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The Maternal Effect: Carrying the Consequences of Nutrition Across Generations

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Carrying the Consequences of Nutrition Across Generations

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A fawn born to a doe in poor nutritional condition may remain relatively small its entire life, even if the fawn enjoys abundant nutrition later in life. This emphasizes the importance of **nutrition** and **patience** in a QDM program.

By Kevin Monteith,
with contributions from Joshua Delger, Dr. Lowell Schmitz, Kyle Monteith, and Dr. Jonathan Jenks

Let's indulge ourselves in a deer-management fantasy for a moment. I'm sure it won't be your first time!

Imagine you are blessed to own and manage your own block of deer country for several years (for many fortunate readers, this is reality, not fantasy). Although the ground you purchase holds plenty of deer, the overgrown forests and grassy meadows might not be providing the nutrition necessary for these deer to achieve their genetic potential. In addition, the 6-foot high browse line resulting from extreme overabundance of deer is a likely indication of why only scrawny looking bucks are typically harvested in the area. However, you know what it takes to have a healthy deer herd and grow bigger bucks, and you can see the potential your property holds. Like any responsible steward of the land, you do your homework and go the extra mile to increase the diversity of the habitat and offer more forage and browse. You establish proper food plots with forage high in digestibility and protein. You harvest numerous does each year to reduce deer numbers to a sustainable level, and conservatively harvest bucks to balance the sex ratio and develop an age structure that includes bucks of many ages. During this time, you also foster a small data-collection program framed around the close monitoring of the harvest each year, and in particular the size and age of the bucks being harvested.

After a few years of intensive management, hard work, and patience, the property appears to be in better shape; a browse line is no longer evident, deer numbers are in check, bucks and does that are harvested exhibit greater fat levels, and the buck harvest is comprised mainly of mature bucks over 4½ years of age. Everything is perfect, right?

There's only one problem you can see. Those 4½-year-old and older bucks are still 120-class bucks, similar to those harvested prior to implementing your management program. Their overall body weight has increased only slightly. After all that effort, time, and money, it seems

as though it has all been a waste. How can nutrition and overall herd health be improved so markedly yet yield little net change in antler size or body weights? Is something critical missing in the diet? Are the deer genetics on your farm just that poor? Neither is likely.

In this type of situation deer have been living under nutritionally stressful conditions for quite some time, with body and antler size being a reflection of the nutritional deprivation. Although you have dramatically improved nutrition and deer are in better condition, it may actually take several generations to reverse the trends in low body weight and poor antler size. Believe it or not, the answer to such delayed effects from management may be found in *mothers*. The nutritional condition of a doe during pregnancy and fawn rearing holds the potential for life-long effects on her offspring, even if nutrition is improved for those offspring later in their lives. This phenomenon is known as a "maternal effect." Regardless of whether or not the father has the genetic potential to grow big antlers, the nutritional state of the mother can override the genetic potential passed on to her offspring.

Let's take a look at a long-term research project that identified the "maternal effect" and its implications for Quality Deer Management programs.

Research Begins

In 1997, our Captive Deer Research Group at South Dakota State University (SDSU) embarked on a long-term research project to better understand the underlying reasons for the disparities in body mass and antler size between deer from two distinct regions in South Dakota: the Black Hills and eastern South Dakota. This research was made possible by funding provided by Federal Aid in Wildlife Restoration administered through the South Dakota Department of Game, Fish and Parks, South Dakota Agricultural Experiment Station, and the National Science Foundation/EPSCoR Foundation.

The Black Hills region is characterized by coniferous forests with little understory forage, whereas eastern South Dakota is dominated by high-quality agricultural crops. Although only one subspecies of white-tailed deer (*O. v. dacotensis*) inhabits South Dakota, deer occupying the Black Hills are noticeably smaller than those in the eastern portion of the state. Average

