Even-aged Silviculture as an Approach to Regeneration of Forests with High Deer Densities

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Abstract: *In many situations where deer impacts are high, even-age silviculture has some distinct advantages over uneven-age silviculture. These advantages derive from faster growth of regeneration in higher light conditions, reduced likelihood of developing secondary deer impacts, such as dense layers of vegetation shading new seedlings, and increased deer forage on the landscape, reducing the impact of deer. Silvicultural planning at the deer home range scale can help the success of even-age silvicultural practices, which will frequently include one or more light thinnings, then shelterwood regeneration sequences. Timing between the shelterwood seed cut and the removal cut, and sensitive use of pre-fencing can be used to manipulate species composition within these broad outlines, as can fertilization of some species after overstory removal. In extreme situations, even-age thinnings may be foregone due to the risk of fostering interfering plants. Herbicide treatments developed to treat interfering plants in the Allegheny hardwood variant of northern hardwoods have been successful in fostering regeneration. They have also been shown to have limited, short term-negative impacts on key non-target organisms, from which recovery has been observed in less than a decade. Fencing to exclude deer is also less expensive within the framework of even-age silvicultural systems, where the periods during which deer need to be excluded are relatively short, compared to uneven-aged systems in which fences have to be erected essentially permanently. Foresters also need to work with hunters to design treatment units to optimize hunter access and opportunity, a dimension of planning not traditionally thought of as silviculture. To our knowledge, however, there are no silvicultural systems that provide benefits comparable to maintaining deer impact levels compatible with management objectives.*

Introduction - Lessons From Pennsylvania

Foresters in northwestern Pennsylvania have accumulated, however unwillingly, about 7 decades of experience of managing forests in the presence of overabundant white-tailed deer (Figure 1). It is difficult to know why this problem, now serious in many parts of the northeast (McGuinness 1996), became so bad so soon in Pennsylvania, but informed speculation is useful. Preventing extirpation of white-tailed deer from Pennsylvania was a principal reason for the creation of the Pennsylvania Game Commission in 1895. It soon imposed seasonal restrictions on all hunting and closed down doe hunting for many years. The Commission also instituted a small reintroduction program for white-tailed deer. All of these initiatives took place as, independently, foresters were creating literally millions of acres of ideal deer habitat through uncontrolled harvests of the commonwealth's forests. When the Allegheny National Forest was created in 1923, for example, locals called the area the Allegheny National Brushheap, because almost the entire half-million acres consisted of browseable regrowth from recent harvesting.

As the whole state entered the poletimber/stem exclusion stage of stand development in the 1930s and 40s, there was a temporary dip in the steady climb of deer numbers, but soon, limited timber harvesting and wide-spread transition to the understory re-initiation stage reinforced the upward tendency of deer numbers. Finally, when two bad winters in a row in the late 1970s combined with the Pennsylvania Game Commission's adoption of habitat-based target densities, deer numbers flattened out in Pennsylvania, and this plateau occurred at densities about 50% greater than the targets set by the Game Commission.

Ash Hough (1965), in the thirties and forties, Ted Grisez (1960) in the fifties and sixties, and Dave Marquis (1981a, 1981b, Marquis and Brenneman 1981, Tilghman 1989, deCalesta 1994, Horsley and others 2003) through the seventies and eighties shone a bright scientific light on the consequences of this overabundance for forests. For purposes of understanding the role of even-age silviculture in regeneration of forests with high deer densities, we need to focus on four lessons from this research.

The first of these is the concept of ***deer impact*** as distinct from ***deer density***. Figure 2, adopted from Marquis and others (1992), illustrates the concept that the impact of deer on forest resources is a joint function of both the ***density*** of deer and the amount of deer forage available within the relevant landscape. This concept emerged as a surprise result midway through a Marquis-designed US Forest Service study of the impact of white-tailed deer on forest regeneration and other resources (Tilghman 1989, deCalesta 1994, Horsley and others 2003). The Deer Exclosure Study had four replicates, widely dispersed across the Allegheny Plateau. At each study site, deer densities of 10, 20, 38, and 64 deer per square mile were simulated by enclosing female deer within fenced, managed forests. Seedlings for deer to browse were stimulated by clearcutting ten percent and thinning thirty percent of the area of each enclosure – the proportions to be expected in a regulated forest on a 100-year rotation.

