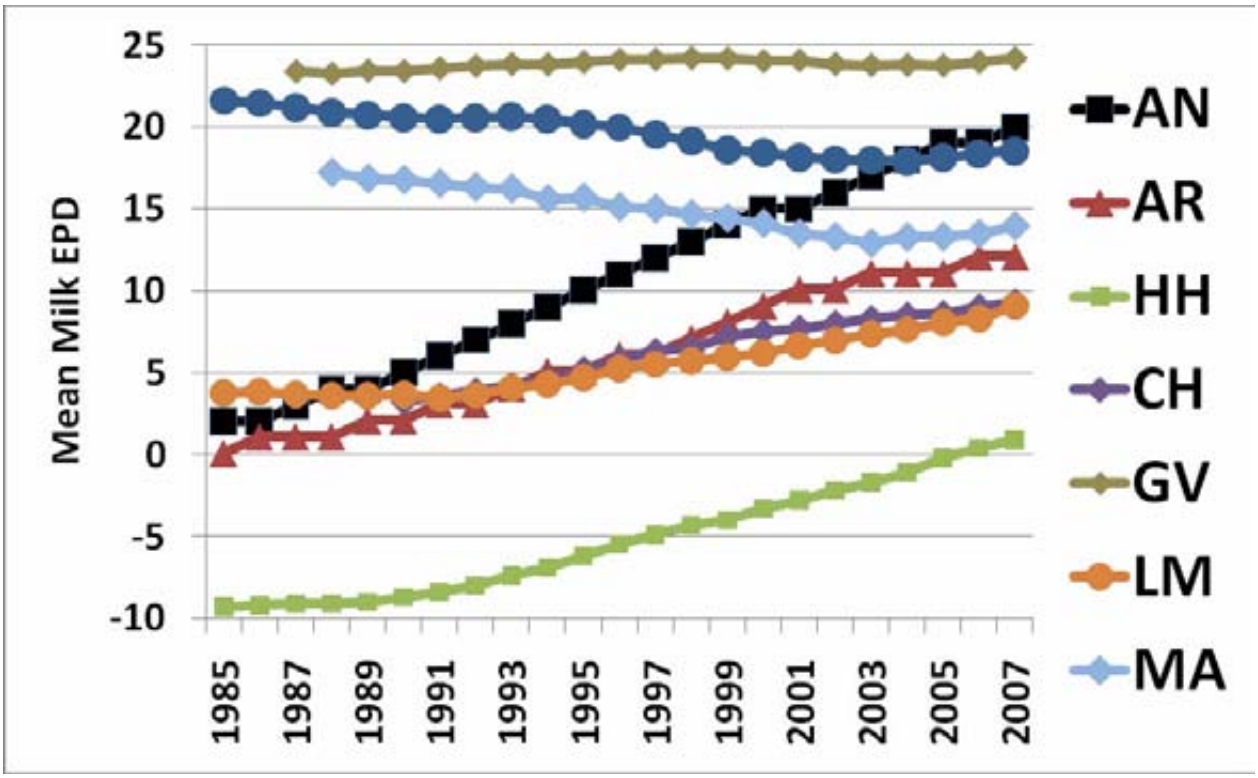

Figure 7. Milk EPD genetic trends converted to Angus base using USDA-MARC across breed EPD adjustment factors for eight major US beef breeds where AN=Angus, AR=Red Angus, HH=Hereford, CH=Charolais, GV=Gelbvieh, LM=Limousin, MA=Maine Anjou, SM=Simmental.

