Proceedings

Michigan Society of American Foresters
"Forest & Wildlife-Striving for Balance"

9-10 June, 2005
Little Bear Conference Center
St. Ignace, Michigan, USA

Edited by Bill Cook

Co-Sponsored by:

The Forestland Group
Grossman Forestry Company
Michigan State University Extension
Michigan Association of Timbermen
NewPage Corporation (formerly MeadWestvaco)
Weyerhaeuser

Table of Contents

Forward 1

Conference Papers

Challenges of deer management from an ecosystem perspective 3
Gary Alt, Wildlife Consultant

Population biology, abundance, and management history of Michigan white-tailed deer 9
Brent Rudolph, Michigan Department of Natural Resources Wildlife Division

Forests for dinner: Exploring a model of how deer affect advance regeneration at stand and landscape scales 31
Joseph LeBouton, Michigan State University

Cost-share programs, deer habitat enhancement, and PNIF implications 47
Tom Ward, Michigan State Forester, USDA Natural Resource Conservation Service

Ecological impacts of deer overabundance on temperate and boreal forests 51
Jean-Pierre Tremblay, Laval Université, Québec

An assessment of long-term biodiversity recovery from intense and sustained deer browse on North Manitou Island, Sleeping Bear Dunes National Lakeshore 85
David Flaspohler, Michigan Technological University

In our opinion: Are Michigan deer hunters satisfied stewards or coerced conservationists? 109
R. Ben Peyton and Peter Bull, Michigan State University

Chronic regeneration failure in northern hardwood stands: A liability to certified forest landowners 125
Gary Donovan, International Paper

Certifying sustainable forestry: The deer factor 131
David deCalesta, Wildlife Analyses Consulting

Even-aged silviculture as an approach to regeneration of forests with high deer densities 135
Susan Stout, USDA Forest Service Northeast Forest Research Station

Adaptive management for deer: A case study from Pennsylvania 145
David deCalesta, Wildlife Analyses Consulting

Deer and sedge : Bottlenecks to seedling regeneration in northern hardwood forests and potential restoration techniques aimed at reversing the effects 157
Jesse Randall, Michigan State University

Strategies in changing deer management policy in Pennsylvania, 1999-2004 161
Gary Alt, Wildlife Consultant

Conference Agenda 165

Speaker Biographies 167

Annotated Bibliography 173

Conference Participants 185

Supporting Papers Recommended by Presenters 195

Frawley, Brian J. 2005. Michigan Deer Harvest Survey Report: 2004 Seasons. Michigan Department of Natural Resources, Wildlife Division Report No. 3444. 39 pp.

Frawley, Brian J. 2004. Demographics, Recruitment, and Retention of Michigan Hunters. Michigan Department of Natural Resources, Wildlife Division Report No. 3426. 39 pp.

LeBouton, Joseph, Michael B. Walters, Jianguo Liu, Frank Lupi, Edward J. Laurent, and Laila Racevskis. 2005 [draft]. White-tailed Deer and Landscape Effects on Forest Structure and Species Composition. Michigan State University Extension Bulletin E-xxxx. 2 pp.

Randall, Jesse A. and Michael B. Walters. 2005 [draft]. Deer and Sedge Impact Tree Regeneration in Working Forests: Possible Restoration Treatments. Michigan State Bulletin E-xxxx. 3 pp.

Marquis, David. 1981. Management of Allegheny Hardwoods for Timber and Wildlife. In the Proceedings of the International Union of Forest Research Organizations. XVII IUFRO World Congress in Japan. pp 369-381.

Forward

This conference, the first on the subject of forests and deer held in Michigan by the SAF, has long been needed. The issues that led to this conference have been debated for decades, not only in Michigan, but across the Lake States, eastern North America, and in many countries around the world. The topic of forest impacts by deer is highly charged and includes many socio-political-cultural aspects. While presentations during this conference primarily focused on research-based information on deer impacts and management/policy alternatives, the Michigan SAF fully recognizes that public attitudes and perceptions have ruled the day and will likely continue to do so for some time. There is little argument over the concept that deer have had, and will continue to have, tremendous impacts on the forest resources of Michigan. However, the level and kind of impacts; and what should and could be done from a management standpoint is highly controversial.

This conference touched on many facets surrounding deer "overabundance" and resource impacts. However, a comprehensive review of all facets would have taken more days than were available. Everyone is encouraged to learn more from the wealth of available literature. The research bank steadily grows, especially as technological advances allow researchers to better address some of the ecosystem and temporal themes. Speaker papers provide references for further study. An annotated bibliography cites many of the commonly referenced papers. Resource managers and other interested individuals are encouraged to use these and other information resources to learn more about white-tailed deer and their ecological, social, and economic impacts.

The original framework was to include three sessions; 1) forest impacts of white-tailed deer, 2) attempts to manage or deal with overabundant populations, and 3) a look to the future of what could and should be done. However, due to the nature of some presentation topics, it became apparent that elements of all three session ideas were best included within individual presentations. The negative impacts of deer in forested landscapes (as well as other landscapes) have been well-documented over the past few decades. There remain, of course, many avenues for additional research. While it may be easiest to focus on ecological impacts, the conference planners hope that participants will come away with a forward-looking perspective and consider what might be needed to work towards securing a sustainable and healthy set of natural resources.

Gary Alt keynoted the conference, bringing with him pioneering experience from the Pennsylvania Game Commission. Pennsylvania may be the state with the greatest and longest-running controversy over deer. Brent Rudolph set the stage by describing deer management in Michigan, a critical topic before impacts and alternative solutions could be discussed. Joseph LeBouton, Jean-Pierre Tremblay, and Dave Flaspohler focused on impacts of deer herbivory. Ben Peyton and Peter Bull reminded us about the critical role that hunters play. Tom Ward, Susan Stout, and Jesse Randall addressed management opportunities in light of high deer densities.

Gary Donovan and Dave deCalesta reviewed deer factors in forest certification, a crucial current topic in Michigan. State lands undergo field audits in September, 2005 and nearly two million acres of industrial land are currently enrolled in certification programs. With forest regeneration as one of the requirements, the ability of forest owners and managers to regenerate not only commercial tree species, but the entire complex of forest flora is challenged by deer herbivory.

Dave deCalesta and Bill Moritz postulated on possible deer management strategies. Finally, Gary Alt closed the conference by sharing insight into the pressures and possibilities of working towards an ecosystem-based approach to forest and deer management.

The geographic focus of this conference was primarily Michigan. However, Michigan has considerable commonality with all the upper Great Lakes States, as well as with other parts of North America. The conference planners attempted to highlight current research based in Michigan, and draw upon a larger body of research and case studies that help contextualize the issues of forests and deer.

The compact disk contains papers and PowerPoint slide presentations used by the conference speakers. In some cases, delivered presentations may be slightly different than the files on the

CD, due to last minute editing. Additional materials include short biographies of each speaker, abstracts of each presentation, and an annotated bibliography for those who might wish to pursue a literature search. Lastly, there is a table of contents, the conference agenda, and other documents related to the conference.

In his essay on wilderness, Aldo Leopold described the phenomenon of deer overpopulation on the forest floor. "The effect of too many deer on the ground flora of the forest deserves special mention because it is an elusive burglary of esthetic wealth, the more dangerous because unintentional and unseen. One is put in mind of Shakespeare's warning that 'virtue, grown to pleurisy, dies of its own too much.' Be this as it may, the forest landscape is deprived of a certain exuberance which arises from a rich variety of plants fighting each other for a place in the sun."

Acknowledgements

Jim Ferris, as the Chair of the Upper Peninsula Chapter of the Michigan Society of American Foresters (SAF), guided the planning process for this conference. Bill Cook and Dean Wilson spearheaded the program team and logistics team, respectively. Chris Burnett, Bob Heyd, Don Howlett, and Jack Penegor also served on the planning team. Mark Bale, as always, competently handled the registration records. Ingrid Klotz and the resources of the Michigan State University Upper Peninsula Tree Improvement Center were essential in the preparation of this conference. A host of other foresters helped with the many duties associated with the mechanics of holding this conference.

Financially, the Michigan SAF is grateful for support from the following organizations: The Forestland Group, Grossman Forestry Company, NewPage Corporation (formerly MeadWestvaco), Michigan Association of Timbermen, Michigan State University Extension, and Weyerhaeuser. Their contributions helped reduce conference registration fees.

These proceedings were assembled and edited by Bill Cook in cooperation with Michigan State University Extension and the Michigan Agricultural Experiment Station.

Keynote Address: Challenges of Deer Management From An Ecosystem Perspective

Gary Alt[1]
Wildlife Consultant

[1]*Retired Supervisor of Deer Management Section, Pennsylvania Game Commission*
2530 Reservoir Road, Madison Township, PA 18444 Email: garyalt@echoes.net

---

Abstract: *Restoring white-tailed deer to their previous range in the early 1900's, after being exterminated from many areas during a century or more of overexploitation, has often been touted as one of wildlife management's greatest success stories. Ironically, now, after decades of overprotection, one of the greatest challenges of wildlife management is to balance this important game species with its forest habitat. Winning support of recreational hunters to reduce deer populations to levels compatible with forest ecosystem management is a critical challenge with important consequences, not only to solving this conflict, but to the future of recreational hunting as well. Further exacerbating this problem is the declining numbers of hunters, their increasing age, lower mobility, and declining land access to hunt. The health and sustainability of forest ecosystems will likely be dependent on increasingly aggressive strategies to bring deer populations in balance. If this challenge is not met, and conflicts between deer and society continue to grow, alternative, untraditional solutions are likely to follow.*

Today, we're here to talk about the challenges of deer management from an ecosystem perspective. First, I would like to state that I did not come here to tell you how to manage deer in Michigan. I did not come here to tell you how to manage your forests either. The people of Michigan will decide that. But I was asked to come here and talk about my experiences of running a deer management program in Pennsylvania. Hopefully, some of our experiences, both good and bad, can help you in your goal to balance deer populations with forests here in Michigan.

I think it's worthy to make comparisons between Michigan and Pennsylvania because we have a lot of similarities. In terms of our deer populations, they are very similar, a little over one-and-a-half million in each state. Michigan currently has about 750,000 hunters and Pennsylvania has about a million, representing some of the largest hunter populations in the United States. What is really significant here is that 93 percent of Pennsylvania's hunters and 89 percent of Michigan's hunters hunt deer, according to a United States Fish and Wildlife Service survey. The significance of this is that when the wildlife agency is funded primarily by hunters, as it is in Pennsylvania, and those hunters demand to have more deer, the agency is under enormous pressure to deliver.

In both Michigan and Pennsylvania, a little more than half of each of our states is forested. In terms of human population, we are both very heavily populated with roughly 10 million people here in Michigan and 12 million in Pennsylvania. The other statistic that I think is significant is that in both states only 8 percent of the total population hunt. The relevancy of this in Pennsylvania, at least, is that we have a very small minority of our society that is deciding how all wildlife management is implemented for all of society. We were able to do that in the 20th century but I do not believe it will be allowed to continue very far into the 21st century. It is not an issue until that minority of society demands the wildlife agency do things that have enormous negative consequences on natural systems or on the impacts to the rest of society. That's a collision I think we're headed for right now with deer management.

Forest certification of our state forests is threatened by the lack of regeneration due to overbrowsing from deer in Pennsylvania. I don't know what the status of forest certification is in Michigan, though I do know you are in the process of getting certified, but certainly overbrowsing will be an issue you will have to deal with.

Which brings us to the age old question, "how many deer should there be?" Well, the answer depends upon who you ask and on their value system. If you ask hunters, they often say we should have more deer. If you ask farmers, we should have fewer. So, how many should we have?

I once lived in an apartment house on two acres in the Pocono Mountains of northeastern Pennsylvania where the guy who owned it came from New York City. His life-long dream was to pave the entire two-acre field. All the vegetation in the field for him was just rubbish. I couldn't help but wonder why he would want to pave it. But I guess he comes from an area where concrete and pavement are more familiar, and that's what he wanted to do. That was his value system. It's his land and if he wants to pave it, he can. But if enough people do that, it changes our entire system.

Deer, too, can change our entire system. They have enormous consequences, not just for some of society, but for all of society. If you drive a car, raise a garden, or are interested in the economic sustainability of forest products, or health and sustainability of our forest ecosystem, then deer will impact you. They impact our economy to the tune of hundreds of millions of dollars annually in terms of damages to agriculture, forestry, and automobiles.

In terms of our agricultural paradigm style of deer management, with "maximum sustained yield" theory, trying to raise the maximum number of deer that can be sustained to appease the demands of recreational hunters, things have not gone well. It seemed like a good idea, but one of the problems I would submit is that we forgot about the sustained part. We have not been able to sustain forests in my state. We've been trying to raise more deer than the land can sustain resulting in declines in the health of our forests and in the numbers of deer. Sounds good on paper, sounds good in theory, but it's not working on the ground.

We need to stop talking about the numbers of deer and we need to start talking about the impacts of deer. Because as these forests lose their ability to regenerate, as we lose the vegetation of the lower understory, you cannot grow deer there the way you once did.

Our state governments have a responsibility to properly manage our natural resources for current and future generations. That, I think, is key. We hold these natural resources in public trust and we are the ones responsible for managing them. For those of us in the profession, whether it be forestry or wildlife, I believe that we have an obligation to help our government to try and make the right decisions about reaching that mission, particularly as it relates to the health and sustainability of our forest ecosystems.

I think that human dimensions research certainly needs to play an important role in the management of our natural resources. It allows us to see what public attitudes and levels of understanding are for various issues. It tells us where we need to focus our educational efforts to try to bring them along about what really is at stake and what needs to happen. The attitudes of our society will often change as they learn more about these issues.

To better understand our dilemma of balancing deer populations with our forests we need to understand where we are now, how we got here, where we want to go and, most importantly, how do we get there?

Where Are We Now?

Where are we now? We have an overabundance of deer that's threatening the health and sustainability of our forest ecosystems. We have significant numbers of hunters who want more deer and who are very effective at lobbying our government to ensure that deer numbers remain higher than is ecologically responsible. We will not have sustainability in forests in my state until we can get the rest of society screaming for fewer deer into the ears of legislators, policy-makers, and administrators louder than the hunters are screaming for more deer.

How Did We Get Here?

How did we get here? What went wrong that allowed deer to get out of balance with forests? In pre-colonial days, we're told the deer densities and their impacts were relatively low. Natural predators, such as wolves, cougars, and Native Americans helped keep deer populations in balance. Then during the 1700s and 1800s came an era of overexploitation. Many of our forest areas were converted to agriculture. Originally, Pennsylvania was over 90 percent forested but by 1890 nearly 70 percent of the state had been converted to agriculture. Much of the land was cleared to raise crops and the remaining old-growth forests were clearcut resulting in a loss of much of our forest wildlife at that time. There were no effective regulations to prevent the unlimited killing of deer, year round. Market hunting took a great toll and we literally wiped out deer and many other wildlife species throughout much of the eastern United States by the end of the 19th century.

Concern for the loss of so much habitat and so many species of wildlife gave rise to a conservation movement and the development of wildlife agencies to manage these wildlife resources and their habitats in an effort to try and bring back these wildlife, in particular game animals such as white-tailed deer. Deer were stocked in many areas and laws were enacted to protect them. The tremendous regeneration in the recently clearcut forests provided perfect habitat for deer populations to increase. So then we wound up with exploding deer populations and increasingly protective regulations which brought us into a new era, an era of overprotection.

As the decades went on, the economic viability of farms declined. They were abandoned and gradually reverting back to forest. As so often is the case, these landscape changes were not in response to any type of planned wildlife or forestry habitat program but rather due to land use changes necessitated by economics. When they couldn't make money raising cows, pigs, sheep, and chickens, they just let the land go. And of course through the process of succession, forests reclaimed the land which once had been agriculture. With this change in habitat, from fields to forests, we have seen the range of deer, bears, turkeys, and grouse increase while rabbits, pheasants, and quail have declined.

Perhaps the greatest mistake that launched a century of overprotection for deer was the "no doe hunting" regulation. In 1917 the executive director of the Pennsylvania Game Commission, Dr. Kalbfus, after being unsuccessful at preventing the establishment of a no doe hunting policy said it best. He knew once this started it would be nearly impossible to stop and in reference to his vision of implications of this act, he sent a letter to future director, Seth Gordon, which said, "Thank God I won't be in charge of this work 10 years from now, because someone is going to have hell to pay." No truer words were stated that could best reflect what happened in the 20th century and what's still happening right now. God help anybody who goes after this issue. For state-agency biologists who push hard to balance deer populations with their habitat, that is often a career-ending experience. I know because mine ended just six months ago.

In my state, I don't believe it is possible for the Pennsylvania Game Commission to balance deer populations with forest ecosystems because of the system that has evolved. The agency is funded almost entirely from hunters. Ninety-three percent of Pennsylvania's hunters hunt deer and surveys indicate that hunter satisfaction is closely tied to the number of deer they see. These hunters demand to see more deer than the land could ever possibly sustain and they very effectively lobby administrators and policy makers (the commissioners), forcing them to implement seasons and bag limits that have no chance of ever balancing the deer herd with their habitat. This action, ironically, leads to severe habitat destruction which leads to deer declines, destroying the very resource they wanted more of. Even more ironic, the hunters feel the declines were caused by shooting too many does and demand even further reductions in antlerless allocations - and again, that is exactly what they get. I believe this is the greatest mistake in the history of Pennsylvania wildlife management and will have negative implications for our wildlife agency and perhaps even the future of sport hunting.

Development of an adequate, sustainable, broader-based conservation funding program will be necessary to solve this and other problems. Currently the Game Commission is almost totally dependent on hunter-generated monies. The numbers of hunters are declining in Pennsylvania, as they are throughout the country. Some of our modeling, based on the demographics of our hunter population, indicates that the number of hunters may drop to half of current levels in 20 to 25 years. In the near future it will not be possible to fund our wildlife programs on this shrinking funding base. A Missouri-type funding program would be desirable in providing a more adequate and sustainable source of revenue to take on broader conservation issues and to prevent deer hunters from hijacking the agency's efforts to balance deer herds with forest ecosystems.

Urban/suburban sprawl is another challenge that deteriorates our ability to manage deer. You can't get hunters into these areas any longer because urban landowners often won't allow hunting on their land. As the density of human dwellings increases, it becomes unsafe to discharge rifles, and our options become more limited and our ability to manage deer becomes more challenging.

Our challenge of balancing deer with forests is not the only conflict our society has with deer. We are picking up about 45,000 dead deer annually on Pennsylvania highways. Some studies indicate that less than half of deer fatalities are picked up along the roads – many deer run off and die undetected. Accordingly, in Pennsylvania, we believe about 100,000 deer are killed on our highways each year. The average repair bill is about $2000 apiece. Just auto repair bills alone cost about $200 million each year, not to mention the human fatalities, medical bills and other problems.

For as long as we have deer, highways, and people, we will always have road kills, accidents, and fatalities. I'm not saying we're going to stop it. What I am saying is that, as a society, we have an obligation, and as a profession we have an obligation. When we try to hold deer densities higher than they should be, even for their own good, and even for the good of the hunters who are demanding to have more deer, we are killing people and shelling out millions and millions of dollars in damages that should never be happening.

Agriculture is also heavily impacted by overabundant deer. There are many areas in Pennsylvania where we cannot grow certain crops because the deer consume so much of it that the farmers cannot make a profit, and so, deer are impacting the ability of agriculture to survive.

But the thing that brings us here today, and the thing that I think is enormously important in the state of Pennsylvania, is our forests. In Pennsylvania, over four billion dollars a year are generated through forest products. That is an economic engine that should be sustainable, but if we don't bring deer under control it won't be sustainable. Make no mistake about it, the control of deer is not just a hunting issue. It is an issue of enormous economic, environmental, and ecological importance to the future of Pennsylvania.

We must continue to educate our public, and especially our hunters, on the relationship between deer and their habitat, and the relationship between nutrition and the ability of deer to reproduce and survive. Does don't start to reproduce until they reach 80 pounds. On good habitat more than half will breed at six months of age with most does producing twins, and some with triplets. On poor, overbrowsed forest habitat almost none will breed at six months, some may not even breed until 2 ½ years of age, and litters usually only consist of a single fawn. Fawn survival also is much lower on overbrowsed habitat. It's a game of energetics. If you want healthy, productive deer then you've got to keep that habitat healthy by controlling deer numbers.

Where Do We Want to Go?

Where do we want to go? We want to try to balance our deer population with forest ecosystems. What are the challenges for that to happen?

I think hunting is, obviously, the most cost-effective way to balance deer herds; it's the only way that really makes sense at this point in time but we have some serious challenges. What are the challenges? We have declining numbers of hunters, nationwide. We know that the age of hunters is above 50 and getting older. With recent hunter movement studies we now know that the mobility of hunters is lower than we once thought. The access of land to hunters is going down. More and more people are posting for a variety of reasons, but the trend is clear. Hunters are losing access to more and more land. We also have the "no doe hunting" deer-hunter culture to deal with as major challenges to balance deer herds with forest ecosystems.

In terms of what's happening in Pennsylvania, in the last 25 years we've seen about a 20-25 percent reduction in the number of licensed hunters. In terms of projecting ahead, when we look at demographics of those hunters, how old they are, and a variety of other statistics, it is not good. We believe, in Pennsylvania, that the number of hunters will go to half of what they are today within 25 years. If that's true, and if we cannot manage them today, how are we going to do it in 25 years? We can't sit around and wait for this to happen at some point in the future. We have to make moves. We have to make them now while we still have enough hunters to give it a try.

<u>How Are We Going to Get There</u>?

How are we going to balance deer populations with forests? We need the support of the public and the hunters. To get their support we need credibility, and conducting research and sharing it with the public leads to credibility.

We launched a series of large-scale studies to learn more about our deer to better manage them, to increase credibility and win support from our hunters and our public. First we launched a fawn mortality study where we captured and radio-collared 212 fawns to find out what was killing them. Then we did a fawn conception study where we examined the uteri of over 3,000 road-killed does in the winter. By inspecting the uteri of road-killed does and measuring embryos we were able to determine rates of pregnancy, litter size, determine the timing of the rut and the birthing period. We measured the number of points, width, and antler beam diameter of over 75,000 harvested bucks for which we knew the county and township of kill, and the age of the buck. This information was crucial to determine what kind and where new antler restrictions should be implemented. We launched a “buck study” where we captured and radio-collared 551 bucks to monitor the compliance and effectiveness of antler restrictions once they were in place.

We contracted out a study of hunter movements to the Pennsylvania State University and the results indicated that hunters were not getting very far off the road. They put GPS units on about 500 hunters in a remote state-owned forest district and tracked their movements. In addition, they had aerial surveys with video cameras to record hunter positions with respect to highways. What they learned was that two-thirds of the hunters stayed within one-third of a mile of the road and much of the more remote forest areas received very little hunting pressure.

We contracted out landowner surveys, hunter surveys, and followed the movements of hunters with GPS units to better understand hunters and landowners. The results of these studies were released everywhere. They were, and still are being, published in professional journals and presented at conferences, published in popular magazines, newspapers, and are the topic of many radio and television shows. This has raised our credibility with the hunters and the public and allowed us to make many policy changes to help bring deer populations in balance with their forest ecosystem. In the past five years we have made more changes to seasons and bag limits of deer than for any other period in our history and we are killing more does than at any point in history. That would not have been possible without a massive research and public education program.

<u>The Future of Hunting and Our Forests</u>?

In terms of balancing deer with our forests, I think we have some very serious issues at hand, much of which I’ve described. But also, I think we have the great risk of compatibility of forest ecosystem management and recreational hunting. Somehow, we have to put the “hunt” back into hunting. We have to find a way to get hunters to exert more energy, to get farther back off the road, to help us balance these deer herds with those forest ecosystems. I do believe the future of sport hunting, as we know it today, is at stake if hunters either will not, or can not, balance deer herds with our forests and the needs of society.

My team and I have done everything we could in the past five years to try and get that message out in Pennsylvania and I’ll continue as a consultant. We must be able to explain what’s “good” about hunting and what is good about guns. Instead of hearing about Columbine, we need to be talking about how hunters are saving forests and bringing back forest health. I believe that will sell. If we fail at this effort I believe society will be forced to seek nontraditional, alternative solutions to this problem and that will not be in the interests of recreational hunting. In the end it will be society that will decide.

Not only is the future of hunting at stake, but the future of our forest ecosystems are as well. The impacts of the decisions we make today as managers will be etched in history for hundreds of years in our trees and in the composition of our forests, as well as all of the other plants and animals that make up these ecosystems. What we decide to do with these forests, and with these deer, will leave a legacy long, long after we are gone. I hope that we can leave a legacy that our descendents will be proud of, one that reflects leadership and stewardship. But if that is to be the case, we have a lot of tough decisions to make and a lot of work ahead of us. It all begins with an acknowledgement of the problem and a willingness to do something about it. For that reason, I thank you for the opportunity to come here and talk with you about this important issue.

Population Biology, Abundance, and Management History of Michigan White-tailed Deer

Brent A. Rudolph[1]
Michigan Department of Natural Resources Wildlife Division

[1]*Wildlife Research Specialist, Michigan DNR, P.O. Box 30444, Lansing, MI 48909-7944, Email: rudolphb@michigan.gov*

Abstract: *Statewide and regional abundance of white-tailed deer in Michigan has varied widely over the last several centuries, and deer hunting regulations have evolved with changing management needs. Recreational hunting continues to provide the only feasible management tool, though recent research raises concerns over the capacity of hunting to meet broad-scale population management objectives. Wildlife management is complicated by commonly held perceptions of simple cause and effect dynamics, though actual system function is considerably more complex. Modern deer management is further complicated by the diverse interests of the hunting public and other stakeholders, combined with the various expectations and concerns arising from deer abundance in recent decades.*

This summary is intended as a broad overview of trends in white-tailed deer (*Odocoileus virginianus*) abundance and management in Michigan. It is exhaustive in details at neither a historic scale nor geographic extent pertaining to localized conditions that vary greatly throughout the state. While I have attempted to provide an objective summary, I will openly admit that my review in particular of the significant challenges facing deer management in Michigan and suggested directions to take to address them reflect my own perspective. Though I suspect there are many that would agree with me on these points, I recognize that many individuals would potentially identify other challenges as more critical.

This material will be organized in four sections. "History Lessons" reviews historic abundance and identifies significant events in Michigan deer management. "Nuts and Bolts" describes the authority and general process of present-day deer management in Michigan. "Brain Surgery and Baseball" illustrates some of the challenges facing Michigan deer management, while "Plotting the Course" provides several suggestions regarding means to address those challenges.

As a final note, the informal style of this review is not intended to trivialize the importance of deer management in Michigan. As one of the leading states in the nation in terms of deer hunting participation and harvest (US Department of the Interior 1998), deer debates are somewhat akin to discussing religion and politics at the dinner table. My approach to addressing the topic is intended to be one small way of defusing that tension, and should not be interpreted as a failure to recognize it.

HISTORY LESSONS: DEER AND DEER MANAGEMENT IN MICHIGAN

At the risk of offending the residents and hunters of the Upper Peninsula (UP) and the Northern Lower Peninsula (NLP), the historic figures and events reviewed herein group those two ecoregions together as "Northern Michigan" and treat the Southern Lower Peninsula (SLP) separately as "Southern Michigan" (Figure 1). There are many differences between (and also within) the NLP and the UP, but most of the historic trends and issues of greatest significance differ most substantially according to these two basic regions. Many of the historic trends reviewed here are presented by Langenau (1994).

It is worth noting that the common contention that modern deer abundance exceeds any ever experienced in North America is disputed by research that reviewed archaeological evidence and historic narratives in an effort to reconstruct historic deer populations (McCabe and McCabe 1984, 1997). Whether or not historic deer abundance has ever equaled or exceeded modern levels is not vital to this review, but does have important implications as to whether impacts of current deer populations can be assumed to be historically unprecedented. Of course, the North American human population is certainly larger than at any previous point in history, so substantial alterations to the ecology of the landscape have occurred regardless of any impacts of deer. Regardless, there is nothing inherently "wrong" with these altered biological interactions. Ultimately it is the view and values of our own species that identify wildlife populations as overabundant based on societal values regarding the consequences associated with such populations (McCabe and McCabe 1997), and it is the responsibility of professional resource managers to help frame such debates and identify appropriate courses of action.

Settlement, Industry, and Evolving Regulations in Michigan

Significant fluctuations in Michigan deer populations (Figure 2) have been driven most strongly by broad and substantial changes in habitat conditions, with the additional impact of little or no regulation of harvest in early years (Table 1). Michigan was officially recognized as a state in 1837, and the settlement that occurred around that time produced significant impacts on deer. Clearing of land for homesteads and farming eliminated cover, and unrestricted utilization of venison contributed to virtual elimination of deer in southern Michigan. However, as logging picked up in northern Michigan later that century, forest canopies were opened and deer habitat was ultimately improved.

In 1859, the era of regulation was entered when a seven month season was established on deer. Although a variety of other regulations were adopted at that time, the increase in northern Michigan logging camps and establishment of railroads created an opportunity for market hunters to access both deer and transportation routes to distribute venison. Added to this unlimited exploitation, the potential benefits associated with accelerating logging were limited by unmanaged slash fires that regularly prevented regeneration of early successional habitat. Northern deer populations, which had initially increased with improved habitat conditions, experienced a steep decline. In response, additional efforts were undertaken to regulate harvest, included hiring of the first Michigan Game Warden in 1887, and requiring deer hunters to purchase a license beginning in 1895.

Professional Resource Management

In 1921, a "buck law" was passed that limited hunters to the harvest of one deer (a buck) per year, and established the definition of a buck as a deer with at least one antler three inches or longer. The Department of Conservation was founded in the same year, and the Game Division was established in 1928 within the Department. Further support for science-based game management was provided in 1937 with the passage of the Pittman-Robertson Act for Federal Aid in Wildlife Restoration. This act collects a federal excise tax on hunting arms and ammunition to be returned to the state for research, land acquisition, and habitat development.

Around this same time, fire control efforts and the abandonment of agricultural lands during the Great Depression produced a flush of suitable deer habitat. In combination with the capacity for informed decisions to be made by a staff of wildlife managers supported by a growing body of research, deer populations experienced their first increase during the era of professional resource management.

Michigan Deer Peak and Decline (Again)

The growing abundance of deer began to be recognized by 1930. In the 1940s, the first regulated antlerless deer hunting since passage of the "buck law" was initiated, primarily to address concerns over crop damage. A system was established to define a limited area in which antlerless hunting could occur and restrict the harvest to a designated quota. Thus the modern system of regulating antlerless harvest arose out of a need to allow limited hunting in specific areas where deer were essentially exceeding human tolerance.

Deer populations continued to increase into the 1950s, by which time forests had matured in many areas, and those food sources that were available became heavily browsed. As a result, northern Michigan deer populations began a downturn in the 1950s and 1960s. The antlerless deer harvest system began expanding from simply establishing hunts in areas experiencing substantial crop damage, but was still limited to defined areas and a defined number of antlerless permits in those places where there was a widely recognized need to reduce deer. In 1956, antlerless harvests occurred in the Upper Peninsula for the first time since passage of the "buck law" in 1921 (Figure 3).

The first public discussion about the impacts of deer browsing on forested systems began during this period. Former Department of Conservation Director Dr. Ralph MacMullan explained the need to harvest antlerless deer even as populations were declining (MacMullan 1966: pages 11-12):

The popular way is not always the right way… Michigan deer seasons… must include as a basic principle the harvest of some antlerless deer every year. To do otherwise would mean not only a tragic waste of a valuable resource but also, and even more important, accelerated deterioration of the winter range and fewer deer for the future.

Challenges to efforts to improve deer habitat during this time were conveyed well by an Oscar "Oz" Warbach illustration (Figure 4). The demand for timber products and/or the unavailability of accessible mills prohibited large-scale treatments.

Several years later, in 1971, the Deer Range Improvement Program (DRIP) was initiated, which earmarked $1.50 from the purchase of deer licenses for improving, maintaining, or purchasing deer habitat. As timber market conditions improved, these efforts were increasingly efficient and successful, and northern Michigan deer populations again began to increase, even as southern Michigan deer populations began expanding to their highest levels in several centuries.

Lessons Learned

Two lessons were foremost amongst those learned during the two dramatic peaks and declines of Michigan deer populations from the 1800s through the late 1900s, with each one well illustrated by Oz Warbach. The first lesson was that deer population management and habitat management must be integrated. Population management essentially is habitat management, and certainly must be addressed if habitat management is to be successful (Figure 5). The second lesson was that, as public resistance to antlerless deer harvest delays proactive management of abundant deer, confusion results from the complex interactions of deer population dynamics, harvests, and habitat conditions. Popular consensus inevitably contends that antlerless deer harvests were the cause of, rather than the response to, deer population declines (Figure 6). This wasn't a lesson learned only in Michigan. Aldo Leopold, a forester by training and founder of the wildlife profession, experienced similar challenges as a Wisconsin Conservation Commissioner in 1943 (Flader 1974).

NUTS AND BOLTS: THE DEER MANAGEMENT SYSTEM IN MICHIGAN

An all-inclusive review of the system used to manage deer in Michigan is not feasible in the space allotted here. A basic review of the legal authority and administrative policy upon which management is based, the primary methods used to assess population size or trends, and the general process used to generate management recommendations and goals should suffice to establish appropriate connections between the history of deer populations and challenges facing deer management in Michigan.

Regulatory Authority

A variety of legal authorities form the basis of deer management in Michigan. The first is Act 451, a public act passed in 1994, known as the Natural Resources and Environmental Protection Act. This legislation identifies all wildlife that are designated as game species in Michigan, establishes the basic framework of licenses and fees, and conveys authority over the method and manner of take of those game species to the Department of Natural Resources (DNR).

The Natural Resources Commission (NRC) is a 7 member board of individuals appointed by the Governor and approved by the Legislature. The NRC establishes policies of the DNR and hires the Director of the Department. As of 1996, following a ballot initiative in which voters adopted Proposal G, the authority for approval of regulations adopted for the taking of game was conveyed to the NRC. The annual cycles of regulations therefore involve the generation of recommendations by DNR biologists that are ultimately brought to the NRC for review, public comment, and adoption as they choose.

Michigan Deer Management Policy

The Department manages deer according to NRC Policy 2007, adopted in 1994. The policy establishes the goal to manage the deer herd using management practices based on scientific research to:

1. Maintain healthy animals and keep the deer population within limits dictated by the carrying capacity of the range and by its effect on native plant communities, agricultural, horticultural, and silvicultural crops and public safety.
2. Maintain an active public information program designed to acquaint the public with the methods of deer management and the conditions needed to maintain a healthy, vigorous herd.

These two components acknowledge both the biological and social aspects of deer management. Deer management recommendations formulated by the DNR must, therefore, address both of these general considerations.

Deer Population Trends and Condition Indices

Buck harvest trends provide a useful index to deer population density. While a variety of factors (e.g., weather conditions, the day of the week upon which hunting opens, etc.) can influence harvest, one of the most substantial influences of long-term harvest trends is actual deer population size. Each year, a mail survey of randomly selected deer license buyers is conducted following completion of the deer hunting season to estimate hunter participation, harvest, and hunting effort in Michigan (Frawley 2004*a*). In comparison to efforts at generating a complete count of deer harvested, using a probability sampling procedure to estimate the Michigan deer harvest has been found to result in reduced cost and greater speed, scope, and accuracy of results (Hawn and Ryel 1969). A recent assessment of methods utilized by state agencies to generate deer harvest estimates indicated that 26 of 48 (54%) survey respondents rely on mail surveys to collect hunter harvest information, and 22 of those states use mail surveys specifically to estimate total deer harvest (Rupp et al. 2000).

The Wildlife Division has been collecting and tabulating measurements from hunter harvested deer for over 50 years. These check station data are used to assess the sex and age composition and condition of the annual harvest and draw inferences to the composition and health of the statewide deer herd. Data are collected when hunters voluntarily bring harvested deer to a check station staffed by DNR employees and other volunteers who have participated in annual training sessions. Average antler beam diameter of yearling bucks serves as one useful index of herd condition in Michigan (Panken 2002), and elsewhere has been correlated with deer body weight (Severinghaus and Moen 1983), which was one of the best indicators of deer condition (Moen and Severinghuas 1981).

The annual number of reported deer-vehicle collisions (DVCs) in Michigan are compiled and summarized by the Michigan State Police. DVCs can be used as an index to deer population numbers, although factors other than deer population density, such as road densities, traffic volumes, and habitat types, also influence the DVC rate. The DVC index is therefore difficult to compare over extended periods of time or across different regions of the state as these factors change over spatial and temporal scales.

Hunters frequently use the presence of deer pellet groups as a measure deer use and abundance in an area. The pellet group survey is a formal extension of this common technique. The use of pellet counts to develop deer population estimates was a survey technique of primary focus in the 1930s and 1940s (O'Connell et al. 1999). Eberhardt (1955) concluded that this information could be used to develop reasonably reliable estimates of deer populations in Michigan. In general, they are useful as tracking overall trends in populations over broad areas. They're not as useful at generating deer population estimates.

Pellet surveys that were previously conducted in much of northern Michigan, but in recent years have mostly been limited to the use in the western Upper Peninsula.

The primary method for generating deer population estimates in Michigan is the sex-age-kill (SAK) technique. The procedure was originally described by Eberhardt (1960), and has been adopted for use in other states and with various modifications (Creed et al. 1984). The SAK technique estimates the number of bucks in the population using estimates of buck harvest generated through the hunter mail survey. The number of does and fawns in the population are then estimated using buck-to-doe and fawn-to-doe ratios calculated from check station data. These ratios are adjusted because Michigan hunters tend to check a higher proportion of the antlered harvest (Cook 2001). To generate estimates using the SAK procedure, the minimum sample for a specific area and time should include data from 100 antlered deer and 200 antlerless deer (Hansen 1998).