An earlier study (Marquis 1981a) assessed regeneration outcomes of regeneration harvests that were divided evenly into a fenced, or zero deer per square mile, area and an unfenced area at ambient deer density of 40-60 deer per square mile. Adequate regeneration failed to develop in about 60 percent of the ambient deer density areas, and of these, 87 percent were successful inside the fence. Thus, we expected that the clearcuts in the high deer density pens would fail to regenerate. At year 5, however, regeneration stocking of desirable species, dominated by black cherry, averaged about 80 percent in the highest deer density pens.

The explanation for this surprise was deer impact (Marquis and others 1992, deCalesta and Stout 1997). In the Allegheny Plateau region, managers used guidelines developed by US Forest Service Research to assess advance regeneration stocking (Marquis and Bjorkbom 1982) and designate areas ready for harvest. In managed landscapes, this created a vicious cycle: overabundant deer prevented development of advance regeneration, which led to decreased forest harvesting rates, which increased deer impact. At the time of the deer study, lack of advance regeneration was a principal reason that only four percent of the Allegheny National Forest was in the 0-10 year old, high-deer-forage-producing, age class. Only thirteen percent of the area was recently thinned (personal communication, R.L. White, Silviculturist, Allegheny National Forest). This meant less forage in the landscape than the ten percent clearcut, thirty percent thinned conditions inside the study enclosures, so any given density of deer had much greater impact outside the study areas than inside. Managers have used this concept to develop practices of concentrating harvests in space and time, to reduce the impact of deer during a regeneration phase.

Over time, we have come to codify the deer impact index into five somewhat subjectively defined levels. Deer Impact Index 1 occurs in Pennsylvania only inside a well-maintained deer fence, and refers to situations in which light, moisture, and nutrients are much more important determinants of seedling survival and growth than are deer. Deer Impact Index 2 is a kind of ideal situation outside a fence, where deer impact is so low that we observe a variety of species with many different deer preference levels, and also observe seedlings, herbaceous plants, and shrubs responding to fluctuations in understory light levels, as well as moisture and nutrient gradients. At Deer Impact Index 3, the abundance of highly preferred species is negatively impacted by deer, as is their ability to respond to variations in light, moisture, and nutrients. Stump sprouts tend to be very heavily browsed. Yet the preferred species are not completely absent, and other species still respond to environmental gradients. At Deer Impact Index 4, preferred species are absent or nearly absent, and the growth of remaining species is largely controlled by deer – plant height is uniform across gradients of light availability, for example, and stump sprouts, with their richer nutrient content, are often entirely absent. Finally, at Deer Impact Index 5, there is usually either a dense carpet of an unpreferred, usually herbaceous, species or nothing at all on the forest floor, and a pronounced browse line is evident.

The second lesson learned from the northwestern PA deer research is the lesson of secondary and tertiary impacts. Horsley and others (2003), for example, showed that the proportion of regeneration sample plots dominated by hay-scented fern, a native plant that interferes with the establishment, growth, and survival of hardwood seedlings, increased significantly as deer impact increased in the exclosure study. This is important because dense fern cover creates situations in which even reducing deer density does not solve the regeneration problem that overabundant deer created. Recent work also suggests that small mammals preferentially remove hardwood seeds under the dense cover of ferns, where they have become established as a result of deer overabundance, further reducing the ability of sites to recover from deer impact.

The third lesson was that deer density and silviculture interact at both the stand and landscape level to affect regeneration trajectories. Horsley and others (2003) separated the results of the ten-year deer enclosure study into impacts in harvested stands, impacts on thinned stands, and impacts on uncut stands within the enclosures. Especially at intermediate deer densities, participation of any given tree species in the outcomes was a function both of the deer density and of the silvicultural practice. Where silviculture created high light conditions and soil scarification in thinnings and final harvest areas, for example, birch was an important species at both 20 and 38 deer per square mile, while it was not significant even at these densities in the uncut stands. Within stands, one indicator of low to moderate deer impact is the ability to observe seedling responses to small gaps and the associated higher light levels. When deer impact levels get high or very high, it is deer and deer alone that determine whether there are any seedlings, what the species composition of the seedling layer is, and how tall the seedlings are. Although this paper focuses on using even-aged silviculture in the face of high deer impact levels, there is no silvicultural practice as effective as managing deer impact levels through managing deer abundance.