3.0 Proliferation of EPDs

As beef cattle breeders became more skilled at phenotype collection and use of EPD, interest in expanding the suite of traits evaluated became strong. At least a portion of the motivation to expand the traits evaluated came from the fact many traits, not just BW, WW, YW and MILK impact the profitability of beef production. In fact, as producers selected for larger weaning and yearling weights the genetic antagonisms became quite obvious (Koots *et al*., 1994). The correlated responses to selection for improved pre- and post-weaning growth included larger birth weights, increased dystocia, larger mature cow weights, and in some cases lower body condition and reduced reproductive rates. These antagonisms, in conjunction with the concept of economically relevant traits (ERT; Golden *et al*., 2000), motivated a wave of phenotype collection and genetic evaluation research to produce EPDs for calving ease, gestation length, stayability and heifer pregnancy. ERT are traits that are directly associated with costs or revenues as viewed by the producer in the context of their production/marketing system. Indicator traits, then, are those traits observed in the production system that are genetically correlated with an ERT. In instances where it is cost prohibitive or otherwise difficult to collect phenotypes on an ERT, the indicator trait is utilized in selection thus relying on the correlated response for improvement.

More recently, beef producers have become more concerned with end-product attributes through the proliferation of individual carcass merit based pricing systems, the emergence of branded or specification beef product channels and through campaigns such as the National Beef Quality Audit that highlight the ability of beef products to satisfy domestic consumer demands. The quality shortcomings and defects identified by these industry-wide surveys of carcasses (NCBA, 2000; Roeber *et al*., 2002; Garcia *et al*., 2008), products and perceptions of packers/processors/consumers have illuminated the opportunities for improvement in the quality and consistency of beef products through genetic selection and application of best management practices. Starting in the late 1990's, seedstock producers began collecting carcass records on progeny of candidate sires. Sire evaluation was conducted through the collection of both carcass and ultrasound observations on progeny. These performance records have been incorporated into effective EPD. The use of these EPD has enabled the positive genetic trends observed in marbling score and rib eye area as illustrated in Figure 8.