Deer Management Units

Management recommendations are provided to the NRC for each Deer Management Unit (DMU) in the state. In the year 2000, the NRC asked Wildlife Division to review and revise Michigan DMUs with consideration as to the clarity of DMU boundaries to hunters, landowners, and the general public, the geographic scale of the areas and the associated reliability of applying data at that scale, and the ecological associations of the units. Adjustments made to DMU boundaries at that time shifted Michigan from having the smallest mean DMU size in the Midwest to having a mean DMU size near the median of Midwestern units (Table 2). Current DMU boundaries within the NLP and SLP primarily follow county boundaries. Although ecological conditions vary widely within some counties, these boundaries are familiar to the majority of the residents of this more heavily populated region, and numerous sources of data that are relevant to deer management decisions (e.g., human population demographics, trends in deer-vehicle accidents, crop damage complaints) are available at this scale over extended time periods. County boundaries are more difficult to distinguish in the UP, and deer in this region are at the northern extent of their range, and therefore more heavily influenced by weather and habitat conditions. DMU boundaries in the UP therefore follow roads, rivers, and other clearly definable features in an effort to represent consistent patterns in climate and ecological condition.

Deer Regulation Recommendations

Wildlife Division uses a participatory system for generating deer management recommendations in which there are successive stages of review and revision. In recent years, the Deer Management Information System (DMIS) has played a significant role in evaluating data and management recommendations. DMIS is a desktop software application accessible to all DNR Wildlife staff for recording, maintaining and viewing information pertaining to deer management. DMIS seeks to provide real-time data access and standardized automated processes to MDNR Wildlife staff involved with deer management planning, implementation, and evaluation. Habitat Biologists, who initiate management recommendations, benefit from immediate access to electronic data to use for tracking hunting trends, generating indices and estimates of deer populations, and reviewing broad habitat composition. Data for each DMU include: (1) historical antlerless license quotas, application rates, and sales figures, (2) deer harvest mail survey results, (3) estimated deer densities, (4) general land ownership and habitat composition, (5) check station biological data by age and sex, and (6) an automated SAK model for population reconstruction. Research and management specialists are able to review summaries of factors used in making the recommendations and are available to assist field staff in interpretation of data and identification of management needs. Management Unit Supervisors are provided immediate review of regulation recommendations and are able to review the consistency of recommendations across areas and with statewide priorities. They are able to modify and approve recommendations online. The system allows more time for staff discussion, as well as online documentation of comments and modification or approval of recommendations.

Michigan Deer Population Goals

Wildlife Division staff are currently developing deer population goals for each DMU that will guide management recommendations for the 2006 through 2010 hunting seasons. While these goals will be expressed in terms of desired population sizes, justification for establishing these goals will be provided to demonstrate the intent to balance the positive and negative impacts of deer. Management recommendations will therefore be generated with the intent to manage deer abundance as necessary to achieve the broader objectives of modifying impacts of deer (Figure 7).

Field staff have generated deer population goal recommendations while soliciting input from other resource managers. Draft versions of these goals will be presented to the NRC for their review, at which time the public portion associated with the NRC meetings will initiate public input. An open public comment period will follow, and at least one public meeting will be held in each Management Unit (Figure 1) to address questions and collect comments.

BRAIN SURGERY AND BASEBALL: CHALLENGES TO DEER MANAGEMENT IN MICHIGAN

Deer management isn't brain surgery – it's harder. This is not necessarily because it's more complex, but because it's more controversial. Another Oz Warbach creation illustrates this point well (Figure 8). The "DOC", which conveniently represented the Department of Conservation at the time, is caught in the middle of a shouting match with which a brain surgeon would never have to contend while performing his job. What is at the root of this source of controversy?

A Large, Diverse Constituency

Michigan residents place a high value on white-tailed deer. Seventy-five percent of our citizens participate in wildlife viewing activities annually (Mertig and Koval 2001), and perhaps as many as 60% of those individuals observe, photograph, or otherwise enjoy deer (US Department of the Interior 1998). Ninety percent of all hunters in Michigan are deer hunters (Frawley 2004*b*). Michigan deer hunting licenses are purchased by more than 800,000 individuals annually, and ten to eleven million hunter days are ultimately invested in the pursuit of whitetails every hunting season (Frawley 2004*a*).

Critique and Criticism

If deer management is more controversial than brain surgery, then it is more like baseball, or professional sports in general. Just as so many individuals in our modern society are fixated on getting the latest updates from the world of sports through the internet and cable television, and as phone-in sports talk shows proliferate on the radio, the hunting population is becoming more interactive and analytical regarding the latest trends and changes in hunting season regulations. With so many individuals spending so many days scouting and hunting the woods and fields, there is ample opportunity to make observations and formulate impressions and opinions, and many of those individuals look for an outlet to share and debate those opinions. The increasing popularity of internet discussion forums are one indicator of this trend.

One example of this debate playing out was provided recently by a recommendation Wildlife Division brought forward to the NRC to add seven days of hunting to the muzzleloader season in southern Michigan. This will certainly provide more recreational opportunity this fall, but the recommendation was suggested as a way to increase harvest of antlerless deer. It is important to note that, in recent seasons, antlerless deer account for 70% of the muzzleloader season harvest, but that these deer only amount to 10% of the overall harvest of antlerless deer (Frawley 2004*a*). Thus, we will have the chance to offer hunters additional recreational opportunity this fall, which will result primarily in an increase in the harvest of antlerless deer, but this will ultimately result in a relatively modest contribution to reducing deer populations. Our motivation and the likely outcome, however, were not viewed in this light by at least several outspoken participants on a popular discussion forum, as evidenced by the following quotes (www.michigan-sportsman.com/forum - Michigan Whitetail Deer Hunting, 4/17/05):

“Wiped ‘em out [up] north. Now it is time to do the same in the Southern part of the state.”

“I agree… until we have a year where there are zero car/deer accidents and no crop damage reports, the insurance lobbyists will keep the checkbook open.”

Furthermore, it’s pretty common to see debate initiated about a relatively narrow issue such as a modest extension of this particular season and see participants take the opportunity to expand the scope of their suggestions to something like this:

“*In [southern Michigan], it should be one buck, eight points or better, and one antlerless. Accidental button buck kills would require use of the buck tag… Mandatory deer check-in within 24 hours of kill… You wanna see big bucks… wait until a few seasons of these rules kick in.”*

Edits to this quote actually removed several other recommendations that this individual saw as the “solution” to the deer “problem” in Michigan, and particularly in southern Michigan. Each of these suggestions is not entirely without merit. My response to them and the inevitability this particular critic perceives would be the outcome, however, would likely be the same as the baseball manager that has studied sports psychology or spent an entire career in the major leagues and is now posed with a fan’s analysis of his latest changes to the starting lineup… it’s just not as simple as that. A few examples may demonstrate why this is the case.

<u>White-tailed Deer Population Growth and Hunting Effort</u>

Female white-tailed deer exhibit density-dependent responses to productivity (McCullough 1990). What this means is that, as competition for resources increases along with population density, fewer animals are in adequate physical condition to bear the maximum number of fawns of which they are capable. In Michigan, this can vary widely across different regions and age classes, but deer may conceive on average greater than 2 fawns each, or some age classes may be entirely incapable of reproducing (Ozoga et al. 1996). A plot of the increment of growth that a deer population will be capable of across a range of densities is, therefore, shaped like an arch, with a small amount of growth attributed to very small and very large populations, and the greatest growth occurring at moderate densities (Figure 9). What is the significance of this? It means that, as deer populations which are at or near their maximum possible sizes are reduced, their growth potential increases. The result is that even more animals must be harvested to maintain populations, let alone further reduce them, once these medium population densities are reached. It also means that largest populations do not provide conditions at which the maximum number of deer can be harvested every fall and replaced through reproduction the next spring. It’s not intuitive that this theoretical smaller population can actually replace a higher harvest level and have healthy productive deer, and it is often a cause of confusion during conversations between deer hunters and deer managers.

Unfortunately, the highest sustained harvests of deer are not achieved at the point at which deer are most visible and most easily harvested (Van Deelen and Etter 2003). The average effort required for each deer harvested is highest at low population densities, and more importantly, as deer densities are decreased, effort increases in a nonlinear fashion (Figure 10). The manager's dilemma, then, is that reduction of a deer population this is near the limit of what the habitat can support will require removal of a greater number of deer than ever before, which will also require a greater amount of effort for each deer removed. The further dilemma is that, while a hunter may eventually see deer only half as often as at some point in the past, this does not necessarily mean there are only half as many deer as before. This is far from intuitively obvious, but has been demonstrated through research as well as hard-learned practical lessons.

Herbivory and Regeneration

Let's now move past concepts regarding the mechanism of management and look at a concept regarding the need for management. While it is apparent that browsing by abundant deer can impact the structure and species composition of forest vegetation, the interactions leading to such outcomes also demonstrate considerable complexity. Sage et al. (2003) examined factors related to failure of northern hardwoods regeneration over 50 years at a research area in the Adirondacks of upstate New York. A series of research projects, each focusing on one factor perceived to be contributing to regeneration failure, failed to provide insight that could be used to regenerate the desired sugar maple (*Acer saccharum*), yellow birch (*Betula allegheniensis*), black cherry (*Prunus serotina*), and white ash (*Fraxinus americana*). The desired regeneration could only be consistently achieved by integrating reduction of deer densities, control of understory American beech (*Fagus grandifolia*), and application of even-aged silvicultural treatments. Factors of herbivory, lighting regimes, and site conditions each were important contributors to the problem, but none of them were ultimately acting alone to frustrate managers' desired outcome.

The Fallout: Hunting as a Deer Management Tool

At this point, a deer manager demonstrating each of these considerations may sound like a baseball manager making excuses why his top payroll team of All-Stars failed to win a pennant. However, there is an important difference between debate over a baseball team and a deer management program that falls short of their goals. Those bickering over deer management step onto the field of play every fall, and it is their performance under the debated guidance of the management program that determines whether goals are met. An organization, whether that means a baseball team or a deer management program, will experience the greatest success only when the goals of the team and the goals of the manager are aligned, but our 800,000 deer management fans are our team.

So, how does our team identify the goals they set, and how can we align them with the direction we'd like to take with deer management in Michigan? A recent New York Times series examining shifting status symbols in the United States may shed some light on this question (Steinhauer 2005). A growing number of sociologists are contending that the old metaphor of "keeping up with the Jones'," or judging your own accomplishments according to those of your neighbors and closest peers, is now outdated. With the growth in specialized print media, cable television, use of the internet, and so forth, people have access to information like they never did before. While this "opens up the world" in some ways, it also isolates as well – fewer people know who their neighbors are than ever before. The new metaphor is "keeping up with the Gates'." The so-called "social norms" that establish what constitutes acceptable behavior and desirable goals are now much more by the lifestyle of millionaires and movie stars.

Now, I don't expect that deer hunters are trying to determine what camouflage pattern Bill Gates endorses, but I do expect that their desires are shaped more by the expanding media to which they are drawn than ever before. Furthermore, the accomplishments of elite hunters appear far more attainable than the accomplishments of the wealthiest entrepreneur or most popular movie star. Indeed, the hunting media enforces this perception by promoting their products and making their tips and tactics, available in each monthly magazine issue, relevant to all of their readers. If an average person with an average job can bag the deer of their dreams every year (Clancy 2000), shouldn't the average magazine subscriber be able to reach the same touted success? I've already discussed how apparently easy it is to assume the perspective gained through repeated field observations can help determine best course of action. Added to the "luxury of choice" offered by the recent phenomenon of abundant deer – the chance to see and select from many deer through the course of a season – this trend in changing norms threatens to pull the goals of our team further and further out of alignment with the goals of the manager.

PLOTTING THE COURSE: THE FUTURE OF DEER MANAGEMENT IN MICHIGAN

Where does all of this leave us, and where do we go from here? While hunters are not likely to adopt a goal to sustain ecological integrity as the guiding principle of their hunting decisions (Holsman 2000), some common ground does exist between hunters and managers. Targeted outreach and education are necessary (Decker and Connelly 1989). We need to do more to identify and understand the distinct segments of our hunting population. For those individuals with selective interests in mature bucks and dedication to learning more about deer management, many of whom are also members of organizations such as the Quality Deer Management Association, demonstrating how management can sustain reduced, healthy, productive deer populations while also producing older, larger bucks would go far to identify mutual goals. For those that are more generally interested in deer hunting as a general form of recreation, we may stand to learn from those with experience in social marketing (Bright 2000). This would involve demonstrating that society at large benefits from having huntable but healthy deer populations, and that managers care about the quality of recreational experiences, but have broader management responsibilities as well. As Oz Warbach illustrates (Figure 11), deer managers, deer hunters, and deer populations are all passengers on the same ship, regardless of how well they do or do not get along. Controversy over deer management is nothing new, and not particularly easy to resolve (Woolf and Roseberry 1998), though some emerging concepts seek to integrate consideration of the entwined biological and sociological challenges faced in many wildlife management scenarios (Riley et al. 2003).

Build and Test Common Understanding

Efforts to build common understanding amongst resource managers and stakeholders will be necessary to move deer management forward. One approach would involve the use of conceptual models (Figure 7) to generate an abstraction of the system dynamics involved in the management of deer populations and impacts. These simplified representations can be useful not only in communicating ideas, but also in testing basic assumptions and examining the consequences faced if those assumptions are inaccurate (Starfield and Bleloch 1989). Perhaps baseball can provide a final useful analogy to deer management. The Oakland Athletics, while having the smallest player payroll of any major league team, managed to finish the season with the second best winning percentage in baseball, just behind the New York Yankees, who had the highest payroll. They accomplished this by questioning the traditional approaches to evaluating talent and team priorities, replacing dogma with analyses of readily available volumes of statistics on the performance of major league players, prospects, and teams (Lewis 2003). I have criticized deer hunters for making what seem to be intuitive assumptions that ultimately prove inaccurate, but I would also challenge managers to make additional efforts to test their presumed understanding of deer management issues if progress is to be made.

Scope of Management

In addition to making efforts to segment the population with a significant interest in deer management, it may be appropriate to segment the issues demanding management attention. For example, while the potential impacts of deer on the structure and species composition of forested systems have very serious consequences (Alverson et al. 1988, Mladenoff and Stearns 1993, Augustine and Frelich 1998, Didier and Porter 2001, Horsley et al. 2003, Cote et al. 2004), these dynamics are difficult to address. Research and management intended to address potential impacts on local areas of high silvicultural or conservation value, while still requiring intensive efforts, may offer better opportunities for success. Female deer in forested northern environments exhibit high site fidelity (Van Deelen et al. 1998, Nelson and Mech 1999) and associate in multigenerational social groups (Tierson et al. 1985, Nelson and Mech 1999). Localized management of matriarchal social groups (Porter et al. 1991, McNulty et al. 1997, Oyer and Porter 2004) may provide an opportunity to tailor deer management efforts and consideration of specific landowner attitudes to mitigate effects of abundant deer, although recent harvest history of female deer may also influence the utility of such an approach (Comer et al. 2005).

Embrace Ecosystem Management

Ultimately, the need to address management of deer populations and their impacts is an issue central to ecosystem management. Ecosystem management is a paradigm being embraced by many resource management agencies, although there is not always clarity in defining what any individual approach encompasses (Yaffee 1999). At a minimum, elevating the focus of above management of individual populations and focusing instead on interactions and ecological processes will require integrated efforts across multiple disciplines. Resource managers from different fields must make collaboration a priority, and individuals with training and experience in multiple areas will be in greater demand. Ultimately, deer managers must recognize that the ship on which they ride with the deer and deer hunters actually carries many more passengers, and making sure it follows the proper course will require levels of cooperation and challenges to which I hope we will be able to rise.

Tables and Figures

Table 1. Selected historical events that significantly influenced Michigan deer habitat and harvest.

Year(s)	Event(s)
1837	Statehood gained, settlement accelerates, unregulated hunting
1859	Statehood gained, settlement accelerates, unregulated hunting
1881	Statehood gained, settlement accelerates, unregulated hunting
1887	Illegal to kill deer in water, or any deer in red or spotted coat
1895	First Michigan Game Warden hired
1921	License required to hunt deer
1921	“Buck Law” limits hunters to one buck per year
1940s	Department of Conservation founded
1950s – 60s	Antlerless deer hunting initiated to address crop damage
1956	Northern Michigan forests mature and severely browsed
1971	First antlerless deer hunting in the UP since the “Buck Law” Deer Range Improvement Program initiated

Table 2. Size of deer management areas (ca. 2000).

State	Unit	Number of Units	Mean Size (mi^2)
Michigan (2000)	DMU	159	360
Indiana	County	92	390
Wisconsin	DMU	118	460
Ohio	County	88	470
Illinois	County	102	550
Michigan (2001)	DMU	90	640
Minnesota	DMU	121	650
South Dakota	DMU	75	1,000
Missouri	DMU	59	1,200
North Dakota	DMU	43	1,700
Iowa	DMU	20	2,800
Kansas	DMU	18	4,100
Nebraska	DMU	17	4,500

Figure 1. *Michigan's three broad ecological regions and the eight Wildlife Division administrative Management Units.*

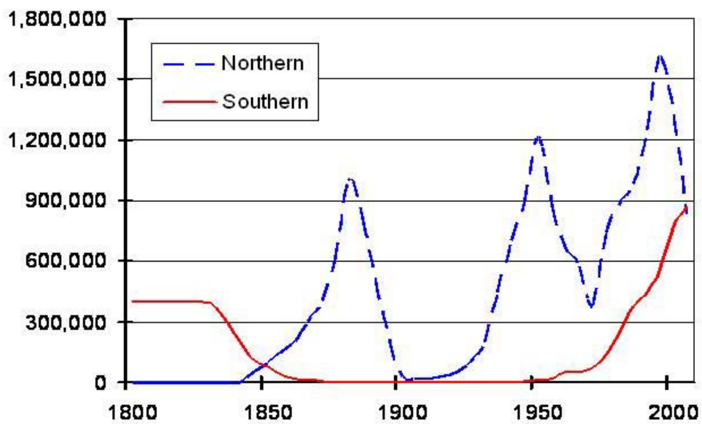


Figure 2. *Trends in deer population estimates in two broad geographic regions of Michigan.*

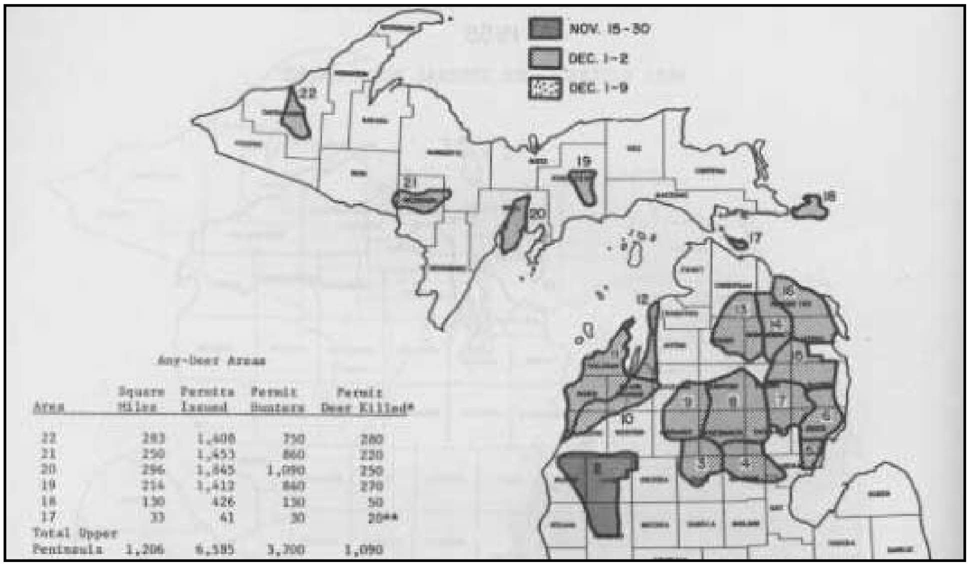


***Figure 3**. Areas open to antlerless deer hunting in Michigan in 1956.*

***Figure 4**. Oscar "Oz" Warbach illustration (ca. 1959) conveying that factors external to wildlife population management significantly impact habitat conditions.*

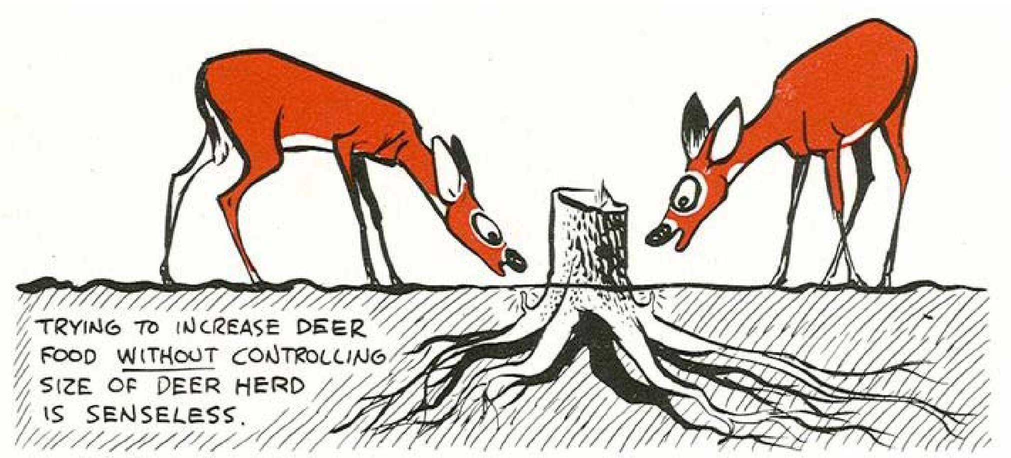


***Figure 5**. Oscar "Oz" Warbach illustration (ca. 1959) conveying that wildlife population management and habitat management must be integrated to be effective.*

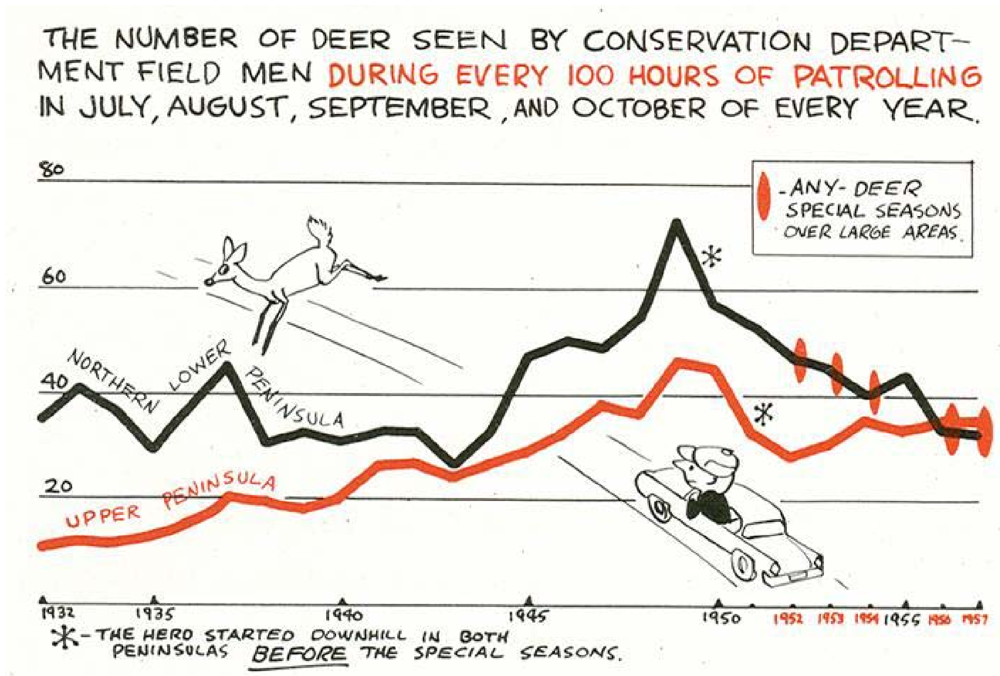
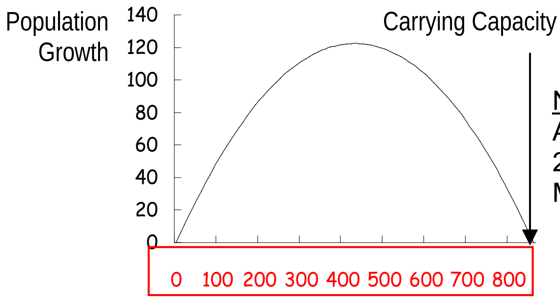


***Figure 6**. Oscar "Oz" Warbach illustration (ca. 1959) conveying that initiation of antlerless deer hunting occurred in response to, and was not the cause of, declines in northern Michigan deer populations.*

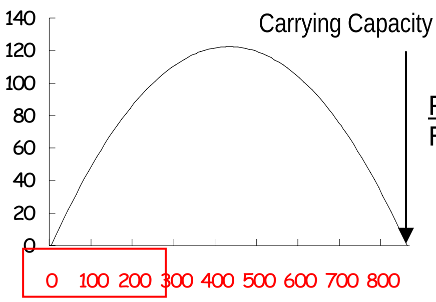
Figure 7*. Conceptual deer population management model for evaluation of regulation of antlerless licenses (licenses) and harvest of antlerless deer for a deer management unit (DMU) of interest from year t to year t+1, where: quota = license quota, sales = total antlerless deer harvest, management = deer population in year t+1 as a function of deer population in year t and harvest, impacts = change in impacts (e.g., economic value of hunting, crop damage, browsing effects on forest structure and wildlife habitat) of deer population from year t to year t+1, and objective = desired optimal balance of impacts.*

Figure 8*. Oscar "Oz" Warbach illustration (ca. 1959) conveying the contentious atmosphere surrounding the management of Michigan deer populations.*

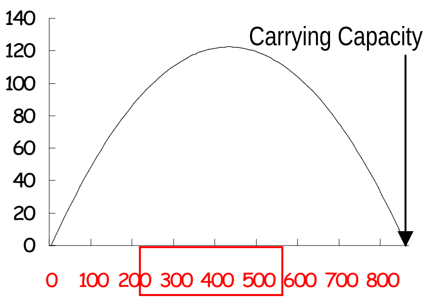


Nutrition High:
All females breed
2-3 fawns per female
Mortality low

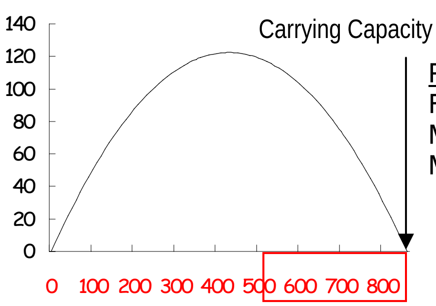
Nutrition Low:
Young females do not breed
0-1 fawns per female
Mortality high



Population Growth at Low Population Density:
Few females X high individual productivity = low growth



Population Growth at Medium Population Density:
Few females X high individual productivity = low growth
More females X high individual productivity = high growth



Population Growth at High Population Density:
Few females X high individual productivity = low growth
More females X high individual productivity = high growth
Many females X low individual productivity = low growth

Figure 9. *White-tailed deer population growth across a range of population densities.*

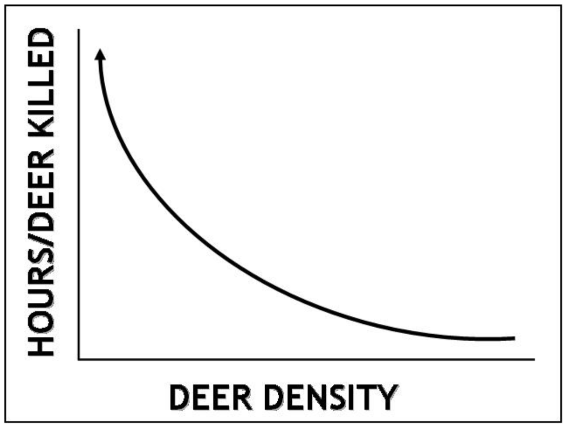


***Figure 10**. Relationship between deer population densities and hunting effort.*

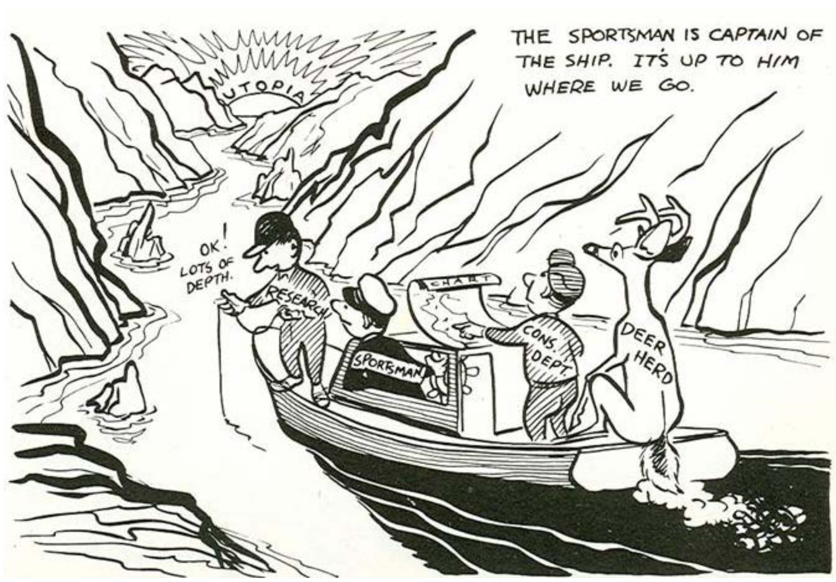


***Figure 11**. Oscar "Oz" Warbach illustration (ca. 1959) conveying the relationships between deer managers and hunters through their roles in management of Michigan deer populations.*

References and Suggested Readings

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forests too deer: edge effects in northern Wisconsin. Conservation Biology 2:348-358.

Augustine, D.J. and L.E. Frelich. 1998. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forests. Conservation Biology 12:995-1004.

Bright, A.D. 2000. The role of social marketing in leisure and recreation management. Journal of Leisure Research 32:12–17.

Brown, T.L., D.J. Decker, S.J. Riley, J.W. Enck, T.B. Lauber, P.D. Curtis, and G.F. Mattfeld. 2000. The future of hunting as a mechanism to control white-tailed deer populations. Wildlife Society Bulletin 28: 797–807.

Clancy, G. 2000. What makes the experts so successful? Deer and deer hunting 24(4):118–128.

Comer, C.E., J.C. Kilgo, G.J. D'Angelo, T.C. Glenn, and K.V. Miller. 2005. Fine-scale genetic structure and social organization in female white-tailed deer. Journal of Wildlife Management 69:332–344.

Conner, M.M., G.C. White, and D.J. Freddy. 2001. Elk movement in response to early-season hunting in northwest Colorado. Journal of Wildlife Management 65:926–940.

Conover, M.R. 1995. What is the urban deer problem and where did it come from? Pages 11–18 in J. B. McAninch, editor. Urban deer: a manageable resource? Proceedings of the 1993 Symposium of the North Central Section, The Wildlife Society, St. Louis, Missouri, USA.

Cook, S.L. 2001. An evaluation of the Michigan Department of Natural Resources' white-tailed deer field survey methodologies. Thesis, Michigan State University, East Lansing, Michigan, USA.

Cote, S.D., T.P. Rooney, J.P. Tremblay, C.Dussault, and D.M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution, and Systematics 35:113-147.

Creed, W.A., F. Haberland, B.E. Kohn, and K.R. McCaffery. 1984. Harvest management: the Wisconsin experience. Pages 243–260 in: L. K. Halls, editor. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Decker, D.J., and N.A. Connelly. 1989. Motivations for deer hunting: implications for antlerless deer harvest as a management tool. Wildlife Society Bulletin 17:455-463.

Decker, D.J., and N.A. Connelly. 1990. The need for hunter education in deer management: insights from New York. Wildlife Society Bulletin 18:447-452.

Didier, K.A., and W.F. Porter. 2003. Relating spatial patterns of sugar maple reproductive success and relative deer density in northern New York State. Forest Ecology and Management 181:253-266.

Eberhardt, L.L. 1955. Information on deer pellet group surveys in Michigan. Michigan Department of Conservation. Game Division Report 2042, Lansing, Michigan, USA.

Eberhardt, L.L. 1960. Estimation of vital characteristics of Michigan deer herds. Michigan Department of Conservation. Game Division Report 2282, Lansing, Michigan, USA.

Flader, S.L. 1974. Thinking like a mountain: Aldo Leopold and the evolution of an ecological attitude about deer, wolves, and forests. University of Missouri Press, Columbia, Missouri, USA.

Frawley, B.J. 2004*a*. Michigan deer harvest survey report: 2003 seasons. Michigan Department of Natural Resources, Wildlife Report 3418, Lansing, Michigan, USA.

Frawley, B.J. 2004*b*. Demographics, recruitment, and retention of Michigan hunters. Michigan Department of Natural Resources, Wildlife Report 3426, Lansing, Michigan, USA.

Giles, B.G., and C.S. Findlay. 2004. Effectiveness of a selective harvest system in regulating deer populations in Ontario. Journal of Wildlife Management 68:266–277.

Hansen, K.M.M. 1998. Integration of archery white-tailed deer harvest data into a sex-age-kill population model. Thesis, Michigan State University, East Lansing, Michigan, USA.

Hawn, L.J. and L.A. Ryel. 1969. Michigan deer harvest estimates: sample versus a complete count. Journal of Wildlife Management 33:871–880.

Holsman, R.H. 2000. Goodwill hunting: exploring the role of hunters as ecosystem stewards. Wildlife Society Bulletin 28:808–816.

Horsley, S.B., S.L. Stout, and D.S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13:98-118.

Hunter, C.M., and M.C. Runge. 2004. The importance of environmental variability and management control error to optimal harvest policies. Journal of Wildlife Management 68:585–594.

Langenau, E. 1994. 100 years of deer management in Michigan. Michigan Department of Natural Resources, Wildlife Report 3213, Lansing, Michigan, USA.

Lewis, M. 2003. Moneyball: the art of winning an unfair game. W.W. Norton and Company, New York, New York, USA.

MacMullan, R. A. 1966. The choice we face. Address during the annual convention of the Michigan Bear Hunters Association. 22 January 1966. Michigan Department of Natural Resources, Lansing, Michigan, USA.

McCabe, T.R., and R.E. McCabe. 1984. Of slings and arrows: an historical retrospection. Pages 19–72 in: L. K. Halls, editor. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

McCabe, T.R. and R.E. McCabe. 1997. Recounting whitetails past. Pages 11–26 in: W. J. McShea, H.B. Underwood, and J.H. Rappole, editors. The science of overabundance: deer ecology and population management. Smithsonian Institution, Washington, D.C., USA.

McCullough, D.R. 1990. The George Reserve deer herd: population ecology of a K-selected species. Fifth edition. University of Michigan, Ann Arbor, Michigan, USA.

McNulty, S.A., W.F. Porter, N.E. Mathews, and J.A. Hill. 1997. Localized management for reducing white-tailed deer populations. Wildlife Society Bulletin 25:265–271.

Moen, A.N. and C.W. Severinghaus. 1981. The annual weight cycle and survival of white-tailed deer in New York. New York Fish and Game Journal 28:162–177.

Mertig, A.G. and M.H. Koval. 2001. Attitudes toward natural resources and their management: a report on the 2000 resource attitudes in Michigan survey. Michigan State University, Department of Fisheries and Wildlife and Department of Sociology. Report to the Michigan Department of Natural Resources Wildlife Division.

Mladenoff, D.J. and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the northern Great Lakes region: a re-examination and model simulation. Conservation Biology 7:889-900.

Nelson, M.E. and L.D. Mech. 1999. Twenty-year home-range dynamics of a white-tailed deer matriline. Canadian Journal of Zoology 77:1128–1135.

O'Connell, A.F. Jr., L. Elyse, and J. Zimmer. 1999. Annotated bibliography of methodologies to census, estimate, and monitor the size of white-tailed deer populations. National Park Service Technical Report NPS/BSO-RNR/NRTR/00-2.

Oyer, A.M. and W.F. Porter. 2004. Localized management of white-tailed deer in the central Adirondack Mountains, New York. Journal of Wildlife Management 68:257–265.

Ozoga, J.J., R.V. Doepker, and M.S. Sargent. 1996. Ecology and management of white-tailed deer in Michigan. Michigan Department of Natural Resources, Wildlife Report 3209, Lansing, Michigan, USA.

Panken, S.L. 2002. An examination of population-level quality indices as a measure of white-tailed deer herd condition in Michigan. Thesis, Michigan State University, East Lansing, MI, USA.

Porter, W.F., M.A. Coffey, and J. Hadidian. 1994. In search of a litmus test: wildlife management in U. S. National Parks. Wildlife Society Bulletin 22:301–306.

Porter, W.F., N.E. Mathews, H.B. Underwood, R.W. Sage, Jr., and D.F. Behrend. 1991. Social organization in deer: implications for localized management. Environmental Management 15:809–814.

Riley, S.J., D.J. Decker, J.W. Enck, P.D. Curtis, T.B. Lauber, and T.L. Brown. 2003. Deer populations up, hunter populations down: implications of interdependence of deer and hunter population dynamics on management. Ecoscience 10:356–362.

Riley, S.J., W.F. Siemer, D.J. Decker, L.H. Carpenter, J.F. Organ, and L.T. Berchielli. 2003. Adaptive impact management: an integrative approach to wildlife management. Human Dimensions of Wildlife 8:81–95.

Rupp, S.P., W.B. Ballard, and M.C. Wallace. 2000. A nationwide evaluation of deer hunter harvest survey techniques. Wildlife Society Bulletin 28:570–578.

Sage, R.W., W.F. Porter, and H.B. Underwood. 2003. Windows of opportunity: white-tailed deer and the dynamics of northern hardwood forests of the northeastern US. Journal for Nature Conservation 10:213–220.

Severinghaus, C. W., and A. N. Moen. 1983. Prediction of weight and reproductive rates of a white-tailed deer population from records of antler beam diameter among yearling males. New York Fish and Game Journal 30: 30–38.