The final lesson that we've learned is that not all regeneration problems are caused by white-tailed deer, even where deer densities are moderate to high. Inadequate seed source, inappropriate biotic and abiotic site conditions, interfering plants, and insect and disease attacks on seedlings are all still at play in forest regeneration, even in forests with too many deer. Blaming deer for everything can backfire. We recommend test exclosures under conditions that you consider optimum for regeneration of desirable species to confirm that deer are a principal limiting factor.

Applying These Lessons Through Silviculture

The Society of American Foresters defines silviculture as "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet diverse needs and values of landowners and society on a sustainable basis" (Society of American Foresters 1994). In the face of overabundant deer herds, even-age silvicultural systems offer several advantages over uneven-age systems for achieving these objectives. These advantages occur because the period of establishment and early growth occur once per rotation and are relatively brief and focused. Seedling growth can be quite rapid in the high light environment created by final even-age harvests. In uneven-age systems, each entry requires establishment and growth of a new cohort of seedlings, and the growth of these seedlings is usually slower in the lower light conditions of small group openings or within single-tree selection stands. In this continuum, two-age systems are more like even-age systems with regard to high deer populations. I'd like to discuss specifics first at the stand level, and then at the landscape level.

Even-age Silviculture at the Stand Level in the Face of High Deer Impact

Our experience in Pennsylvania comes from systems that are largely advance regeneration dependent. The birches, yellow-poplar, and pin cherry are the only major species we work with that can become established after a final harvest and still play a role in new stands. So our practice is built around a combination inventory of understory and overstory conditions prior to the regeneration period. We have developed guidelines for recognizing when there is enough advance regeneration to indicate high likelihood of regeneration success, and practices to develop advance regeneration when it is inadequate. The understory inventory includes estimated counts of seedlings on 6' radius plots well-distributed throughout the stand. When 70% of these plots have adequate numbers of established seedlings, and fewer of the plots have established interfering plant problems, the stand is ready for an overstory removal. Our research in Pennsylvania suggests that at high deer densities, 100 sugar or red maple seedlings are required on any 6' radius plot to consider it stocked. A plot is stocked at high deer density with only 25 black cherry, which is a less-preferred species. We count any seedling that is established – rooted in the mineral soil. In cherry, this can happen by the time a seedling is 2" tall and has 2 normal size leaves, while with sugar and red maple, seedlings must pass the "tug test" – a firm pull will not remove the seedling from the forest floor – in order to be considered established.

If the inventory shows that advance regeneration is inadequate, we recommend a shelterwood seed cut. Shelterwood seed cuts that leave relatively heavy overstory residuals – about 60% of full stocking – can create conditions that allow for the establishment of small advance seedlings. At high deer density, this treatment will favor species that are resilient to deer browsing or less-preferred by deer.

In our case, American beech and striped maple are resilient to deer browsing, while black cherry is relatively unpreferred by deer, and so these three species have increased in relative abundance in our understories through decades of deer overabundance. Our experience, not formally tested through research, has been that small seedlings established after these lighter shelterwood seed cuts are not overly attractive to deer. When advance seedlings are established and well-distributed across the stand, a prompt removal cut provides the high sunlight that allows for maximum growth out of the reach of deer.

There are a variety of problems related to deer overabundance that complicate this scenario. When deer overabundance has been prolonged, less preferred and resilient species in the understory can themselves become a barrier to the success of the shelterwood seed cut. Hay-scented and New York fern are important example of this in Pennsylvania. Alternatively, the resilient species beech and striped maple can form a monoculture understory layer so dense that other species are unable to become established, even after a shelterwood seed cut in the overstory. When this is the case, we recommend the use of herbicide treatments to remove these barriers to seedling establishment. Some landowners are treating woody interference by requiring harvesters to fell all of these saplings at the time of the seed cut, and where there is prompt overstory removal and fast-growing desirable seedlings, this may be effective.

