

Wildlife enterprises are increasingly important for ranch income, and in many cases now provide the highest net revenues for landowners. High-end elk and mule deer hunts can bring \$12,000 to \$15,000 per animal, and even less intensive operations can easily receive more than \$2,500 for mule deer. The high revenue from wildlife enterprises has heightened competition among landowners (as well as state agencies, based on proliferation of “Governor’s Tags” and similar authorizations) for the hunter’s dollar, and this competition has resulted in significant interest in increasing the quality (i.e., antler or horn size) of elk, deer, and other ungulates. Attempts to improve quality (quality management; QM) can include establishing habitat improvement or feeding programs, purchasing semen from “superior” sires, and even purchasing breeding stock, often at more than \$50,000 per individual. While these and other practices can increase overall herd quality, there is often a trade-off between returns and costs. Additionally, while many practices may work with intensive breeding or high fence operations, they may fare poorly in traditional extensive ranching operations. Finally, a “more is better” approach meshes poorly with QM, so more intensive operations may actually produce fewer quality animals, or may produce them for neighboring areas because of increased dispersal. Hence, a basic understanding of what is and is not important and appropriate is needed for those considering a QM approach.

The keys to QM, in order of importance, are (1) age structure, (2) nutrition, and (3) genetics. Population age structure affects both productivity and development of secondary sexual characteristics such as horns, pronghorns, and antlers; to keep things simple, this guide will primarily discuss antlers, although the management concepts are similar



Figure 1. Trophy bull elk? Maybe...maybe not. Note the small body size of this adult bull, which makes his antlers appear larger than they actually are because of the smaller body-associated visual references. Photo courtesy Jason Schlie.

for all species. At its most basic, males simply have to live long enough to grow large antlers. More specifically, though, males will not maximize antler size until after body mass has been maximized, because it is body size—not antler size—that determines reproductive success. Additionally, body mass and antler mass are positively correlated, so bigger males tend to grow bigger antlers (Figure 1).

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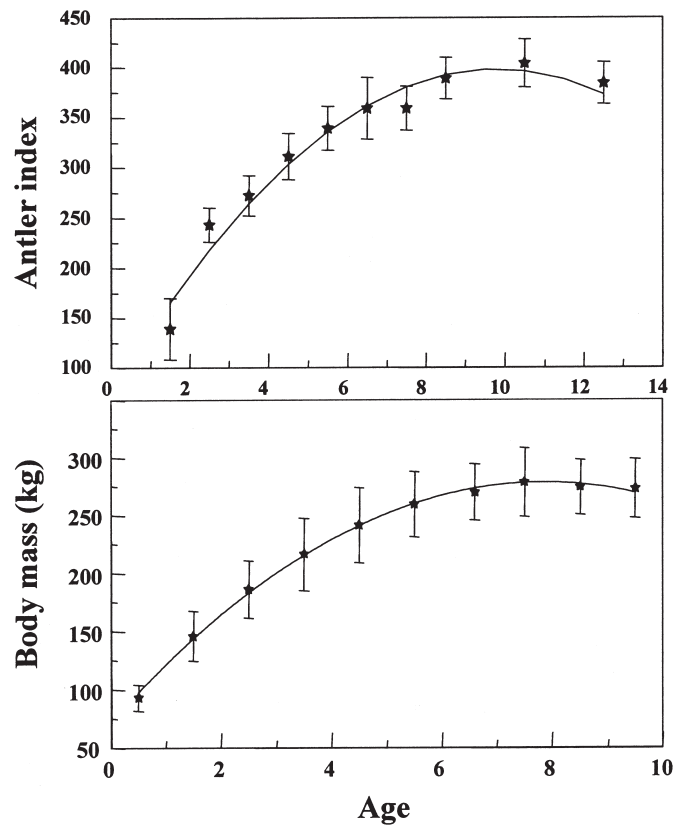


Figure 2. Common to most ungulates, the peak in antler development in elk occurs 2 to 3 years after the peak in body mass. Data from Bender (2008).

AGE STRUCTURE

What is not often appreciated is just how old bulls and bucks must be to maximize antler development. Elk tend to peak antler development at age 8 to 10, about 2 to 3 years after they peak body mass (Figure 2). Mule and white-tailed deer will peak antler mass at age 5 to 7, again 2 to 3 years after peaking body mass. All will begin to lose antler configuration after the peak ages, although mass may remain high. The exception to this is pronghorn, which peak prong development relatively early in life at age 3 to 5.