Starfield, A.M., and A.L. Bleloch. 1991. Building models for conservation and wildlife management. Second edition. Burgess International Group, Edina, Minnesota, USA.

Stedman, R.C., D.R. Diefenbach, C.B. Swope, J.C. Finley, A.E. Luloff, H.C. Zinn, G.J. San Julian, and G.A. Wang. 2004. Integrating wildlife and human-dimensions research methods to study hunters. Journal of Wildlife Management 68:762–773.

Steinhauer, J. 2005. When the Joneses wear jeans. The New York Times. 29 May 2005; section A:1.

Tierson, W.C., G.F. Mattfeld, R.W. Sage, Jr., and D.F. Behrend. 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. Journal of Wildlife Management 49:760–769.

United States Department of the Interior. 1998. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Michigan. U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census, Washington, D.C., USA.

Vieira, M.E.P., M.M. Conner, G.C. White, and D.J. Freddy. 2003. Effects of archery hunter numbers and opening dates on elk movement. Journal of Wildlife Management 67:717–728.

Van Deelen, T.R., H. Campa III, M. Hamady, and J.B. Haufler. 1998. Migration and seasonal range dynamics of deer using adjacent deeryards in northern Michigan. Journal of Wildlife Management 62:205–213.

Van Deelen, T.R. and D.R. Etter. 2003. Effort and the functional response of deer hunters. Human Dimensions of Wildlife 8:97–108.

Warren, R.J. 1997. The challenge of deer overabundance in the 21st century. Wildlife Society Bulletin 25:213–214.

Woolf, A. and J.L. Roseberry. 1998. Deer management: our profession's symbol of success or failure? Wildlife Society Bulletin 26:515–521.

Yaffee, S. L. 1999. Three faces of ecosystem management. Conservation Biology 13:713-725

Forests for Dinner: Exploring a Model of How Deer Affect Advance Regeneration at Stand and Landscape Scales

Joseph P. LeBouton
Michigan State University Department of Forestry

Joseph P. LeBouton[1,2], Edward J. Laurent[3,4], Michael B. Walters[2], Jianguo Liu[4]
[1]Corresponding author: J.P. LeBouton Email: lebouton@msu.edu
[2]Michigan State University Department of Forestry
[3]North Carolina State University, Southeast Gap Analysis Project
[4]Michigan State University, Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife

---

Abstract: *White-tailed deer herbivory is widely perceived by forestry professionals to be the leading cause of regeneration failure in managed uneven-aged forests in the Eastern United States. However, few studies have examined the chain of processes that link deer density, landscape structure, herbivory, and forest composition and structure. In this paper we identify and quantify some of these linkages in northern hardwood stands within a ~400,000 acre study area in Michigan's western Upper Peninsula. In this region we found that winter deer density in a focal northern hardwood stand could be predicted by distance to winter thermal cover (i.e. conifer forest). However, observed browse damage to tree seedlings in a stand was not a simple function of winter deer density whether measured overall or subset by tree species. We tested seedling stem density in three height categories representing browse-susceptible (0.5 to 1.5m tall), browse-marginal (1.5 to 2.5m tall), and browse-escaped (2.5 to 5.5 m tall). Overall stem density remained constant in the browse-susceptible size class, and decreased with increasing observed browse damage in the taller height classes. Analyzed by species, stem density in each of these height categories generally decreased for Acer saccharum, a preferred-browse species, and generally increased for Ostrya virginiana, a non-preferred species, with increasing average browse damage at the stand level, and also with increasing local deer density. In summary high deer browse pressure decreases the recruitment of tree seedlings to taller height classes and changes the composition of the seedling community to less preferred browse species.*

Introduction

White-tailed deer herbivory is widely perceived by forestry professionals to be the leading cause of regeneration failure in managing uneven-aged forests in the Eastern United States. There are scores of studies that quantify the effect of deer presence and absence on forest vertical structure. These studies mainly document two effects of deer herbivory: regeneration failure (Bowles and Campbell 1993;Kittredge and Ashton 1995;Anderson and Loucks 1979;Anderson and Katz 1993;Strole and Anderson 1992), and shifts in the understory species composition of local vegetation communities (Alverson et al. 1988;Waller and Alverson 1997;Stromayer and Warren 1997;Augustine et al. 1998;Tilghman 1989). Mainly these studies have either used exclosures to contrast 'ambient' deer density with zero deer density, or have contrasted forest characteristics in high-deer-density vs. low-deer-density landscapes. Few studies have quantified the sensitivity of forest vegetation to a continuous range of deer densities (but see (Tilghman 1989), and no study of which we are aware has examined the processes that link deer density, landscape structure, herbivory, and vegetation community composition and structure. This information is important because real forested landscapes are characterized by broad ranges of deer densities that are highly variable spatially, and deer density impacts on forest regeneration are likely best described as a continuous function. In other words, forest managers are not confronted with decisions based on the homogeneous presence of high deer densities or absence of deer. Instead they confronted with questions like 1) how many deer is too many to regenerate desirable species at sufficient densities? and 2) how does proximity of a managed stand to winter deer yards influence deer density and thus browsing pressure on regeneration.

In this paper we identify and quantify some of the linkages among deer, landscapes, and vegetation. Quantifying these linkages is critical to understanding whether, why, and how deer affect plant communities including advance reproduction in uneven-aged forest silvicultural systems. By extension, a quantitative understanding of these mechanisms may shed light on how best to work with and limit negative deer impacts on vegetation in an environment of high deer density.

Hypotheses

We propose a conceptual model for studying deer-forest interactions, and specifically the effect of deer herbivory in uneven-aged northern hardwood forests (

Figure 1). The conceptual model identifies the specific core factors that we hypothesize to drive deer-landscape-vegetation interactions in these forests. We hypothesize that:

1. Local deer density within a given northern hardwood forest stand is driven by the amount of winter thermal cover nearby;
2. Browse damage to seedlings and saplings is correlated with local deer density;
3. Deer browse intensity varies with tree species;
4. Seedling densities in critical height classes within a stand are negatively correlated with deer density and deer browse intensity;
5. The correlation between stem density in critical height classes and deer density varies with species.

Methods

We collected field data on vegetation community structure and composition in northern hardwood forest between 2001 and 2003. White-tailed deer fecal pellet density was surveyed on transects surrounding the vegetation plots, and was used as an index of deer use of local landscapes between 2002 and 2004. We used landcover map developed for the state of Michigan from classified satellite imagery (Space Imaging Solutions 2001) as a measure of landscape composition. Data were analyzed using least squares regression available in the R open source statistical package (R Development Core Team 2004). Detailed methods are as follows.

Study Area and Study Sites

The study region comprises ~400,000 ha in the Upper Peninsula (UP) of Michigan (Figure 2). The region was chosen to focus on a primarily forested region with a minimum of intensive human land uses such as agriculture, urban, suburban, or rural settlements see (Laurent et al. In Press). The primary land use in the study area is forest management for timber products.

A total of 145 study plots located in northern hardwood forest were surveyed for vegetation characteristics and fecal pellet group density in 2002, 2003, or 2004 (see Laurent et al. In press). In general, we used a stratified random procedure to select study sites as follows. In a GIS environment (ArcView 3.2) we randomly selected landscape units (LU) of either USGS quarter-quarter quads or General Land Office survey sections (2002 and 2003). Within each randomly chosen LU, plots of 30m radius chosen for vegetation sampling based on ownership, land cover, and proximity to other sampled plots. Survey plots encompassed a 30-m radius area to roughly match the spatial resolution of a single pixel of Landsat 7 ETM+ imagery (used to classify land cover) sensed over plot centers. The specific plot selection was made in the field using the criterion that a hypothetical 30-m x 30-m square could be placed anywhere within the plot and perceived by the field crews as having the same vegetation structure and composition as a similar square placed anywhere else within the plot.

Deer Density Data

Fecal pellet counts provided a convenient and spatially explicit index of deer density across a landscape (Litvaitis et al. 1996). White-tailed deer fecal pellet group deposition rates are affected by time of year, food availability, weather, stress, and in general the health of a deer herd (Litvaitis et al. 1996). Despite these many complicating factors, a simple approach to estimating deposition rates may be sufficient for many purposes (Hill 2001). However, the index is not comparable to a true estimate of population sizes across deer range, which requires more detailed demographic data.

There are several factors that need to be measured or assumed in order to use fecal pellet counts as a spatially precise estimate of deer density. These include: 1) the rate of production of pellet groups (pellet groups/deer/day), 2) the period of time over which they are deposited; and 3) the degree to which deer deposit fecal pellet groups randomly with respect to their daily movements. For example,(McCain 1948) estimated that mean deer pellet deposition is 13.4 pellet groups/day in Michigan, while (Fuller 1991) used 33 pellet groups/day in Minnesota. In this paper we use the Michigan figure of 13.4 pellet groups/day because it allows comparison with State of Michigan deer population calculations based on historical Michigan Department of Natural Resources (MDNR) pellet group surveys.

At each of 145 study plots with deciduous or mixed forest types, we positioned and surveyed ten transects arranged in a “bow tie” configuration established within a 155m radius of the plot center (7ha, Figure 1c).. Each of the ten transects measured 50x4m (0.02ha). Within each fecal pellet group survey transect, we sampled pellet group density using a modification of the MDNR annual deer pellet sampling methodology that has been performed since 1959 (Hill 2001). We performed all surveys between April 30th and May 20th in three survey years (2002, 2003, and 2004), to represent winter deer density for the time period beginning with leaf-off and ending with counting date. Deer pellet density estimates from all ten transects were averaged to arrive at a deer density index for the landscape surrounding each vegetation plot.

Vegetation Data

We collected data on species, stem density, and stem height for understory woody vegetation >0.25m and <1.5m tall for each vegetation plot. Data were collected on a 3 by 3 grid of sample points located within a 30m radius of each plot center. N-tree distance sampling was used for tree density (Lessard et al. 1994). From each survey point within a plot, we measured the distance to the nearest 5 trees. Species, height, diameter at 10cm above the ground, and browse category (Table 1) were recorded for each of the 5 closest trees. Density estimates were generated following Lessard et al. (1994). Because many of the species encountered were present at a small subsample of sites, we used only the two most common species in these analyses: *Acer saccharum* (sugar maple) and *Ostrya virginiana* (ironwood).

Landscape Description

The land cover map was used to describe areas surrounding sampled plots. In ArcView 3.2, the distance from each vegetation plot center to the nearest conifer land cover was measured. This distance to conifer was used as the descriptor of the landscape context of each stand.

Deer Density vs. Distance Analyses

The relationship between local winter deer density and distance to the nearest conifer stand was analyzed in two different ways: 1) average deer density as a function of distance from the nearest conifer stand; and 2) maximum deer density in each of 16 distance categories (0-50m, 50-100m, …, 750-800m) as a function of distance from conifer. The first analysis assumes that distance to conifer is the main landscape factor; if this is the case, low deer density and high deer density areas should both be predicted equally well. The second analysis assumes that distance to conifer is a limiting factor only, and that deer require conifer in a mix with other resources. In this case, distance to conifer would be correlated with the upper limit of deer density at a site, but not necessarily with the lower limit of deer density.

<u>Results and Discussion</u>

1. Local deer density on a landscape was driven by the distance to winter thermal cover.

An analysis of observed deer density as a function of distance to coniferous forest showed that both average deer density (β=-0.004, R^2=0.03, p<0.001) and maximum deer density (β=-0.013, R^2=0.19, p=0.015) were negatively correlated with distance to conifer (Figure 3). While only 2.5% of the variation in average deer density was explained by distance to confer, 18% of the variation in maximum observed deer density in 50m distance categories was explained by distance to conifer cover. Thus, the maximum number of deer was highly sensitive to distance to conifer, but, at short distances to conifer deer numbers vary broadly, presumably because they are reacting to factors other than proximity to conifer at those distances.

2. Browse damage to seedlings and saplings was correlated with local deer density.

Browse damage of saplings <1.5m in height of all woody species showed a saturating response to deer density (Figure 4) because it increased rapidly with increasing deer density at low deer densities (0-5 deer/km^2), but increased more slowly (approaching a maximum of ~2.5) at deer densities >20/km^2 (Figure 4). The relationship was significant (p=0.018), but explained only 3.8% of the overall variation in browse index by using site-level winter deer density alone (Figure 4). Part of the difficulty with this analysis was that winter deer density is measured for a time period including only the previous winter, while the browse damage measurement effectively integrates any browse damage that has occurred over the life of the seedling being measured, which may be several years or even decades in the case of some species, depending on the stand.

3. Deer browse intensity varied with local deer density, but NOT with tree species.

Examining each species separately revealed that both *A. saccharum* (a preferred-browse species) and *O. virginiana* (a non-preferred browse species) exhibit a similar pattern of browse damage with increasing winter deer density (Figure 5). This is not intuitive, and indicates how little we really know about how deer affect different species on the ground. We had hypothesized that browse-preferred species such as *A. saccharum* would be more intensely browsed as deer density increased, while non-preferred browse species would not be as intensely browsed. However, the data indicate that both species respond similarly to increasing local winter deer density. This is a very interesting result, and requires further study. It suggests that browse damage occurs to both of these species equally, and is not limited mainly to purportedly preferred-browse species.

4. **Seedling densities in critical height classes within a stand were negatively correlated with deer density.**

Seedling density in the browse-susceptible height class (0.5 to 1.5m tall) was not affected by deer browse pressure (Figure 6a), but responded negatively to local winter deer density (Figure 6b). Seedling density decreased with increasing browse pressure in height classes recently escaped from deer browse pressure (1.5 to 2.5m tall, Figure 6c). However, stem density in this recent escape height class increased with local deer density from 6 to approximately 18 deer/km^2. At deer densities above 18/km^2, stem density in this 1.5 to 2.5m height class was virtually zero (Figure 6d). In the tallest sub-canopy height class (2.5 to 5.5m tall), stem density generally decreased with browse category (Figure 6e), and also decreased with deer density (

Figure 6f) except for the 18 deer/km^2 level. This result indicates that 18 deer/km^2 may be a threshold deer density, beyond which seedlings of any species are unable to grow quickly enough to escape deer browse pressure. Interestingly, this is the same threshold deer density observed by Tilghman (1989).

5.1 The correlation between deer density and stem density in critical height classes varied with species.

We compared stem density of two key overstory species to both observed browse damage to existing understory seedlings, and to observed local deer density. Stem density of *Acer saccharum* in the browse-susceptible height class decreased by more than half (from 5000 to 1800 stems/ha) as observed deer browse damage increased (

Figure 7a). In the same stands, stem density of *Ostrya virginiana* doubled (from 900 to 1800 stems/ha) over that same browse damage gradient (

Figure 7b). In the recently escaped height class, *A. saccharum* showed no change in stem density with increasing browse pressure (

Figure 7c), while *O. virginiana* increased 300% as average browse damage increased from <10% to >90% of available twigs (

Figure 7d). In the tallest height classes, *A. saccharum* again showed little decrease in stem density per ha as browse damage increased (

Figure 7e), while *O. virginiana* increased 600% as browse damage increased from <10% to >90% (

Figure 7f).

5.2 The correlation between browse damage and stem density in critical height classes varied with seedling species.

Comparison with observed local deer density returned less clear-cut results. *A. saccharum* density in browse-susceptible height class decreased from 0 to 18 deer/km^2, but increased greatly in the highest deer density stands (

Figure 8a). *O. virginiana* showed no change over that deer density gradient (

Figure 8b). Recently-escaped *A. saccharum* seedlings 1.5 to 2.5m tall decreased from an average of 125 stems/ha to less than 50 stems/ha (

Figure 8c). *O. virginiana* stem density in the same height class decreased from 160 to 40 stems/ha from 0 to 18 deer/km^2, but increased to 100 stems/ha in the highest deer density class (24 deer/km^2). However, the highest deer density class was represented by only two sites, so may not have been a reliable estimate of actual behavior of the deer-forest system.
In summary, browse intensity was more highly correlated with seedling densities in these height classes than is local deer density. This was likely because the browse damage measurement takes into account damage from previous seasons as well as the year in which it was measured, but local deer density is specific only to the year in which it was measured. Tree seedlings exist in the understory for many years, so browse damage was probably a better measure of long-term deer effects on tree regeneration than was the local density of deer in any given year.

Summary and Conclusions

Four of our five hypotheses were corroborated by our data: 1) local winter deer density is greater in stands near to winter thermal cover; 2) browse damage to seedlings is greater with higher deer density; 4) Seedling density decreases with browse category and deer density in all height classes considered; and 5) the relationship of stem density to deer density and to deer browse varies with tree species observed. Contrary to the third hypothesis, the correlation between browse damage and local winter deer density did not appear to vary by tree species. However, it appeared that deer do affect vertical structure (i.e., stem density in different height classes) and species composition of the vertical structure regardless of whether deer browsed different species at different intensities.

Based on these results, it appears likely that deciduous forest stands near to conifer stands may be characterized by a distinctive vertical structure such as a higher density of seedlings in the height class 0.5 to 1.5m tall, and a lower density of saplings in taller height classes (1.5 to 5.5m tall). It is also possible that a change in species composition will be caused by high deer density, resulting in stands with more *O. virginiana* and less *A. saccharum* in the understory, and eventually in the overstory, in landscapes where deer density is high. Nevertheless, not one of these relationships explains a large percentage of the variation in stem density.

There are several possible reasons for this which require further study. Stand productivity (e.g., site index or Habitat Type) was not considered in this study, and may have an important bearing on the composition, density and growth rates of regenerating trees. Likewise, stand history was not accounted for in this study, other than to limit the study to stands between 20 and $31 m^2$/ha (90 and $140 ft^2$/acre) basal area. Higher density of seedlings and saplings is expected for some successional stages than for others. A third important consideration is how these relationships vary across the study region; for example, is distance to conifer more important in areas where there is less conifer (e.g., western Marquette county) and less important where conifer is very common on the local landscape (e.g., northern Menominee county)? Is conifer more important in the snow belt than in the southern part of the landscape?

Finally, deer density and deer browse data used here were gathered over a very short time, and represent a snapshot of the state of the forest between 2001 and 2004. Seedlings of the tree species we studied often occupy the forest floor for decades, and deer populations fluctuate annually and across decades. Even as we try to understand and document the present relationship between deer and tree seedling dynamics, we should acknowledge that the relationship itself is the summation of forest management, wildlife management, and natural disturbance regimes superimposed on a landscape over a century or more. Therefore the relationships between wildlife and forest management is a response to several dynamic forces, including forest and wildlife management strategies themselves. The interactions between wildlife and forest vegetation are complex, and may not always be intuitive. Thus careful observation and tracking of the results of management activities must be conducted, and the assumptions behind management decisions need to be reevaluated frequently to ensure that both forestry and wildlife goals can be met.

Acknowledgements

For funding: Michigan DNR FMFM and Wildlife Divisions, the McIntyre-Stennis Cooperative Forestry Initiative, and the USDA managed ecosystems program.

For technical assistance: R. Doepker, B. Hasse, H. Hill, O. Jacob, G. Wykoff.

For countless hours of blood, sweat, and tears in the field and lab: A. Chediack, M.E. Daniels, S. Kissman, K. Campbell, H. Todd, R. Bernard, L.. Gilner, P. Nagelkirk, R. Nagelkirk, T. Balk, K. Dougherty, N. Brown, A. Levine, A. Keavey, M. Straus, E.-M. Morriset, C. Cox, M. Covell, D. Morrison, E. Leachman, Y. LeBouton-Chediack, F.T. Browny, M.M. Merenguito, and L. Jane.

Tables and Figures

Table 1. Browse category explanation. Browse category is measured on individual seedlings (45 seedlings/plot). It represents the proportion of twigs and branches on each seedling that show evidence of deer browse divided by the total number of twigs/branches on the seedling.

Browse Category	%Browse
0	0 to 1
1	1 to 10
2	10 to 50
3	50 to 90
4	90 to 99
5	100

Table 2. Regression results for models of local deer density as a function of distance to conifer. The model of average deer density includes all sites. The model of maximum deer density includes the site within each 50m distance category in which the maximum deer density was observed.

y	Beta	R2	p-value
Distance (average deer density)	-0.004	0.026	<0.001
Distance Category (maximum deer density)	-0.013	0.188	0.015

Table 3. Regression of Michaelis-Menton (saturation) function results to predict browse category. Vmax=1, k=1.

<table>
<tr><th>Coefficients:</th><th>Estimate</th><th>Std.Error</th><th>t value</th><th>Pr(>|t|)</th><th></th></tr>
<tr><td>(Intercept)</td><td>1.5740</td><td>0.2169</td><td>7.258</td><td>4.37e-11</td><td>***</td></tr>
<tr><td>pred</td><td>1.0058</td><td>0.4211</td><td>2.389</td><td>0.0185</td><td>*</td></tr>
</table>

Signif. codes: 0 `***' 0.001 `**' 0.01 `*' 0.05 `.' 0.1 ` ' 1
Residual standard error: 0.725 on 119 degrees of freedom
Multiple R-Squared: 0.04575,   Adjusted R-squared: 0.03773
F-statistic: 5.705 on 1 and 119 DF, p-value: 0.01849

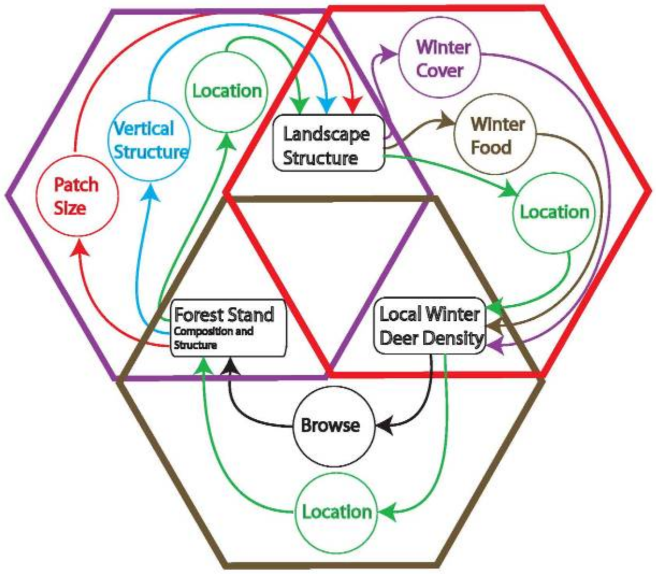


Figure 1. *Conceptual model of pathways among landscape characteristics, winter deer density, and forest stand structure and composition.*

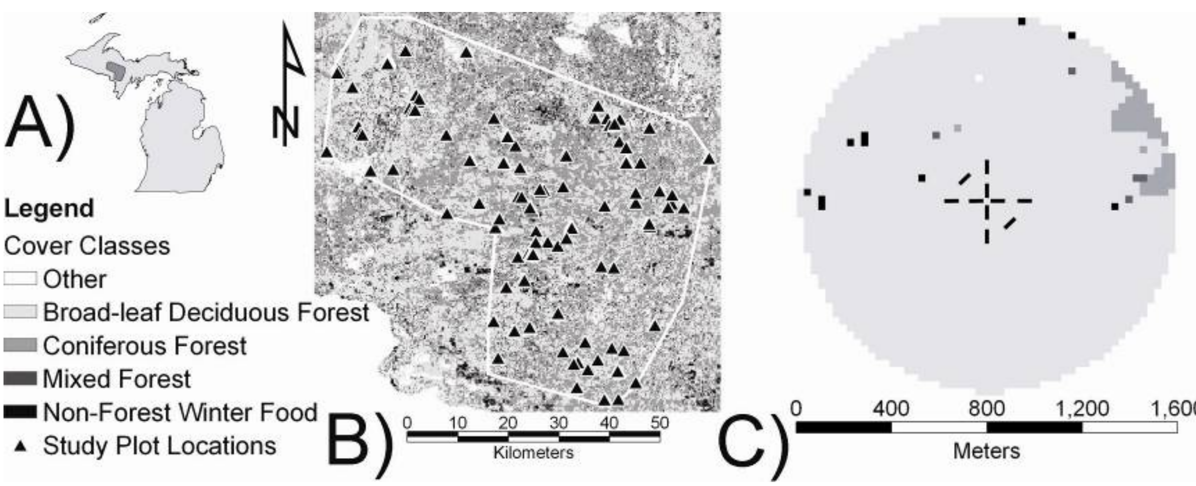


Figure 2. *Study area. A) Location of study area in Upper Peninsula of Michigan, USA. B) Locations of study sites within study area. C) Example 800m radius landscape with deer pellet transect locations. Vegetation plot is located in the center of the deer pellet transect.*

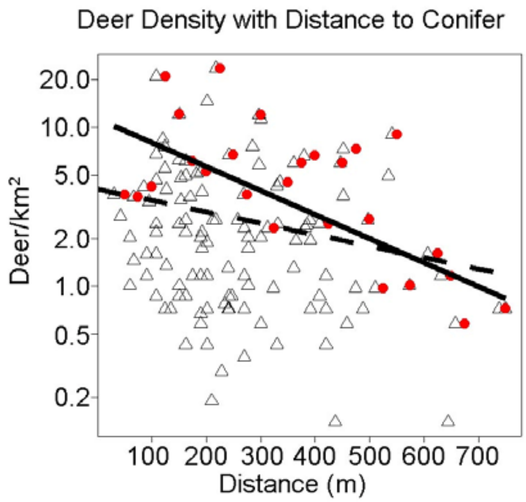


***Figure 3**. Local winter deer density response to distance from conifer land cover. Open triangles and dashed line indicate relationship of deer density to distance for all sites. Filled circles and solid line indicate highest deer density observed within each of sixteen 50m distance categories. Distance is treated as an ordinal variable in this analysis.*

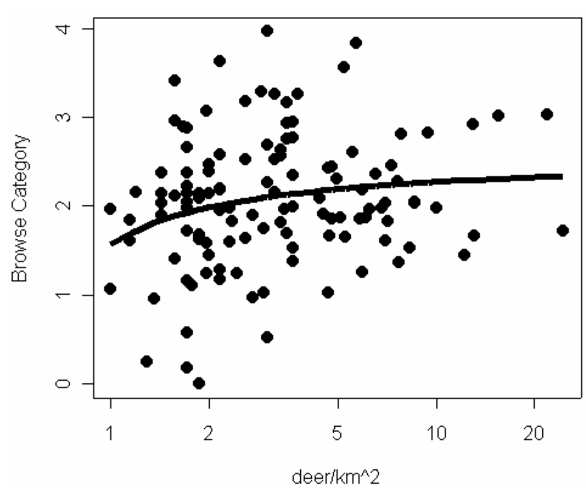


***Figure 4**. Browse index vs. winter deer density follows a Michaelis-Menton model with maximum expected browse index = 2.5 (i.e., Vmax + regression intercept), and the critical density (k) = 1 deer/km^2. Browse index of 2.5 corresponds to 10-50% of available twigs being browsed.*

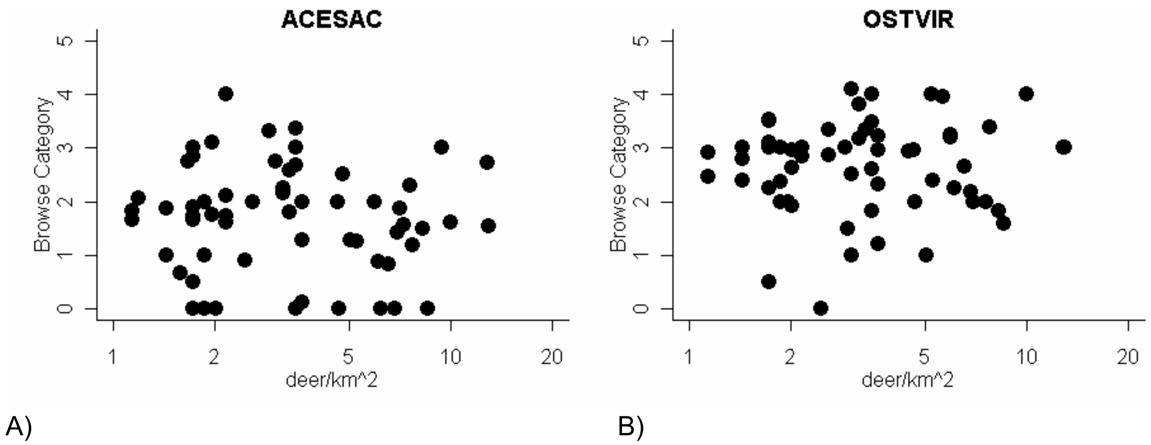


***Figure 5**. Biplots of browse damage occurring to seedlings <1.5m tall of Acer saccharum and Ostrya virginiana across a range of local winter deer densities. Local deer density alone is not a good predictor of local browse damage.*

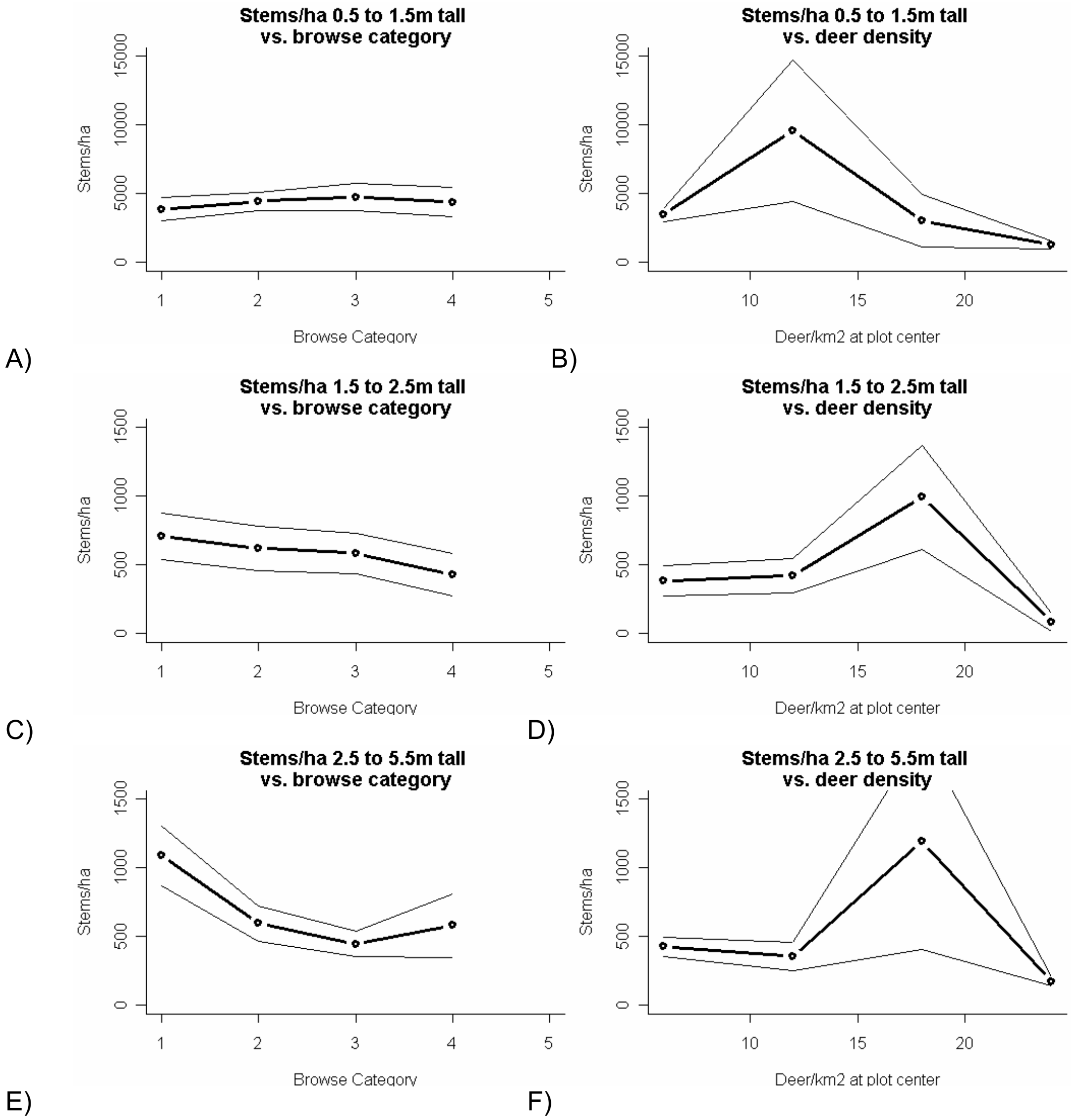


Figure 6. *Seedling density in three height classes vs average browse intensity category across all seedlings >0.5 and <1.5m tall. Sample size n = 25, 76, 77, and 21 sites for browse categories 1, 2, 3, and 4, respectively. For deer density data, n = 85,16, 3, and 3 sites, respectively, for 0, 12, 18, and 24 deer/km^2, respectively. Thick lines are the average stem density per site within each browse category or deer density category; thin lines are one standard error of the mean above and below the mean value. Browse damage measurements account for seedling damage due to deer that occurred several years prior to the measurement. We assume that the browse damage assessment, as an indicator of past as well as present browse pressure, indicates conditions that were prevalent during the time the taller height class tree seedlings (i.e., those >1.5m tall) were within browse range (i.e., 0.5-1.5 m tall.) In contrast, deer density represents only the previous year's condition (though it may indicate a long-term local trend in deer density).*

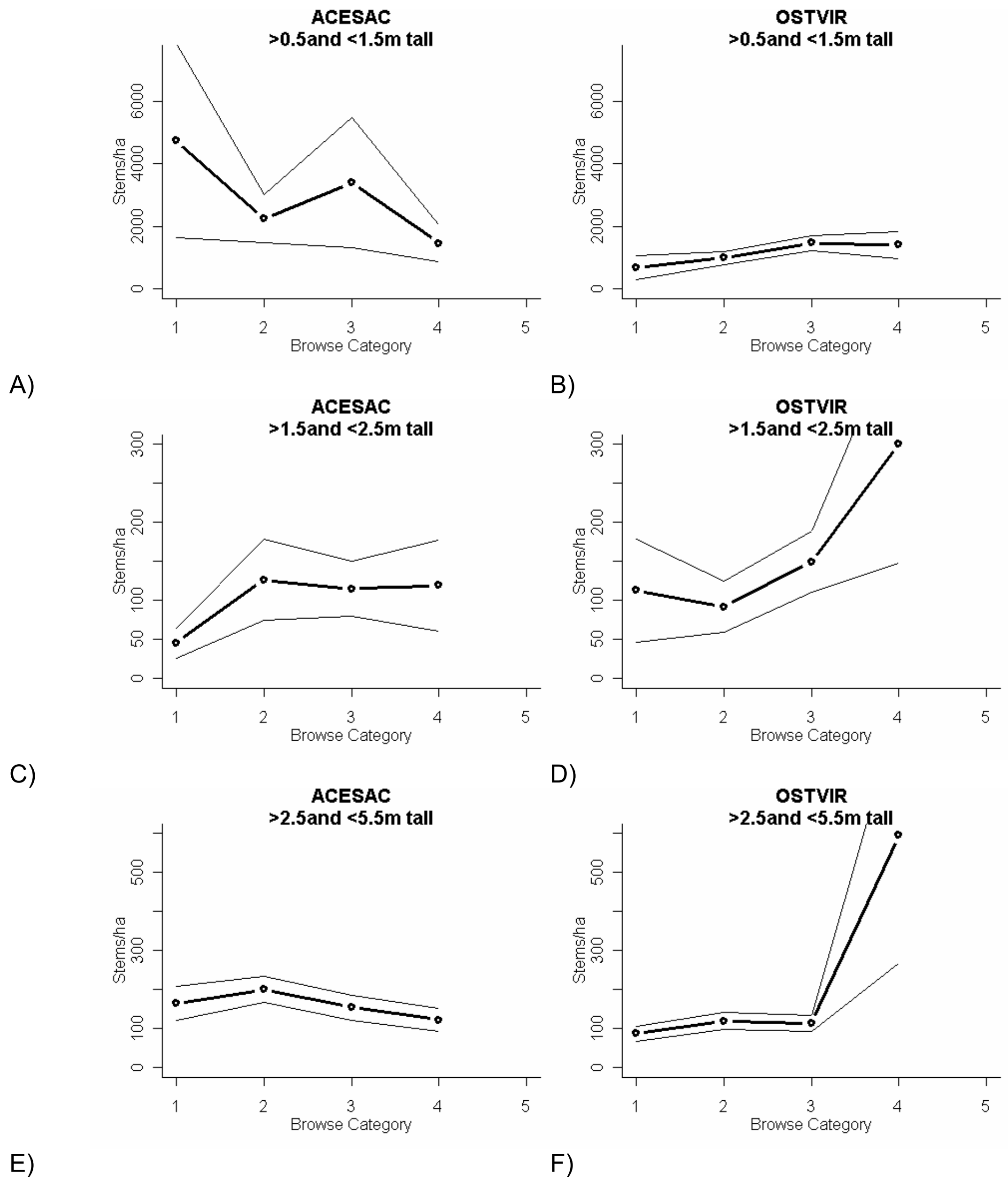
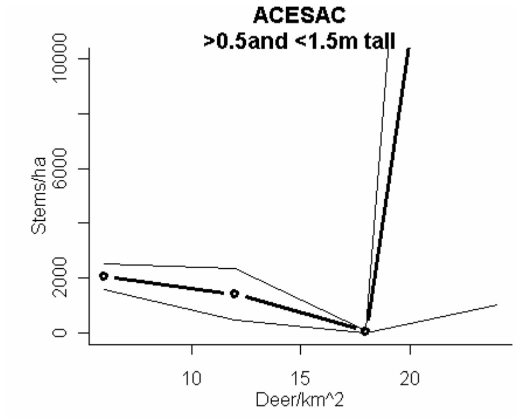
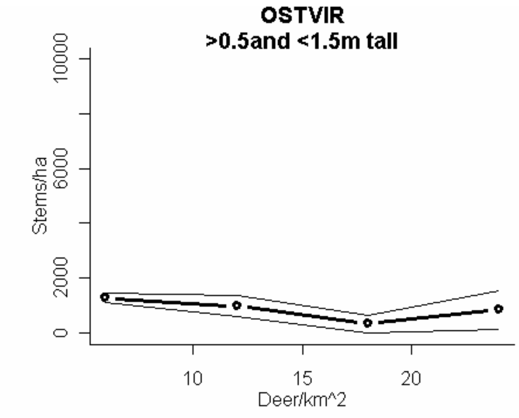


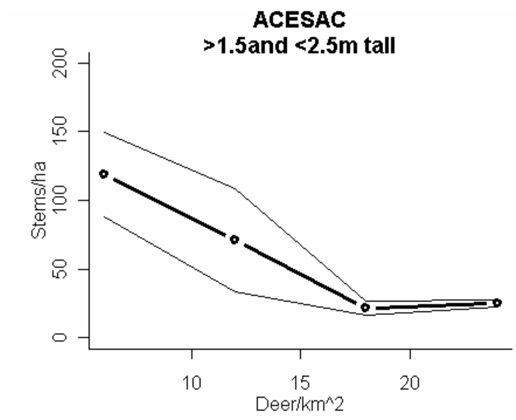
***Figure 7**. Stem density for three height classes of Acer saccharum and Ostrya virginiana in relation to site-average browse category. Sample size n=5, 48, 57, and 16 for browse categories 1, 2, 3, and 4, respectively. Thick solid lines are the average stem density per site within each browse category or deer density category; thin lines are one standard error of the mean above and below the mean value. See Figure 6 legend for details regarding browse category assumptions.*



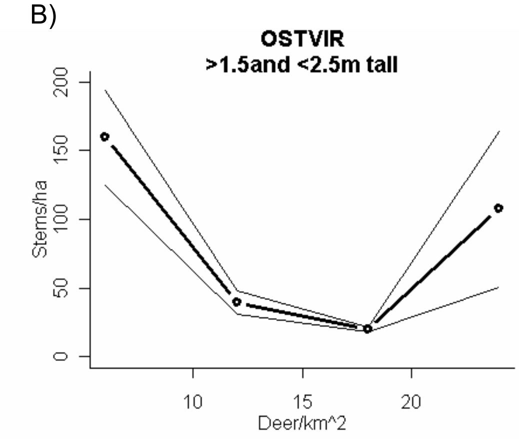
A)



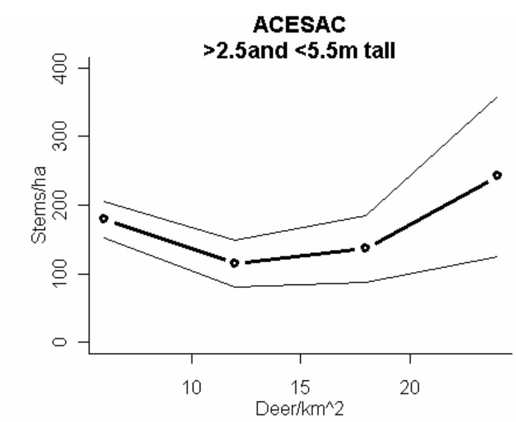
B)



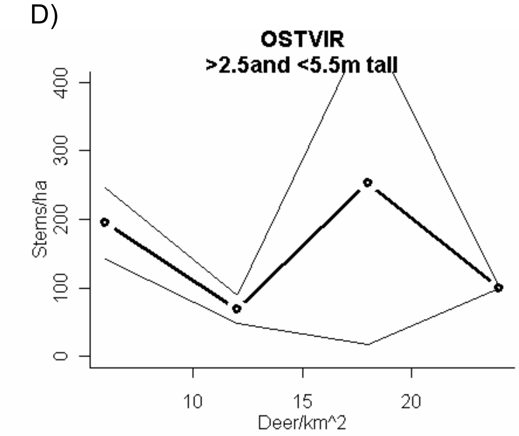
C)



D)



E)



F)

***Figure 8**. Stem density of three height classes of seedlings and saplings in relation to local winter deer density. Sample size n=103, 12, 2, and 2 for both species in deer density categories 0-6, 6-12, 12-18, and 18-24, respectively. Thick solid lines are the average stem density per site within each browse category or deer density category; thin lines are one standard error of the mean above and below the mean value.*

Literature Cited

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forests too deer - edge effects in northern Wisconsin. Conservation Biology 2: 348-358.