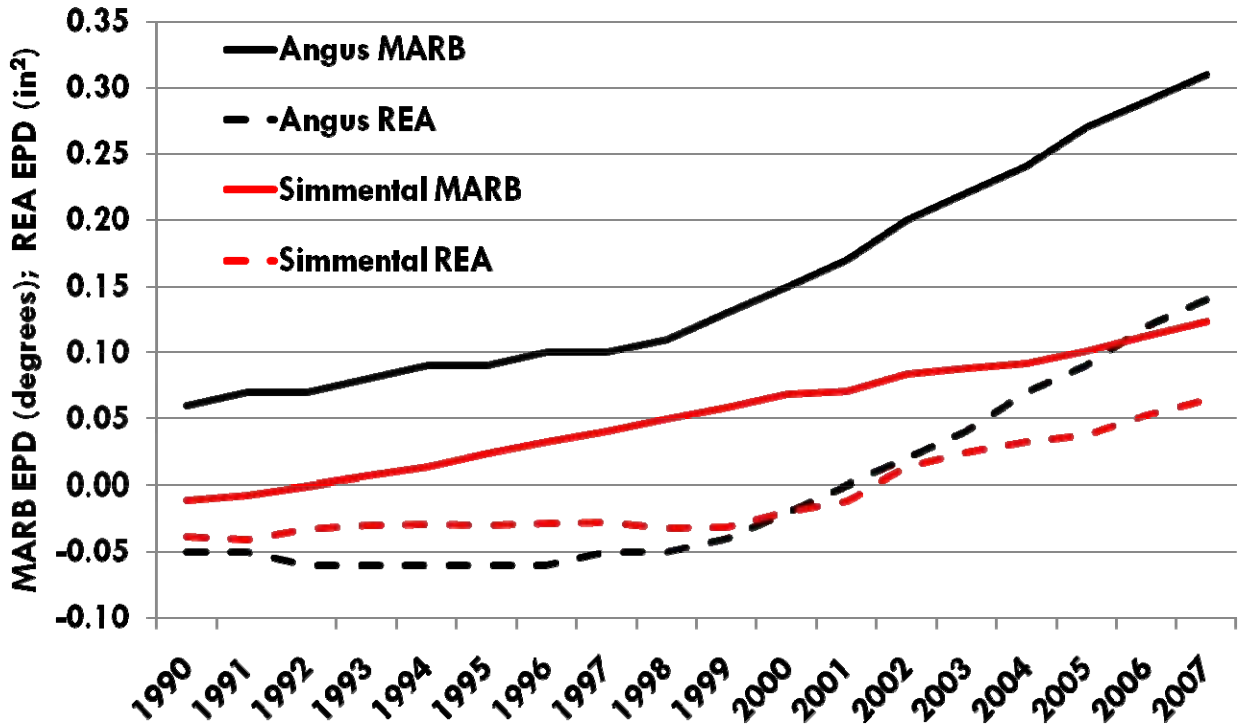

Figure 8. Marbling score (MARB) and rib eye area (REA) EPD genetic trends for Angus and Simmental breeds.

A host of other traits and genetic evaluation model features have been developed by breeds to address specific needs. The current EPD produced by eight major beef breeds for genetic improvement are listed in Table 1. The main categories reported by nearly all breeds are growth, reproduction (calving ease direct (CED) and calving ease maternal (CEM)) and carcass traits. The Angus and Limousin breeds have adopted standards for reporting measures of docility while Red Angus, Angus and Simmental have adopted a heifer pregnancy EPD. Several breeds now report stayability EPD describing differences in the expected longevity of daughters in the herd. In addition to expanding the number of traits offered, several breed associations, lead by model developments by the American Simmental Association and Cornell University, have developed multi-breed evaluations. These evaluation systems for growth traits account for breed, direct and maternal heterosis, and heteroscedastic additive and residual variances to more appropriately analyze data structures that include large numbers of animals from different breeds and their respective crosses. A number of breeds continue to work towards implementation of multi-breed genetic evaluations to capitalize on composite and systematic crossbreeding programs.

Table 1. Current EPD available in 2010 from eight major beef breeds in the United States.

	Growth								Reproduction					Carcass							Ultrasound				Other		
Breed	**Birth Weight**	**Weaning Weight**	**Milk**	**Yearling Weight**	**Total Maternal**	**Yearling Height**	**Mature Height**	**Mature Weight**	**Scrotal Circumference**	**Gestation Length**	**Calving Ease Direct**	**Calving Ease Maternal**	**Heifer Pregnancy**	**Carcass Weight**	**Ribeye Area**	**Fat Thickness**	**Marbling**	**Retail Product**	**Yield Grade**	**Tenderness**	**Percent Intramuscular Fat**	**Ribeye Area**	**Fat Thickness**	**Retail Product**	**Stayability**	**Maintenance Energy**	**Docility**
Angus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X			X
Charolais	X	X	X	X	X				X		X	X		X	X	X	X										
Gelbvieh	X	X	X	X	X				X	X	X	X		X	X		X								X		
Hereford	X	X	X	X	X				X		X										X	X	X				
Limousin	X	X	X	X					X		X														X		X
Maine Anjou	X	X	X	X	X									X	X	X	X	X									
Red Angus	X	X	X	X	X						X	X	X		X	X	X								X	X	
Simmental	X	X	X	X	X		X	X			X	X	X	X	X	X	X		X	X					X		

4.0 Participation in beef cattle performance recording grows

Seed stock breeders continue to see value in performance record collection and EPD generated through national cattle evaluation systems. EPD are used by both seed stock and commercial producers for selection and to some extent in marketing. Commercial cow-calf producers generally expect complete EPD profiles on young sire candidates available for purchase. To that end, seed stock breeders collect and report performance records for a large number of traits (see Table 1 above). Beginning in the late 1960s seed stock breeders began recording growth trait data and performance recording programs were initiated by the major breed associations. From humble beginnings and through structured performance record standards developed by the Beef Improvement Federation, performance recording programs are now at the core of the modern breed association's activities. Growth in the weaning weight performance record collection system at the American Angus Association from 1962 – 2009 is depicted in Figure 9. Since 2001, Angus breeders submit more weaning weight records than animals registered. This is achieved through a fee based performance collection system that operates independent of the registration system. Now, an overwhelming majority of animals are evaluated. The Angus national cattle evaluation system now utilizes more than 6 million weaning records, 5.5 million birth weights, 3 million yearling weights and over 1 million ultrasound scan records (Figure 10). While recent years recording of birth weights and weaning weights is equal to or greater than registrations, several traits lag behind in record collection as illustrated in Figure 11. For instance, only about 50% of animals registered have calving ease scores or ultrasound body composition measures reported. Angus breeders would be among the most complete record collectors in the beef business, but many other breeds have large performance record systems that match the saturation level of trait recording. Several breeds have adopted whole herd reporting schemes that make record collection and submission a requirement for registration. In