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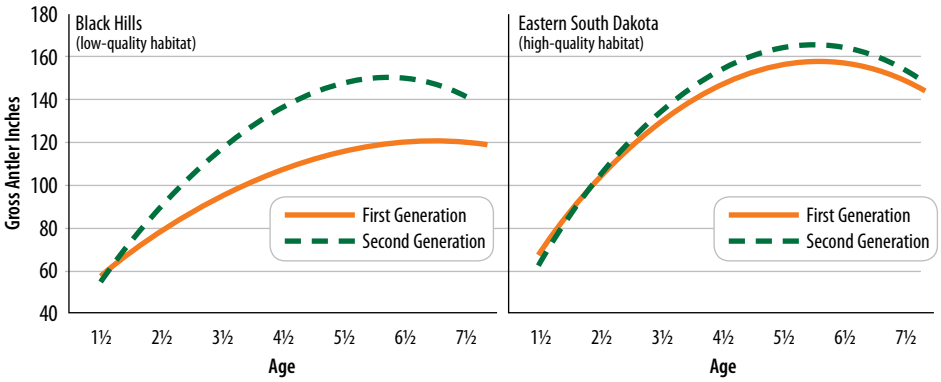
The Maternal Effect on Antler Size



Antler size for first-generation bucks captured as newborn fawns in the Black Hills was significantly smaller compared with bucks obtained from eastern South Dakota. Antler size of male offspring from those Black Hills bucks, however, increased well above antler size of their fathers and approached the size of antlers exhibited by eastern South Dakota bucks. In contrast, patterns of antler growth were nearly identical for first-generation males from eastern South Dakota and their offspring.

Pug
Age 6½
205 lbs.
136 B&C

Levi
Age 6½
245 lbs.
168 B&C

Dewey
Age 6½
248 lbs.
149 B&C

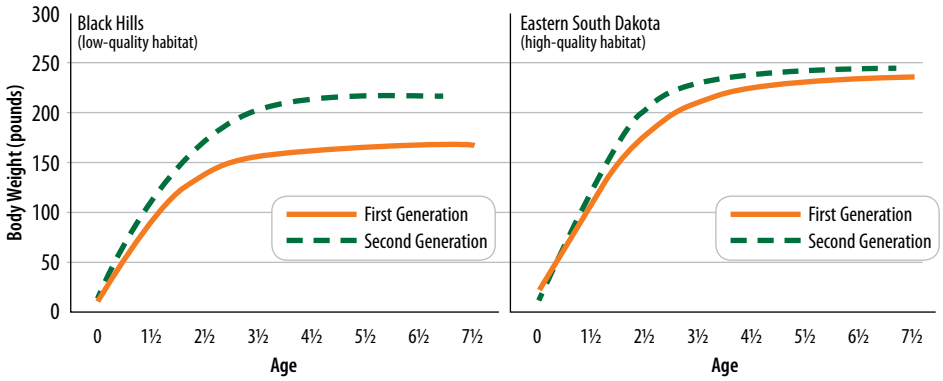
Pug was captured as a newborn fawn in the Black Hills and was bred in captivity with a Black Hills doe. The differences in both body weight and antler size between Pug and his sons were substantial as the second generation broke away from the "maternal effect."

Moe
Age 5½
190 lbs.
107 B&C

Dwight
Age 5½
256 lbs.
143 B&C

Moe was another buck that was captured as a fawn in the Black Hills and was bred to another Black Hills doe. Moe's son Dwight was 60 pounds heavier than his father at maturity, and his antlers were 34 percent larger.

The Maternal Effect on Body Weights



Despite being raised in a controlled environment with high-quality nutrition, bucks captured as newborn fawns in the Black Hills remained markedly smaller throughout life compared with bucks from eastern South Dakota. Nevertheless, male offspring of those first-generation bucks from the Black Hills grew significantly larger than their fathers and approached the size of bucks from eastern South Dakota. Offspring of first-generation bucks from eastern South Dakota, however, were comparable in body size to their fathers.

body mass of adult does from eastern South Dakota is 25 percent heavier than does from the Black Hills.

To conduct this research, we captured newborn fawns from both regions and hand-raised them using identical husbandry practices, which controlled for environmental influences on diet, growth, and variability in the fawn-rearing ability of does. Simply put, fawns from the Black Hills and eastern South Dakota were raised under identical conditions to avoid the potential for other factors to affect their growth. All animals were housed in a controlled environment and were provided high-quality nutrition that was representative of that available to deer in eastern South Dakota. The deer that had been wild-captured (the first generation in the study) were bred in captivity to obtain offspring from first-generation Black Hills and eastern South Dakota animals, meaning that deer from their respective regions were only bred with other deer obtained from the same region. The second-generation animals were raised under conditions identical to the first-generation. We weighed bucks frequently throughout the study, and annual growth of antlers was measured using the Boone & Crockett scoring system for ages up to 7½ years.