Anderson, R.C. and O.L. Loucks. 1979. White-tailed deer (Odocoileus virginianus) influence on structure and composition of *Tsuga canadensis* forests. Journal of Applied Ecology 16: 855-862.

Anderson, R.C. and A.J. Katz. 1993. Recovery of browse-sensitive tree species following release from white-tailed deer *Odocoileus virginianus Zimmerman* browsing pressure. Biological Conservation 63: 203-208.

Augustine, D. ., L.E. Frelich, and P.A. Jordan. 1998. Evidence for two alternate stable states in an ungulate grazing system. Ecological Applications 8: 1260-1269.

Bowles, G.H. and J.M. Campbell. 1993. Relationship between population density of white-tailed deer and the density of understory trees in forests of Erie County, PA. Journal of the Pennsylvania Academy of Science 67: 109-114.

Fuller, T.K. 1991. Do pellet counts index white-tailed deer numbers and population-change. Journal of Wildlife Management 55: 393-396.

Hill, H.R. The 2001 deer pellet group surveys. 2001. Michigan Department of Natural Resources, Lansing, Michigan.

Kittredge, D.B. and P.M.S. Ashton. 1995. Impact of deer browsing on regeneration in mixed stands in southern New England. Northern Journal of Applied Forestry 12: 115-120.

Laurent, E.J., H. Shi, D. Gatziolis, J.P. LeBouton, M.B. Walters, and J. Liu. In Press. Using the spatial and spectral precision of satellite imagery to predict wildlife occurrence patterns. Remote Sensing of Environment .

Lessard, V., D.D. Reed, and N. Monkevich. 1994. Comparing N-tree distance sampling with point and plot sampling in northern Michigan forest types. Northern Journal of Applied Forestry 11: 12-16.

Litvaitis, J.A., K. Titus, and E.M. Anderson. 1996. Measuring vertebrate use of terrestrial habitats and foods. In T.A. Bookhout [ed.], Research and Management Techniques for Wildlife and Habitats 254-274. The Wildlife Society, Bethesda, MD.

McCain, R. 1948. A method for measuring deer range use. Transactions of the North American Wildlife Conference 13: 431-441.

R: A language and environment for statistical computing. R Development Core Team. 2004. Vienna, Austria. R Foundation for Statistical Computing.

Space Imaging Solutions. Integrated forest monitoring assessment and prescription: IFMAP. Space Imaging Solutions. 2001. Pacific Meridian Resources. Ann Arbor, Michigan.

Strole, T.A. and R.C. Anderson. 1992. White-tailed deer browsing: Species preferences and implications for central Illinois forests. Natural Areas Journal 12: 139-144.

Stromayer, K.A.K. and R.J. Warren. 1997. Are overabundant deer herds in the eastern United States creating alternate stable states in forest plant communities? Wildlife Society Bulletin 25: 227-234.

Tilghman, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53: 524-532.

Waller, D.M. and W.S. Alverson. 1997. The white-tailed deer: A keystone herbivore. Wildlife Society Bulletin 25: 217-226.

Cost-share Programs, Deer Habitat Enhancement, and PNIF Implications

Thomas Ward[1]
USDA Natural Resources Conservation Service

[1]*State Forester, Michigan Natural Resource Conservation Service, 3001 Coolidge Road, Suite 250, East Lansing, MI 48823 Email: tom.ward@mi.usda.gov*

Background

Government cost-share programs provide both financial and technical assistance to Private Non-Industrial Forest (PNIF) landowners. Practices like "wildlife food plots" have been designed specifically to benefit white-tailed deer. Conifer tree plantations have been established to provide winter thermal cover for deer. Forest stand improvement (or "timber stand improvement") has been used to create openings, improve deer visibility, and generally design the perfect deer stand. Are state and federal cost-share programs still being used to improve habitat for white-tails? How do program managers steer assistance away from wildlife species that don't need it and toward those that do? A look at a few of the more well known programs that address wildlife habitat will give an idea of present program direction.

The Landowner Incentives Program (LIP)

Administered by the Michigan Department of Natural Resources (MDNR), the purpose of LIP is to "…enhance, restore, and protect wetland and grassland habitats for species at risk." LIP provides private landowners with advice, management plans, technical and financial assistance to: plant prairies, restore wetlands, remnant prairies and savannas, remove invasive species, and conduct prescribed burns on grasslands and wetlands. LIP also assists in establishing or restoring jack pine habitat on the Northern Lower Peninsula and mesic conifers on the Upper Peninsula. Although deer may benefit indirectly from LIP projects the focus of the program is providing habitat for rare, endangered, or declining wildlife species.

Partners for Fish and Wildlife

Administered by US Fish and Wildlife Service, Partners for Fish and Wildlife provides technical and financial assistance for habitat restoration and improvement projects on private lands. The Partners Program focuses on improving habitat for federal trust resources: migratory birds, federally-listed endangered or threatened species, and inter-jurisdictional fish. In Michigan, restoration of wetlands has been, and remains, the primary focus for the Partners Program. The program also includes restoration of grasslands, streams (both in the channel and within the riparian corridor), and specific habitats used by federally-listed endangered or threatened species. Although Partners for Fish and Wildlife is not mandated to work only on rare and declining species and habitats, it is clearly focused on wildlife species other than white-tailed deer.

Conservation Reserve Program (CRP)

Administered by the USDA Farm Service Agency (FSA), with some technical assistance from USDA Natural Resources Conservation Service (NRCS) and MDNR, the purpose of CRP is to "… *establish long-term, resource conserving covers on eligible farmland*." CRP goals include reducing soil erosion, protecting water and air quality, restoring wetlands, and improving wildlife habitat. Wildlife habitat goals include "…*establishing vegetative covers defined as best suited for wildlife*." Wildlife vegetative covers must "…*generally meet multiple seasonal (e.g. nesting cover, winter cover) requirements for wildlife of* *local or regional concern*". Another wildlife goal of CRP is "Sensitive wildlife ecosystem restorations", specifically "…*wetland restoration, wildlife corridors, riparian buffers, longleaf pines and rare and declining habitats*." Ranking criteria are used to emphasize plant species composition and seed mixes that most favor priority wildlife. The Hardwood Tree Planting practice (CP3A), for example, awards the most points to applicants who include at least 3 mast-producing species in their tree plantations. Wildlife Food Plots (CP12), on the other hand, cannot earn an applicant additional points. Since CRP is very competitive, food plots will not help an applicant qualify for the program. In addition, food plots must conform to the NRCS Upland Wildlife Habitat Management standard, which emphasizes wildlife species diversity and pre-settlement vegetation establishment. Food plots are only eligible in conjunction with certain other CRP practices, most of which call for native grasses and deciduous trees and shrubs. Food plots are limited in size (no more than 10% of a field, a maximum of 5 acres). Cost-share is not available for establishment of wildlife food plots. Can deer habitat be established through CRP? Perhaps, but the program is clearly directed toward other, less common habitats and wildlife species.

Environment Quality Incentives Program (EQIP)

Administered by NRCS, EQIP resource concerns for Michigan include: threatened, endangered, or special concerns species systems, integrated (into cropland) wildlife management systems, riparian corridor management systems, and forestry systems. The wildlife emphasis in EQIP is on creating wildlife habitat in areas (particularly cropland) where there is presently little or none. The wildlife species targeted for habitat creation are described as "threatened, endangered, or of special concern". White-tailed deer would not fit this description in most Michigan counties, so obviously EQIP is aimed at other species and habitats.

Wildlife Habitat Incentives Program (WHIP)

Administered by NRCS, the purpose of WHIP is to create or enhance wildlife habitat on non-cropland systems (as opposed to EQIP, which is directed at cropland systems). WHIP in Michigan is focused on specific Priority Habitats: herbaceous habitats (grassland prairies, savannas, and barrens), aquatic buffers (adjacent to wetlands, streams, and water bodies), forestland expansion or improvement, and habitats preferred by threatened or endangered species. Cost-share for annual food plots is explicitly excluded from WHIP.

To summarize the direction of the programs described above, assistance is being focused as much as possible on specific rare or declining habitats, which in turn most favors rare and declining wildlife species that utilize these habitats. The means used to focus assistance includes clear descriptions of the plant species composition, hydrology and landscape location of individual practices, using ranking criteria to favor certain practices (e.g. warm season grass plantations) and limiting other practices (e.g. annual food plots). Its been pointed out that despite the best intentions many cost-shared practices will still benefit deer, but other wildlife species may be even more benefited.

The dilemma facing agency personnel who administer cost-share programs is how to respond to a PNIF owner who seeks assistance in establishing practices specifically to favor deer. NRCS uses a conservation planning process that requires identification of all resource concerns on each tract. If deer impacts can be identified, such as browse lines and lack of forest regeneration, during the resource inventory process, the landowner can be introduced to the idea that maybe the deer population does not need to be increased. In the conservation planning process several alternatives can be developed to address the identified resource concerns. Alternatives can include practices that favor wildlife species other than deer. Finally, if deer habitat improvement is still the goal, the conservation planner can point out that the forestry/wildlife assistance programs in most cases can't help because they are not targeted at white-tailed deer. Even if the landowner is willing to proceed without program assistance a conservation planner can explain that workload and agency policy makes technical assistance for deer habitat a low priority. It may be some time before a site visit or conservation plan can be completed. Although it's a subtle, voluntary process a good conservation planner is often able to assist a PNIF landowner to identify and begin to address resource concerns, even if the resource concerns, such as deer impacts, are not at first fully appreciated.

References

Conservation Reserve Program (CRP) Fiscal Year 2003 Program Summary, *www.fsa.usda.gov/dafp/cepd/stats/FY2003.pdf*

Environmental Quality Incentives Program (EQIP), 2005, *www.mi.nrcs.usda.gov/programs/eqip2003.html*

Partners for Fish and Wildlife, Working Together to Restore Habitat *www.fws.gov/partners*

USDA-NRCS electronic Field Office Technical Guide (eFOTG): *http://efotg.nrcs.usda.gov/treemenuFS.aspx?Fips=26065&MenuName=menuMI.zip*

Wildlife Habitat Incentives Program (WHIP) *www.mi.nrcs.usda.gov/programs/whip.html*

Ecological Impacts of Deer Overabundance on Temperate and Boreal Forests

Jean-Pierre Tremblay[1]
University of Laval, Quebec

Presentation of the review: **Ecological Impacts of Deer Overabundance** *2004 by Annual Reviews. All rights reserved. First published online as a Review in Advance on June 10, 2004*

Reprinted with permission from the Annual Review of Ecology, Evolution, and Systematics. Volume 35 2004 by Annual Reviews www.annualreviews.org

Steeve D. Cote,[1] Thomas P. Rooney,[2] Jean-PierreTremblay,[1] Christian Dussault,[1] and Donald M. Waller[2]

[1]Chaire de Recherche Industrielle CRSNG-Produits forestiers Anticosti, Departement de Biologie and Centre d'etudes nordiques, Universite Laval, Quebec G1K 7P4, Canada;
email: steeve.cote@bio.ulaval.ca, jean-pierre.tremblay@bio.ulaval.ca, christian.dussault@fapaq.gouv.qc.ca
[2]Department of Botany, University of Wisconsin, Madison, Wisconsin 53706; email: tprooney@facstaff.wisc.edu, dmwaller@wisc.edu

---

Abstract: *Deer have expanded their range and increased dramatically in abundance worldwide in recent decades. They inflict major economic losses in forestry, agriculture, and transportation and contribute to the transmission of several animal and human diseases. Their impact on natural ecosystems is also dramatic but less quantified. By foraging selectively, deer affect the growth and survival of many herb, shrub, and tree species, modifying patterns of relative abundance and vegetation dynamics. Cascading effects on other species extend to insects, birds, and other mammals. In forests, sustained overbrowsing reduces plant cover and diversity, alters nutrient and carbon cycling, and redirects succession to shift future overstory composition. Many of these simplified alternative states appear to be stable and difficult to reverse. Given the influence of deer on other organisms and natural processes, ecologists should actively participate in efforts to understand, monitor, and reduce the impact of deer on ecosystems.*

Key Words *browsing, Cervidae, forest regeneration, herbivory, plant-herbivore interactions*

INTRODUCTION

Deer have excited the interest of ecologists since the birth of our discipline. Interest in managing game populations fostered the development of ecology, particularly the emergence of wildlife ecology (Leopold 1933). Deer management began with understanding which habitat conditions were most favorable for deer. Later, ecologists became interested in the effects of predators and hunters on deer and in the effects of deer on plant populations and habitat conditions. Ironically, within a century, deer management has reversed course from a preoccupation with aug-menting population growth through habitat protection, hunting regulations, and predator control to serious concerns about how best to limit deer densities and the consequentimpactsoftheseanimalsonotherecosystemconstituentsandfunctions (Garrott et al. 1993).

Overabundance is a value judgment that has a clear meaning only when placed in a specific context (McShea et al. 1997b). Caughley (1981) proposed a series of definitions to summarize the ecological and nonecological values upon which overabundance diagnostics have been based: Animals are overabundant when they:

(*a*) threaten human life or livelihood, (*b*) are too numerous for their "own good,"
(*c*) depress the densities of economically or aesthetically important species, or
(*d*) cause ecosystem dysfunction.

Here, we follow this sequence and explore some of the human-deer conflicts implicit in points (*a*) and (*c*). We then emphasize point (*d*) throughout the review and show that negative effects of abundant deer occur at various densities in different habitats. The density-dependent effects on life-history traits implicit in point (*b*) are not addressed here, but see McCullough (1979, 1999) for more information.

We review some historic studies of the impact of overabundant deer and sum-marize how shifts in habitat conditions and levels of predation have boosted deer population growth in many temperate ecosystems. We explore how overabundant deer affect human health, forestry, and agriculture and describe the various methods used to evaluate how deer affect tree seedlings, shrubs, and herbaceous plants. We consider how deer alter interactions among competing plants; patterns of forest regeneration; succession; populations of insects, birds, and other mammals; ecosystem processes; and overall community structure. The number and significance of these effects make clear that deer can tip forest ecosystems toward alternative states by acting as "ecosystem engineers" or "keystone herbivores," greatly affecting the structure and functioning of temperate and boreal forests (McShea & Rappole 1992, Stromayer & Warren 1997, Waller & Alverson 1997). These profound impacts lead us to ponder how ecology might inform approaches to mitigating the effects of overabundant deer. We discuss how ecological research might be extended and linked more tightly to deer management. Because space and our expertise are limited, we focus our attention on interactions between deer (family Cervidae) and temperate/boreal forests, primarily in Europe and North America.

HISTORICAL INTEREST IN DEER IMPACTS ON PLANT COMMUNITIES AND ECOSYSTEM STRUCTURE

By the nineteenth century, natural historians recognized that overabundant deer could exclude certain plants from the landscape (Watson1983).Systematic studies of deer overabundance, however, did not occur until after the emergence of wildlife ecology, developed by Aldo Leopold. Based on his experiences with the dangers of deer overabundance, Leopold was the first to discuss threats posed by growing deer herds (Leopold 1933, Leopold et al. 1947). Leopold's warnings sparked an initial period of concern in the 1940s and 1950s, mainly in the midwestern United States, which prompted the construction of exclosures to demonstrate the influence of native deer on forest regeneration (Beals et al. 1960, Pimlott 1963, Stoeckler et al. 1957, Webb et al. 1956). Interest in deer impacts expanded in the 1970s, primarily in the Midwest and the Allegheny region of Pennsylvania (Anderson & Loucks 1979, Behrend et al. 1970, Harlow & Downing 1970), but with added attention to the introduced Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in the Queen Charlotte Islands of Canada (Pojar et al. 1980). Concerns about the impact of native deer populations in Europe (Dzieciolowski 1980) and introduced deer in New Zealand (Caughley 1983, Stewart & Burrows 1989) developed at the same time.

Seminal experiments on the population dynamics of white-tailed deer (*Odocoileus virginianus*)on the George Reserve in Michigan were conducted in the 1970s (McCullough 1979). The introduction of deer into a fenced area demonstrated that, because deer have such a high potential rate of increase, they can easily overwhelm the carrying capacity of their environment and consequently have strong and persistent negative impacts on vegetation (McCullough 1979, 1997).

In North America, the study of deer impacts soon broadened to include birds (Casey & Hein 1983), interactions with weeds (Horsley & Marquis 1983), and long-term effects on forest composition (Frelich & Lorimer 1985) and sapling-bank diversity (Whitney 1984). By the late 1980s and early 1990s, the impacts resulting from high densities of deer were being tallied in review articles (Alverson et al. 1988; Gill 1992a, b; McShea & Rappole 1992; Miller et al. 1992). Broad considerations of deer impacts also emerged in the 1994 conference hosted by the Smithsonian Institution (McShea et al. 1997b) and a 1997 special topics issue of the *Wildlife*

Society Bulletin (Vol. 25, No. 2). Similar recent review issues of *Forestry* (2001, Vol. 74, No. 3) and *Forest Ecology and Management* (2003, Vol. 181, No. 2–3) focused mostly on how deer affect European forests.

CAUSES OF DEER OVERABUNDANCE

Overexploitation in the second half of the nineteenth century led to major declines in deer numbers and range. Subsequent protection of deer via restricted seasons and game laws then led to rapid population increases across Europe and North America over the past 75 to 150 years (Fuller & Gill 2001, Jedrzejewska et al. 1997, Leopold et al. 947, McShea et al. 1997b, Mysterud et al. 2000). In Virginia, white-tailed deer increased from an estimated 25,000 animals in 1931 to 900,000 animals by the early 1990s (Knox 1997). Although whether North American deer are currently more abundant than before European colonization is not known, the evidence suggests that current deer numbers are unprecedented (McCabe & McCabe 1997).

Deer populations in North America have grown rapidly since the 1960s to 1970s in response to changes in their environment and reduction of hunting pres-sure (McShea et al. 1997b). The number of moose (*Alces alces*) in Scandinavia has similarly increased three to five times since the 1970s (Skolving 1985, Solberg et al. 1999). Deer densities above 10/km^2 are now common throughout temperate zones (Fuller & Gill 2001, Russell et al. 2001). In North America, deer have been reintroduced in many states (McShea et al.1997b) and introduced to islands free of predators (e.g., Anticosti, PQ, Canada) (Cote et al. 2004). These introductions contributed to the recovery and subsequent overabundance of deer populations (Knox 1997).

The most obvious factor contributing to the rapid growth of deer populations is increased forage. Widespread agricultural and silvicultural activities considerably improved deer habitat throughout the twentieth century (Alverson et al. 1988, Fuller & Gill 2001, Porter & Underwood 1999). Tree planting after logging and early successional forested landscapes provide abundant, high-quality food that increases deer habitat carrying capacity (Bobek et al. 1984, Fuller & Gill 2001, Sinclair 1997). Forest harvesting and the resulting interspersion of habitats provide good cover and abundant forage for deer (Diefenbach et al. 997). Many openings are also intentionally managed to boost forage quality and population growth (Waller & Alverson 1997).

Reductions in hunting and natural predators across Europe and North America have also contributed to increasing deer populations. Since the1920s, strict hunting regulations in North America have favored deer population increases, especially on some private lands and in parks where hunting was banned (Brown et al. 2000, Diefenbach et al. 1997, Porter & Underwood 1999). Even where hunting is allowed, game laws favor the killing of males, increasing female survival and, thus, population growth (Ozoga & Verme 1986, Solberg et al. 1999). In recent decades, the pressure has increased to reform game laws to allow hunting of more does and fawns in response to overabundant herds. Hunters, however, have been reluctant to embrace such reforms (Riley et al. 2003). The number of deer hunters has also stabilized or decreased with declines in the social acceptability of hunting (Brown et al. 2000, Enck et al. 2000, Riley et al. 2003). At the same time, land owners and municipalities increasingly prohibit hunting in response to safety concerns (Kilpatrick et al. 2002), which further diminishes hunting pressure (Brown et al. 2000).

By the middle of the twentieth century, wolves (*Canis lupus*) had disappeared from continental Europe and most areas south of the North American boreal forests (Boitani 1995, Paquet & Carbyn 2003). Mountain lions (*Puma concolor*) were also extirpated in eastern North America (McCullough 1997). Without predators, ungulate populations increase rapidly to (or beyond) the carrying capacity of available forage (McCullough 1997, Messier 1994, Potvin et al. 2003, Sæther et al. 1996). Their high intrinsic rate of population increase may also allow deer to escape predator control while making overshoot of habitat carrying capacity and fluctuations in population size more likely. Moderate climates as experienced recently may also contribute to deer overabundance (Forchhammer et al. 1998, Solberg et al. 1999). Mild winters increase deer body mass (Mysterud et al. 2001) and winter survival (Loison et al. 1999), which favor population growth.

SOCIAL AND ECONOMIC CONSEQUENCES OF DEER OVERABUNDANCE

Impacts on Human Activities

Deer generate both positive and negative economic values, and negative values increase as deer become overabundant (Conover 1997). Browsing of tree seedlings by deer reduces economic value, ecological stability, and species diversity of forests, in addition to reducing tree growth, which, in turn, diminishes protection from erosion and floods (Reimoser 2003). The total cost of deer damage to the forest industry is difficult to estimate. The loss of young trees, for example, results in long-term economic losses only if the composition and quality of the final stand are affected. Despite the apparent severity of deer damage to agriculture and forestry in Britain, the economic significance is considered negligible or small in many cases (Putman 1986, Putman & Moore 1998). In contrast, deer damage is considered a major problem in the United States and in Austria, where their annual impacts are estimated at more than $750 million (Conover 1997) and more than 220 million (Reimoser 2003), respectively. In northern temperate forests, saplings 30 to 60 cm tall are most vulnerable to browsing (Andren & Angelstam 1993, Gill 1992a, Kay 1993, Welch et al. 1991). Browsing by deer can kill seedlings or reduce height growth, which results in lower-density stands and requires longer stand rotations (Kullberg & Bergstrom 2001). Stands subjected to heavy browsing of seedlings and saplings exhibit a size structure biased toward medium and large stems (Anderson & Loucks 1979, Potvin et al. 2003, Stromayer & Warren 1997, Tilghman 1989). When the terminal bud is browsed, the tree develops multiple leaders (Putman & Moore 1998), which decreases its commercial value. Lavsund (1987) indicated that the proportion of quality stems dropped from 63% to 18% in a stand subjected to heavy browsing by moose in Sweden. Bark stripping may kill trees but often decreases quality by girdling, growth reduction, and increased risk of fungal infections (Gill 1992b, Putman & Moore 1998).

Reimoser (2003) suggested that the severity of damage to trees depends more on forest attractiveness to deer than on deer abundance. Stands become more susceptible to deer damage with (*a*) a low density of alternate food plants (Gill 1992a, Partl et al. 2002, Welch et al. 1991), (*b*) a low density of seedlings (Andren & Angelstam 1993, Lyly & Saksa 1992, Reimoser & Gossow 1996), (*c*) abundant nitrogen in the foliage or soil (Gill 1992a), (*d*) hiding cover (Gill 1992a, Kay 1993, Partl et al. 2002), and (*e*) the presence of edges (Kay 1993, Lavsund 1987, Reimoser & Gossow 1996). On larger scales, deer impacts on vegetation are greater in fragmented landscapes (Hornberg 2001, Reimoser 2003) or low-productivity habitats (Danell et al. 1991).

White-tailed deer damage many agricultural crops in the United States (Conover 2001). In 1996, 14% of nursery owners in the northeastern United States reported damages exceeding $10,000 (Lemieux et al. 2000). Deer damage to corn fields in the United States was estimated at 0.23% of the total production ($26 million) in 1993 (Wywialowski 1996). Abundant deer also damage gardens and ornamentals (McCullough et al. 1997, West & Parkhurst 2002). Deer damage to households and agriculture in the United States totaled $351 million in 1991 (Conover 1997).

A primary cost to society of deer overabundance is increased vehicle accident rates, now a serious problem in Europe, the United States, and Japan. Deer-vehicle collisions increase as deer density and traffic volume increase (Groot Bruinderink & Hasbrouck 1996). Groot Bruinderink & Hazebroek (1996) estimated that 507,000 collisions between vehicles and ungulates occur annually in Europe (excluding Russia) and result in 300 deaths, 30,000 injuries, and $1 billion in material damage. In the United States, such accidents increased from 200,000 in 1980 to 500,000 in 1991 (Romin & Bissonette 1996) and cost more than $1 billion in 1991 (Conover 1997). Many airports in Canada and the United States also experience deer-aircraft problems (Bashore & Bellis 1982, Fagerstone & Clay 1997).

Transmission of Wildlife Diseases and Zoonoses

In general, high population densities of deer favor the transmission of infectious agents (Davidson & Doster 1997). Increased deer densities appear to increase the transmission of tick-borne zoonoses directly by increasing tick (*Ixodes* spp.) abundance (Ostfeld et al. 1996, Wilson & Childs 1997). In North America, two tick-borne diseases threaten human health: Lyme disease and ehrlichiosis (<5% mortality in humans) (Telford III 2002). Lyme disease has quickly become the most common vector-borne disease in the United States (13,000 cases in 1994; Conover 1997) and is also found in Europe and Asia (Steere 1994). The incidence of Lyme disease appears to track deer density in the eastern United States (Telford III 2002; Wilson et al. 1988, 1990).

Deer transmit infectious agents directly to other deer, to livestock, and to humans, especially if deer density is high. Bovine tuberculosis (*Mycobacterium bovis*) causes mortality in deer, livestock, other wildlife species, and humans (Schmitt et al. 1997). *M. bovis* affects deer populations of New Zealand and Europe to various degrees (Clifton-Hadley & Wilesmith 1991). It has been rare in North America, but incidence could increase as deer densities increase (Schmitt et al. 1997). A recent outbreak in Michigan led to concern that it would spread to domestic cattle and to a ban on deer feeding (Miller et al. 2003).

Chronic wasting disease (CWD) is a transmissible spongiform encephalopathy similar to "mad cow" disease (Williams et al. 2002). The disease was first noticed in 1967 in mule deer (*Odocoileus hemionus*) and has now spread to elk (*Cervus elaphus*), white-tailed deer, and black-tailed deer across a broad region (Figure 1) (Williams et al. 2002). The pattern of spread

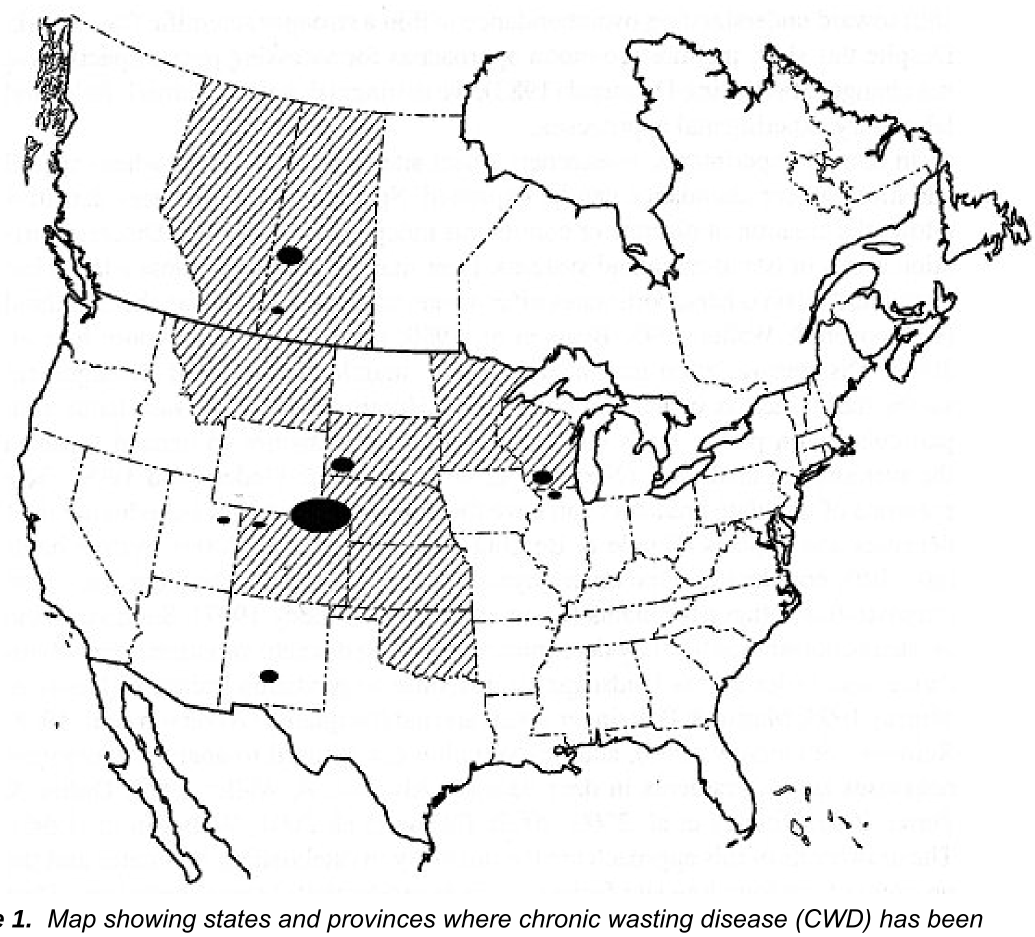


***Figure 1.** Map showing states and provinces where chronic wasting disease (CWD) has been found in wild deer or elk populations or in captive herds across North America. Note the association between captive animals with CWD and escape into the wild.*

suggests that the disease may be transmitted from farm-raised herds (25 identified with CWD by 2002) to wild animals (Williams et al. 2002). Although it can be transmitted within and among cervid species (Gross & Miller 2001), transmission to humans or noncervid species appears unlikely (Raymond et al. 2000). Because it develops slowly, it would not appear to limit population growth greatly, but some experts express concern that it could cause population extinctions (Williams et al. 2002). Concerns over potential human health risks from CWD could also substantially reduce hunter efforts, which already appear too low to control deer populations effectively (see the Management Issues section).

ASSESSING ECOLOGICAL EFFECTS OF DEER OVERABUNDANCE

Through most of the twentieth century, research focused on how deer affected particular species of interest (often trees) or specific areas of concern. Because site-specific management concerns drove research programs, pseudoreplication was a common feature of early research (Hurlbert 1984). There has been a gradual shift toward understanding overabundance within a stronger scientific framework. Despite this shift, the most common approaches for assessing deer impacts have not changed. Following Diamond (1983), we distinguish among natural, field, and laboratory experimental approaches.

In natural experiments, researchers select sites and collect data where spatial variation in deer abundance can be exploited. Spatial variation in deer densities allows the creation of discrete or continuous independent variables. Discrete variation arises in island-mainland systems. Deer may be absent on some islands but overabundant on others; both states offer a contrast to populations on the mainland (Balgooyen & Waller 1995, Beals et al. 1960, Cote et al. 2004, Vourc'h et al. 2001). Discrete variation may also appear in mainland systems if management varies starkly across ownership boundaries. Hunting bans on private lands and, particularly, on public lands can cause population densities to exceed those in the surrounding landscape (Nixon et al. 1991, Porter & Underwood 1999). The presence of ungulate predators can have the opposite effect; that is, reducing deer densities and impacts (Ripple & Beschta 2003, White et al. 2003). Within habitats, cliffs, boulder tops, and other physical features of the environment can create ungulate-free refuges for plants (Long et al. 1998, Rooney 1997). Such variation creates opportunities to study deer impacts by using discrete variation. Deer abundance also varies across landscapes in response to predation pressure (Lewis & Murray 1993, Martin & Baltzinger 2002) and habitat quality (Alverson et al. 1988, Reimoser & Gossow 1996), and this variation can be used to analyze ecosystem responses across gradients in deer density (Alverson & Waller 1997; Didier & Porter 2003; Rooney et al. 2000, 2002; Takada et al. 2001; Waller et al. 1996). The drawbacks of this approach are the difficulty in establishing replicates and the problem of confounding site factors (such as productivity) that themselves affect deer densities or responses to herbivory (Bergstrom & Edenius 2003).

The effects of overabundant deer on plants can also be studied across time. Vila et al. (2001, 2003), for example, tied browsing scars and historical variation in growth rates to fluctuating deer densities on the Queen Charlotte Islands, Canada. Before-and-after or snapshot-type studies have also been used to infer how species respond to fluctuating browsing pressure when baseline data exist (Husheer et al. 2003, Rooney & Dress 1997, Sage et al. 2003, Whitney 1984). Many such studies reflect conspicuous "signatures" of deer browsing as community composition shifts toward browse-tolerant or unpalatable species (Husheer et al. 2003). Long-term monitoring can, thus, provide powerful insights into how deer drive changes in plant communities, particularly when combined with exclosures or direct observations of which plants deer preferentially consume.

In field experiments, researchers manipulate deer densities or vegetation to study deer impacts. The use of fencing (exclosures) to exclude deer from study plots is a venerable experimental approach (Daubenmire 1940). Despite all the insights that exclosure studies bring to our understanding of deer-forest interactions, they are limited to binary treatments: They allow researchers to infer what alternate trajectory a site would take in the absence of deer. Controlled grazing experiments that utilize known deer density in enclosures appear more realistic and can be used to infer whole-community responses to manipulated deer densities (Cot et al. 2004, deCalesta 1994, Hester et al. 2000, Horsley et al. 2003, McShea & Rappole 2000, Tilghman 1989). Deer densities can also be manipulated through culling. Researchers can take advantage of culling efforts in parks and natural areas by monitoring vegetation or other response variables (Cooke & Farrell 2001). Direct manipulations of density through localized management can also be conducted under scientific objectives (Cote et al. 2004). Alternatively, vegetation can be subjected to experimental treatment. Simulated browsing treatments reveal how plants respond to defoliation in natural environments (Bergstrom & Danell 1995, Rooney & Waller 2001). Experimental plantings in conjunction with exclosures more accurately compare the effects of deer browsing on plant growth and mortality (Alverson & Waller 1997, Fletcher et al. 2001b, Ruhren & Handel 2003).