Furthermore, when management objectives include either species diversity or the regeneration of preferred species, we have found that fencing stands to exclude deer at the time of the shelterwood seed cut is essential at high or very high deer density. Because fences are both expensive to erect and expensive to maintain, this is best done with even-age silvicultural systems, as the fencing period will occur only once per rotation. We also recommend fencing prior to the shelterwood seed cut when the desired species are shade tolerant and slow-growing or have very infrequent seed years.

Research conducted in Wisconsin (Alverson and Waller 1997) suggests that in those forests, sugar maple is relatively less preferred by deer, so these treatments may be effective in stands where sugar maple is the target desirable species. Factors other than deer may limit the establishment of sugar maple advance regeneration. Research in Pennsylvania suggests that sugar maple seed crops are prompted by low moisture availability in the early summer of the previous year (Long and others 1997), and that sugar maple flower and seed crops, and sugar maple seedling survival and growth can be limited by soil availability of calcium and magnesium. Thus sugar maple regeneration challenges are a good example of a situation in which some replicated evidence of deer as a principal problem is important.

Even-age Silviculture at the Landscape Level in the Face of High Deer Impact

Evidence from deer biology suggests that deer have a high level of site loyalty (Brenneman 1987). Females seem to establish home ranges that overlap those of their mother, while male deer disperse greater distances and less predictably. Brenneman's (1987) work in Pennsylvania suggested that while deer would alter their pattern of movement within a home range to take advantage of additional forage created by timber harvesting activity, they would not alter their home range to include a new area in which additional browse had been stimulated by timber harvesting. Thus, in the short term, timber harvests can be used to reduce ***deer impact*** within a deer home range area by increasing forage availability where harvests are associated with dense advance regeneration.

This effect can be strengthened by careful planning of the spatial arrangement and timing of harvests. Marquis (1987) used equations relating seedling size and herbaceous cover to dry weight of browseable twigs and foliage less than 5 feet above ground (Parrow and others 1976) to estimate the forage production on 2 square mile landscapes (about the size of a deer home range) with a range of seedling density in harvest units (Table 1). In uncut stands, about 100 pounds of deer food are produced per acre per year. In thinned stands, Marquis estimated about 225 pounds per acre per year. At low seedling densities, about 10,000 seedlings per acre, final harvest units produced about 250 pounds of deer food per acre per year. At moderate seedling densities, final harvest units produced about 450 pounds per acre per year. At high seedling densities, the production was estimated at 1,350 pounds per acre per year. Where seedling densities were low or moderate, doubling the proportion of the landscape in final harvest units from 5 percent to 10 percent made only a modest difference in landscape forage production. But where seedling densities were very high, doubling the proportion of the area in final harvest cuttings increased landscape forage production by more than a third. While selection system stands were not included in Marquis' estimates, I believe that these stands produce forage roughly equivalent to that in thinned even-age stands.

Researchers at the Northeastern Forest Experiment Station tested the use of intensive, localized even-age management *without* increased hunting pressure on a 1,100 acre compartment of the Allegheny National Forest during the 1980 and 90s. At the time of case-study initiation, none of the 37 stands within the compartment met established guidelines for advance regeneration. Mean regeneration stocking before treatment was 17 percent, and deer density was estimated at 29 deer per square mile, for a high deer impact.

Five stands were nonetheless chosen for even-age removal cuts. These stands represented 13 percent of the area of the compartment and had 32 percent average advance regeneration stocking (range from 14 to 54 percent) – the best in the compartment. Another 14 stands were chosen for thinnings, representing about thirty percent of the compartment's area. In these, advance regeneration stocking averaged 17 percent, just as it did across the compartment. Operators of the timber sale, which was completed between 1989 and 1991, were required to complete the thinnings, which ringed the proposed final harvest cuts, prior to the final harvests.