Quality management requires that individuals live long enough to reach these optimal ages, which is no easy task. The proportion of the population surviving to optimal ages is determined by the overall mortality rate of males. Because harvest makes up the majority of male mortality, harvest rates

must therefore be low enough to allow survivorship well beyond age 5. The question is how low, and how do you achieve these lower harvest rates?

In general, annual male survival rates must be above 60% to get sufficient numbers of bucks into older age classes (Figure 3), assuming that harvest is proportional across age classes. The more selective the harvest is for older males, the lower the harvest rate must be to allow individuals to reach optimal ages. There is no panacea for getting these high survival rates other than remembering that the only way to have older males is to not kill them. Antler-point restrictions, or selective harvest criteria (SHC), such as 3- or 4-point minimums that protect younger males from harvest, are frequently touted to increase survival of older males. For example, many practitioners of Quality Deer Management (QDM) in the Southeast use this ap-

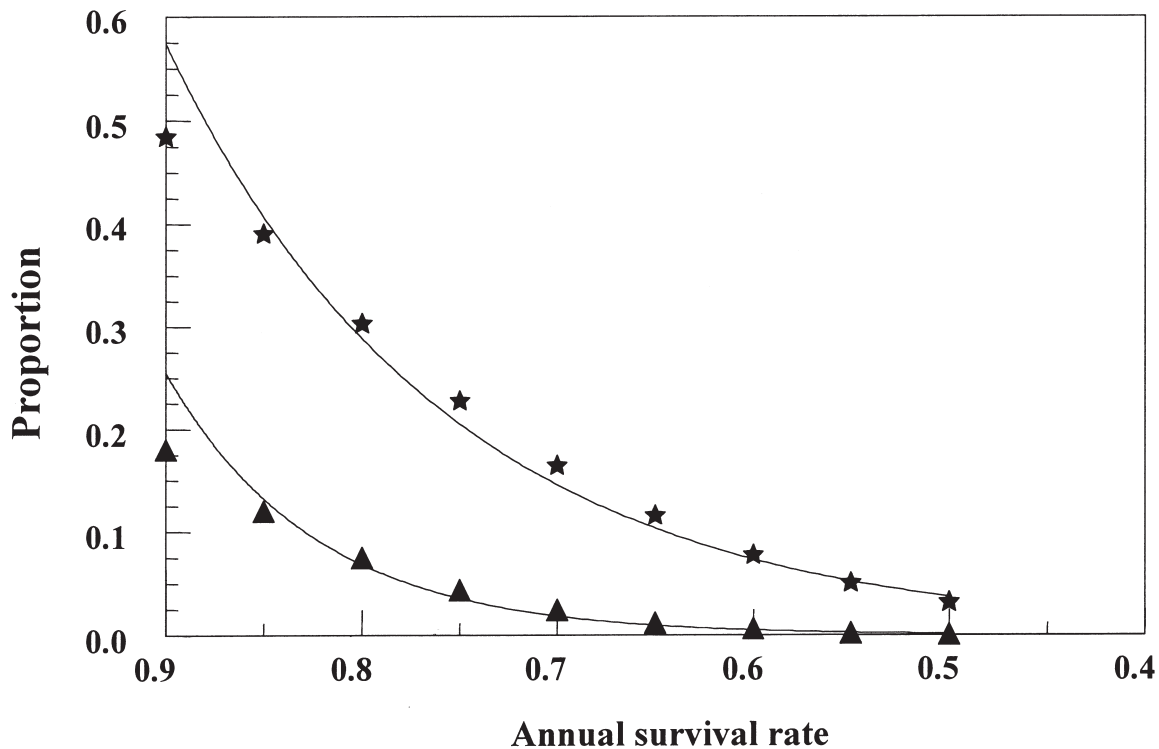


Figure 3. Proportion of males surviving to age 5 (★) or age 10 (▲) given various annual male survival rates assuming that harvest is proportional across age classes. Notice that less than 10% of males live to age 5 until survival reaches more than 60%, and less than 10% reach age 10 until survival reaches more than 85%. Data from Bender (2008).

proach. However, it is NOT the antler restriction that results in more mature bucks in QDM; rather, it is severely limiting the numbers of adults harvested, usually to less than 30% of the age 2 and older population. This is key, because if overall harvest is NOT limited under a 3- or 4-point restriction, the result is often elimination of virtually all males older than age 3 (the only males that can be harvested with the SHC). Remember, *it is the overall mortality (harvest) rate that determines survivorship—not any SHC*. Any harvest strategy can—or cannot—produce trophy males, depending on just how many males are harvested.