some case s these syst ems are br eed wi de (Re d Angus) or may be an alternative method of doi ng business with an association (Simmental) rather than the traditional pay-as-you-go registration system.

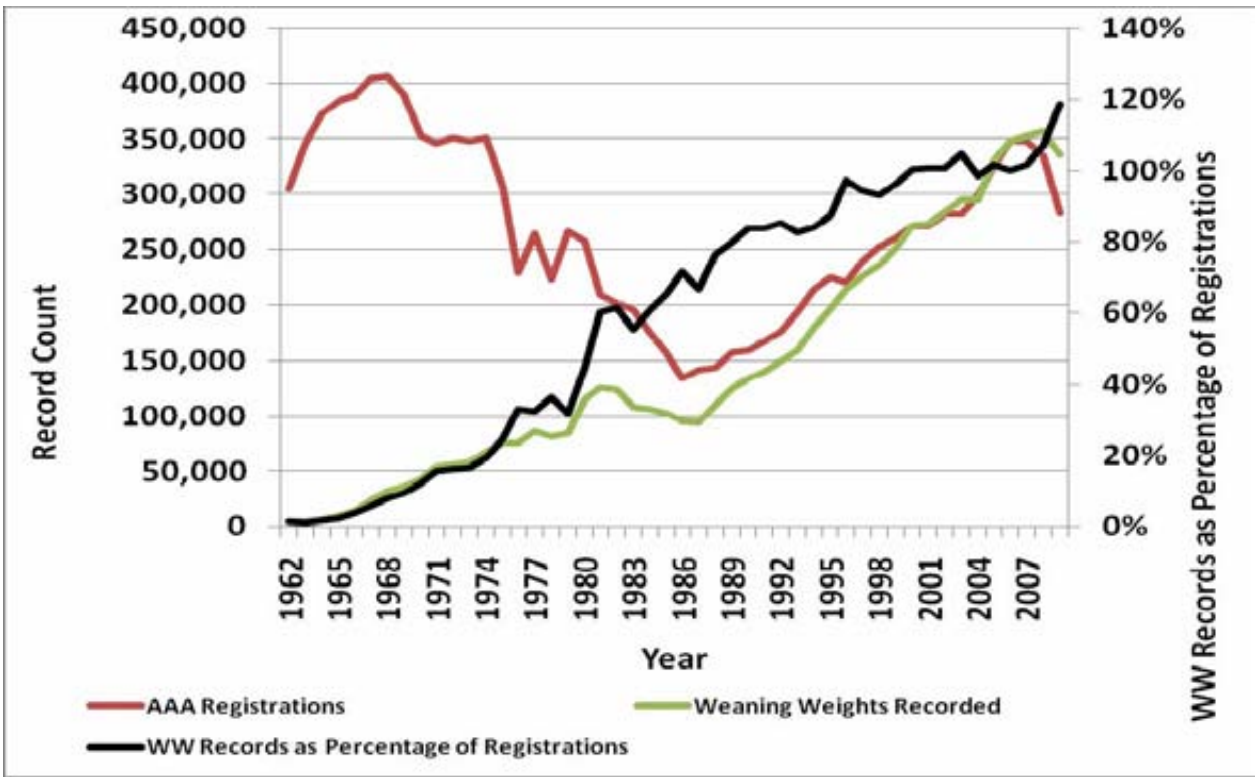

Figure 9. American Angus Association registrations and weaning weight records by year with weaning weight records as a percentage of registrations. (Am. Angus Association, 2010b).