First-Generation Checkup

Considering that all deer were offered high-quality forage on an unrestricted basis, they were in superb nutritional condition. Nevertheless, adult bucks that originated from the low-quality habitat of the Black Hills averaged 170 pounds and 104 inches of antler at 5½ years. Eastern South Dakota bucks weighed an average of 238 pounds and grew 142 inches of antler at the same age.

Black Hills bucks also ceased rapid growth 41 days earlier than bucks from eastern South Dakota, were 29 percent smaller in body weight, and grew 27 percent smaller antlers. These differences were statistically significant and also quite visually apparent – bucks originating from the Black Hills appeared stunted next to bucks from eastern South Dakota. Some believe that the lack of stress from living in captivity, in and of itself, is enough to "create" big deer beyond what an animal would be capable of in the wild. Nevertheless, both stocks (Black Hills and eastern South Dakota deer) did not respond in any manner that would support this theory. That is, Black Hills deer continued to exhibit poor growth compared with eastern South Dakota deer. And, eastern South Dakota deer were similar in size to those documented for the region, despite being raised in a controlled environment.

Based on those initial results, it was not entirely clear if the differences in body mass and antler size of bucks from those two regions were genetically based, or if they could be a result of an underlying nutritional problem in the Black Hills. At this point the difference in pattern of growth of bucks from the two regions when raised in the same environment could support either conclusion. Nevertheless, the patterns of growth of their offspring would eventually indicate the underlying cause.

Second-Generation Checkup

Interestingly, first-generation does from the Black Hills and eastern South Dakota gave birth to similar-size young, which would not have been expected if second-generation bucks from the Black Hills were going to remain small

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throughout their lives like their fathers. Accordingly, those second-generation bucks of Black Hills origin exhibited rapid growth for 41 days longer than their fathers, and attained a 30 percent larger body weight and grew 31 percent larger antlers than their sires at 5½ years. Second-generation bucks of Black Hills origin averaged 222 pounds at maturity and grew an average of 136 inches of antler at 5½ years, which approached the size of bucks originating from eastern South Dakota. Indeed, second-generation bucks of Black Hills origin exhibited faster growth and achieved larger body weight and antlers compared with their fathers. The photographs on page 65 provide examples of the dramatic increase in size of sons born in our captive research facility compared with their fathers that were captured as newborns in the Black Hills.

If second-generation bucks of eastern South Dakota origin also exhibited increases in either body mass or antler size above those of their sires, then the responsive growth by second-generation bucks of Black Hills origin might just have been a result of being raised in a nutritionally controlled environment. Yet, those second-generation bucks born to bucks from eastern South Dakota were only slightly larger in both body weight (244 pounds) and antler size (150 inches) at maturity when compared with their fathers. Based on those results, it was apparent that deer from eastern South Dakota were not nutritionally limited and were likely representative of the potential for size of deer in that region. Conversely, deer residing in the Black Hills lacked access to the higher-quality nutrients available to deer in eastern South Dakota, and as a result exhibited restricted growth of both body and antlers.

The Maternal Effect

The increased growth of second-generation bucks of Black Hills origin following improved nutrition supports the existence of an underlying negative "maternal effect" that hampered growth of animals born to does originating from the Black Hills. That maternal effect persisted for a lifetime for the first-generation deer and resulted in poor growth of bucks from the Black Hills, despite receiving high-quality nutrition immediately after being born and throughout life in captivity. Conditions during gestation alone led to life-long consequences on growth for bucks born to does in the Black Hills. Nevertheless, following improved nutrition, second-generation bucks exhibited rapid growth and approached the body and antler size of bucks from eastern South Dakota. That response in growth does not support a genetic effect as the underlying reason for differences in size of deer from the two regions in South Dakota. The increased growth by second-generation bucks of Black Hills origin would not have occurred if genetics was the cause for the comparatively poor performance of their fathers. (For more on the suspected causes of the "maternal effect," see the sidebar on page 70).