Two years after harvest, regeneration stocking in the final harvest units ranged from 82 to 97 percent and averaged 90 percent. Advance regeneration in the thinned stands had improved to an average of 64 percent. A very small sample of regeneration in uncut stands in 1995 suggested improvements there, as well, with both stocking and diversity at surprising levels. In the small sample of uncut stands, preferred species like red maple, eastern hemlock, and cucumber magnolia were represented by seedlings more than 1 foot tall.

This case study also taught us an important caveat about this technique. In the absence of increased hunting pressure, this increased landscape forage also stimulated the productivity of the deer herd, and ***deer impact*** returned to its previous level as a result of an increase in ***deer density.*** In our case study, hunting pressure was not increased in parallel with increased timber harvesting, and by 1996, the ***deer density*** in the case study area was up to 38 deer per square mile. Less preferred species began to dominate the understory again, and the window of opportunity closed.

Applying These Principals on Kinzua Quality Deer Cooperative

A coalition of five public and private landowners have formed an informal cooperative with hunters, a local tourist promotion agency, and the Sand County Foundation to manage deer and habitat jointly. The effort is based on about 74,000 acres of managed forest in the northeast corner of the Allegheny National Forest. The cooperative is working hard to engage hunters in activities throughout the year to understand habitat and the deer herd. This is important in terms of sustaining the support of local economic development interests. So we try to bring hunters to the area in the spring to conduct pellet group counts, in late summer to conduct daylight counts, and in the dead of winter for a thank-you banquet (at which packages for stays at local hotels and meals at local restaurants are among the prizes). We know that hunters want to know as much as they can about the herd where they hunt, so we conduct voluntary check stations for doe AND bucks during hunting seasons, and then share the results of the check stations, the pellet group counts, and the daylight counts at our winter Hunter Appreciation Banquet. We've also conducted very detailed vegetation surveys in two growing seasons, and we plan to monitor recovery if we are able to sustain better deer impact over time.

This program has had many successes. One is the numbers of does brought to the check station, which has steadily increased since we began the check station program. Certainly the fact that hunters get two raffle tickets per doe and only one per buck helped, but there is some evidence that we are helping to change the culture, too. Another was the great interest and participation that we observe from hunters, even as we ask them to help us make dramatic reductions in deer abundance on the area. When the Pennsylvania Game Commission created a Deer Management Assistance Program, making extra antlerless tags available to landowners with at least a minimum acreage and a management plan, hunters snapped up 9,000 bonus tags within days, and used them to achieve effectively about a 1/3 reduction in deer abundance on the area within two years. KQDC is now at a deer density that landowners believe will equal an appropriate deer impact, and the landowners have reduced their application for DMAP coupons to 700 for this year.

In addition to these successes, KQDC has stimulated landowners to think about silvicultural and management strategies that will increase hunter success. These include things like concentrating activities that increase visibility (shelterwood seed cuts with manual or herbicide low shade reductions) to achieve local sharp reductions in deer abundance prior to final harvest cuts and maintaining uncut corridors to facilitate hunter movement through early successional habitat. We also develop maps of previous hunter success areas and of areas that our population and impact sampling suggest still have high populations. With the on-the-ground success achieved in reducing deer impact, landowners hope to be able to reduce the use of fencing in conjunction with management, a programmatic change that will benefit landowners and hunters.

Summary

In areas with moderate to high deer herds, even-age silviculture has benefits at both the stand and landscape level. At the stand level, a shelterwood seed cut can be used to stimulate development of a carpet of small advance regeneration. After overstory removal, these seedlings will grow rapidly out of the reach of deer in the high light conditions of early successional stands. Where deer density is very high, where biodiversity is a principal objective, or where legacy effects of previous deer overabundance are important, this shelterwood sequence may need to be accompanied by herbicide treatments or fencing, both of which occur less frequently and are therefore less expensive within the context of even-age silviculture.

At the landscape scale, early successional openings with abundant seedlings can overwhelm deer and effectively reduce deer *impact*. Clever timing and spatial arrangement of cutting units can ease the pressure on units planned for future harvests. This is only effective if the cutting units have abundant seedlings, rather than interference from fern or less-preferred woody species, and obviously doesn't work at deer densities where fencing is required to ensure successful regeneration.