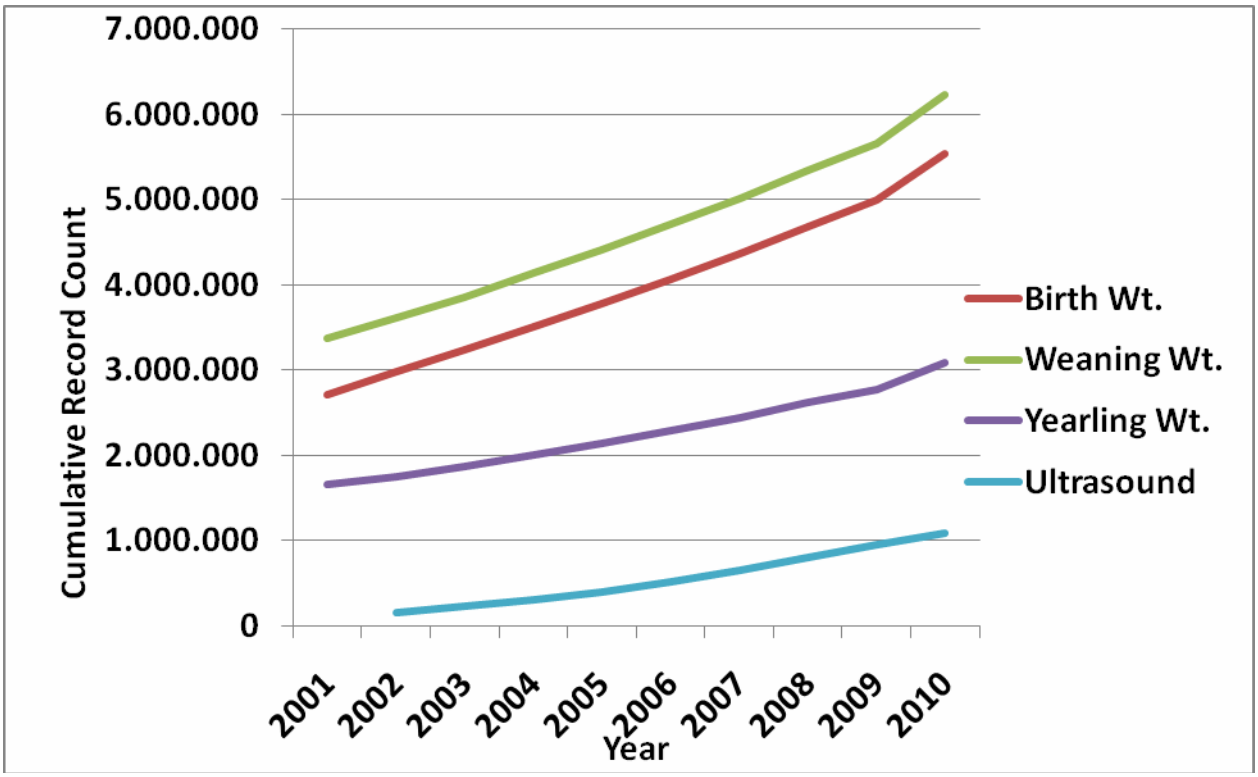

Figure 10. Cumulative performance record counts utilized in Am. Angus Association genetic evaluations. (Am. Angus Association, 2010b).