Laboratory experiments give researchers a high degree of control over experimental systems. Defoliation experiments can be conducted under a range of controlled environmental conditions in greenhouses or growth chambers to investigate the mechanisms of plant responses (Canham et al. 1994). Simulation models also allow researchers to forecast how deer might affect ecosystems under a broad range of deer-population and forest-management scenarios (Tremblay et al. 2004).

Each of these approaches has its strengths and weaknesses. Stronger inferences can be drawn when they are combined. Waller & Alverson (1997), for example, combined experimental plantings, exclosures, and geographic variation in deer densities to examine the effects of deer browsing on *Tsuga canadensis* growth and survival rates across a broad region. Augustine et al. (1998) combined exclosures, geographic variation in deer densities, and a simple plant-herbivore functional response model to predict time-to-extinction of forest herb populations as a function of initial abundance. Balgooyen & Waller (1995) and Martin & Balzinger (2002) compared plant responses across islands that varied in deer abundance because of hunting and introductions, both currently and historically. Meta-analysis can similarly strengthen our inferences. Gill & Beardall (2001) combined data from 13 studies to examine the effects of ungulate browsing on richness and diversity of tree species in British woodlands.

ECOLOGICAL CONSEQUENCES OF DEER OVERABUNDANCE

Plant Tolerance and Resistance to Herbivory

Deer directly affect the growth, reproduction, and survival of plants by consuming leaves, stems, flowers, and fruits. Plants defend themselves against herbivores in various ways that affect which plants are attacked, how they respond to those attacks, how herbivore individuals and populations respond to those defenses, and, ultimately, how herbivores affect ecosystem productivity and rates of nutrient cycling. Plants are often classified according to the degree to which they either resistherbivoryortolerateit.Resistantplantshavetraitsthatreduceplantselection (such as chemical defenses or low digestible content) or traits that reduce intake rates (such as leaf toughness or morphological defenses). Tolerant species can endure some defoliation with little change in growth, survival, or reproduction, whereas intolerant species are more sensitive to defoliation. In addition, woody plants often reduce their chemical and physical defenses as they grow beyond the range of mammal browsing (Bryant & Raffa 1995).

In environments with herbivores, natural selection should favor enhanced morphological and chemical defenses in plants with low tolerance. Takada et al (2001) examined populations of the shrub *Damnacanthus indicus* (Rubiaceae) in areas with and without deer. Individual plants in areas with deer increased allocation to thorns: Both spine thickness and density were greater where deer were present. Induced and constitutive chemical defenses can make plants less palatable to deer. Red deer (*Cervus elaphus*) tend to avoid *Picea sitchensis* saplings that have higher concentrations of monoterpenes in their foliage (Duncan et al. 2001). Vourc'h et al. (2001) demonstrated that *Thuja plicata* saplings growing on islands with-out deer had evolved lower concentrations of foliar monoterpenes than mainland saplings growing in areas with deer. The rapid evolution of reduced defenses in cases like these strongly implies that anti-herbivore defenses are costly in terms of energy (or fitness) in situations where herbivores are scarce or absent. In environments without herbivores, undefended plants outperform defended plants (Gomez & Zamora 2002). However, selection will rarely occur quickly enough to rescue palatable populations faced with sustained overabundant deer, especially in trees where reproducing individuals are not subjected to browsing.

Tolerance to herbivory differs among species and among individuals within species. It depends on the timing and intensity of herbivory (Doak 1992, Saunders & Puettmann 1999), individual plant genotype (Hochwender et al. 2000), specific growth strategies (Canham et al. 1994, Danell et al. 1994), history of past defoliation or other stress (Cronin & Hay 1996, Gill 1992b), the density of competitors, and the degree to which the plant is under nutrient or moisture stress (Canham et al. 1994, Maschinski & Whitham 1989). Plants that lose only a small fraction of their leaves or flowers, store resources underground, hide their meristems (as in grasses), or regrow quickly via indeterminate growth tolerate deer herbivory better (Augustine & McNaughton 1998). Such species include many annuals, graminoids, deciduous trees, and shrubs and many herbs and forbs that mature in late summer. Some of the browse-tolerant species even appear to gain more biomass (or more flowers and seeds) over the course of a season than undefoliated control plants (Hobbs 1996, McNaughton 1979, Paige & Whitham 1987). Increases in final biomass yield could reflect shifts in either allocation and growth form, increased photosynthetic rates, or both. Browsing alters plant growth forms when a single terminal leader is removed, apical dominance is broken, and axillary buds give rise to a profusion of branches. Photosynthetic rates rise when changes in the water balance of residual leaves lead to an increase in stomatal conductance and foliar concentrations of carboxylating enzymes (McNaughton 1983). Although such overcompensation might be temporary, plants such as graminoids no doubt thrive under repeated grazing. Other plants can compensate at low to moderate levels of defoliation but decline once herbivore densities are high (Bergelson & Crawley 1992). Plants may also reallocate resources to grow taller or shorter when browsed (Bergstrom & Danell 1995, Canham et al. 1994, Edenius et al. 1993, Saunders & Puettmann 1999). Compensatory growth, however, can limit radial growth and rarely appears under repeated and heavy browsing pressure. Trees with a history of browsing also appear more susceptible to new browsing, reflecting reduced reserves, changes in tree morphology, or both (Bergqvist et al. 2003, Danell et al. 1994, Palmer & Truscott 2003, Welch et al. 1992). Deer, however, often avoid previously browsed twigs, perhaps because of induced defenses (Duncan et al. 1998).

In general, slow-growing plants will tolerate browsing less, particularly if such browsing is repeated. Shady forest understory plants, including shade-tolerant shrubs and tree seedlings, may thus be particularly vulnerable to deer browsing. Small spring ephemeral and early summer forest herbs that lose all their leaves or flowers in a single bite and cannot regrow also tolerate herbivory poorly (Augustine & McNaughton 1998, Augustine & DeCalesta 2003). Browse-intolerant species such as *Trillium* regularly suffer low or negative growth after defoliation (Rooney &Waller 2001).

Browsing directly affects reproduction in many plants, particularly if deer preferentially forage on reproductive plants or consume flowers (Augustine & Frelich 1998). Individuals of some species may not flower again for several seasons after defoliation (Whigham 1990). Where deer are abundant, browse-intolerant herbs tend to be smaller, less likely to flower, and less likely to survive relative to plants in exclosures (Anderson 1994; Augustine & Frelich 1998; Fletcher et al. 2001a; Ruhren&Handel2000,2003). Overtime, the density of such intolerant plants tends to decline, and populations may be extirpated (Rooney & Dress 1997). Palatable herbs and shrubs such as *Taxus canadensis* remain susceptible to deer browsing throughout their lives and usually become more vulnerable to browsing as they grow larger. Deer forage selectively on the larger *Trillium grandiflorum* plants (Anderson 1994, Knight 2003). This foraging does not kill these plants because they have large, below-ground storage organs. However, defoliation often takes tall flowering stems and may cause the plants to regress in size (Knight 2003, Rooney & Waller 2001). Thus, populations subjected to abundant deer become both scarcer and dominated by small, often nonreproductive plants (Anderson 1994, Knight 2003).

Trees are obviously most vulnerable to herbivory as seeds (e.g., *Quercus* acorns), seedlings, or small saplings (Potvin et al. 2003). *Tsuga canadensis* seedlings and saplings have become scarce across much of their range in the upper Midwest in apparent response to deer browsing (Alverson & Waller 1997, Anderson & Katz 1993, Frelich & Lorimer 1985, Rooney et al. 2000, Waller et al. 1996). *Thuja occidentalis* is also disappearing from most sites in this region because deer have eliminated nearly every sapling taller than 30 cm (Rooney et al. 2002). Persistent mature trees could repopulate sites with new seedlings and saplings if browsing declined for some window of time, but this window may be as long as 70 years for slow-growing understory species such as *Tsuga* (Anderson & Katz 1993). Evergreen conifers may be particularly intolerant of browsing because they invest heavily in leaves, retain them, and do not retranslocate nutrients to stems and roots as much as deciduous species do (Ammer 1996). In addition, deer focus their browsing on evergreens in winter as other food becomes scarce.

Effects on Plant Community Structure and Interspecific Competition

Because deer forage selectively, they strongly affect competitive relationships among plant species. These shifts, in turn, may either increase or decrease overall cover and diversity. The result depends on whether or not deer primarily consume dominant species. Selective foraging on tall dominant plants in an alpine meadow favored short-statured plants, which caused species richness to increase (Schutz et al. 2003). On Isle Royale, Risenhoover & Maass (1987) attributed the higher diversity of woody vegetation in moose-browsed areas to increased light in the understory. Deer play a similar keystone role on other Lake Superior islands, where they can either enhance herbaceous plant cover and diversity (by removing *Taxus canadensis* cover) or reduce this cover and diversity as they become overabundant (Judziewicz & Koch 1993). Declines in plant cover and species richness usually occur once resistant or browse-tolerant species become dominant. Overabundant deer also commonly cause tree diversity to decline (Gill & Beardall 2001, Horsley et al. 2003, Kuiters & Slim 2002). We summarize contemporary browse-related compositional shifts in boreal and temperate forests in Table 1.

Table 1. Compositional shifts in dominant tree species induced by deer browsing in boreal and temperate forests.

Former dominant	New dominant	Source
Balsam fir (*Abies balsamea*)	White spruce (*Picea glauca*)	Brandner et al. 1990, McInnes et al. 1992, Potvin et al. 2003
Birch (*Betula* spp.)	Norway spruce (*Picea abies*)	Engelmark et al. 1998
Eastern hemlock (*Tsuga canadensis*)	Sugar maple (*Acer saccharum*)	Alverson & Waller 1997, Anderson & Loucks 1979, Frelich & Lorimer 1985, Rooney et al. 2000
Mixed hardwoods	Black cherry (*Prunus serotina*)	Horsley et al. 2003, Tilghman 1989
Oak (*Quercus* spp.)	Savanna type system	Healy et al. 1997
Scots pine (*Pinus sylvestris*)	Hardwoods and Norway spruce	Gill 1992b

Effects on Forest Succession

Contemporary models of succession include multiple directional pathways and alternative stable states that are dependent on the local abundance and colonization potential of species, competitive interactions, and disturbance regimes (Connell & Slatyer 1977, Glenn-Lewin & van der Maarel 1992). Sustained selective browsing can sway these factors enough to affect forest succession dramatically (Engelmark et al. 1998, Frelich & Lorimer 1985, Hobbs 1996, Huntly 1991). Succession accelerates if deer break up the vegetation matrix enough to favor the establishment of later successional plants (Crawley 1997, Hobbs 1996) or if deer prefer species from early seral stages (Seagle & Liang 2001). Alternatively, succession may be stalled if browsing reduces colonization, growth, or survival in later successional species (Hobbs 1996, Ritchie et al. 1998).

Effects on Ecosystem Properties

Byaffectingcompetitiveinteractionsamongplantswithvaryinglevelsofchemical defenses and by altering successional trajectories, deer alter ecosystem processes that include energy transfer, soil development, and nutrient and water cycles (Hobbs 1996, Paine 2000). When deer consume an amount of biomass that is small relative to the standing crop, as it is in grassland systems, effects on net primary productivity may be negligible or positive (Hobbs 1996). Thus, in open and productive grassland systems, grazing can increase primary production if grazing induces overcompensation in individual plants, favors more productive species, and accelerates soil processes (McNaughton 1979, 1983; Ritchie et al. 1998). Browsers accelerate nitrogen and carbon cycling if they increase the quantity and the quality of litter returned to the soil (Wardle et al. 2002). This phenomenon is more prevalent in nutrient-rich systems (Bardgett & Wardle 2003) or when deer browsing shifts the canopy composition from conifers to deciduous hardwoods (Frelich & Lorimer 1985). Browsing in early successional communities can also facilitate successional transitions toward nitrogen-fixing species such as *Alnus* sp. (Kielland & Bryant 1998). Animal excretion also increases nitrogen cycling and modifies its distribution across the landscape, which locally enhances availability (Bardgett & Wardle 2003, Singer & Schoenecker 2003). In some cases, the relative contribution of this source of nitrogen may be small compared with the adverse effects of browsing (Pastor & Naiman 1992, Pastor et al. 1993).

With an overabundant deer population, the biomass deer consume becomes large relative to standing crops, particularly in low-productivity environments such as forest understories (Brathen & Oksanen 2001). Thus, we generally expect deer to reduce productivity and decelerate nutrient cycling in forest ecosystems. Here, compensation is uncommon, growth rates are low, and deer browsing decreases the quality and quantity of litter inputs (e.g., Ritchie et al. 1998). Browsed forest plots generally show reductions in understory and woody biomass accumulation (Ammer 1996, Riggs et al. 2000). Similarly, if nitrogen limits productivity, converting plant communities from palatable, deciduous, nitrogen-rich species to species with low tissue nitrogen and more chemical defenses (e.g., conifers) will decelerate nutrient cycling as the quantity and quality of litter available to de-composers decline (Bardgett & Wardle 2003, Pastor & Naiman 1992, Pastor et al. 1993, Ritchie et al. 1998). Browsing has also been shown to reduce ectomycorrhizal infections, which amplifies reductions in nutrient intake (Rossow et al. 1997).

Cascading Effects on Animal Species

Deer exert cascading effects on animals both by competing directly for resources with other herbivores and by indirectly modifying the composition and physical structure of habitats (Fuller 2001, Stewart 2001, van Wieren 1998). For example, browsing by deer affects the population and community composition of many invertebrates, birds, and small mammals (Table2). Maximum diversity within a stand often appears to occur at moderate browsing levels (deCalesta & Stout 1997, Fuller 2001, Rooney & Waller 2003, Suominen et al. 2003, van Wieren 1998). Heavier browsing reduces vegetative cover and complexity in the understory, which often leads to reduced habitat availability for animals. Invertebrate and bird communities are sensitive to changes in forest understory, especially foliage density (McShea & Rappole 1997, Miyashita et al. 2004). Ungulates also disrupt associations of plants and pollinators by shifting patterns of relative flower abundance (Vazquez & Simberloff 2003). Few studies have experimentally manipulated deer densities, which makes drawing strong inferences about the relationship between animal diversity and deer density difficult. A notable exception is the study by deCalesta (1994) of songbirds, in which a controlled grazing experiment (Horsley et al. 2003) was used to demonstrate negative and nonlinear relationships between bird diversity and deer abundance.

By modifying species abundance and diversity, deer can modify trophic interactions among species. For example, deer potentially change the interactions between mast availability, small mammals, birds, and insects (McShea 2000, McShea & Schwede 1993, Ostfeld et al. 1996). Effects on interactions within the food web may be particularly important in ecosystems where several species of large herbivores coexist, such as in western North America, Spain, or the United Kingdom.

Table 2. Summary of studies addressing the effects of deer browsing on community structure of invertebrates, birds, and small mammals, using either experimental manipulation of deer browsing pressure (including exclosure studies) or field experiments with adequate replications.

Taxon/source	Forest type and site	Cervid species	Results	Comments
Invertebrates				
Bailey & Whitham 2002	*Populus tremuloides* grasslands (Arizona, US)	*Cervus elaphus*	Increase by 30% in arthropod species richness and 40% increase in abundance after intermediate-severity fire and browsing exclusion; 69% and 72%declines in richness and abundance, respectively, after high-severity fire and heavy browsing (n = 3)	
Baines et al. 1994	*Pinus sylvestris* coniferous forest (Scotland, UK)	*Cervus elaphus*	Higher abundance of most taxa in ungrazed sites (n = 8); 83% of variation in number of lepidopterous larvae explained by two indices of grazing intensity, mean annual rainfall, altitude, and tree density	
Danell & Huss-Danell 1985	*Betula pendula*, *Betula pubescens* boreal forest (Sweden)	*Alces alces*	Higher abundance of leaf-eating insects on moderately browsed birches	
Suominen et al. 1999a	*Pinus sylvestris* coniferous forest (Sweden)	*Alces alces*, *Capreolus capreolus*	Lower abundance and higher diversity of ground-dwelling insects in grazed sites in a productive location (n = 5); no consistent differences in abundance, species richness, and diversity between grazed and ungrazed sites (n = 4) in an unproductive location	High moose density; effect of browsing on plant community composition
Suominen et al. . 1999b	*Salix*. sp.—*Populus balsamifera* early successional boreal ,forest (Alaska, US)	*Alces alces*	Trends toward higher abundance and species richness of ground-dwelling insects in browsed sites (n=7), except for specialized herbivores (Curculionidae)	Moderate moose density
Suominen et al. 2003	*Pinus sylvestris or Betula pubescens or Picea abies* boreal	*Rangifer tarandus*	Higher abundance, species richness, and diversity of ground-dwelling beetles in grazed sites (n = 15 in four locations), except for unproductive sites where diversity was lower than in grazed sites	Large geographical extent

Wardle et al. 2001	forest (Finland) Southern temperate forest (New Zealand)		Lower abundance of microarthropods and macrofaunal groups in grazed sites(n = 30)	
Birds				
deCalesta 1994	*Prunus serotina*, *Acer rubrum*, *A. saccharum*, *Fagus grandifolia* northern hardwoods (Pennsylvania, US)	*Odocoileus virginianus*	Declines of 27% and 37% in species richness and abundance of intermediate canopy nesters between lowest and highest deer densities; no effect on ground and canopy nesters; density threshold between 7.9 and 14.9 deer/km^2	Controlled grazing experiment with four simulated densities
DeGraaf et al. 1991	*Quercus* sp. Dominated northern hardwoods (Massachusetts, US)	*Odocoileus virginianus*	Lower species richness and abundance of canopy feeders at higher deer density; lower migratory species richness and higher resident species richness in thinned stands with high browsing; no difference in omnivorous, insectivorous, and ground-feeding species richness and abundance (n = 12)	
McShea & Rappole 2000	*Quercus* sp. dominated mixed hardwoods (Virginia, US)	*Odocoileus virginianus*	Increased abundance of ground nesters and intermediate canopy nesters as understory vegetation resumed growth in exclosures (n = 4), but no increase in diversity because of species replacement	Exclosures of 20 to 40ha
Moser & Witmer 2000	*Pinus ponderosa* coniferous forest (Oregon, US)	*Cervus elaphus*	No difference in abundance, species richness and diversity between ungrazed (n = 3) and grazed (n = 3) sites	
Small mammals				
McShea 2000	*Quercus* sp. dominated mixed hardwoods (Virginia, US)	*Odocoileus virginianus*	Interaction between deer browsing and previous year acorn crop: higher *Tamias striatus* and *Peromyscus leucopus* abundance in exclosures (n	Exclosures of 20 to 40 ha
Moser & Witmer 2000		*Cervus elaphus*		

		= 4) after low-mast years, but no difference after good-mast years
	Pinus ponderosa coniferous forest (Oregon, US)	Higher abundance, species richness, and diversity in ungrazed (n = 3) than in grazed (n = 3) sites

Dynamics and Reversibility of Deer Impacts

Large herbivores have the ability to act as "biological switches" that move forest communities toward alternative successional pathways and distinct stable states (Hobbs 1996, Laycock 1991, Schmitz & Sinclair 1997). Models of forest dynamics also demonstrate how browsing by deer can alter the rate of succession (Seagle & Liang 2001), forest structure and composition (Kienast et al. 1999), successional pathways (Jorritsma et al. 1999, Tester et al. 1997), and ultimate stable states (Kramer et al. 2003). In classical succession models, the relation between deer browsing and plant abundance is gradual (Figure 2*a*) or sudden (Figure 2*b*) but in both cases, reversible. Unlike succession, however, alternative stable states are not readily reversible when the browsing pressure is reduced (Scheffer et al. 2001, Westoby et al. 1989). In Figure 2*c*, the system may not appear to change much as deer densities gradually increase. Then, a sudden transition may occur that sharply reduces plant population levels (or overall system diversity or productivity). Even dramatic declines in deer density at this point have little effect; recovery only occurs if deer densities remain low through some extended period of time and interventions favoring vegetation recovery are applied (May 1977, Scheffer et al. 2001, Schmitz & Sinclair 1997). By analogy with physical systems, such lags and history dependence are termed "ecological hysteresis." Such nonlinear dynamics have been described in range land pastures (May 1977, Laycock 1991, Lockwood & Lockwood 1993), savanna-woodland systems (Dublin 1995, Scheffer et al. 2001), and temperate and boreal forests (Augustine et al. 1998, Pastor et al. 1993).

Interactions with Predators

The role of predators in controlling ungulate populations remains uncertain, at least in some systems. Particular examples exist where the introduction of a predator did not, by itself, control ungulate populations. Wolves moving onto Isle Royale did not prevent moose overpopulation, food depletion, and a subsequent crash caused by starvation (Peterson 1999).

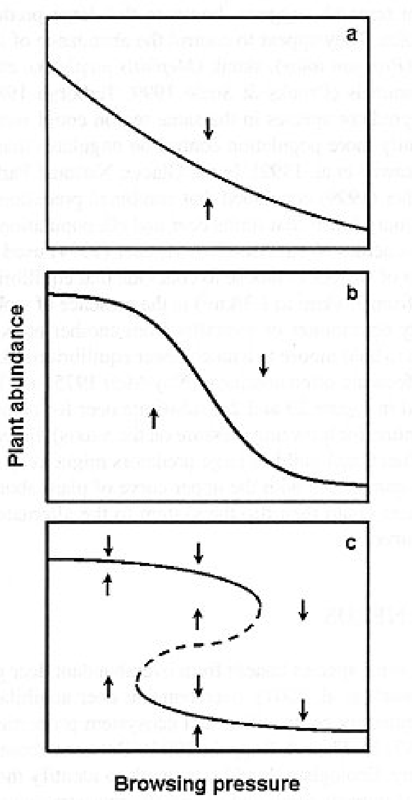


Figure 2. *Three hypothetical relationships between the abundance of a forage plant and deer browsing pressure. (a) Deer have only modest and monotonic effects on the population. (b)A reversible threshold exists beyond which plant abundance drops precipitously. (c) Browsing beyond a certain threshold point causes a nonlinear de-cline that is not simply reversible. The plant population requires a large (or pro-longed) reduction in browsing as well as a disturbance factor that promotes an increase of its abundance to recover. This requirement indicates an "alternate stable state." Arrows indicate dynamic changes at various points. Modified from Scheffer et al. (2001).*

Recent research suggests, however, that large predators play important eco-logical roles. They appear to control the abundance of the "mesopredators" [e.g., raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*), etc.] that prey on birds and small mammals (Crooks & Soule 1999, Terborgh 1988). The presence of two or more predator species in the same region could work synergistically to exert significantly more population control on ungulates than either alone could exert (e.g., Gasaway et al. 1992). In the Glacier National Park area, a study by Kunkel & Pletscher (1999) concluded that combined predation from cougar and wolves is the primary factor that limits deer and elk populations. Analyzing results from 27 studies across North America, Messier (1994) used functional and numerical responses of wolves to moose to conclude that equilibrial moose densities would decline (from 2.0/km2 to 1.3/km^2) in the presence of wolves. Furthermore, if habitat quality deteriorates or mortality from another predator increases, wolves are predicted to hold moose to a much lower equilibrium (0.2 to 0.4 moose/km^2). Predation effects are often nonlinear (Noy-Meir 1975) and involve lags in the manner illustrated in Figure 2*b* and 2*c* (substitute deer for plant abundance on the *y*-axis and predation for browsing pressure on the *x*-axis). Indeed, under a combined scenario, a functional guild of large predators might keep deer populations down to densities compatible with the upper curve of plant abundance in Figure 2*c*. Loss of predators could then flip the system to the alternate state represented by the bottom curve.

RESEARCH NEEDS

Whereas some species benefit from overabundant deer populations (Fuller & Gill 2001, Russell et al. 2001), overabundant deer annihilate many taxa, which disrupts community composition and ecosystem properties (Table 2) (deCalesta & Stout 1997, McShea & Rappole 1997). Between these extremes, we face much uncertainty. Ecologists should now work to identify threshold densities at which substantial impacts occur and devise effective strategies to limit deer impacts and sustain ecosystem integrity, i.e., the capacity of an ecosystem to preserve all its components and the functional relationships among those components following an external perturbation (sensu De Leo & Levin 1997; see also Hester et al. 2000, Scheffer & Carpenter 2003). Which species are affected by deer and at what densities? How fast do impacts occur? How quickly do plant populations, forest structure, and ecosystem processes recover? To what extent are deer populations and impacts constrained by food resources, predators, diseases, or hunting, and how do these limiting factors interact? This uncertainty places ecologists in an awkward position when they try to make deer management recommendations (see final section, (How) Can We Limit Deer Impacts?). Because forest communities can suffer long-term effects that are difficult to reverse, ecologists should make precautionary recommendations.

Given potential threshold effects and alternative stable states, how should we design our research? We need more controlled experiments that directly manipulate deer densities and other factors known to influence forest dynamics (e.g., logging) (Bergstrom & Edenius 2003, Fuller 2001, Healy et al. 1997, Hester et al. 2000, Hobbs 1996, Rooney & Waller 2003). Such experiments should span different forest types, which would allow us to predict how forest types will respond to variable deer densities (Hjalten et al. 1993, Riggs et al. 2000). We should also monitor both immediate and delayed effects and track dynamic responses to both increases and decreases in deer density. Results from such manipulations would allow us to identify what windows of low deer density are needed across space and time to allow deer-sensitive plants to persist or recover in the landscape (Sage et al. 2003, Westoby et al. 1989). Eventually, results from such experiments will allow ecologists to make specific recommendations at the right scales, such as 10 years of fewer than 7 deer/km^2 over areas of at least 60 km^2 (Hobbs 2003, Weisberg et al. 2004).

Deer management must move beyond a population-based approach to an approach that considers whole-ecosystem effects (McShea et al. 1997b). Fuller & Gill (2001) suggest that we quantify the relationships between community com-position across taxa and deer at various abundances to understand the full range of deer impacts on biodiversity. Knowing how deer affect the moss layer, herbs, shrubs, saplings, trees, invertebrates, small mammals, and birds at low, intermediate, and high grazing intensities would be a major step forward. In the absence of fenced-in areas with known numbers of deer, such approaches will require that we improve our ability to estimate local deer abundances. Indicators based on vegetation measurements increase our capacity to implement localized management programs and to monitor progress toward specific management goals (Augustine & DeCalesta 2003, Augustine & Jordan 1998, Balgooyen & Waller 1995, McShea & Rappole 2000). Applied research extends to include the selection of species, varieties, and genotypes more resistant to browsing (Gill 1992b) and evaluating the risks of epidemics associated with high deer densities.

We must also learn more about how forage conditions, predator populations, and human hunting interact to affect deer population dynamics. We should seek to understand the potentially complex dynamics of tritrophic-level interactions. We need more data from a variety of systems on when predators can, alone or in combination with other factors, control deer densities. Likewise, we need to learn more about the "ecology of fear" (Brown et al. 1999), that is, how predators might influence browsing behavior even before they are numerous enough to reduce population growth appreciably (Ripple & Beschta 2003). We also have more to learn about sport hunting. We cannot yet predict, for example, how local hunting of philopatric females influences subsequent local deer densities (Cot et al. 2004, McNulty et al. 1997, but see Oyer & Porter 2004).

Finally, ecologists should work to integrate the results of individual studies into models capable of forecasting deer populations and impacts accurately enough to provide managers with sound guidance when they make decisions. Such models should integrate deer population dynamics with forest dynamics and deer hunter impacts (Tester et al. 1997). They should also incorporate the uncertainty that underpins interactions between management and science (Bergstrom & Edenius 2003, Bugmann & Weisberg 2003, Tremblay et al. 2004). Such models, and the research previously mentioned, have a logical place in hunter education programs and revised programs of deer management.

MANAGEMENT ISSUES

Historically, game managers strove to augment and protect deer populations, and hunters learned to limit takes and favor bucks. Today, such precepts are outmoded, but unlearning old lessons and reversing this cultural momentum has proved difficult.

The management of deer and the management of vegetation remains divorced, and this situation hampers our ability to manage them jointly (Healy et al. 1997). Their management commonly occurs in different agencies with contrasting goals and paradigms. Even the scales are different; deer density is usually estimated regionally, whereas forest managers operate on individual stands. In contrast, adaptive management seeks to merge research with management by using management prescriptions as experimental manipulations, with appropriate control areas, and by regularly incorporating research results into revised management practices (Holling 1978, Walters 1986). Ecosystem management is a further extension of conventional management that emphasizes historical patterns of abundance and disturbance and ecosystem dynamics at various scales (Christensen et al. 1996). Such approaches emphasize the importance of managing deer as part of a complex system. That promise has yet to be fully realized. Nevertheless, ecologists and wildlife managers are beginning to integrate biodiversity concerns into deer management (deCalesta & Stout 1997, Rooney 2001).

(How) Can We Limit Deer Impacts?

Foresters exploit a variety of techniques to control deer impacts locally. Keeping sapling stem density high through thinning or planting and increasing hunting pressure, for example, can allow a greater proportion of stems to escape browsing (Lyly & Saksa 1992, Martin & Baltzinger 2002, Welch et al. 1991, Reimoser 2003). Evidence indicates that within species, individual seedlings differ genetically in their susceptibility to browsing (Gill 1992b, Roche & Fritz 1997, Rousi et al. 1997, Vourc'h et al. 2002), which suggests that selection for more resistant saplings might be possible. Individual plastic tubes and wire fencing efficiently exclude deer but are costly, which limits their use to valuable seedlings or stands (Cote et al. 2004, Lavsund 1987). Electric fences are less effective but are also less expensive (Hygnstrom & Craven 1988). Repellents are also available. The most efficient repellents create fear (e.g., predator urine) (Nolte 1998, Nolte et al. 1994, Swihart et al. 1991, Wagner & Nolte 2001). The effectiveness of repellents increases with their concentration (Andelt et al. 1992, Baker et al. 1999) but decreases with (*a*) time since application (Andelt et al. 1992, Nolte 1998), (*b*) attractiveness of the food (Nolte 1998, Swihart et al. 1991, Wagner & Nolte 2001), (*c*) deer hunger (Andelt et al. 1992), and (*d*) rainfall (Sayre & Richmond 1992). Similar methods are often employed to prevent accidents near airfields and highways (Groot Bruinderink & Hazebroek 1996, Putman 1997). Reflectors (Groot Bruinderink & Hazebroek 1996) and sound devices (Bomford & O'Brien 1990), such as gas exploders, appear ineffective in deterring deer for long periods unless the devices are activated by motion sensors (Belant et al. 1996).

Sport hunting and relocation are two methods available for controlling deer populations.Mostwildlifemanagersconsidersporthuntingtobethemostefficient and cost-effective method of controlling deer over large areas (Brown et al. 2000). Relocation is expensive, and relocated deer do not remain in the area of release. They also suffer high mortality (Beringer et al. 2002, McCullough et al. 1997). Sport hunting is often limited, however. For example, sport hunting cannot take place on private lands posted against hunting, in remote locations, or in urban and suburban areas. The number of hunters is also declining (Enck et al. 2000). Hunters rarely focus on young animals or hunt throughout the year as other predators do. Thus, the effectiveness of hunters is reduced. These trends, combined with growing deer populations, suggest that deer may have surpassed the point where sport hunting can reliably control their numbers (Brown et al. 2000, Giles & Findlay 2004). "Quality deer management" programs constitute an important countertrend. These programs emphasize killing doe and young animals to reduce densities, which favors the growth of large trophy bucks (Miller & Marchinton 1995).

The need for intentional culling will continue for the foreseeable future as deer populations continue to increase worldwide (McIntosh et al. 1995, McLean 1999). Hunting antlerless deer generally reduces abundance on a local scale be-cause social groups of females usually remain in the same area from year to year (Kilpatrick et al. 2001, McNulty et al. 1997, Sage et al. 2003). This behavior prevents a rapid recolonization of the hunted area (Oyer & Porter 2004). Some affluent suburban neighborhoods employ sharpshooters working at night with low-light optics and silencers to control deer. Others have begun to experiment with birth control methods. Various fertility control and immunocontraceptive techniques can limit reproduction in deer (McShea et al. 1997a, Turner et al. 1992, Waddell et al. 2001). However, these methods are labor intensive and disrupt nor-mal reproductive behavior (Nettles 1997); thus, their application is expensive and difficult to scale up (McCullough et al. 1997, McShea et al. 1997a, Turner et al. 1992).

Deer control efforts to date have focused on redirecting sport hunting, applying hunts specifically to reduce deer numbers, and a few high-cost techniques aimed at protecting small areas that are typically of high value. All these methods have proved inadequate thus far in preventing deer from overpopulating broad areas. Some hunters and deer managers dispute that we have any problem associated with high deer density. Still others argue that such problems are temporary or local. Even where we have agreement on the need to control deer, we see little consensus on how to achieve it. No new hunter ethos emphasizing the ecological role of hunters in limiting deer numbers and impacts has yet emerged.

Experimental hunting sites with longer seasons, liberalization of bag limits (especially for antlerless deer), and increased hunter participation could help reduce local deer density (Brown et al. 2000, Cote et al. 2004, Martin & Baltzinger 2002). Because hunters rarely fully understand deer effects on ecosystems (Diefenbach et al. 1997), scientists should provide them and society with specific goals, strategies, and actions to conserve ecosystems better.

Given divergent opinions and uncertainty, what should ecologists recommend to wildlife and land managers? The answer clearly depends on local situations and what is known about them. We urge ecologists to promote a precautionary approach. Because overabundant deer can cause severe, long-term impacts that are difficult to reverse, ecologists should persuade managers to reduce deer numbers before and not after such impacts become evident. Although research results and active involvement by ecologists may not change attitudes quickly, they play crucial long-term roles in redirecting people's attitudes and patterns of management.

ACKNOWLEDGEMENTS

We thank D. Simberloff for the invitation to write this review and S. de Bellefeuille for precious help with the literature review. Research by S.D.C. and J.P.T. on deer-forest ecology is supported by the Natural Sciences and Engineering Research Council of Canada, Produits forestiers Anticosti Inc., the Fonds quebecois de la recherche sur la nature et les technologies, Laval University, the Centre d'etudes nordiques, and the Ministere des Ressources Naturelles, de la Faune et des Parcs du Quebec. Research by D.M.W. and T.P.R. is supported by the National Science Foundation Ecology Program (DEB-023633) and the United States Department of Agriculture (NRI-CRIS-2003–02472).

The *Annual Review of Ecology, Evolution, and Systematics* is online at
http://ecolsys.annualreviews.org

LITERATURE CITED

Alverson W.S. and Waller D.M. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests. See McShea et al. 1997b, pp. 280–97

Anderson R.C. 1994. Height of white-flowered trillium (*Trillium grandiflorum*) as an index of deer browsing intensity. *Ecol. Appl.* 4:104–9

Alverson W.S., Waller D.M., and Solheim S.L. 1988. Forests too deer: edge effects in northern Wisconsin. *Conserv. Biol.* 2:348–58

Anderson R.C. and Katz A.J. 1993. Recovery of browse-sensitive tree species following release from white-tailed deer *Odocoileus virginianus* zimmerman browsing pressure. *Biol. Conserv.* 63:203–8

Ammer C. 1996. Impact of ungulates on structure and dynamics of natural regeneration of mixed mountain forests in the Bavarian Alps. *For. Ecol. Manag.* 88:43–53

Andelt W.F., Baker D.L., and Burnham K.P. 1992. Relative preference of captive cow elk for repellent-treated diets. *J. Wildl. Manag.* 56: 164–73

Anderson R.C. and Loucks O.L. 1979. White-tail deer (*Odocoileus virginianus*) influence on Structure and composition of *Tsuga canadensis* forests. *J. Appl. Ecol.* 16:855–61

Andren H. and Angelstam P. 1993. Moose browsing on Scots pine in relation to stand size and distance to forest edge. *J.Appl.Ecol.* 30:133–42

Augustine D.J. and deCalesta D. 2003. Defining deer overabundance and threats to forest communities: from individual plants to landscape structure. *Ecoscience* 10:472–86

Augustine D.J. and Frelich L.E. 1998. Effects of whitetailed deer on populations of an understory forb in fragmented deciduous forests. *Conserv. Biol.* 12:995–1004

Augustine D.J., Frelich L.E., and Jordan P.A. 1998. Evidence for two alternate stable states in an ungulate grazing system. *Ecol.Appl.* 8:1260–69

Augustine D.J. and Jordan P.A. 1998. Predictors of white-tailed deer grazing intensity in fragmented deciduous forests. *J. Wildl. Manag.* 62:1076–85

Augustine D.J. and McNaughton S.J. 1998. Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. *J. Wildl. Manag.* 62:1165–83

Bailey J.K. and Whitham T.G. 2002. Interactions among fire, aspen, and elk affect insect diversity: reversal of a community response. *Ecology* 83:1701–12

Baines D., Sage R.B., and Baines M.M. 1994. The implications of red deer grazing to ground vegetation and invertebrate communities of Scottish native pinewoods. *J. Appl. Ecol.* 31:776–83

Baker D.L., Andelt W.F., Burnham K.P., and Shepperd W.D. 1999. Effectiveness of Hot Sauce and Deer Away repellents for deterring elk browsing of aspen sprouts. *J. Wildl. Manag.* 63:1327–36

Balgooyen C.P. and Waller D.M. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. *Nat. Areas J.* 15:308–18

Bardgett R.D. and Wardle D.A. 2003. Herbivore-mediated linkages between aboveground and belowground communities. *Ecology* 84:2258–68

Bashore T.L. and Bellis E.D. 1982. Deer on Pennsylvania airfields: problems and means of control. *Wildl. Soc. Bull.* 10:386–88

Beals E.W., Cottam G., and Vogel R.J. 1960. Influence of deer on vegetation of the Apostle Islands, Wisconsin. *J. Wildl. Manag.* 24:68–80

Behrend D.F., Mattfeld G.F., Tierson W.C., and Wiley J.E. III. 1970. Deer density control for comprehensive forest management. *J. For.* 68:695– 700

Belant J.L., Seamans T.W., and Dwyer C.P. 1996. Evaluation of propane exploders as white-tailed deer deterrents. *Crop Prot.* 15:575–78

Bergelson J. and Crawley M.J. 1992. The effects of grazers on the performance of individuals and populations of scarlet gilia, *Ipomopsis aggregata.* *Oecologia* 90:435–44

Bergqvist G., Bergstrom R., and Edenius L. 2003. Effects of moose (*Alces alces*) rebrowsing on damage development in young stands of Scots pine (*Pinus sylvestris*). *For. Ecol. Manag.* 176:397–403

Bergstrom R. and Danell K. 1995. Effects of simulated summer browsing by moose on leaf and shoot biomass of birch, *Betula pendula*. *Oikos* 72:132–38

Bergstrom R., Edenius L. 2003. From twigs to landscapes—methods for studying ecological effects of forest ungulates. *J. Nat. Con-serv.* 10:203–11

Beringer J., Hansen L.P., Demand J.A., Sartwell J., Wallendorf M., and Mange R. 2002. Efficacy of translocation to control urban deer in Mis-souri: costs, efficiency, and outcome. *Wildl. Soc. Bull.* 30:767–74

Bobek B., Boyce M.S. and Kosobucka M. 1984. Factors affecting red deer (*Cervus elaphus*) population density in southeastern Poland. *J. Appl. Ecol.* 21:881–90

Boitani L. 1995. Ecological and cultural diversities in the evolution of wolf-human relationships. In *Ecology and Conservation of Wolves in a Changing World*, ed. LN Carbyn, SH Fritz, DR Seip, pp. 3–11. Edmonton, Alberta: Can. Circumpolar Inst., Occas. Publ. 35. 642 pp.