How do you know what the mortality rate is? Age structure gives a good approximation. If you perform prehunt composition surveys, look for the percent of the herd that are yearlings; this will approximate the overall mortality rate (Bender, 2006).

If you keep harvest data, look at the proportions between age classes in the harvest; this will do the same (Bender, 2006). Last, because the adult sex ratio (ASR) is simply the result of female mortality rate divided by male mortality rate, you can use ASR to approximate mortality rates as well. Male/female ratios of more than 60/100 in stable or increasing herds result from adequately low male mortality (see Bender, 2006 for details).

Managing for older age structure does have behavioral challenges. Lower male mortality rates result in more adult males in the population, which in turn increases stress from social interactions (and possibly less nutrition if overall population densities are not controlled). Increased stress and lower nutrition both compromise the immune system and can lower the quality of antlers produced (Ozoga and Verme, 1982). High stress caused by high adult

male densities also results in more dispersal, and possibly more antler damage from frequent social dominance interactions. Deer breeders in the eastern U.S. and in Europe, where programs designed to produce “super bucks” have the longest history, particularly try to limit stress by limiting the numbers of adult males in close proximity (i.e., in the same pens, holding pastures). Because stress hormones from constant social interactions can affect size and symmetry of antlers, managing densities is critical for optimizing antlers, especially in more intensive operations.

Stress, lowered nutrition, and unintended genetic influences can also decrease body sizes, and, in general, larger males grow bigger antlers. For example, antler mass is proportional to body mass^{-1.6} in red deer (elk; Hyvarinen et al., 1977), and there are strong correlations ($r > 0.94$) among all cervids between metabolic body mass and antler length (Bubenik, 1985). Body mass is primarily an age and nutritional effect, although body mass also has moderate heritability and thus can also be influenced by genetics.

NUTRITION

As early as the 1940s, pioneering nutritional work by Franz Vogt in Germany demonstrated the overwhelming effect of nutrition on antler development (summarized in Geist, 1986). Vogt found that pregnant deer fed a supplement high in protein, energy, and minerals over generations produced superior bucks even if the original genetic stock was mediocre. For example, one group doubled in body mass and more than doubled in antler mass in just three generations. Clearly, nutrition has to be optimal for either age or genetic effects to be seen in antlers.

Unfortunately, nutritional requirements for antler development in wild herbivores are poorly understood. Some general guidelines likely apply, however.

1. As noted above, body mass will be maximized before antlers because antlers are a luxury tissue, so while nutrition can maximize potential within an age-class, it cannot compensate for survival to optimal ages.
2. Nutritional requirements for optimal antler growth probably mirror needs of females for

lactation. These needs are high: for elk, diets of more than 67% digestibility and more than 16% protein, and more than 70% digestibility and more than 18% protein for deer.

3. While little firm knowledge is available on mineral requirements for antler growth, anecdotal evidence suggests that mineral supplements can enhance development.

Nutrition is best managed through proper habitat management, habitat enhancements, and animal densities; this concept is called “density dependence.” Higher densities mean fewer resources (food, space, etc.) for each individual, which in turn results in less productivity, whether productivity is defined as young produced, size of individuals, or antler development. That means overall herd size must be controlled, which is not easy for free-ranging operations in states like New Mexico where no female harvest is permitted for species such as mule deer. This is especially problematic because low mortality rates result in an advanced age structure, which can also limit the overall productivity of herds, and thus economic returns, because fecundity of females declines with age (Figure 4; Bender, 2008). Keeping female densities low can increase habitat quality for males as well as overall productivity of herds. The same is true for males; selective harvesting of younger males increases resources available for older males.

In arid regions like New Mexico, even optimal habitat management may result in poor antler expression because of frequent annual and seasonal droughts. Consequently, many managers feed or supplement wildlife to maintain individual quality even during years of poor habitat productivity. To be biologically and economically effective, supplementation should provide the individual with nutrients they need, when they need them. Nutrient needs, in turn, are determined by the timing, composition, and growth of antlers. During their active growth phase, antlers are approximately 80% protein, clearly indicating the need for a high-protein supplement. During mineralization and after hardening, antlers are approximately 60% mineral (still 40% protein), primarily calcium (Ca), phosphorous (P), and magnesium (Mg). To grow antlers, individuals must get these nutrients from