Silviculturists and forest managers can learn to plan the spatial and temporal arrangement of harvest openings in ways that help hunters have success in hunting. They can also establish relationships with hunters that acknowledge and reward the ecosystem management services hunters provide.

All of these strategies can contribute importantly to management of forests with overabundant white-tailed deer. None, however, are as effective as managing deer impact through direct management of deer numbers.

Table 1. (After Marquis 1987) Total production of deer food on a 2 square mile landscape as affected by proportion of regeneration openings and density of seedlings.

		PROPORTION OF AREA IN REGENERATION OPENINGS			
		5%		10%	
Stand type	Food production (lbs/acre)	Area (acres)	Food production(lbs/yr)	Area (acres)	Food production(lbs/yr)
LOW SEEDLING DENSITY (10,000 SEEDLINGS PER ACRE)					
Final harvest	250	64	16,000	128	32,000
Thinned	225	192	43,200	192	43,200
Uncut	100	1,024	102,400	960	96,000
TOTAL		1,280	161,600	1,280	171,200
MODERATE SEEDLING DENSITY (30,000 SEEDLINGS PER ACRE)					
Final harvest	450	64	28,800	128	57,600
Thinned	225	192	43,200	192	43,200
Uncut	100	1,024	102,400	960	96,000
TOTAL		1,280	174,400	1,280	196,800
HIGH SEEDLING DENSITY (120,000 SEEDLINGS PER ACRE)					
Final harvest	1,350	64	86,400	128	172,800
Thinned	225	192	43,200	192	43,200
Uncut	100	1,024	102,400	960	96,000
TOTAL		1,280	232,000	1,280	312,000