The negative maternal effect in Black Hills deer was likely brought on by severe nutritional limitation in the Black Hills of southwestern South Dakota. At the time fawns were collected for this study, suppression of wildfire in the Black Hills had led to canopy closure with decreased quantity and quality of understory vegetation. Moreover, this population of white-tailed deer had been in decline for decades, and other research has pointed toward

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the poor nutritional condition of deer in the Black Hills, which has been attributed to overpopulation and habitat deterioration. Nevertheless, our results suggest that given sufficient time following habitat improvements or release from nutritional limitation caused by competition for forage, white-tailed deer from the Black Hills could exhibit body weight and antler characteristics comparable to deer from eastern South Dakota.

The negative maternal effect was based on conditions during gestation alone, because all animals were hand-raised to control for differences in post-natal care by individual mothers. Mothers in poor physical condition are more likely to give birth to small, weak young, which may die as fawns. For those that survive to adulthood, as we have shown, the consequences for growth and development are life-long. Young born to mothers in poor nutritional condition may never attain their potential their entire life, regardless of changes in nutrition later in life.

Conclusion

The effects of maternal and grandmaternal nutrition on subsequent growth, survival, and reproduction of their fawns can make it difficult for deer managers to predict and measure success in early stages of QDM. Oftentimes when we improve conditions in a relatively poor nutritional environment, we expect to see immediate results or at least a response from bucks within a couple of years. But in some instances, full recovery following severe nutritional deprivation may take multiple generations. This is a fairly simple and long-overlooked concept. Our study demonstrated that time lags in population response are a reality and should be recognized as a potential lurking variable in any QDM program. In the end, our results emphasize the need for patience and diligence, and underscore the pervasive effects of nutrition. In short, offer high-quality forage and browse year-round and maintain the population in balance with those resources. And if you are managing deer in an area where deer have been nutritionally challenged for some time, patience is even more important. Results will come – it's just a matter of time.

The Mystery of the Maternal Effect

Our study found that fawns born to nutritionally challenged does would underperform for their lifetime, regardless of increased nutrition. Why? The exact mechanism remains unclear. The underlying physiological mechanism could be related to levels of cortisol (a stress hormone) present in the intrauterine environment. Hormones transmitted to fawns during gestation may have life-long consequences on the fawn's own hormone production, which could lead to negative effects on growth and reproduction. Indeed, we documented higher levels of cortisol in first-generation deer from the Black Hills compared with deer from eastern South Dakota. A similar phenomenon has also been reported in other mammals.

Another potential mechanism may be a form of epigenetic programming that has only recently become known in humans, and some small mammals. In epigenetic programming, conditions during early life can result in the alteration of the expression of genes without a direct change in DNA.

***About the Authors**: Kevin Monteith is a doctoral candidate at Idaho State University in biological sciences. Kevin obtained his bachelor's and master's degrees in wildlife and fisheries sciences at South Dakota State University (SDSU) and has conducted research on large ungulates since 1999.*

The Captive Deer Research Group at SDSU, with "Maximus," who is anesthetized for data collection. L-R: Kyle Monteith, Joshua Delger, Kevin Monteith, and Dr. Lowell Schmitz. The group's academic advisor, Dr. Jonathan Jenks, is not pictured.

Joshua Delger obtained his bachelor's and master's degrees in wildlife and fisheries sciences from SDSU. He is currently a resource biologist for the National Park Service at Badlands National Park.

Dr. Lowell Schmitz is a wildlife biologist with the South Dakota Department of Game, Fish & Parks. In 1997, he began the first project conducted by the Captive Deer Research Group at SDSU.

Kyle Monteith is a master's student in wildlife and fisheries sciences at SDSU who is currently conducting research at the captive deer research facilities.

Dr. Jonathan A. Jenks is a Distinguished Professor of wildlife and fisheries sciences at South Dakota State University. He has been the academic advisor for the Captive Deer Research Group and has provided oversight on all research activities at SDSU's captive deer research facilities since its inception in 1997.