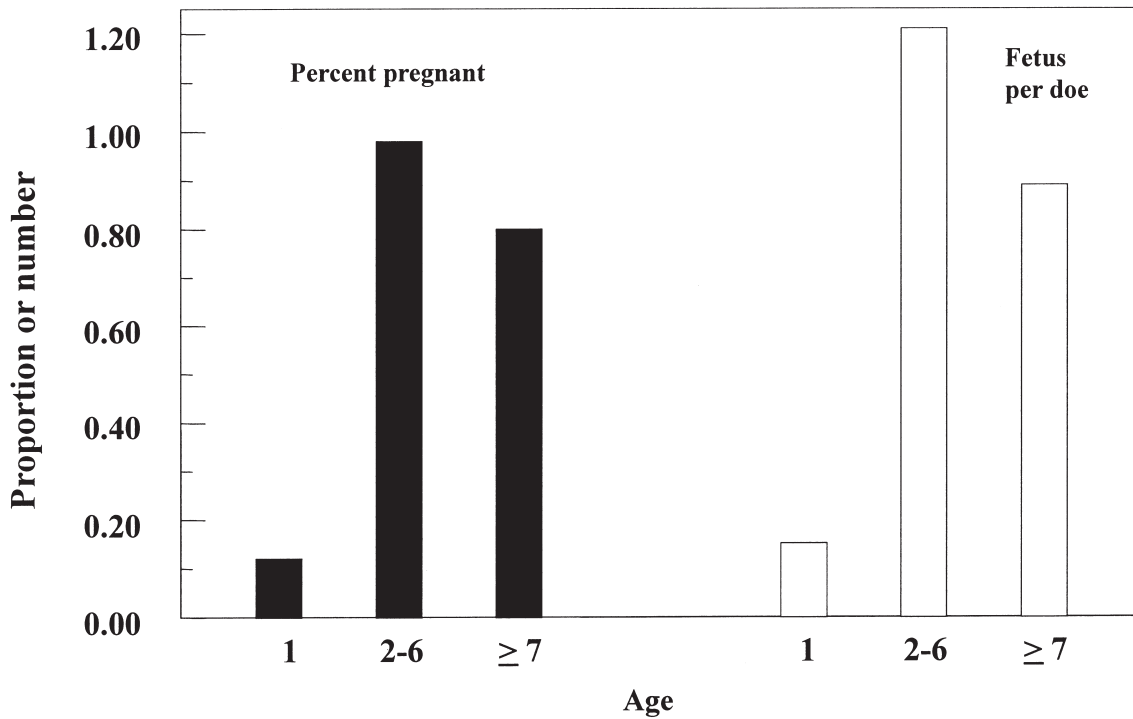


Figure 4. Pregnancy and number of fetuses per pregnant doe both decline with age of doe mule deer in southern New Mexico. Mule deer does can live more than 15 years, so the majority of does in unharvested populations show decreased reproductive potential.

their feed or from their body. While individuals can frequently get adequate protein from forage, they usually mobilize most minerals from their bones, particularly the ribs, reserves that are stored throughout the year.

Supplementation with a high-protein feed—at least 18%, but more than 20% is better—and a good mineral mix that includes Ca, P, and Mg, as well as vitamin D (or its precursors), can provide individuals with all their needs to maximize their antler potential. For the mineral mix, a 2:1 Ca:P ratio is probably adequate, with Mg present in lesser amounts (maybe at 2:1:0.1). Vitamin D or precursors potentially aid dietary mineral absorption, although the mechanisms involved in heightened mineral absorption in wild ungulates are unclear (Brown, 1990). The exact quantities in the mineral mix are likely less important than the ratios and covering the basic nutrients listed above; wild herbivores will regulate their intake to satisfy their cravings.

Late April through September is the critical time for antler growth (the March-June period is similarly critical for adult survival and production of juveniles), and is the period to supplement if desired. Note that there is no need to feed all year unless trying to artificially increase carrying capacity of the operation; however, this practice is NOT recommended because wild ungulates will preferentially use green feed as palatability increases, leading to overuse of natural forage. However, if feeding later or throughout the year, managers should decrease protein and increase energy as animals look to build up body fat later in the year, not muscle mass. Continuing a high-protein supplement past September has little effect on males, but makes it more difficult for females to recover condition during and after weaning. It can, however, dramatically improve juvenile growth and survival. Finally, remember to either introduce animals to the supplement slowly in late winter or provide it in lesser amounts

throughout the year to allow digestive physiology to adjust to the supplement.