Bomford M. and O'Brien P.H. 1990. Sonic deter-rents in animal damage control: a review of device tests and effectiveness. *Wildl. Soc. Bull.* 18:411–22

Brandner T.A., Peterson R.O., and Risenhoover K.L. 1990. Balsam fir on Isle Royale: effects of moose herbivory and population density. *Ecology* 71:155–64

Brathen K.A. and Oksanen J. 2001. Reindeer reduce biomass of preferred plant species. *J.Veg.Sci.* 12:473–80

Brown J.S., Laundr´e J.W., and Gurung M. 1999. The ecology of fear: optimal foraging, game theory, and trophic interactions. *J. Mamm.* 80:385–99

Brown T.L., Decker D.J., Riley S.J., Enck J.W., Lauber T.B., et al. 2000. The future of hunting as a mechanism to control white-tailed deer populations. *Wildl. Soc. Bull.* 28:797– 807

Bryant J.P. and Raffa K.F. 1995. Chemical antiherbivore defense. In *Plant Stems: Physiology and Functional Morphology*, ed. BL Gartner, 1:365–81. San Diego, CA: Academic. 440 pp.

Bugmann H. and Weisberg P.J. 2003. Forest-ungulate interactions: monitoring, modeling and management. *J. Nat. Conserv.* 10:193– 201

Canham C.D., McAninch J.B., and Wood D.M. 1994. Effects of the frequency, timing, and intensity of simulated browsing on growth and mortality of tree seedlings. *Can. J. For. Res.* 24: 817– 25

Casey D. and Hein D. 1983. Effects of heavy browsing on a bird community in deciduous forest. *J. Wildl. Manag.* 47:829–36

Caughley G. 1981. Overpopulation. In *Problems in Management of Locally Abundant Wild Mammals*, ed. PA Jewell, S Holt, 1:7– 20. New York: Academic. 361 pp.

Caughley G. 1983. *The Deer Wars: The Story of Deer in New Zealand*. Auckland, NZ: Heinemann. 187 pp.

Christensen N.L., Bartuska A.M., Carpenter S., D'Antonio C., Francis R., et al. 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. *Ecol. Appl.* 6:665–91

Clifton-Hadley R.S. and Wilesmith J,W. 1991. Tuberculosis in deer: a review. *Vet. Rec.* 129:5–12

Connell J,H, and Slatyer R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *Am. Nat.* 111:1119–44

Conover M.R. 1997. Monetary and intangible valuation of deer in the United States. *Wildl. Soc. Bull.* 25:298–305

Conover M.R. 2001. Effect of hunting and trap-ping on wildlife damage. *Wildl. Soc. Bull.* 29:521–32

Cooke A.S and Farrell L. 2001. Impact of muntjac deer (*Muntiacus reevesi*) at Monks Wood National Nature Reserve, Cambridgeshire, eastern England. *Forestry* 74:241–50

Cote S.D., Dussault C., Huot J., Potvin F., Tremblay J.P., et al. 2004. High herbivore density and boreal forest ecology: introduced white-tailed deer on Anticosti Island. In *Lessons from the Islands: Introduced Species and What They Tell Us About How Ecosystems Work. Proc. Res. Group Introd. Species 2002 Conf.*, ed. AJ Gaston, TE Golumbia, JL Martin, ST Sharpe. Queen Charlotte City, BC: Can. Wildl. Serv., Ottawa. In press

Crawley M.J. 1997. Plant-herbivore dynamics. In *Plant Ecology*, ed. MJ Crawley, 2: 401–74. Oxford: Blackwell Sci. 717 pp.

Cronin G. and, Hay M.E. 1996. Susceptibility to herbivores depends on recent history of both the plant and animal. *Ecology* 77:1531–43

Crooks K.R. and Soule M.E. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. *Nature* 400:563–66

Danell K., Bergstrom R., and Edenius L. 1994. Effects of large mammalian browsers on architecture, biomass, and nutrients of woody plants. *J. Mamm.* 75:833–44

Danell K. and Huss-Danell K. 1985. Feeding by in-sects and hares on birches earlier affected by moose browsing. *Oikos* 44:75–81

Danell K., Niemela P., Varvikko T., and Vuorisalo T. 1991. Moose browsing on Scots pine along a gradient of plant productivity. *Ecology* 72:1624–33

Daubenmire R.F. 1940. Exclosure technique in ecology. *Ecology* 21:514–15

Davidson W.R. and Doster G.L. 1997. Health characteristics and white-tailed deer population density in southeastern United States. See McShea et al. 1997b, pp. 164–84

deCalesta D.S. 1994. Effect of white-tailed deer on song birds within managed forests in Pennsylvania. *J. Wildl. Manag.* 58:711–18

deCalesta D.S. and Stout S.L. 1997. Relative deer density and sustainability: a conceptual framework for integrating deer management with ecosystem management. *Wildl. Soc. Bull.* 25:252–58

DeGraaf R.M., Healy W.M., and Brooks R.T. 1991. Effects of thinning and deer browsing on breeding birds in New England oak woodlands. *For. Ecol. Manag.* 41:179–91

DeLeo G.A. and Levin S. 1997. The multifaceted aspects of ecosystem integrity. *Conserv. Ecol.* 1. *http://www.consecol.org/vol1/iss1/art3*

Diamond J.M. 1983. Laboratory, field, and natural experiments. *Nature* 304:586–87

Didier K.A. and Porter W.F. 2003. Relating spatial patterns of sugar maple reproductive success and relative deer density in northern New York State. *For. Ecol. Manag.* 181:253–66

Diefenbach D.R., Palmer W.L., and Shope W.K. 1997. Attitudes of Pennsylvania sportsmen towards managing white-tailed deer to protect the ecological integrity of forests. *Wildl. Soc. Bull.* 25:244–51

Doak D.F. 1992. Lifetime impacts of herbivory for a perennial plant. *Ecology* 73:2086–99

Dublin H.T. 1995. Vegetation dynamics in the Serengeti-Mara ecosystem: the role of elephants, fire and other factors. In *Serengeti II: Dynamics, Management and Conservation of an Ecosystem*, ed. ARE Sinclair, P Arcese, 1:71–90. Chicago: Univ. Chicago Press. 666 pp.

Duncan A.J., Hartley S.E., and Iason G.R. 1998. The effect of previous browsing damage on the morphology and chemical composition of Sitka spruce (*Picea sitchensis*) saplings and on their subsequent susceptibility to browsing by red deer (*Cervus elaphus*). *For. Ecol. Manag.* 103:57–67

Duncan A.J., Hartley S.E., Thurlow M., Young S., and Staines B.W. 2001. Clonal variation in monoterpene concentrations in Sitka spruce (*Picea sitchensis*) saplings and its effect on their susceptibility to browsing damage by red deer (*Cervus elaphus*). *For. Ecol. Manag.* 148:259–69

Dzieciolowski R. 1980. Impact of deer browsing upon forest regeneration and under-growth. *Ekol. Pol.* 28:583–99

Edenius L., Danell K., and Bergstrom R. 1993. Impact of herbivory and competition on compensatory growth in woody plants: winter browsing by moose on Scots pine. *Oikos* 66:286–92

Enck J.W., Decker D.J., and Brown T.L. 2000. Status of hunter recruitment and retention in the United States. *Wildl. Soc. Bull.* 28:817–24

Engelmark O., Hofgaard A., and Arnborg T. 1998. Successional trends 219 years after fire in an old *Pinus sylvestris* stand, northern Sweden. *J. Veg. Sci.* 9:583–92

Fagerstone K.A. and Clay W.H. 1997. Overview of USDA animal damage control efforts to manage overabundant deer. *Wildl. Soc. Bull.* 25:413–17

Fletcher J.D., McShea W.J., Shipley L.A., and Shumway D. 2001a. Use of common forest forbs to measure browsing pressure by white-tailed deer (*Odocoileus virginianus* Zimmerman) in Virginia, USA. *Nat.AreasJ.* 21:172– 76

Fletcher J.D., Shipley L.A., McShea W.J., and Shumway D. 2001b. Wildlife herbivory and rare plants: the effects of white-tailed deer, rodents, and insects on growth and survival of Turk's cap lily. *Biol.Conserv.* 101:229–38

Forchhammer M.C., Stenseth N.C., Post E., and Lang-vatn R. 1998. Population dynamics of Norwegian red deer: density-dependence and climatic variation. *Proc. R. Soc. London Ser. B* 265:341–50

Frelich L.E. and Lorimer C.G. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, USA. *Biol. Conserv.* 34:99–120

Fuller R.J. 2001. Responses of woodland birds to increasing numbers of deer: a review of evidence and mechanisms. *Forestry* 74:289– 98

Fuller R.J. and Gill R.M.A. 2001. Ecological impacts of increasing numbers of deer in British woodland. *Forestry* 74:193–99

Garrott R.A., White P.J., and White C.A.V. 1993. Over-abundance: an issue for conservation biologists? *Conserv. Biol.* 7:946–49

Gasaway W.C., Boertje R.D., Grangaard D.V., Kelleyhouse D.G., Stephenson R.O., and Larsen D.G. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. *Wildl. Monogr.* 120:1–59

George L.O. and Bazzaz F.A. 1999. The fern understory as an ecological filter: emergence and establishment of canopy-tree seedlings. *Ecology* 80:833–45

Giles B.G. and Findlay C.S. 2004. Effectiveness of a selective harvest system in regulating deer populations in Ontario. *J. Wildl. Manag.* 68: 266–77

Gill R.M.A. 1992a. A review of damage by mammals in north temperate forests: 1.Deer. *Forestry* 65:145–69

Gill R.M.A. 1992b. A review of damage by mammals in north temperate forests: 3. Impact on trees and forests. *Forestry* 65:363–88

Gill R.M.A. and Beardall V. 2001. The impact of deer on woodlands: the effects of browsing and seed dispersal on vegetation structure and composition. *Forestry* 74:209–18

Glenn-Lewin D.C. and van der Maarel E. 1992. Patterns and processes of vegetation dynamics. In *Plant Succession: Theory and Prediction. Popul. Community Biol. Ser. 11*, ed. D.C. Glenn-Lewin, R.K. Peet, T.T. Veblen, 1:11–59. New York: Chapman & Hall. 352 pp.

Gomez J.M. and Zamora R. 2002. Thorns as mechanical defense in a long-lived shrub (*Hormathophylla spinosa*, Cruciferae). *Ecology* 83:885–90

Groot Bruinderink G.W.T.A. and Hazebroek E. 1996. Ungulate traffic collisions in Europe. *Conserv. Biol.* 10:1059–67

Gross J.E. and Miller M.W. 2001. Chronic wasting disease in mule deer: disease dynamics and control. *J. Wildl. Manag.* 65:205–15

Harlow R.F. and Downing R.L. 1970. Deer browsing and hardwood regeneration in the southern Appalachians. *J. For.* 68:298– 300

Healy W.M., deCalesta D.S., and Stout S.L. 1997. A research perspective on white-tailed deer over-abundance in the northeastern United States. *Wildl. Soc. Bull.* 25:253–63

Hester A.J., Edenius L., Buttenschøn R.M., and Kuiters A.T. 2000. Interactions between forests and herbivores: the role of controlled grazing experiments. *Forestry* 73:381–91

Hjalten J., Danell K., and Ericson L. 1993. Effects of simulated herbivory and intraspecific competition on the compensatory ability of birches. *Ecology* 74:1136–42

Hobbs N.T. 1996. Modification of ecosystems by ungulates. *J. Wildl. Manag.* 60:695–713

Hobbs N.T. 2003. Challenges and opportunities in integrating ecological knowledge across scales. *For. Ecol. Manag.* 181:223–38

Hochwender C.G., Marquis R.J., and Stowe K.A. 2000. The potential for and constraints on the evolution of compensatory ability in *Asclepias syriaca*. *Oecologia* 122:361–70

Holling C.S. 1978. *Adaptive Environmental Assessment and Management.* New York: Wiley. 377 pp.

Hornberg S. 2001. Changes in population density of moose (*Alces alces*) and damage to forests in Sweden. *For. Ecol. Manag.* 149: 141–51

Horsley S.B. and Marquis D.A. 1983. Interference by weeds and deer with Allegheny hardwood reproduction. *Can. J. For. Res.* 13:61–69

Horsley S.B., Stout S.L., and deCalesta D.S. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecol. Appl.* 13:98–118

Huntly N. 1991. Herbivores and the dynamics of communities and ecosystems. *Annu. Rev. Ecol. Syst.* 22:477–503

Hurlbert S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecol. Monogr.* 54:187–211

Husheer S.W., Coomes D.A., and Robertson A.W. 2003. Long-term influences of introduced deer on the composition and structure of New Zealand *Nothofagus* forests. *For. Ecol. Manag.* 181:99–117

Hygnstrom S.E. and Craven S.R. 1988. Electric fences and commercial repellents for reduc-ing deer damage in cornfields. *Wildl. Soc. Bull.* 16:291–96

Jedrzejewska B.,Jedrzejewski W., Bunevich A.N., Milkowski L., and Krasinski Z.A. 1997. Factors shaping population densities and increase rates of ungulates in Bialowieza Primeval Forest (Poland and Belarus) in the 19th and 20th centuries. *Acta Theriol.* 42:399–451

Jorritsma I.T.M., van Hees A.F.M., and Mohren G.M.J. 1999. Forest development inrelation to ungulate grazing: a modeling approach. *For. Ecol. Manag.* 120:23–34

Judziewicz E.J. and Koch R.G. 1993. Flora and vegetation of the Apostle Islands National Lake shore and Madeline Island, Ashland and Bayfield Counties, Wisconsin. *Mich. Bot.* 32:43–189

Kay S. 1993. Factors affecting severity of deer browsing damage within coppiced wood-lands in the south of England. *Biol. Conserv.* 63:217–22

Kielland K. and Bryant J.P. 1998. Moose herbivory in taiga: effects on biogeochemistry and vegetation dynamics in primary succession. *Oikos* 82:377–83

Kienast F., Fritschi J., Bissegger M., and Abderhalden W.. 1999. Modeling successional patterns of high-elevation forests under changing herbivore pressure—responses at the landscape level. *For. Ecol. Manag.* 120:35–46

Kilpatrick H.J., LaBonte A.M., and Seymour J.T. 2002. A shotgun-archery deer hunt in a residential community: evaluation of hunt strategies and effectiveness. *Wildl. Soc. Bull.* 30:478–486

Kilpatrick H.J., Spohr S.M., and Lima K.K. 2001. Effects of population reduction on home ranges of female white-tailed deer at high densities. *Can. J. Zool.* 79:949–54

Knight T.M. 2003. Effects of herbivory and its timing across populations of *Trillium grandiflorum* (Liliaceae). *Am. J. Bot.* 90:1207–14

Knox W.M. 1997. Historical changes in the abundance and distribution of deer in Virginia. See McShea et al. 1997b, pp. 27–36

Kramer K., Groen T.A., and van Wieren S.E. 2003. The interacting effects of ungulates and fire on forest dynamics: an analysis using the model FORSPACE. *For. Ecol. Manag.* 181: 205–22

Kuiters A.T. and Slim P.A. 2002. Regeneration of mixed deciduous forest in a Dutch forest-heathland, following a reduction of ungulate densities. *Biol. Conserv.* 105:65–74

Kullberg Y. and Bergstrom R. 2001. Winter browsing by large herbivores on planted deciduous seedlings in southern Sweden. *Scand. J. For. Res.* 16:371–78

Kunkel K. and Pletscher D.H. 1999. Species-specific population dynamics of cervids in a multipredator ecosystem. *J. Wildl. Manag.* 63:1082–93

Lavsund S. 1987. Moose relationships to forestry in Finland, Norway and Sweden. *Swed. Wildl. Res.* 1(Suppl.):229–44

Laycock W.A. 1991. Stable states and thresholds of range condition on North American range-lands: a viewpoint. *J.RangeManag.* 44:427– 33

Lemieux N., Maynard B.K., and Johnson W.A. 2000. A regional survey of deer damage throughout Northeast nurseries and orchards. *J. Environ. Hort.* 18:1–4

Leopold A. 1933. *Game Management*. New York: Scribner's. 481 pp.

Leopold A., Sowls L.K., and Spencer D.L. 1947. A survey of overpopulated deer range in the United States. *J. Wildl. Manag.* 11:162–77

Lewis M.A. and Murray J.D. 1993. Modelling territoriality and wolf-deer interactions. *Nature* 366:738–40

Lockwood J.A. and Lockwood D.R. 1993. Catastrophe theory: a unified paradigm for range-land ecosystem dynamics. *J. Range Manag.* 46:282–88

Loison A., Langvatn R., and Solberg E.J. 1999. Body mass and winter mortality in red deer calves: disentangling sex and climate effects. *Ecography* 22:20–30

Long Z.T., Carson W.P., and Peterson C.J. 1998. Can disturbance create refugia from herbivores: an example with hemlock regeneration on tree fall mounds. *J. Torrey Bot. Soc.* 125:165– 68

Lyly O. and Saksa T. 1992. The effect of stand density on moose damage in young *Pinus sylvestris* stands. *Scand. J. For. Res.* 7:393– 403

Martin J.L. and Baltzinger C. 2002. Interaction among deer browse, hunting, and tree regeneration. *Can. J. For. Res.* 32:1254–64

Maschinski J. and Whitham T.G. 1989. The continuum of plant responses to herbivory: the influence of plant association, nutrient avail-ability, and timing. *Am. Nat.* 134:1–19

May R.M. 1977. Thresholds and breakpoints in ecosystems with a multiplicity of stable states. *Nature* 269:471–77

McCabe T.R. and McCabe R.E. 1997. Recounting whitetails past. See McShea et al. 1997b, pp. 11–26

McCullough D.R. 1979. *The George Reserve Deer Herd*. Ann Arbor: Mich. Univ. Press. 271 pp.

McCullough D.R. 1997. Irruptive behavior in ungulates. See McShea et al. 1997b, pp. 69– 98

McCullough D.R. 1999. Density dependence and life-history strategies of ungulates. *J. Mammal.* 80:1130–46

McCullough D.R., Jennings K.W., Gates N.B., Elliott B.G., and Didonato J.E. 1997. Overabundant deer populations in California. *Wildl. Soc. Bull.* 25:478–83

McInnes PF, Naiman RJ, Pastor J, Cohen Y. 1992. Effects of moose browsing on vegeta tion and litter of the boreal forest, Isle Royale, Michigan, USA. *Ecology* 73:2059–75

McIntosh R., Burlton F.E.W., and McReddie G. 1995. Monitoring the density of a roe deer *Caproleus caproleus* population subjected to heavy hunting pressure. *For. Ecol. Manag.* 79:99–106

McLean C. 1999. The effect of deer culling on tree regeneration on Scaniport Estate, Inverness-shire: a study by the Deer Com-mission for Scotland. *Scot. For.* 53:225–30

McNaughton S.J. 1979. Grazing as an optimization process: grass-ungulate relationships in the Serengeti. *Am. Nat.* 113:691–703

McNaughton S.J. 1983. Compensatory plant growth as a response to herbivory. *Oikos* 40:329–36

McNulty S.A., Porter W.F., Mathews N.E., and Hill J.A. 1997. Localized management for reducing white-tailed deer populations . *Wildl.Soc. Bull.* 25:265–71

McShea W.J. 2000. The influence of acorn crops on annual variation in rodent and bird populations. *Ecology* 81:228–38

McShea W.J, Monfort S.L., Hakim S., Kirkpatrick J., Liu .I, et al. 1997a. The effect of immunocontraception on the behavior and reproduction of white-tailed deer. *J. Wildl. Manag.* 61:560–69

McShea W.J. and Rappole J.H. 1992. White-tailed deer as keystone species within forested habitats of Virginia. *Va.J. Sci.* 43:177–86

McShea W.J. and Rappole J.H. 1997. Herbivores and the ecology of forest understory birds. See McShea et al. 1997b, pp. 298–309

McShea W.J. and Rappole J.H. 2000. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. *Conserv. Biol.* 14:1161–70

McShea W.J. and Schwede G. 1993. Variable acorn crops: responses of white-tailed deer and other mast consumers. *J. Mammal.* 74:999– 1006

McShea W.J., Underwood H.B., and Rappole J.H, eds. 1997b. *The Science of Overabundance: Deer Ecology and Population Management*. Washington, DC: Smithson. Inst. Press. 402 pp.

Messier F. 1994. Ungulate population models with predation: a case study with the North American moose. *Ecology* 75:478–88

Miller K.V. and Marchinton R.L. 1995. *Quality Whitetails: The Why and How of Quality Deer Management*. Mechanicsburg, PA: Stackpole Books. 320 pp.

Miller R., Kaneene J.B., Fitzgerald S.D., and Schmitt S.M. 2003. Evaluation of the influence of supplemental feeding of white-tailed deer (*Odocoileus virginianus*)on the prevalence of bovine tuberculosis in the Michigan wild deer population. *J. Wildl. Dis.* 39:84–95

Miller S.G., Bratton S.P., and Hadidian J. 1992. Impacts of white-tailed deer on endangered plants and threatened vascular plants. *Nat. Areas J.* 12:67–74

Miyashita T., Takada M., and Shimazaki A. 2004. Indirect effects of herbivory by deer reduce abundance and species richness of web spiders. *Ecoscience* 11:74–79

Moser B.W. and Witmer G.W. 2000. The effects of elk and cattle foraging on the vegetation, birds, and small mammals of the Bridge Creek Wildlife Area, Oregon. *Int. Biodeter. Biodegrad.* 45:151–57

Mysterud A. 2000. The relationship between ecological segregation and sexual body size dimorphism in large herbivores. *Oecologia* 124:40–54

Mysterud A., Stenseth N.C., Yoccoz N.G., Lang-vatn R., and Steinheim G. 2001. Nonlinear effects of large-scale climatic variability on wild and domestic herbivores. *Nature* 410:1096–99

Nettles V.F. 1997. Potential consequences and problems with wildlife contraceptives. *Reprod. Fertil. Dev.* 9:137–43

Nixon C.M., Hansen L.P., Brewer P.A., and Chelsvig J.E. 1991. Ecology of white-tailed deer in an intensively farmed region of Illinois. *Wildl. Monogr.* 118:1–77

Nolte D.L. 1998. Efficacy of selected repellents to deter deer browsing on conifer seedlings. *Int. Biodeter. Biodegrad.* 42:101–7

Nolte D.L., Mason J.R., Epple G., Aronov E., and Campbell D.L. 1994. Why are predator urines aversive to prey? *J. Chem. Ecol.* 20:1505– 16

Noy-Meir I. 1975. Stability of grazing systems: an application of predator-prey graphs. *J. Ecol.* 63:459–81

Otsfeld R.S., Jones C.G., and Wolff J.O. 1996. Of mice and mast: ecological connections in eastern deciduous forests. *BioScience* 46:323–30

Oyer A.M. and Porter W.F. 2004. Localized management of white-tailed deer in the central Adirondack Mountains, New York. *J. Wildl. Manag.* 68:257–65

Ozoga J.J. and Verme L.J. 1986. Relation of maternal age to fawn-rearing success in white-tailed deer. *J. Wildl. Manag.* 50:480–86

Paige K.N. and Whitham T.G. 1987. Overcompensation in response to mammalian herbivory: the advantage of being eaten. *Am. Nat.* 129:407– 16

Paine R.T. 2000. Phycology for the mammalogist: marine rocky shores and mammal-dominated communities—how different are the structuring processes? *J. Mammal.* 81: 637–48

Palmer S.C.F. and Truscott A.M. 2003. Browsing by deer on naturally regenerating Scots pine (*Pinus sylvestris* L.) and its effects on sapling growth. *For. Ecol. Manag.* 182:31–47

Paquet P.C. and Carbyn L.N. 2003. Gray wolf. In *Wild Mammals of North America: Biology, Management*, *and Conservation*, ed. GA Feldhamer, BC Thompson, JA Chapman, 2:482–510. Baltimore/London: Johns Hopkins Univ. Press. 1216 pp.

Partl E., Szinovatz V., Reimoser F., and Schweiger-Adler J. 2002. Forest restoration and browsing impact by roe deer. *For. Ecol. Manag.* 159:87–100

Pastor J., Dewey B., Naiman R.J., McInnes P.F., and Cohen Y. 1993. Moose browsing and soil fertility in the boreal forests of Isle Royale National Park. *Ecology* 74:467–80

Pastor J. and Naiman R.J. 1992. Selective foraging and ecosystem processes in boreal forests. *Am. Nat.* 139:690–705

Peterson R.O. 1999. Wolf-moose interaction on Isle Royale: the end of natural regulation? *Ecol. Appl.* 9:10–16

Pimlott D.H. 1963. Influence of deer and moose on boreal forest vegetation in two areas of eastern Canada. In *Transactions of the Sixth Congress of the International Union of Game Biologists, Bournemouth*, ed. TH Blank, pp. 105–16. London: Nat. Conserv.

Pojar J., Lewis T., Roemer H., and Wilford D.J. 1980. *Relationships Between Introduced Black-Tailed Deer and the Plant Life in the Queen Charlotte Islands, B.C.* Smithers: B.C. Minist. For. 63 pp.

Porter W.F. and Underwood H.B. 1999. Of elephants and blind men: deer management in the U.S. national parks. *Ecol. Appl.* 9:3–9

Potvin F., Beaupre P., and Laprise G. 2003. The eradication of balsam fir stands by white-tailed deer on Anticosti Island, Quebec: a 150 year process. *Ecoscience* 10:487–95

Putman R.J. 1986. Foraging by roe deer in agricultural areas and impact on arable crops. *J. Appl. Ecol.* 23:91–99

Putman R.J. 1997. Deer and road traffic accidents: options for management. *J. Environ. Manag.* 51:43–57

Putman R.J. and Moore N.P. 1998. Impact of deer in lowland Britain on agriculture, forestry and conservation habitats. *Mamm. Rev.* 28:141– 64

Raymond G.J., Bossers A., Raymond L.D., O'Rourke K.I., McHolland L.E., et al. 2000. Evidence of a molecular barrier limiting susceptibility of humans, cattle and sheep to chronic wasting disease. *EMBO J.* 17:4425– 30

Reimoser F. 2003. Steering the impacts of ungulates on temperate forests.   *J. Nat. Conserv.* 10:243–52

Reimoser F. and Gossow H. 1996. Impact of ungulates on forest vegetation and its dependence on the silvicultural system. *For. Ecol. Manag.* 88:107–19

Riggs R.A., Tiedemann A.R., Cook J.G., Ballard T.M., Edgerton P.J., et al. 2000. Modification of mixed-conifer forests by ruminant herbivores in the Blue Mountains Ecological Province. *Res. Pap. PNW-RP-527.* USDA For. Serv., Portland, OR. 77 pp.

Riley S.J., Decker D.J., Enck J.W., Curtis P.D., Lauber T.B., and Brown T.L. 2003. Deer populations up, hunter populations down: implications of interdependence of deer and hunter population dynamics on management. *Ecoscience* 10:455–61

Ripple W.J. and Beschta R.L. 2003. Wolf reintroduction, predation risk, and cottonwood recovery in Yellowstone National Park. *For. Ecol. Manag.* 184:299–313

Risenhoover K.L. and Maass S.A. 1987. The influence of moose on the composition and structure of Isle Royale forests. *Can. J. For. Res.* 17:357–64

Ritchie M.E. and Tilman D., and Knops J.M.H. 1998. Herbivore effects on plant and nitrogen dynamics in oak savanna. *Ecology* 79:165–77

Roche B.M. and Fritz R.S. 1997. Genetics of resistanceof *Salixsericea* to a diverse community of herbivores. *Evolution* 51:1490–98

Romin L.A. and Bissonette J.A. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. *Wildl. Soc. Bull.* 24:276–83

Rooney T.P. 1997. Escaping herbivory: refuge effects on the morphology and shoot demography of the clonal forest herb *Maianthemum canadense.* *J. Torrey Bot. Soc.* 124:280–85

Rooney T.P. 2001. Deer impacts on forest ecosystems: a North American perspective. *Forestry* 74:201–8

Rooney T.P. and Dress W.J. 1997. Species loss over sixty-six years in the ground-layer vegetation of Heart's Content, an old-growth forest in Pennsylvania USA. *Nat. Areas J.* 17:297–305

Rooney T.P., McCormick R.J., Solheim S.L., and Waller D.M. 2000. Regional variation in recruitment of hemlock seedlings and saplings in the upper Great Lakes, USA. *Ecol. Appl.* 10:1119–32

Rooney T.P., Solheim S.L., and Waller D.M. 2002. Factors affecting the regeneration of northern white cedar in lowland forests of the upper Great Lakes region, USA. *For. Ecol. Manag.* 163:119–30

Rooney T.P. and Waller D.M. 2001. How experimental defoliation and leaf height affect growth and reproduction in *Trillium grandiflorum. J. Torrey Bot. Soc.* 128:393–99

Rooney T.P. and Waller D.M. 2003. Direct and indirect effects of deer in forest ecosystems. *For. Ecol. Manag.* 181:165–76

Rossow L.J., Bryant J.P., and Kielland K. 1997. Effects of above-ground browsing by mammals on mycorrhizal infection in an early successional taiga ecosystem. *Oecologia* 110:94– 98

Rousi M., Tahvanainen J., Henttonen H., Herms D.A., and Uotila I. 1997. Clonal variation in susceptibility of white birches (*Betula* spp.) to mammalian and insect herbivores. *For. Sci.* 43:396–402

Ruhren S. and Handel S.L. 2000. Considering herbivory, reproduction, and gender when monitoring plants: a case study of Jack-in-the-pulpit (*Arisaema triphyllum* [L.] Schott). *Nat. Areas J.* 20:261–66

Ruhren S. and Handel S.L. 2003. Herbivory constrains survival, reproduction, and mutualisms when restoring nine temperate forest herbs. *J. Torrey Bot. Soc.* 130:34–42

Russell F.L., Zippin D.B., and Fowler N.L. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations and communities: a review. *Am. Midl. Nat.* 146: 1–26

Sæther B.E., Andersen R., Hjeljord O., and Heim M. 1996. Ecological correlates of regional variation in life history of the moose *AlcesAlces. Ecology* 77:1493–500

Sage R.W., Porter W.F., and Underwood H.B. 2003. Windows of opportunity: white-tailed deer and the dynamics of northern hardwood forests of the northeastern US. *J. Nat. Conserv.* 10:213–20

Saunders M.R. and Puettmann K.J. 1999. Effects of overstory and understory competition and simulated herbivory on growth and survival of white pine seedlings. *Can. J. For. Res.* 29:536–46

Sayre R.W. and Richmond M.E. 1992. Evaluation of a new deer repellent on Japanese yews at suburban homesites. *Proc. East. Wildl. Damage Control Conf.* 5:38–43

Scheffer M. and Carpenter S.R. 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. *Trends Ecol. Evol.* 18:648–56

Scheffer M., Carpenter S.R., Foley J.A., Folke C., and Walker B. 2001. Catastrophic shifts in ecosystems. *Nature* 413:591–96

Schmitt S.M., Fitzgerald S.D., Cooley T.M., Bruning-Fann C.S., Sullivan L., et al. 1997. Bovine tuberculosis in free-ranging white-tailed deer from Michigan. *J. Wildl. Dis.* 33:749–58

Schmitz O.J. and Sinclair R.E. 1997. Rethinking the role of deer in forest ecosystem dynamics. See McShea et al. 1997b, pp. 201–23

Schutz M., Risch A.C., Leuzinger E., Krusi B.O., and Achermann G. 2003. Impact of herbivory by red deer (*Cervus elaphus* L.) on patterns and processes in subalpine grasslands in the Swiss National Park. *For.Ecol.Manag.* 181:177–88

Seagle S. and Liang S. 2001. Application of a forest gap model for prediction of browsing effects on riparian forest succession. *Ecol. Model.* 144:213–29

Sinclair A.R.E. 1997. Carrying capacity and the overabundance of deer: a framework for management. See McShea et al. 1997b, pp. 380–94

Singer F.J. and Schoenecker K.A. 2003. Do ungulates accelerate or decelerate nitrogen cycling? *For. Ecol. Manag.* 181:189–204

Skolving H. 1985. Traffic accidents with moose and roe-deer in Sweden: report of research, development and measures. *Actes du Colloque Routes et Faune Sauvage*, pp. 317–25. Strasbourg: Conseil Eur. 406 pp.

Solberg E.,J., Sæther B-E., Strand O., and Loison A. 1999. Dynamics of a harvested moose population in a variable environment. *J. Anim. Ecol.* 68:186–204

Steere A.C. 1994. Lyme disease: a growing threat to urban populations. *Proc.Natl.Acad. Sci. USA* 91:2378–83

Stewart A.J.A. 2001. The impact of deer on low-land woodland invertebrates: a review of the evidence and priorities for future research. *Forestry* 74:259–70

Stewart G.H. and Burrows L.E. 1989. The impact of white-tailed deer *Odocoileus virginianus* on regeneration in the coastal forests of Stewart Island, New Zealand. *Biol.Conserv.* 49:275– 93

Stoeckler J.H., Strothmann R.O., and Kreftint L.W. 1957. Effect of deer browsing on reproduction in the northern hardwood-hemlock type in northeastern Wisconsin. *J. Wildl. Manag.* 21:75–80

Stromayer K.A.K. and Warren R.J. 1997. Are over-abundant deer herds in the eastern United States creating alternate stable states in forest plant communities? *Wildl.Soc.Bull.* 25:227– 34

Suominen O., Danell K., and Bergstrom R. 1999a. Moose, trees, and ground-living invertebrates: indirect interactions in Swedish pine forests. *Oikos* 84:215–26

Suominen O., Danell K., and Bryant J.P. 1999b. Indirect effects of mammalian browsers on vegetation and ground-dwelling insects in an Alaskan floodplain. *Ecoscience* 6:505–10

Suominen O., Niemela J., Martikainen P., Niemela P., and Kojola I. 2003. Impact of reindeer grazing on ground-dwelling Carabidae and Curculionidae assemblages in Lapland. *Ecography* 26:503–13

Swihart R.K., Pignatello J.J., and Mattina M.J.I. 1991. Aversive response of white-tailed deer, *Odocoileus virginianus*, to predatorurines. *J. Chem. Ecol.* 17:767–77

Takada M., Asada M., and Miyashita T. 2001. Regional differences in the morphology of a shrub *Damnacanthus indicus*: an induced resistance to deer herbivory? *Ecol. Res.* 16: 809–13

Telford S.R. III. 2002. Deer tick-transmitted zoonoses in the eastern United States. In *Conservation Medicine: Ecological Health in Practice*, ed. A Aguirre, RS Ostfeld, GM Tabor, C House, MC Pearl, pp. 310–24. New York: Oxford Univ. Press. 407 pp.

Terborgh J.. 1988. The big things that run the world—a sequel to E.O. Wilson. *Conserv. Biol.* 2:402–3

Tester J.R., Starfield A.M., and Frelich L.E. 1997. Modeling for ecosystem management in Minnesota pine forests. *Biol. Conserv.* 80: 313–24

Tilghman N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. *J. Wildl. Manag.* 53:524–32

Tremblay J.P., Hester A., McLeod J., and Huot J. 2004. Choice and development of decision support tools for the sustainable management of deer-forest systems. *For. Ecol. Manag.* 191:1–16

Turner J.W., Liu I.K.M., and Kirkpatrick J.F. 1992. Remotely delivered immunocontraception in captive white-tailed deer. *J. Wildl. Manag.* 56:154–57

VanWieren S.E. 1998. Effects of large herbivores upon the animal community. In *Grazing and Conservation Management*, ed. MF Wallis DeVries, JP Bakker, SE Van Wieren, pp. 185–214. Boston: Kluwer Acad. 390 pp.