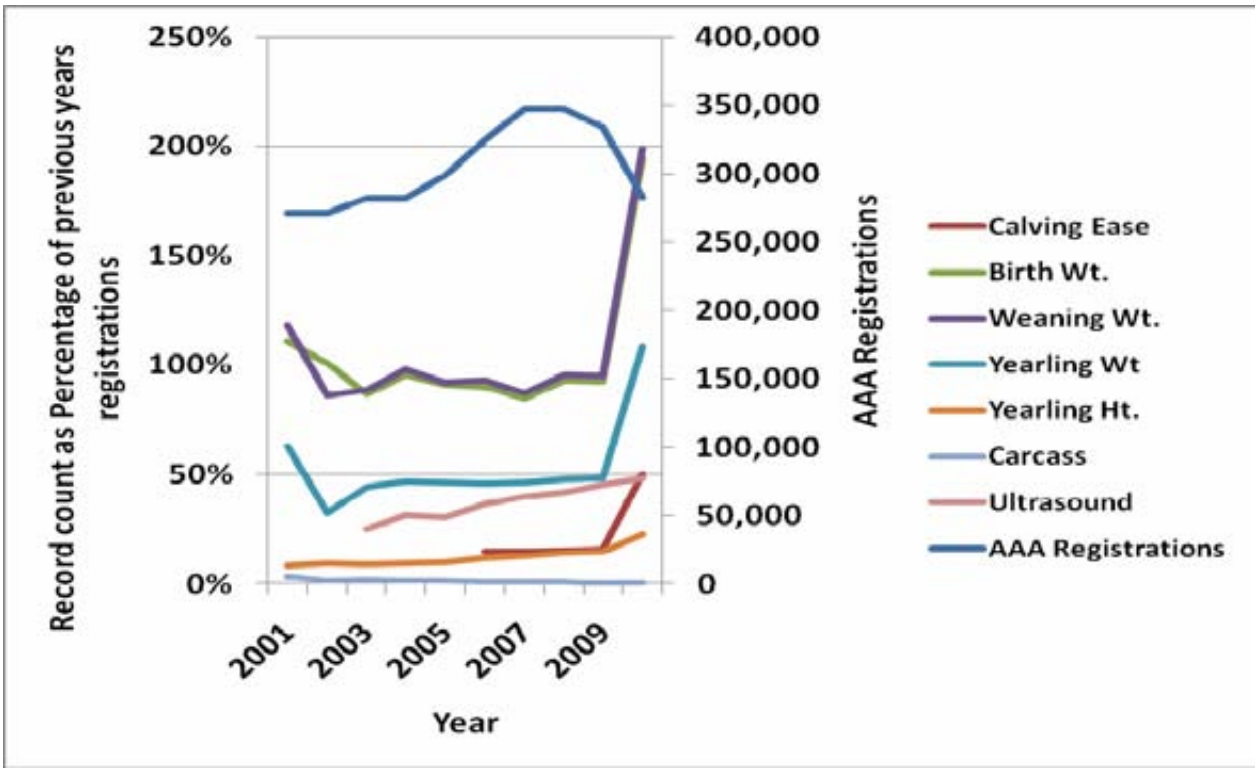

Figure 11. Trends in Am. Angus Association performance data recording as a percentage of prior year's registrations. (Am. Angus Association, 2010b).

5.0 Deployment and implementation of selection indexes

While the tools provided by genetic evaluation systems have proven effective for creating change in one or more traits, efficient multiple trait selection has remained challenging. The complications of multiple-trait selection and animal breeding decisions may be best summarized by Dr. Lanoy N. Hazel in the opening paragraph of his landmark paper on the topic of selection indexes published in the journal Genetics in 1943:

The idea of a yardstick or selection index for measuring the net merit of breeding animals is probably almost as old as the art of animal breeding itself. In practice several or many traits influence an animal's practical value, although they do so in varying degrees. The information regarding different traits may vary widely, some coming from an animal's relatives and some from the animal's own performance for traits which are expressed once or repeatedly during its lifetime....These factors make wise selection a complicated and uncertain procedure; in addition fluctuating, vague, and sometimes erroneous ideals often cause the improvement resulting from selection to be much less than could be achieved if these obstacles were overcome.

Hazel points to the complexities of selection of individuals when many traits are observed and when the 'information' or performance record of an individual and its ancestors, collateral relatives and progeny may vary considerably. Indeed, the overall net merit of the individual, considering several traits of economic importance, provides a superior selection criterion than other forms of selection including single trait selection and multiple trait selection via independent culling levels (Hazel and Lush, 1943).