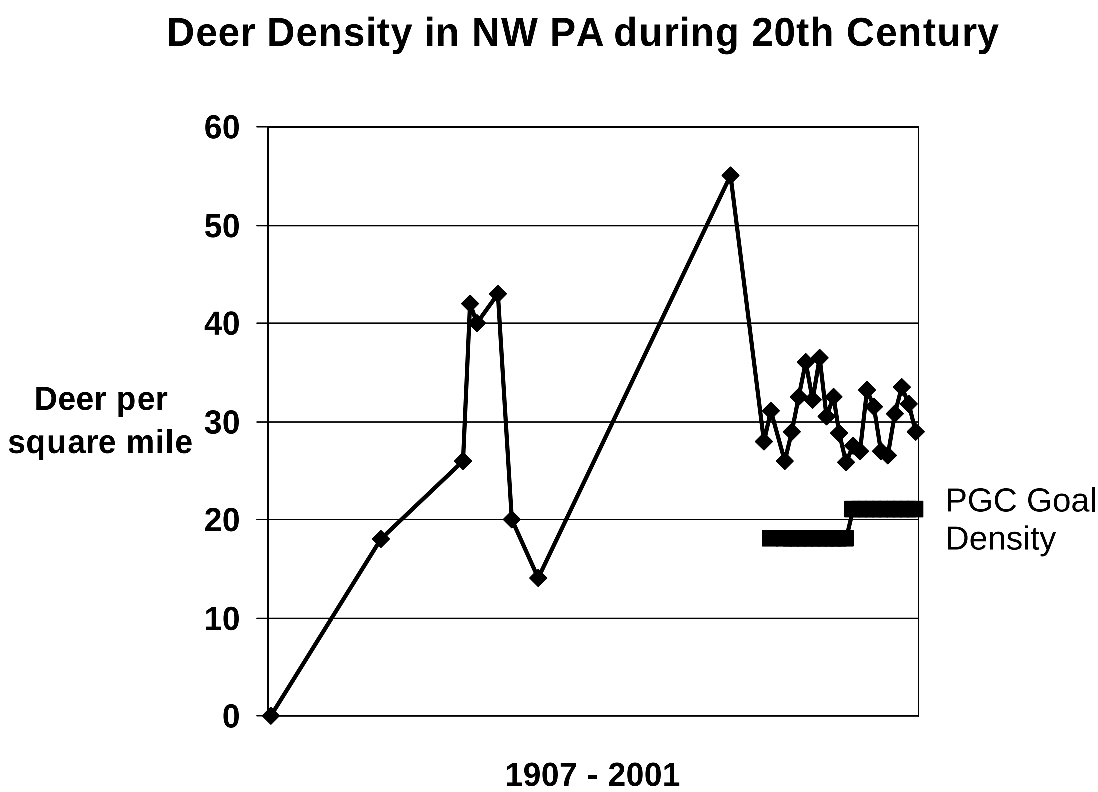

***Figure 1**. Estimated deer density in northwestern Pennsylvania during the 20th century.*

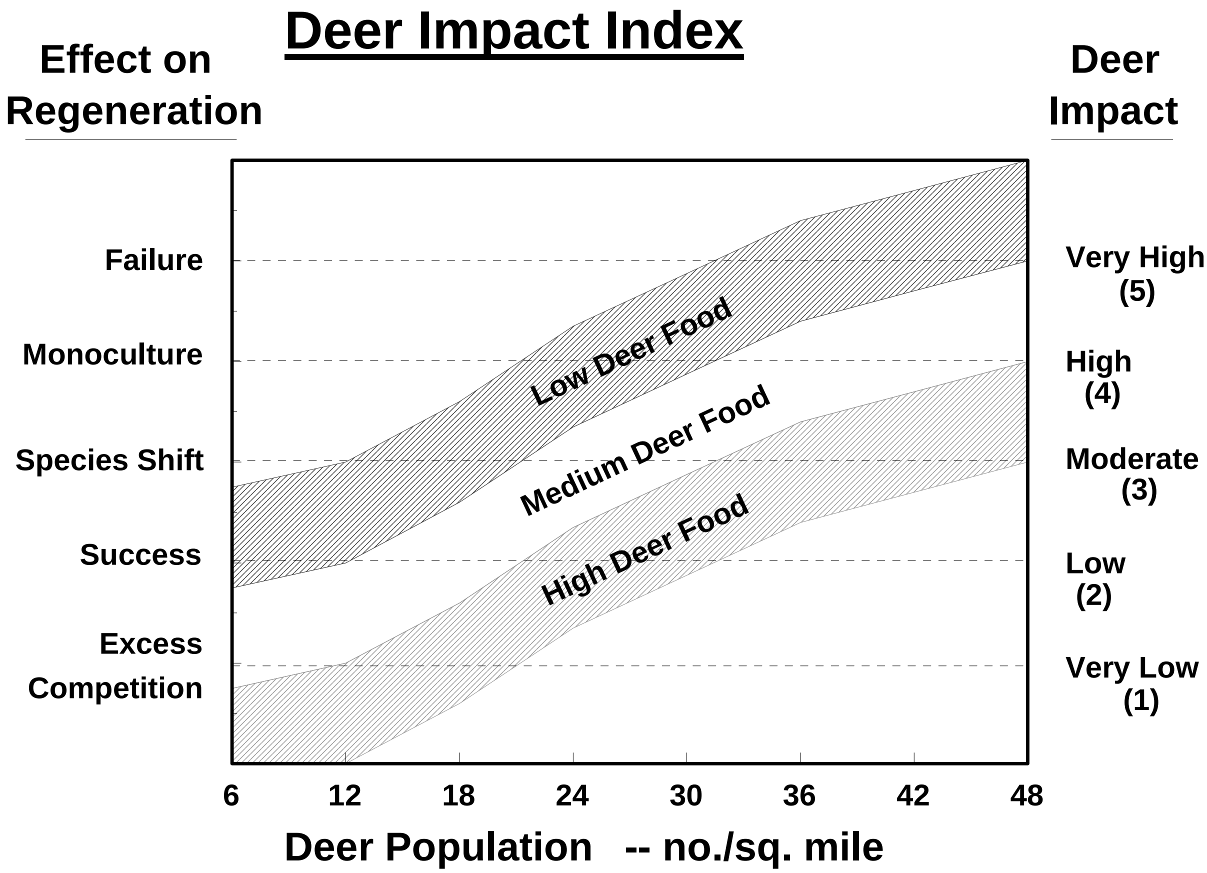

Figure 2. *Deer Impact Index is a way of visually displaying the fact that the impact of deer on forests is a function of both their density and the amount of forage found within the landscape.*

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