Vazquez D.P. and Simberloff D. 2003. Changes in interaction biodiversity induced by an introduced ungulate. *Ecol. Lett.* 6:1077–83

Vila B., Keller T., and Guibal F. 2001. Influence of Browsing cessation on *Piceasitchensis* radial growth. *Ann. For. Sci.* 58:853–59

Vila B., Torre F., Guibal F., and Martin J.L. 2003. Growth change of young *Picea sitchensis* in response to deer browsing. *For.Ecol.Manag.* 180:413–24

Vourc'h G., Martin J.L., Duncan P., Escarre J., and Clausen T.P. 2001. Defensive adaptations of *Thuja plicata* to ungulate browsing: a comparative study between mainland and island populations. *Oecologia* 126:84–93

Vourc'h G., Vila B., Gillon D., Escarre J., Guibal F., et al. 2002. Disentangling the causes of damage variation by deer browsing on young *Thuja plicata. Oikos* 98:271–83

Waddell R.B., Osborn D.A., Warren R.J., Griffin J.C., and Kesler D.J. 2001. Prostaglandin F2 alpha-mediated fertility control in captive white-tailed deer. *Wildl. Soc. Bull.* 29:1067– 74

Wagner K.K. and Nolte D.L. 2001. Comparison of active ingredients and delivery systems in deer repellents. *Wildl. Soc. Bull.* 29:322–30

Waller D.M. and Alverson W.S. 1997. The white-tailed deer: a keystone herbivore. *Wildl. Soc. Bull.* 25:217–26

Waller D.M., Alverson W.S., and Solheim S. 1996. Local and regional factors influencing the regeneration of Eastern Hemlock. In *Hemlock Ecology and Management, Conf. Proc.*, ed.G Mroz, J Martin, pp. 73–90. Houghton: Mich. Technol. Univ.

Walters C.J. 1986. *Adaptive Management of Renewable Resources*. New York: Macmillan. 374 pp.

Wardle D.A., Barker G.M., Yeates G.M., Bonner K.I., and Ghani A. 2001. Introduced browsing mammals in New Zealand natural forests: aboveground and belowground consequences. *Ecol. Monogr.* 71:587–614

Wardle D.A., Bonner K.I., and Barker G.M. 2002. Linkages between plant litter decomposition, litter quality, and vegetation responses to herbivores. *Funct. Ecol.* 16:585–95

Watson A. 1983. Eighteenth century deer numbers and pine regeneration near Braemar, Scotland. *Biol. Conserv.* 25:289–305

Webb W.L., King R.T., and Patric E.F. 1956. Effect of white-tailed deer on a mature northern hardwood forest. *J. For.* 54:391–98

Weisberg P.J., Coughenour M.B., and Bugmann, H. 2004. Modeling of large herbivore-vegetation interactions in a landscape con-text. In *Large Herbivore Ecology and Ecosystem Dynamics*, ed. K Danell, R Bergstom, P Duncan, H Olff. Cambridge, UK: Cambridge Univ. Press. In press

Welch D., Staines B.W., Scott D., and French D.D. 1992. Leader browsing by red and roe deer on young Sitka spruce trees in western Scotland. II. Effects on growth and tree form. *Forestry* 65:309–30

Welch D., Staines B.W., Scott D., French D.D., and Catt D.C. 1991. Leader browsing by red and roe deer on young Sitka spruce trees in western Scotland: I. Damage rates and the influence of habitat factors. *Forestry* 64:61–82

West B.C. and Parkhurst J.A. 2002. Interactions between deer damage, deer density, and stake-holder attitudes in Virginia. *Wildl. Soc. Bull.* 30:139–47

Westoby M., Walker B., and Noy-Meir I. 1989. Opportunistic management for rangelands not at equilibrium. *J. Range Manag.* 42:266–74

Whigham D.F. 1990. The effect of experimental defoliation on the growth and reproduction of a woodland orchid, *Tipularia discolor. Can. J. Bot.* 68:1812–16

White C.A., Feller M.C., and Bayley S. 2003. Predation risk and the functional response of elk-aspen herbivory. *For. Ecol. Manag.* 181:77– 98

Whitney G.G. 1984. Fifty years of change in the arboreal vegetation of Heart's Content, an old-growth hemlock-white pine-northern hardwood stand. *Ecology* 65:403–8

Williams E.S., Miller M.W., Kreeger T.J., Kahn R.H., and Thorne E.T. 2002. Chronic wasting disease of deer and elk: a review with recommendations for management. *J. Wildl. Manag.* 66:551–63

Wilson M.L. and Childs J.E. 1997. Vertebrate abundance and the epidemiology of zoonotic diseases. See McShea et al. 1997b, pp. 224– 48

Wilson M.L., Ducey A.M., Litwin T.S., Gavin T.A., and Spielman A. 1990. Microgeographic distribution of immature *Ixodes dammini* ticks correlated with that of deer. *Med. Vet. Entomol.* 4:151–59

Wilson M.L., Telford S.R., Piesman J., and Spielman A. 1988. Reduced abundance of immature *Ixodes dammini* (Acari: Isodidae) following elimination of deer. *J. Med. Entomol.* 25:224–28

Wywialowski A.P. 1996. Wildlife damage to field corn in 1993. *Wildl. Soc. Bull.* 24:264– 71

An Assessment of Long-term Biodiversity Recovery From Intense and Sustained Deer Browse on North Manitou Island, Sleeping Bear Dunes National Lakeshore

Peter M. Hurley[1] and David Flaspohler[2]
Michigan Technological University
School of Forest Resources & Environmental Science

[1] *Ph.D Candidate, School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931*

[2] *Associate Professor, School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931*
906-487-3608, Email: djflaspo@mtu.edu, http://forest.mtu.edu/faculty/flaspohler

---

Abstract: *Forty years of overbrowse by white-tailed deer (Odocoileus virginianus) and the impacts of irruptive population growth in the late 1970's and early 1980's left an enduring ecological legacy on Sleeping Bear Dunes National Lakeshore's North Manitou Island (NMI). Results of an ongoing study reveal that, relative to ecologically similar but unbrowsed forests on South Manitou Island (SMI), historically catastrophic levels of deer browse altered understory species composition and forest community trajectory from the probable composition and trajectory in the absence of browse. The forest herb and shrub communities on NMI show little evidence of recovery, a possible consequence both dispersal limitation and intense competition with tree seedlings and saplings that now occupy much of the understory and herbaceous layer growing space. The sapling layer is dominated by relatively unpalatable American beech (Fagus grandifolia). Sugar maple is absent in the small sapling size classes, likely a consequence of inability to recruit into the sapling layer during a period of especially strong browse pressure. Deer browse shows less of an effect on large saplings and overstory trees. The sapling recruitment patterns on NMI are in stark contrast to patterns documented for SMI, suggesting that past browse will have a lasting effect on future forest development, including an alteration of forest gap dynamics and overstory recruitment patterns. Recovery of herb communities has been particularly slow and warrants further study to determine if current ecological trajectory will result in desired future condition.*

Introduction

Historical land use practices often leave enduring legacies on population, community, and ecosystem dynamics, even where natural processes have largely been restored. Ecologists and natural resource managers have increasingly recognized the influence of land use legacies on current and projected future ecological processes and conditions (Foster et al. 2003). Land use legacies are ubiquitous, even in areas that did not directly suffer direct land conversion. Patches of old-growth forest in the Upper Great Lakes region of the United States, for example, have never been cut or otherwise subjected to logging practices, yet ecological processes within these patches are often heavily influenced by the surrounding "humanized" landscape, even where that landscape remains in a largely forested condition. Aldo Leopold made reference to this phenomenon over 60 years ago in his work for large private land club in Michigan's Upper Peninsula:

"*The size-scale of a wilderness area for scientific study greatly affects its value. A small area may be "natural" in respect of its plants, but wholly unnatural in respect of its mobile animals or water. However, mobile animals greatly affect plant life, so that a small virgin forest may appear to be natural when actually it has been profoundly affected by forces applied to animals,* *waters, or climate at points far distant. (Thus the deer populations determined by laws passed in Lansing, by hunters camping at Big Bay, and by lumbering operations on the Little Huron, have apparently exterminated the ground hemlock [Canada yew, Taxus canadensis] from the "virgin" forest of Mountain Lake*)" (Leopold 1938).

Additionally, the surrounding human dominated 'metacommunity' serves as constant source of propagule pressure for both native and non-native species, with the potential to alter colonization/extinction dynamics and ecological drift within the old growth or otherwise protected patch (sensu Hubbell 2001).

Herbivory by white-tailed deer is a common problem confronting managers of old growth and other natural areas in the eastern United States (Rooney 2001). Current land use practices, coupled with the extermination of natural predators, have resulted in regional deer populations that are much higher than during pre-Euro-American times (Côté et al. 2004, McCabe and McCabe 1997, Russell et al. 2001, Rooney and Gross 2003). In some cases, land managers are confronted with current rates of browse pressure that will inevitably alter community structure and dynamics, with the extinction of browse-sensitive species a likely outcome. In other cases, natural area managers must contend with a legacy of overbrowse that may persist for decades or even centuries.

Numerous studies have documented the effects of deer overabundance on forest ecosystems (Côté et al. 2004, Frankland and Nelson 2003, Ruhren and Handel 2003, Russell et al. 2001, Webster and Parker 1997). This work has led researchers to conclude that deer are a keystone herbivore in eastern deciduous forests of North America (Côté et al. 2004, Rooney 2001, Waller and Alverson 1997). The literature on deer impacts is dominated by studies of the effects of past and current browse levels on forests that currently support large deer populations (Russell et al. 2001, Frankland and Nelson 2003); fewer studies have examined the recovery of forests after deer densities have been reduced to levels that are not likely to have large continuing impacts on forest community structure and composition (e.g., Balgooyen and Waller 1995, Webster et al. 2005).

In this paper, we investigate a legacy of overbrowse on North Manitou Island (NMI), Sleeping Bear Dunes National Lakeshore, Michigan. We use data on current forest conditions to assess recovery of forest understories on NMI from almost four decades of intense, chronic browse. Deer were introduced to NMI in 1926 and populations were artificially maintained at high levels for several decades before a population reduction program was instituted in the mid-1980s. McCullough and Case (1987) studied NMI deer population dynamics and the impacts of the deer herd on plant communities in the late 1970's and early 1980's. They documented dramatic effects of deer on the understory tree and herbaceous plant communities at a time when herbivory pressure was likely at its peak. They also suggested that if deer densities were reduced, the forest community would eventually recover. However, they noted that the time averaged impacts of 40 years of deer overabundance would not likely be evident for many years.

To assess recovery, we use forest conditions on South Manitou Island (SMI) as a deer-free reference system. Deer were never introduced to SMI, and there is currently no evidence that deer ever colonized either island on their own. Thus SMI's Holocene plant communities have evolved in the absence of ungulate browse pressure, and provide a good reference for investigating the recovery of NMI plant communities to pre-deer conditions. Provided SMI remains deer-free, long-term data on the differences in forest structure and community composition between the two islands and between SMI and the mainland will provide a unique and invaluable reference for restoration and management. The greatest scientific value of SMI is its role as a base datum of what a large deer-free system looks like.

Therefore, the specific objectives of this study are to (1) provide baseline forest structure data of a large, deer free system (SMI) for inter-regional comparison with other areas heavily impacted by current or past overbrowse , (2) assess forest recovery on NMI, with emphasis on the herbaceous layer and forest understory, and (3) set up a system of permanent monitoring plots for continued, long-term study of forest development on the two islands.

The Study System

North and South Manitou Islands were included as part of SLBE in 1970, and are, by Great Lakes standards, fairly large at 6,070 ha and 2,020 ha respectively. The lakeshore covers approximately 23,470 ha of land and 4,860 ha of water. There are 103 km of Lake Michigan shoreline included in the Lakeshore. Both islands were predominantly forested before Euro-American settlement, with relatively greater sand dune cover on SMI. Northern hardwood/beech-maple forest is the dominant forest type on both islands, covering over 4,819 ha on NMI and 1,014 ha on SMI. Mixed hardwood/conifer forest covers 136 ha on NMI and 254 ha on SMI. Non-forested cover types on the islands include inland lake, wetland, dunes and shore, and abandoned agricultural fields. The islands experienced extensive logging in the 19th century as forests were cut for firewood, and then converted to agricultural uses. As human populations on the islands declined, forests recovered and currently, the majority of the northern hardwood forest on both islands is mature, uneven-aged second growth, with current conditions reflecting spatially variable but similar 19th century and early 20th century logging. Some areas were logged more recently on both islands (Hazlett 1988), but these areas were excluded from the present study.

Prior to its current ownership and management by the NPS, NMI was privately owned and largely managed as a game preserve for the human-introduced white-tailed deer. The deer were introduced to the island in 1926, and a supplemental feeding program for the deer was instituted in 1937. Supplemental feeding continued until 1977, when NPS acquisition and litigation over the purchase price of the island began. During the time that the feeding program was active, island owners maintained artificially high deer population densities (> 30 deer/km^2). Upon cessation of the feeding program, the deer population went through a period of rapidly fluctuating population levels, with a population crash followed by a boom and then another crash in a period of only five years (McCullough 1997). Case and McCullough (1987) reported detrimental impacts of the irruptive deer population on the woody and herbaceous vegetation in the forest understory, resulting in an obvious browse line and an understory devoid of all but a few unpalatable species such as American beech (*Fagus grandifolia*). Since implementation of population control measures in 1985 (i.e., annual hunts), the deer population has stabilized at a much lower density (~ 3 deer/km^2, S. Yancho, pers. comm.), and the forest understory has visibly recovered (NPS sources, pers. obs.).

Pre-Euro-American settlement data is generally not available on forest understory conditions. Nor is there much useful information on the understory flora for NMI or SMI for the period prior to deer introduction on NMI. There is little reason to believe, however, that the understory flora in the northern hardwood forest type on the two islands differed markedly prior to the introduction of deer to NMI. Any differences stemming from different colonization histories following the last glaciation were likely to be small since both islands are similarly isolated from the mainland and contain similar mixtures of soils, slope, aspect, etc. We would expect that any differences resulting from Euro-American colonists deliberately or accidentally bringing new native plant species to the islands would also be minor since colonists would have had little incentive to pursue such introductions; even if they had, we know of no reason to expect that one island would have experienced dramatically different patterns of introduction. It is likely that we will never know precisely how similar the islands' understory flora was in 1850 or 1900. However, it seems far more likely that they were quite similar than the alternative - two islands, just three miles apart had ground floras that differed substantially in the relative abundance of many species. We therefore, make the assumption that prior to the introduction of deer to NMI, the understory and ground flora of both islands were very similar. We believe that SMI offers the best available model for the restoration of NMI to conditions resembling pre-Euro-American settlement. Moreover, we believe that the differing deer histories of NMI and SMI provide an outstanding opportunity to understand the long-term effects of sustained high densities of deer on forest ecosystems.

Methods

We sampled overall forest community structure, with an emphasis on woody plants in 2003, whereas in 2004 our sampling focused on herbaceous layer in mature northern hardwood forests. For both years, sampling was conducted in mature northern hardwood forest on level to moderately sloping ground. Additionally, soils were either sandy loams or loamy sands, and the sample space, as defined by a GIS analysis, was therefore relatively homogenous. Our intent was not to provide a representative sample of forest communities on the islands, but rather to investigate whether differences existed between the two islands that reflect primarily differences in cultural legacies (e.g., deer browse on NMI) rather than variation in underlying environmental heterogeneity.

Therefore, we selected sites within areas of mature northern hardwoods forest with the constraints that sites had to be located on loamy sands or sandy loams, and slopes had to be less than 10 degrees. We used a GIS (ESRI ArcView, version 3.3) analysis to select suitable areas – correct forest type, soils and slopes. We obtained spatial data, including digital elevation models (USGS 7.5' DEMs), detailed soils data (USDA Natural Resources Conservation Service SSURGO data), and landcover data, from the NPS website http://www.nps.gov/gis/data_info. We first created a polygon theme of suitable areas and randomly selected points within the resultant polygons such that they were at least 240 m apart and 70 m from the edges of the polygons. This ensured that the plots would be distant enough from ecotones or edges where vegetation, soil, slope, might be considerably different. Thus an "edge" effect is not likely in our samples. By selecting relatively homogenous areas for sampling, we effectively reduced the confounding potential of unaccounted variables.

In 2003, we randomly selected 32 sites on SMI and 35 sites on NMI. At each site we used modified Forest Inventory and Analysis (FIA) protocols to set up an array of four 8-m radius circular plots, with the center of plot located at the site center and the center of plots 2, 3, and 4 located 39 m and 0°, 120°, and 240° respectively from the center of plot 1 (see Figure 1a). We recorded species and dbh (diameter at breast height, 1.4 m) of each woody stem with dbh ≥ 10 cm in each plot. We also measured height and age of a single representative canopy tree in each plot. In smaller, 4-m radius subplots centered at plot centers, we recorded species and diameter of saplings, defined here as woody stems with dbh < 10 cm and height > 1.8 m. Finally, we recorded counts (within 4 height classes) and percent cover of woody stems < 1.8 tall in 1 m^2 quadrats. We established 3 quadrats within each plot located 5 m and 30°, 150° and 270° from the plot center (Figure 1b). We also recorded, in each quadrat, coverage by herbaceous plants, litter, bare mineral soil, mosses, and coarse woody debris.

In 2004, we designed our sampling to look specifically at the herbaceous layer. We randomly selected 10 sites on each island, and set up 100 m long transects, with their origin at site center and a direction randomly selected between 0° and 360°. Along each transect, we located a systematic array of 40, 1-m^2 quadrats, as depicted in Figure 1c. Within each quadrat, we recorded species and percent cover of all woody and herbaceous plants. We limited our sampling of woody species to individuals with heights ≤ 1 m. Additionally, we noted flowering status of herb species, and recorded more detailed demographic data for two focal species, Large-flower trillium (*Trillium grandiflorum*) and Jack-in-the-pulpit (*Arisaema triphyllum*). (See appendices for common and latin names of plants). We have not yet analyzed demographic data from these two species, and the methodology and analytical results will be described in a future manuscript.

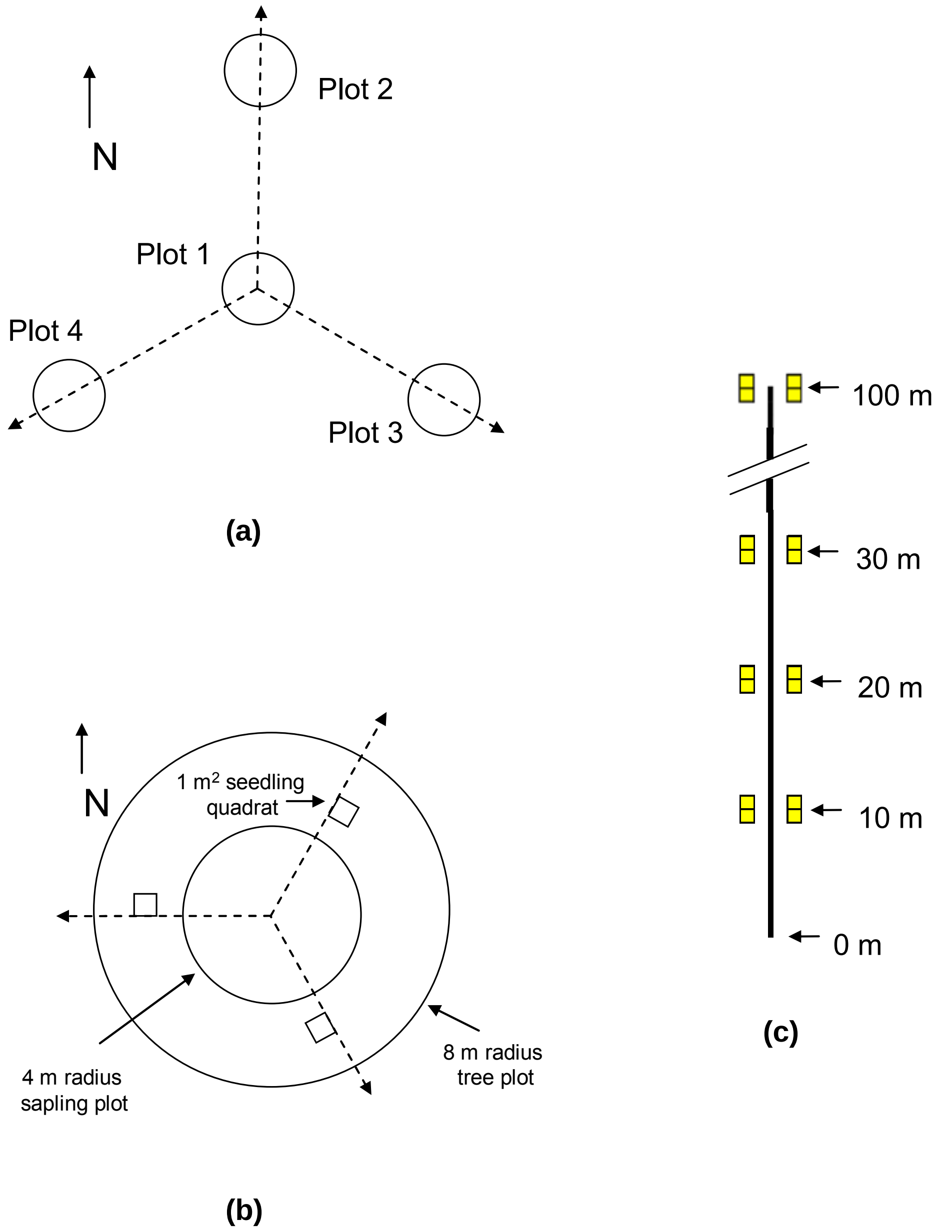


Figure 1. *Plot and transect layout for 2003 and 2004 sampling.*

Results

Our study of the current condition of forest vegetation in the northern hardwood forest type (the dominant vegetative cover type on the islands) reveals that, relative to the ecologically similar but unbrowsed forests of SMI, historically high levels of deer browse have altered understory species composition and forest community trajectory on NMI. Following the peak of deer densities in the late 1980s, anecdotal reports describe much of NMI's forests as having a park-like appearance with little or no green vegetation below 2 m. Today, the understory no longer lacks green vegetation, but its current composition and likely future trajectories are considerably altered from the probable composition and trajectory in the absence of excessive deer browse.

Tree Seedlings

On the two islands, we found dramatic differences in the total abundance and relative abundance of woody seedlings (defined as woody plants less than 1.8 m in height). NMI has more stems of both dominant tree species in all seedling height classes (by approximately 4:1) but is dominated by the relatively unpalatable American beech, especially in the smaller height classes (Figure 2c and 2b). SMI has fewer woody seedlings overall and the difference among the islands in this respect is most pronounced for American beech. In fact, American beech seedlings are more than twenty times more abundant on NMI than on SMI (Figure 2b). Sugar maple seedlings in these height classes are also more abundant on NMI than SMI and the difference is most pronounced in the smallest seedlings. The smallest sugar maple seedlings (height < 0.5 m) are four times more abundant on NMI than on SMI (Figure 2a).

Small diameter saplings

We also found differences among the islands' understory tree species in small diameter saplings (> 1.8 m tall, ≤ 5cm dbh; Figure 3). As with the smaller seedlings, NMI has more small diameter saplings in the two smallest size classes (Figure 3c) and sugar maple is virtually absent in all size classes (Figure 3a), likely as a result of poor recruitment into the sapling layer during a period when browse pressure was especially heavy. On NMI, American beech saplings are abundant in the smaller size classes, a pattern that is also consistent with this unpalatable species being favored by selective browse on its competitors 20-40 years ago (Figure 3b). On SMI, sugar maple saplings are abundant in all size classes and American beech saplings are scarce (Figure 3a). This too is consistent with patterns one would expect from deer preferentially browsing sugar maple (relative to American Beech) on NMI and the absence of deer on SMI. The sapling recruitment patterns on NMI contrast greatly with the patterns documented for SMI, and this difference likely will result in a lasting effect on patterns of future forest development, including an alteration in future patterns of gap dynamics and eventual overstory composition.

Large diameter saplings

Saplings in larger size classes (6-10 cm dbh) and small diameter understory trees on the two islands differed less than seedlings and small diameter saplings. In general, among these larger saplings, SMI had more although differences between the islands were minor for most size classes (Figure 2.6c, 2.7c). Large diameter sugar maple saplings were more abundant on SMI than on NMI but again, differences were not dramatic (Figure 4a). American beech abundance in these size classes was also similar (Figure 4b). This pattern is generally consistent with what one would expect if browsing pressure had its greatest impact on the cohort of tree seedlings and saplings that were within the deer browse zone immediately following the removal of the supplementary feeding program in 1977.

Understory and Overstory Trees

Deer impacts are least evident on the composition of larger diameter stems that comprise the understory and overstory of northern hardwood forest on the islands. There are differences between the two islands (Figure 5 and Appendix 1), but the differences can likely be attributed to a number of historical factors. There is no obvious signal in the data suggesting that a legacy of overbrowse by deer on NMI accounts for the observed differences in overstory trees. Rather, logging and other human activity since settlement may have had differential impacts on forest communities on the two islands. Additionally, GLO survey data suggest that forest structure and composition differed somewhat even prior to Euro-American settlement (unpublished data) and these differences in conjunction with differing human legacies likely account for many of the observed differences.

Notable differences between the two islands include the rarity of white ash (*Fraxinus americana*) on NMI relative to SMI, and the much higher importance of black cherry (*Prunus serotina*) on NMI. Additionally, American beech importance is greater on NMI relative to SMI, whereas sugar maple achieves greater importance on SMI. The role that deer may have played in the historic establishment and recruitment dynamics that determined the current composition of the overstory is not known. We have not yet fully analyzed the age structure of the overstory trees, but preliminary work suggests that establishment of the current overstory in the sampled mature northern hardwood forest occurred prior to the introduction of deer to the island in 1926, and certainly occurred before intensive management and supplemental feeding of deer began in the 1940s.

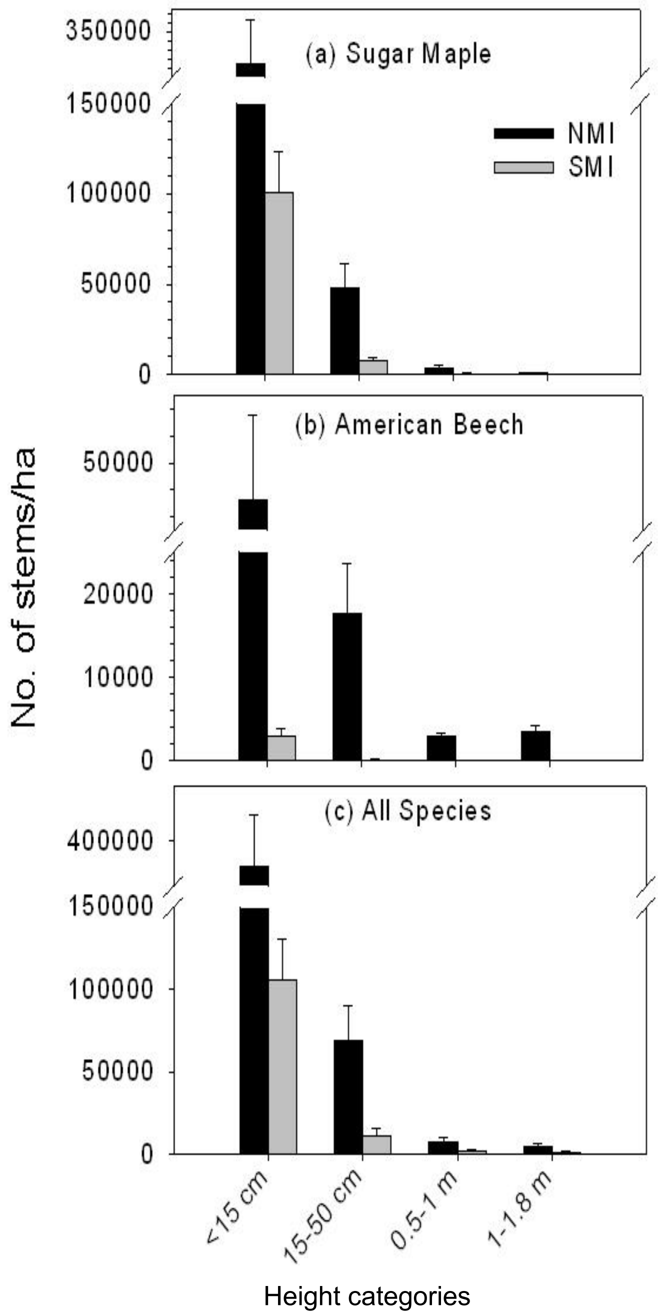


Figure 2. *Mean ± SE for tree seedlings in four height categories across plots on North and South Manitou Islands.*

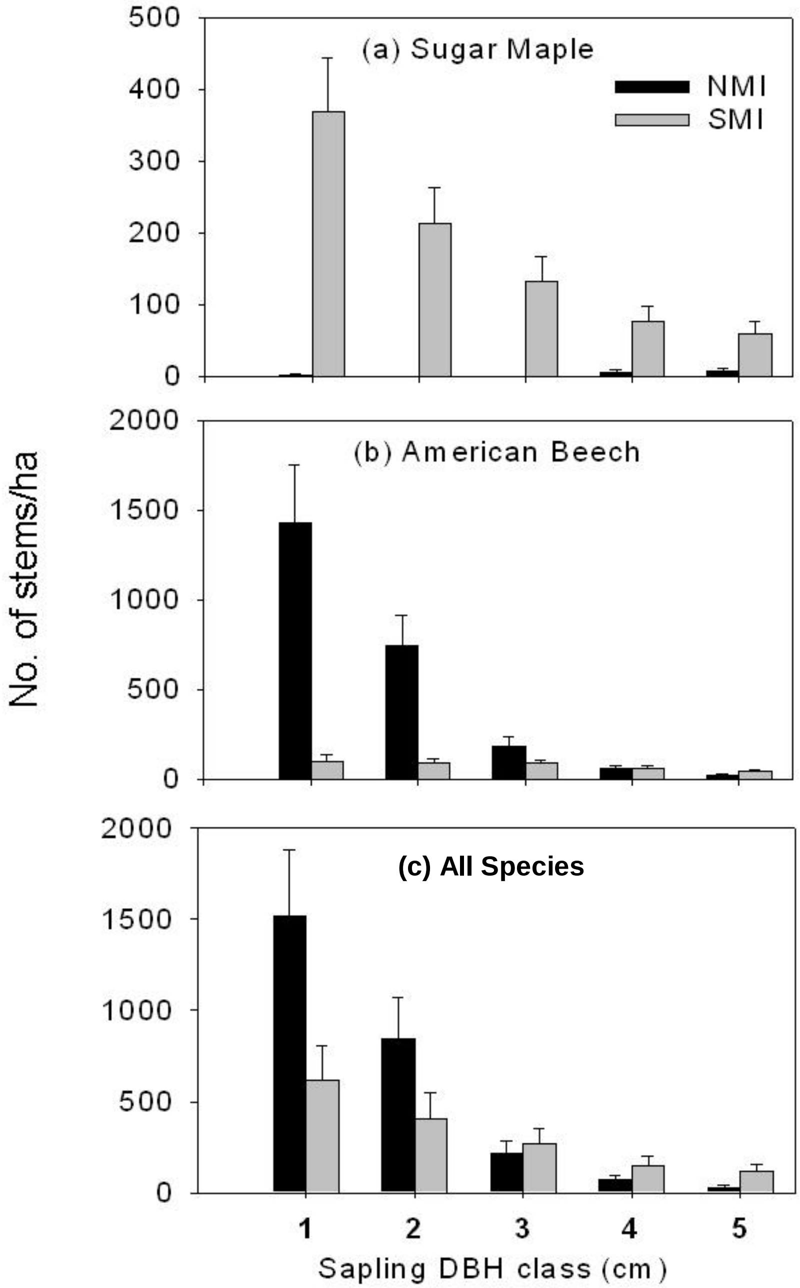


Figure 3. *Mean ± SE for small diameter tree saplings across plots on North and South Manitou Islands.*

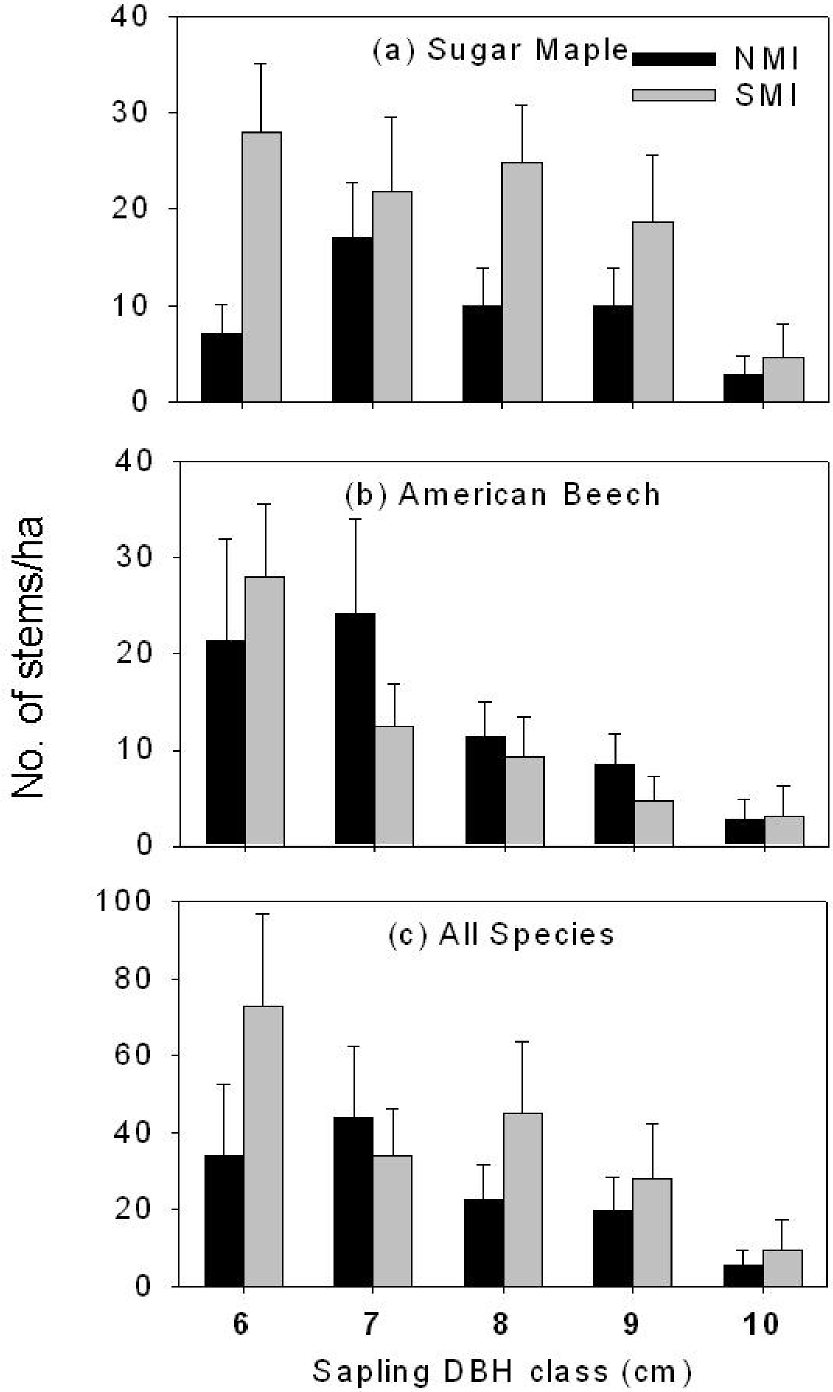


Figure 4*. Mean ± SE for large diameter tree saplings across plots on North and South Manitou Islands.*

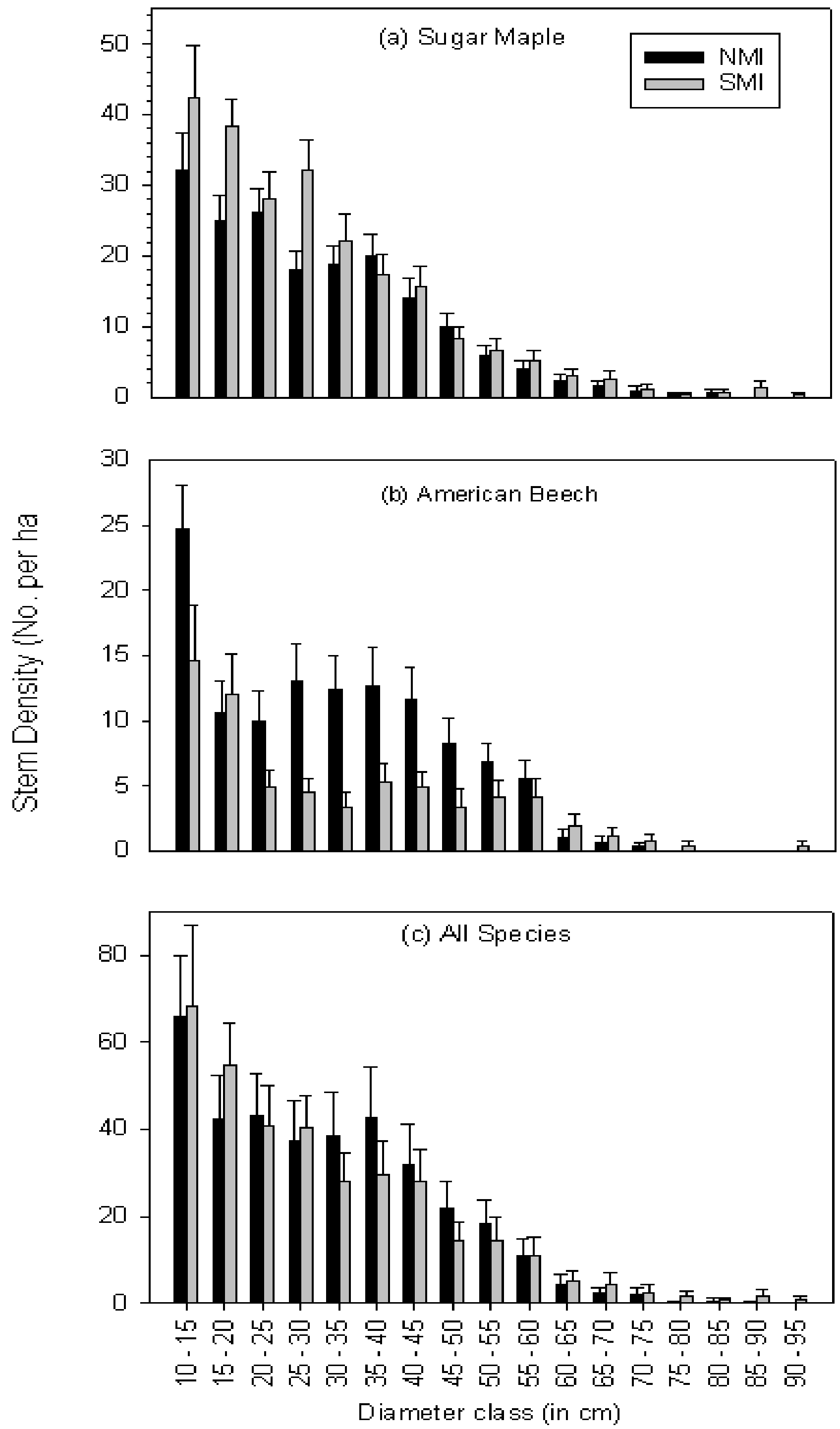


Figure 5. *Diameter distributions (mean ±SE) for trees in northern hardwood forest on North and South Manitou Islands.*