Hazel's pioneering work solidified the idea of a breeding objective or goal using a quantitative method. The aggregate genotype described by Hazel was a linear function (selection index) of observations such that the observations of each trait were weighted by the relative economic value of that trait. The result was a single value for each animal that represented an objective valuation of the overall satisfaction with that animal. In production agriculture, our level of satisfaction with an animal or system is generally measured in profit. The selection index provided a natural connection between the net merit of an animal's genotype and its relationship with profit.

As beef producers, we know that more than one trait exhibited by beef cattle contribute to profit at the enterprise level. Clearly, a cow-calf producer that sells calves at weaning depends on more than just the average weaning weight of calves for profitability. Simple ranch accounting suggests that reproduction

rate, calf survivability, cow maintenance feed costs, length of productive life and others influence the total pay weight of weaned calf produced and the cost required to produce that weight. Likewise, the producer that sells calves at harvest relies on more than just marbling score or quality grade to pay the bills. Reproductive rate of the cow herd, maintenance costs, longevity, not to mention carcass weight, are all factors affecting profitability. Thus, breeding objectives should include all the traits that are of economic relevance.

The original work by Hazel and later the work of Henderson (1951), who incorporated the use of EPD into selection indexes, stimulated a great deal of activity in the area of genetic prediction. Significant time and monetary resources have been devoted by producers, breed associations, beef improvement organizations, public sources, and academics to produce the sophisticated genetic predictions at our disposal today. However, comparatively little work has been devoted to full implementation of multiple-trait predictions into the multiple-trait prediction tools (Bourdon, 1998) envisioned by the originators. While the EPD produced today are of sufficient precision and accuracy, they are presented without context. Bourdon goes on to state that, "There is no easily accessible, objective way for breeders, particularly breeders in the beef and sheep industries where ownership is diverse and production environments vary greatly, to use these predictions intelligently." Academic animal breeders are encouraged to solve this problem. The solution to the problem of intelligent use of multiple-trait EPD is to integrate genetic predictions with multiple-trait selection strategy usable on a large scale (Bourdon, 1998).

During the last decade, animal breeders have developed a series of selection indexes for use by seedstock and commercial producers. These indexes vary considerably in the approach utilized to develop the economic weights. The vast majority of the indexes are end point focused and seek to capture important genetic variation related to profit within that industry segment. Dr. Mike McNeil (personal communication) has developed several indexes for the Hereford and Simmental breeds that utilize a bio-economic simulation of individual animals at the herd or firm level to generate economic weight through perturbation of the levels of genetic merit and monitoring effects on profit. Currently, the Angus, Hereford, Simmental, Charolais, Gelbvieh breeds offer selection indexes for multiple trait selection.

6.0 Privatization of genetic evaluation systems

With the contraction of federal and state level support of agriculture experiment stations at land grant universities in the US, many animal breeding programs that have historically provided genetic evaluation services are re-tasking scientists to focus on new research developments. As such, the service components that have provided EPDs to many breed associations are being discontinued. Breed associations have responded in a variety of ways to this threat. Angus and Simmental have invested heavily in computing and staff resources to move the evaluations 'in house.' Others have sought the service of these organizations for genetic evaluations. Several independent start-ups have been initiated to license software developed at universities and through the National Beef Cattle Evaluation Consortium to provide genetic evaluations as fee for service. Given the funding trends in land grant universities, it is unlikely that new players will emerge to satisfy the industry needs for genetic evaluation. Breeds will likely need to develop strategies and cooperative relationships to develop economically sustainable genetic evaluations service provider(s) with a robust product offering.