GENETICS

Things become more complicated and even more uncertain with the genetics of antler development. The strength of the link between genetics and quality can be very blurry; most work on genetics is hopelessly confounded by superior nutrition typical of studies of penned wildlife. Despite this, a couple of conclusions can be drawn. First, genetic potential can be fully expressed if and only if nutrition is superior and individuals can reach optimal ages. If age structure is lacking and individuals cannot achieve large body sizes, there is much less opportunity for antler genetics to contribute to quality. Second, be aware that management for “optimal” genetics can have unintended consequences as well.

Most of the genetic work on antler development has involved white-tailed deer in penned studies at multiple public and private facilities. Results have generally shown that bucks with superior mass and antler development as yearlings maintained larger body sizes and better antler development throughout their lives, with body mass averaging 10 to 25% greater and antler mass more than 50% heavier by age 5 and older (see, e.g., Harmel, 1982). Progeny of these superior bucks similarly had a greater tendency to be branched as yearlings, and some subsequent genetic analyses indicated that most antler traits (as well as body mass) appear to have moderate to high heritability (Williams et al., 1994). Thus, studies that selected only the best yearlings for breeding under identical diets were able to gradually increase the average antler size of the study herds (e.g., Frels et al., 2002). Similar results have been seen with elk and red deer on private ranches, though little has been done with mule deer.

However, these results are not invariant. Work with free-ranging white-tailed deer in Texas found no relationship between antler quality as yearlings and mature deer (Koerth and Kroll, 2008). In a penned study at Texas A&M, a superior sire produced 4 spikes and 4 yearling offspring with 4 to 11 points despite identical high-quality diets (Brown, 1990). Similarly, research in Mississippi found that environment had a much greater effect on antler development of yearlings than did the

sire, and also found low heritability of antler characteristics (Lukefahr and Jacobson, 1998). Further complicating this, males receive half of their genetic propensity for antlers from their mother, for which genetic potential is frequently unknown.

I have also noticed that highly selective breeding operations often produce superior antler development in younger animals, but this early advantage is lost by the time individuals reach their age of maximum antler development. These observations are partially influenced by nutritional status as well as age, because most intensive breeding programs keep individuals at high density, limiting their nutrition as well as elevating social stress. Further, many of the superior individuals are harvested at younger ages because of their antler development (e.g., shot as a 350-inch bull at age 5, 2 to 3 years before peak).

Along with inconsistent results on early antler expression, there is also the potential for unintended deleterious effects when breeding for superior genetics. In several cases, I have noticed that bucks and bulls from intensive breeding programs showed smaller body sizes, and, as noted above, there is a positive correlation between body mass and antler mass. Similarly, use of SHC can potentially negatively affect the genetic stock as well. Because of the apparent heritability of antler characteristics and the predictability of future antler quality based on yearling development, SHCs selecting bucks with 3 or more antler points can potentially remove the superior bucks from a herd by harvesting yearlings that show branched antlers in areas where yearlings are able to maximize their antler potential (i.e., areas of high habitat quality, fenced operations, etc.) (Harmel, 1982; Strickland et al., 2001).

CONCLUSION

So, how to implement a QM strategy? First, QM will work best where habitat quality is high; the most important aspect of high-quality habitat is good available nutrition (nutrition effect). Second, responses will be faster as the male mortality (harvest) rate becomes lower (age effect). Third, overall population densities—both male and female—need to be kept low to (1) maximize resource capture and hence diet quality, (2) minimize competition among males and between males and females, (3) minimize stress and social encounters that may lead

to antler breakage, and (4) minimize proximate cues to disperse. These density effects can be mitigated by supplementation programs, although it must be emphasized that feeding will affect only resource capture, so it alone is only a partial solution. Finally, there are few—probably no—areas that lack the genetic potential in existing herds to grow trophy bulls and bucks in New Mexico. Aside from high-intensity breeding or high fence operations, resources are best invested in enhanced nutrition and age structure for QM. Even intensive operations probably could increase their quality by focusing on nutrition and stress; few if any studies have shown a measurable gain from adding “superior” individuals to established herds (Miller and Marchinton, 1995).

ACKNOWLEDGEMENTS

I thank R. Baldwin, University of California Kearney Research Station; J. Boren, New Mexico State University; J. Heffelfinger, Arizona Game and Fish Department; B. Hoenes, Washington Department of Fish and Wildlife; and A. Darrow, Mexico Coast Land and Cattle, for reviewing this publication.

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