7.0 Convergence of molecular and traditional quantitative genetics

Molecular genetics and associated technologies such as marker assisted selection, whole genome selection, genome sequencing, marker assisted management and others provide a great deal of promise to cattle breeders for traits that are difficult and/or expensive to phenotype. Much work has been undertaken in the US to identify DNA markers associated with growth, meat quality and fatty acid composition, female reproductive efficiency, animal health and feed intake/efficiency. Additionally strategies for implementation of genomic selection systems are in development. The ultimate success of many of these tools will be cost effective delivery of selection information and their ability to converge with existing genetic evaluation systems. The American Angus Association has recently deployed genomically enhanced carcass EPDs that leverage information for existing carcass performance records, ultrasound performance records and DNA markers (MacNeil *et al*. 2010). The beauty of the converged systems is that they communicate genetic merit as EPD and index values, selection currency with which producers are already quite familiar. Convergence alleviates the conflicting estimates of merit that exist when disparate sources of information are utilized. Familiarity will ease implementation and speed uptake by producers.

8.0 References

Am. Angus Association. 2010a. 2009 Angus Sire Evaluation report. http://www.angus.org/Nce/AHIRAvg.aspx. Accessed May 20, 2010.

Am. Angus Association. 2010b. Personal communication: Historic performance record and registration counts time series.

Bourden, R. M. 1998. Shortcomings of current genetic evaluation systems. J. Anim. Sci. 76:2308-2323

Garcia, L. G., K. L. Nicholson, T. W. Hoffman, T. E. Lawrence, D. S. Hale, D. B. Griffin, J. W. Savell, D. L. VanOverbeke, J. B. Morgan, K. E. Belk, T. G. Field, J. A. Scanga, J. D. Tatum, and G. C. Smith. 2008. National Beef Quality Audit–2005: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci. 86:3533-3543.

Golden, B. L., D. J. Garrick, S. Newman, and R. M. Enns. 2000. Economically Relevant Traits A Framework for the Next Generation of EPDs. Proc. 32nd Annual Research Symposium and Annual Meeting, Beef Improvement Federation, Wichita, Kansas.

Hazel, L. N. 1943. The genetic basis for constructing selection indexes. Genetics 28:476-490.

Hazel L. N. and J. L. Lush. 1943. The efficiency of three methods of selection. Journ. Hered. 33:393-399.

Henderson, C. R. 1951. Mimeo published by Cornell University. Ithaca, NY.

Koots, K. R., J. P. Gibson, and J. W. Wilton. 1994. Analyses of published genetic parameter estimates for beef production traits. 2. Phenotypic and genetic correlations. An Breeding Abstr 62:825.

MacNeil, M. D., J. D. Nkrumah, B. W. Woodward, and S. L. Northcutt. 2010. Genetic evaluation of Angus cattle for carcass marbling using ultrasound and genomic indicators. J Anim Sci 2010 88: 517-522.

National Cattlemen's Beef Association (NCBA). 2000. Executive Summary of the 2000 National Beef Quality Audit. Accessed on May 7, 2007 at: http://www.texasbeef.org/files/publication_4_NBQA2000.pdf

Roeber, D. L., D. R. McKenna, P. K. Bates, T. B. Schmidt, K. E. Belk, T. G. Field, J. A. Scanga, J. W. Savell, J. B. Morgan, T. H. Montgomery, and G. C. Smith. 2002. The 2000 National Beef Quality Audits: Views of producers, packers, and merchandisers on current quality characteristics of beef. Prof. An. Sci. 18:112-119.

USDA. 2009a. 2007 Census of Agriculture: United States Summary and State Data. Vol. 1, Geographic Series, Part 51, Pages 7,19.

USDA. 2009b. National Weekly Direct Slaughter Cattle - Formulated and Forward Contract – Domestic. Accessed on 07/08/2009 at: http://mpr.datamart.ams.usda.gov/menu.do?path=\Species\Cattle\Weekly Cattle\(LM_CT151) National Weekly Direct Slaughter Cattle - Formulated and Forward Contract - Domestic

USDA. 2009c. National Weekly Direct Slaughter Cattle - Negotiated Purchases. Accessed on 07/08/2009 at: http://mpr.datamart.ams.usda.gov/menu.do?path=\Species\Cattle\Weekly Cattle\(LM_CT154) National Weekly Direct Slaughter Cattle - Negotiated Purchases