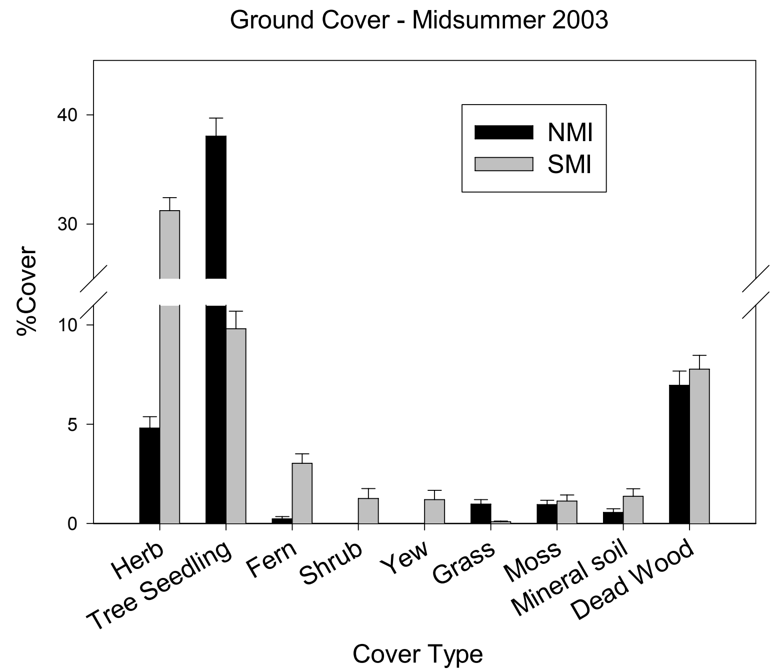


Figure 6. *Percent ground cover in mature second growth northern hardwood forest on North and South Manitou Islands. Tree seedling cover was estimated for all seedlings woody stems < 1.8 m tall.*

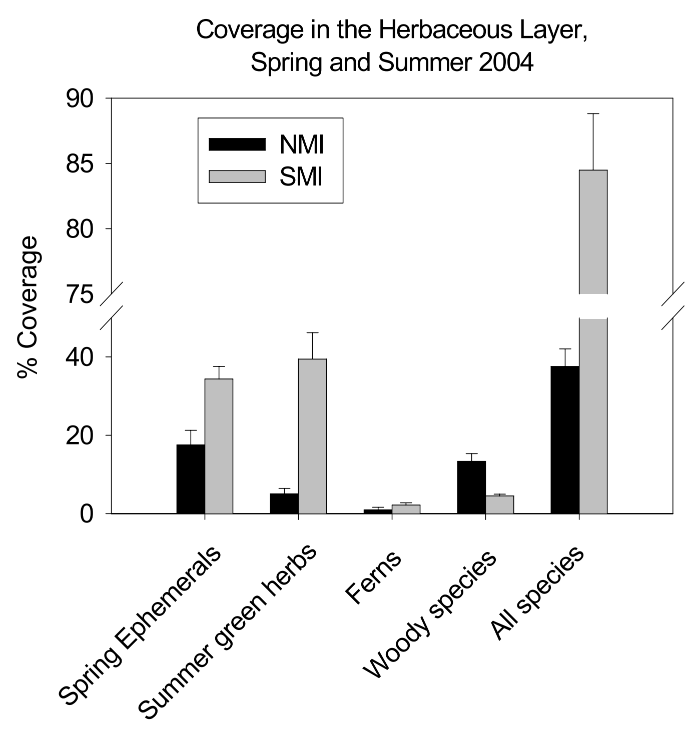


Figure 7. *Herbaceous layer percent cover in mature second growth northern hardwood forest on North and South Manitou Islands. Tree seedling cover was estimated for all woody stems < 1 m tall.*

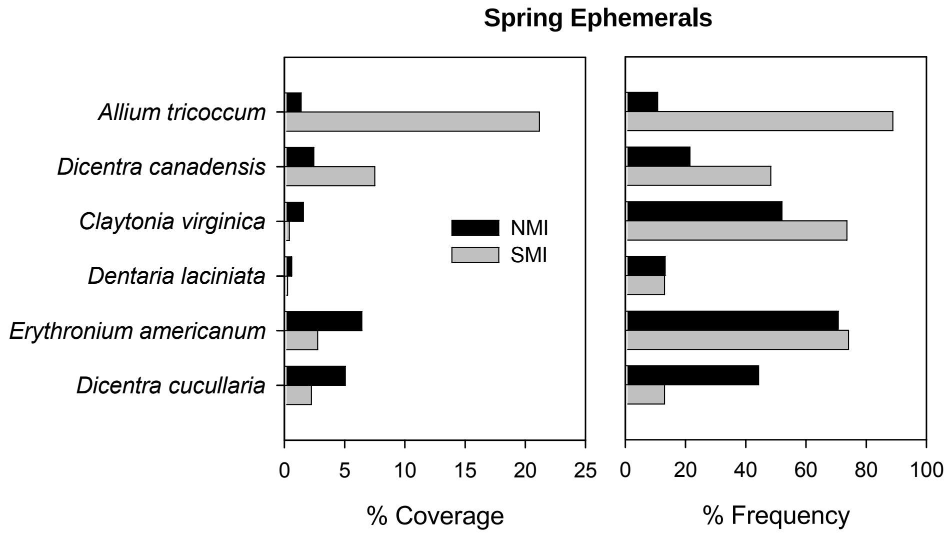


Figure 8. *Percent coverage and frequency (quadrat level) for spring ephemeral forest herbs on North and South Manitou Islands. Species are ranked by mean in quadrat level frequency between the two islands for six species that occurred in at least one percent of quadrats.*

Forest Herbs and Understory Shrubs

Comparing NMI and SMI northern hardwood forests, we found profound differences in the relative frequency and/or abundance of many species of forest herbs and shrubs (Figures 8, 9, and 10 and Appendices 2, 3 and 4) as well as major differences in the total amount of forest floor covered by herbs versus tree seedlings (Figure 6 and 7).

Many of these differences are consistent with what one would expect given known browse preferences of deer. Our data on shrubs and herbs suggest that some species have been functionally extirpated from NMI (e.g., *Taxus canadensis*, *Acer spicatum*, *Viburnum acerfolium*, *Ribes cynosbati*, *Caulophyllum thalictroides*, and *Uvularia grandiflora*). This means that while a few individuals may remain in protected microsites, the functional role of these plants has been greatly reduced or eliminated from the forest ecosystem. Many palatable herb species that do remain on NMI (e.g., *Allium tricoccum and Arisaema triphyllum*) are far less abundant than on SMI. In midsummer (late June and July, 2003 survey, Figure 6), understory herbaceous plants cover only 5% of the forest floor on NMI compared to 35% (41% in 2004 survey) of the forest floor on SMI.

There is some evidence of recovery since the mid 1980's, however. In particular, the frequency and cover of spring ephemeral herb species on NMI (18% cover, measured in mid May, 2004) now approaches that found on SMI (34% cover). *Eyrthronium americanum* (trout lily) actually had higher average cover and was encountered asfrequently on NMI as on SMI (Figure 8). Of the spring ephemerals, only *Allium tricoccum* (wild leek) appears not to have recovered substantially on NMI. Also, several summer green herb species that Hazlett (1985) reported as absent from NMI (e.g., *Actaea pachypoda*, *Sanguinaria canadensis*, *Smilacena racemosa*, and *Thalictrum dioicum*) now occur at low, but detectable, frequencies (Figure 9).

Trillium grandiflorum, in particular, has recovered substantially on NMI, with both average cover and frequency approaching that found on SMI. A handful of summer green herbs were actually more common on NMI, but most species had much lower cover and were far less abundant on NMI, with average total cover of summer green herbs on NMI being only 5% compared to 31% (39% 2004 survey) for SMI.

Shrubs and some understory tree species have also recovered slowly on NMI. Several species that were encountered on sampling plots on SMI were not present on NMI sampling plots, including *Taxus canadensis* (Canada yew), *Sambucus canadensis* (elderberry), and *Acer spicatum* (mountain maple) (Figure 10, Appendix 1) Only two woody species that regularly grow and reproduce in the forest understory, *Acer pennsylvanicm* (striped maple) and *Ostrya virginiana* (ironwood), were more common on NMI than on SMI, and deer generally avoid both of these species.

The slow recovery of the summer green herb and shrub communities on NMI may be in part due to competition with vigorous advance regeneration of American beech and sugar maple. As pointed out previously, densities of small saplings (primarily American beech) are much higher on NMI than on SMI. Additionally, the abundance of seedlings (defined here as trees less than 1.8m tall) is much greater on NMI (Figure 2.8), with midsummer (late June and July, 2003 survey) percent cover for seedlings on NMI at 38% vs. 10% for SMI.

The total woody and herbaceous midsummer plant cover (< 1.8 m, 2003 survey) in the herbaceous layer on NMI is 44% compared to 46% for SMI, suggesting that growing space is equally occupied on the two islands. Apparently advance regeneration of overstory tree species, with a ready seed source from reproductive canopy trees and absence of competition from perennial herbs and shrubs, has opportunistically taken over. Whether this is an ephemeral phenomenon, or represents an alternate dynamic equilibrium, is currently unclear.

In addition to large differences in frequency and percent coverage between the two islands, we also found interesting differences in herbaceous layer species richness, particularly for summer green herbs (Figure 11). While NMI had fewer summer green herb species than SMI, the magnitude of the differences between the two islands depended on the spatial scale at which it was measured. NMI had on average 81% fewer species per 1-m^2 sampling quadrat than SMI, whereas at the whole island scale (400 1-m^2 quadrats) NMI had just 31% fewer species. This pattern suggests relatively more clumped species distributions and/or lower species evenness on NMI compared to SMI. However, calculation of Simpson's index of evenness ($E_{1/D}$) indicates a somewhat more even species distribution for NMI summer green herbs ($E_{1/D}$ = 0.438) relative to SMI ($E_{1/D}$ = 0.359), though the difference was not statistically significant (Student's t = -1.44, df = 18, p = 0.167). We found no differences in evenness between the two islands when all species (spring ephemerals, summer green herbs, and woody species) were considered, either.

We did find evidence of a greater degree of clumping on NMI, with the majority of species for which it was possible to estimate a dispersion index (Green's coefficient of dispersion, G_c) (Krebs 1999) showing a more clumped dispersion pattern on NMI than SMI (see Appendix 5). Moreover, differences in the degree of dispersion between the two islands depended on the spatial scale at which we measured dispersion. For example, *Trillium grandiflorum* showed a markedly more clumped pattern on NMI relative to SMI when dispersion was measured at an island level spatial scale (i.e., across transects). However, at a smaller spatial scale, that of quadrats within transects, G_c values for *T. grandiflorum* indicated more or less equal levels of clumping between the two islands. Additionally, we found a general pattern across all species of greater within-transect relative to between-transect clumping on SMI. Nevertheless, G_c values for species on SMI were generally smaller, indicating a more random and less clumped dispersion pattern, at both within- and between-transect spatial scales. Across transects, 18 of 22 herb species were more clumped on NMI, 1 was more clumped on SMI, and 3 species showed more or less equal levels of clumping between the islands (X^2 = 23.5, df = 2, p < 0.001). Across quadrats within transects, the pattern was similar, with 15 species demonstrating higher clumping on NMI, 5 species with higher clumping on SMI, and 1 species showing equal levels of clumping (X^2 = 12.6, df = 2, p < 0.002).

Careful study of dominance-diversity curves (Whittaker plots, after Whittaker 1965) for the two islands (Figure 12) does reveal further differences in the distributions of species abundances (e.g., degree of dominance) that a simple index of evenness does not, however. Curves for both islands resemble the characteristic S-shape of a lognormal distribution of species relative abundance. However, the overall shape of the two curves more strongly suggest Hubbell's (2001) asymmetric zero-sum multinomial distribution, particularly as predicted by a neutral community model that assumes dispersal limitation. This may have important implications for restoration and for testing models of community assembly, in that neutral theory emphasizes the importance of stochastic relative to deterministic processes. If chance and history play dominant roles in determining community structure and dynamics, restoration may play a more important role in determining the future state of the islands' biodiversity.

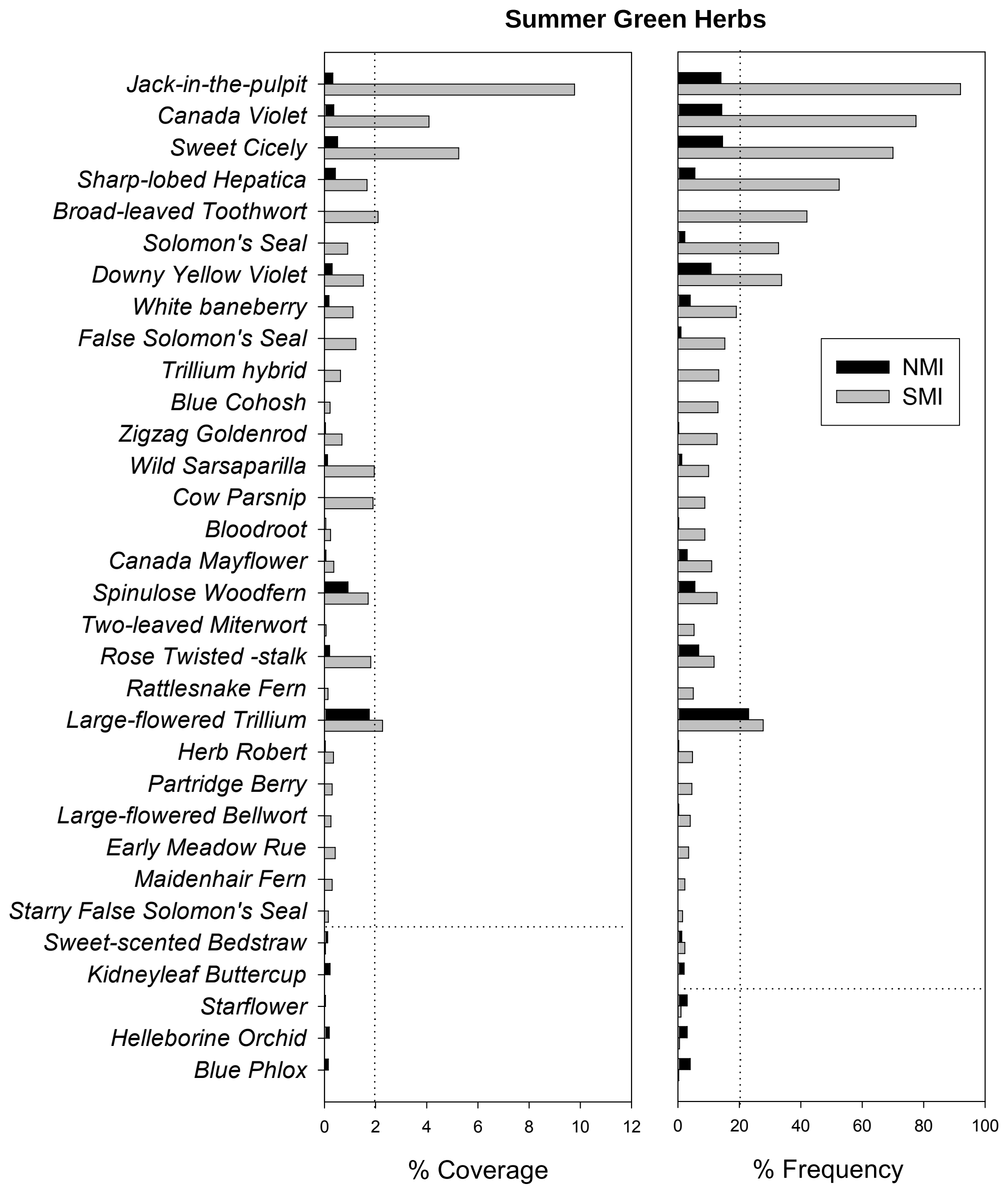


Figure 9. *Percent coverage and frequency (quadrat level) for summer green forest herbs on North and South Manitou Islands. Species are ranked by mean difference in quadrat level frequency between the two islands for 33 species that occurred in at least one percent of quadrats.*

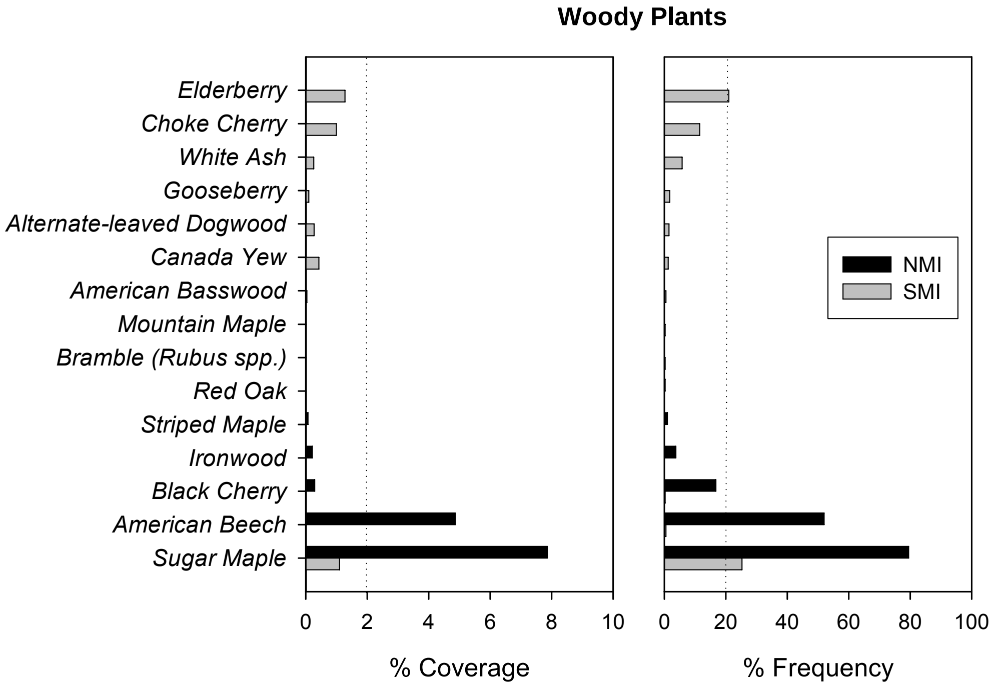


Figure 10. *Percent coverage and frequency (quadrat level) for woody plants (height ≤ 1 m) on North and South Manitou Islands. Species are ranked by mean difference in quadrat level frequency between the two islands for 15 species that occurred in at least one percent of quadrats.*

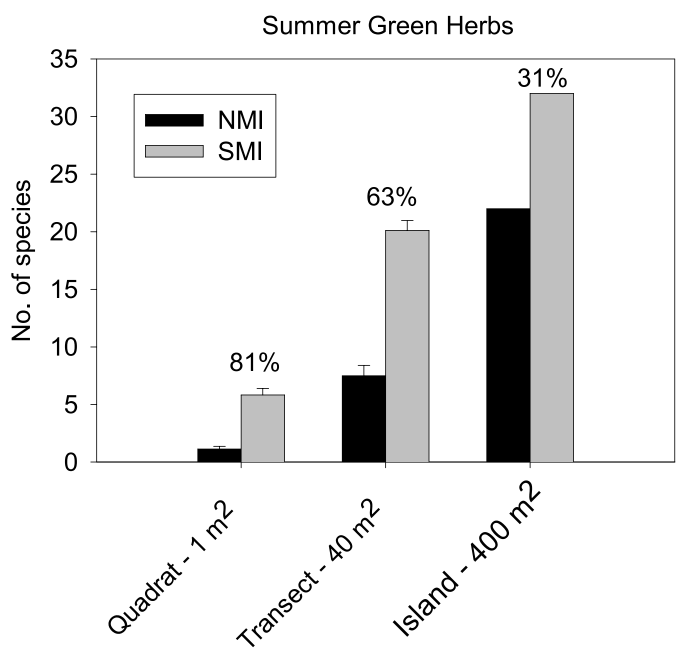


Figure 11. *Herbaceous layer species richness (mean ± SE) in mature second growth northern hardwood forest on North and South Manitou Islands. Average richness is shown at three spatial scales. Numbers above bars represent the percentage decrease in richness on NMI relative to SMI.*

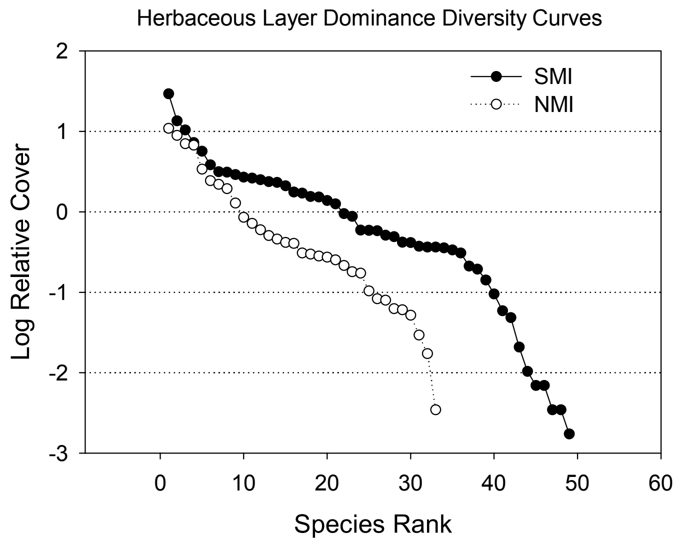


Figure 12. *Herbaceous layer dominance-diversity curves (Whitaker plots) for mature second growth northern hardwood forest on North and South Manitou Islands.*

Conclusion

Studies of entire herb communities recovering from historic, chronic overbrowse by white-tailed deer or other ungulates are extremely rare (although see Webster et al. 2005). Exclosure studies, while common, do not allow assessment of recovery at an appropriate scale (i.e., whole community or stand level vs. plot level). Exclosures provide an effective means of documenting deer impacts on plant communities primarily in the early stages of overbrowse, before local extirpation of preferred or browse intolerant species. Long-term, chronic herbivory often results in loss of species from large areas (Leopold 1938, Côté et al. 2004) as evident in this and other studies (e.g., Webster 2005). Many forest herbs are dispersal limited (Ehrl and Eriksson 2000), with little ability to recolonize an area if source populations are distant or dispersal must occur a across a relatively hostile matrix. Thus for locally extirpated, dispersal limited herb species, exclosures are of limited utility in documenting either browse impacts or recovery from browse. In such cases, comparison with an appropriate reference system(s), such as SMI, is necessary to provide a suitable baseline for recovery.

Comparison of the forest understory and herbaceous layers on the two islands indicate that recovery from intense, chronic browse on NMI may take decades to proceed appreciably. Forest herb communities, in particular, are slow to respond to reduced deer densities. Sustained browse levels were great enough on NMI to severely alter ecosystem trajectory and cause biotic impoverishment of island forest communities, particularly forest herbs. Since NPS took over management of the island, some recovery is evident and the deer that remain on NMI, while likely inhibiting recovery of some plant species, do not appear to be continuing to erode the island's biotic integrity (as indexed by species richness, number of plant extirpations, etc.). However, the role of this introduced ungulate in shaping current forest ecosystem processes, especially with regard to the recovery of understory plant communities, is not well understood and warrants further study.

Although deer do exhibit selective browsing when resources are abundant (Strole and Anderson 1992), Seagle and Liang (1997) suggested that overabundant deer can lower availability of vegetative browse to a point where deer become generalists and all species are equally utilized. Such a switch from a selective to nonselective foraging strategy likely occurred on NMI, at least for deer foraging in the forest understory (see Case and McCullough 1987). Even unpalatable beech leaves were conspicuously browsed, and it seems likely that most if not all forest herbaceous species were heavily browsed, with some populations declining to the point where they became barely detectable or were eliminated entirely (Hazlett 1985, 1988). Thus population recovery may not reflect selective browsing in the past so much as the suite of factors which have limited recovery since deer numbers were reduced to their current levels. However, even if the overabundant deer of the past browsed all herbs more-or-less equally, current selective foraging patterns by deer may have differential impacts on recovery rates of different understory species, depending on palatability. Deer may avoid woody species in favor of foraging on more palatable forest herbs. Under this scenario, even a relatively low density of deer might be capable of suppressing many herb species made rare by intense browse in the past. This could result in an alteration of competitive dynamics between different forest understory species or species' guilds, producing an alternate dynamic trajectory (sensu Augustine et al. 1998's "alternate stable states") where tree seedlings and saplings maintain dominance over herbs into the foreseeable future.

We believe that the shrub and herbaceous plant communities have and will continue to recover much more slowly than the understory tree community. While the composition of established understory trees was almost certainly altered by past deer browse, current low rates of deer browse are unlikely to continue to have a profound impact. As evidence of this, tree seedling abundance is actually higher for some browse sensitive species (e.g., *Acer saccharum*) on NMI than on SMI. Thus trees seem to be coming back unassisted, likely due to a steady seed rain from the reproductively mature overstory.

In contrast, understory shrubs and herbaceous plants that were greatly reduced in abundance or locally extirpated, do not have a locally abundant seed source, and thus recovery may be seed limited. Factors that may limit herb and shrub recovery include: 1) resource competition with tree seedlings and saplings, 2) lack of and/or competition for suitable germination microsites, 3) pollen or pollinator limitations, 4) seed predation, 5) herbivory by deer or other animals, and 6) life history traits that predispose understory plants to slow dispersal and slow growth. More than one of these factors may interact in complex ways to limit growth, dispersal and thus population recovery. A better understanding of the processes that limit growth, reproduction and dispersal of forest herbs would be helpful for future restoration of this component of NMI's forests.

In this paper, we have highlighted structural and functional components of the forests on NMI that were likely most impacted by chronic overbrowse. Given sufficient time, unmanipulated ecological succession may continue to move the islands' forests toward the desired condition, whatever that may be (e.g., mid-19th century). On the other hand, some of the conditions documented in this study that are the result of past deer browse may not be ameliorated by decades or even centuries of natural succession.

Literature Cited

Augustine, D.J., and L.E. Frelich. 1998. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forest. Conservation Biology 12:995-1004.

Augustine, D.J., L.E. Frelich, and P.A. Jordan. 1998. Evidence for two alternate stable states in an ungulate grazing system. Ecological Applications [Ecol. Appl.] 8: 1260-1269.

Balgooyen, C.P. and D.M. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. Natural Areas Journal 15:308-318.

Case, D.J., and D.R. McCullough. 1987. The white-tailed deer of North Manitou Island. Hilgardia 55: 57 pp.

Côté, S.D., T.P. Rooney, J. Tremblay, C. Dussault, and D.M. Waller. 2004. Ecological impacts of deer overabundance. Ann. Rev. Ecol. Evol. Syst. 35: 113-147.

Ehrl, J. and O. Rriksson. 2000. Dispersal limitation and patch occupancy in forest herbs. Ecology 81: 1667-1674.

Foster, D., F. Swanson, J. Aber, I. Burke, N. Brokaw, D. Tilman, and A. Knapp. 2003. The Importance of Land-Use Legacies to Ecology and Conservation. Bioscience 53: 77-88.

Frankland, F. and T. Nelson. 2003. Impacts of White-tailed Deer on Spring Wildflowers in Illinois, USA. Natural Areas Journal 23: 341-348.

Hazlett, B.T. 1985. The terrestrial vegetation and flora of North and South Manitou Islands, Sleeping Bear Dunes National Lakeshore, Leelanau County, Michigan. Univ. of Michigan Bio. Sta. Tech. Rpt. 11. 143 pp.

Hubbell, S.P. 2001. The Unified Neutral Theory of Biodiversity and Biogeography. Monographs in population biology 32. Princeton University Press, Princeton, New Jersey.

Leopold, A. 1938. Report on Huron Mountain Club. Huron Mountain Wildlife Foundation, private publisher.

Krebs, C.J. 1999. Ecological methodology, 2nd edition. Benjamin Cummings. 624 pp.

McCabe, T.R. and R.E. McCabe. 1997. Recounting whitetails past. *In* The science of overabundance: deer ecology and population management (Editors W.J. McShea, H.B. Underwood, and J.H.Rappole), pp.11-36. Smithsonian Institution, Washington, D.C.

Rooney, T.P. 2001. Deer impacts on forest ecosystems: a North American perspective. Forestry 74:201-208.

Rooney, T.P. and K. Gross. 2003. A demographic study of deer browsing impacts on *Trillium grandiflorum.* Plant Ecology 168: 267-277.

Ruhren, S. and S.N. Handel. 2003. Herbivory constrains survival, reproduction and mutualisms when restoring nine temperate forest herbs. Journal of the Torrey Botanical Society 130: 34-42.

Russell, F.L., D.B. Zippin, and N.L. Fowler. 2001. Effects of White-tailed Deer (*Odocoileus virginianus*) on Plants, Plant Populations and Communities: A Review. American Midland Naturalist 146(1):1-26.

Seagle, S.W. and S.Y. Liang. 2001. Application of a forest gap model for prediction of browsing effects on riparian forest succession. Ecological Modelling [Ecol. Model.] 144: 2-3.

Strole, T.A. and R.C. Anderson. 1992. White-tailed deer browsing: species preferences and implications for central Illinois forest. Natural Areas Journal 12:138.

Waller, D.M. and W.S. Alverson. 1997. The white tailed deer: a keystone herbivore. Wildlife Society Bulletin 25:217-226.

Webster, C.R .and G.R. Parker. 1997. The effects of white-tailed deer on plant communities within Indiana state parks. Proceedings of the Indiana Academy of Science 106:213-231.

Webster, C.R., M.A. Jenkins, and J.H. Rock. 2005. Twenty years of change in the woodlots of Cades Cove, Great Smokey Mountains National Park. Biological Conservation 125:297-307.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities. Science 147:250-259.

Appendix 1. Importance values for all tree species sampled within tree plots during 2003 survey, sorted in descending order of combined importance values on the two islands.

Scientific Name	Common Name	Relative Frequency		Relative Density		Relative Dominance		Importance Values	
		NMI	SMI	NMI	SMI	NMI	SMI	NMI	SMI
Acer saccharum	Sugar Maple	38.21	42.96	49.67	65.12	46.16	58.70	44.68	55.59
Fagus grandifolia	American Beech	30.75	28.52	32.39	18.90	33.45	22.34	32.20	23.25
Fraxinus americana	White Ash	0.00	13.38	0.00	9.29	0.00	13.21	0.00	11.96
Prunus serotina	Black Cherry	8.66	0.70	4.44	0.22	8.58	0.65	7.23	0.52
Betula alleghaniensis	Yellow Birch	6.57	3.87	3.59	1.51	3.26	1.42	4.47	2.27
Tsuga canadensis	Eastern Hemlock	3.28	2.82	3.40	1.51	0.98	1.50	2.56	1.94
Ostrya virginiana	Ironwood	4.78	2.82	2.27	1.62	0.51	0.12	2.52	1.52
Tilia americana	American Basswood	2.39	2.11	1.23	0.65	2.25	1.12	1.96	1.29
Betula papyrifera	White Birch	2.99	1.41	1.23	0.65	1.45	0.62	1.89	0.89
Populus grandidentata	Bigtooth Aspen	0.90	0.00	1.23	0.00	1.87	0.00	1.33	0.00
Acer rubrum	Red Maple	0.60	0.00	0.28	0.00	0.35	0.00	0.41	0.00
Quercus rubra	Red Oak	0.30	0.00	0.09	0.00	0.81	0.00	0.40	0.00
Prunus virginiana	Choke Cherry	0.00	0.70	0.00	0.32	0.00	0.09	0.00	0.37
Pinus strobus	White Pine	0.30	0.00	0.09	0.00	0.32	0.00	0.24	0.00
Juglans nigra	Black Walnut	0.00	0.35	0.00	0.11	0.00	0.23	0.00	0.23
Cornus alternafolia	Alternate-leaved Dogwood	0.00	0.35	0.00	0.11	0.00	0.00	0.00	0.15
Populus tremuloides	Quaking Aspen	0.30	0.00	0.09	0.00	0.00	0.00	0.13	0.00

Appendix 2. Frequency of herbaceous plant species encountered within plots during 2003 surveys, sorted in descending order of occurrence frequency on South Manitou Island. Data represent all herbs observed within the 8-m radius tree plots, not the 1-m2 quadrats nested within tree plots. Spring ephemerals and some early summer green herbs are under-represented, particularly for South Manitou, because sampling was conducted in midsummer.

Scientific Name	Common Name	Species Code	North Manitou Island	South Manitou Island
Arisaema triphyllum	Jack-in-the-pulpit	ARTR	51.43	100.00
Hepatica acutiloba	Sharp-lobed Hepatica	HEAC	48.57	100.00
Viola sp.	Violet	VIOL	71.43	100.00
Allium tricoccum	Wild Leek	ALTR	74.29	96.88
Osmorhiza claytoni	Sweet Cicely	OSCL	77.14	96.88
Actaea pachypoda	White Baneberry	ACPA	8.57	90.63
Polygonatum pubescens	Solomon's Seal	POBI	68.57	87.51
Dryopteris spinulosa	Spinulose Woodfern	DRSP	60.00	81.25
Sanguinaria canadensis	Bloodroot	SACA	25.71	78.13
Smilacene racemosa	False Solomon's Seal	SMRA	17.14	75.00
Dryopteris marginalis	Marginal Wood Fern	DRMA	11.43	68.75
Botrychium virginianum	Rattlesnake Fern	RAFE	17.14	68.75
Trillium grandiflorum	Large-flowered Trillium	TRGR	82.86	65.63
Caulophyllum thalictroides	Blue Cohosh	CATH	0.00	56.25
Maianthemum canadense	Wild Lily of the Valley	MACA	34.29	56.25
Solidago flexicaulis	Zigzag goldenrod	SOFL	8.57	56.25
Galium sp.	Bedstraw	GASP	22.86	53.13
Ribes sp.	Gooseberry	RISP	0.00	53.13
Mitchella repens	Partridgeberry	MIRE	14.29	46.88
Streptopus roseus	Rose Twisted-stalk	STRO	11.43	46.88
Uvularia grandiflora	Large-flowered Bellwort	UVGR	0.00	43.75
Heracleum maximum	Cow-parsnip	HEMA	0.00	40.63
Mitella diphylla	Bishop's Cap	MIDI	0.00	40.63
Taxus canadensis	Canada Yew	TACA	0.00	40.63
Thalictrum dioicum	Meadow Rue	THSP	14.29	53.13
Geranium robertianum	Herb Robert	GERO	45.71	25.00
Adiantum pedatum	Maiden-hair Fern	MHFE	2.86	21.88
Aralia nudicaulus	Wild Sarsaparilla	ARSP	2.86	15.63
Aralia racemosa	Spikenard	ARRA	0.00	12.50
Anemone quiquefolia	Wood Anemone	ANQU	0.00	9.38
Dentaria laciniata	Cut-leaf Toothwort	DELA	8.57	6.25
Smilacene trifolia	Three-leaved False Solomon's Seal	SMTR	0.00	6.25
Acer spicatum	Mountain Maple	ACSP	0.00	3.13
Aralia hispida	Bristly Sarsaparilla	ARHI	2.86	3.13
Clintonia borealis	Clintonia, Corn Lily	CLBO	0.00	3.13
Dentaria diphylla	Toothwort	DEDI	5.71	3.13
Equisetum sp	Horsetail	EQSP	5.71	3.13
Panax quinquefolius	Ginseng	PAQU	0.00	3.13
Sagittaria latifolia	Broad-leaved Arrowhead	SALA	0.00	3.13
Vitus sp.	Wild Grape	VISP	0.00	3.13
Lycopodium sp.	Club Moss	CLMO	5.71	0.00
Dicentra canadensis	Squirrel Corn	DICA	28.57	0.00
Erythronium americanum	Trout Lily	ERAM	17.14	0.00
Galium asprellum	Rough Bedstraw	GAAS	11.43	0.00
Galium triflorum	Fragrant Bedstraw	GATR	5.71	0.00
Phlox divaricata	Blue Phlox	PHDI	20.00	0.00
Onoclea sensibilis	Sensitive Fern	SEFE	2.86	0.00
Senecio obovatus	Roundleaf Ragwort	SEOB	2.86	0.00
Stellaria sp	Chickweed	STSP	2.86	0.00
Taraxacum officnale	Common Dandelion	TAOF	2.86	0.00
Trientalis borealis	Starflower	TRBO	22.86	0.00
Viola canadensis	Canada Violet	VICA	17.14	0.00
Viola pubescens	Downy Yelow Violet	VIPU	5.71	0.00

Appendix 3. Means ± SE for herbaceous layer percent frequency in northern hardwood forests on North and South Manitou Islands, summarized for 2004 for surveys.

Scientific Name	Common Name	Frequency - % of quadrats NMI	Frequency - % of quadrats SMI	Frequency - % of sites NMI	Frequency - % of sites SMI
Spring Ephemerals					
Allium tricoccum	Wild Leek	10.75	88.89	60	100
Claytonia virginica	Spring Beauty	52.00	73.61	100	100
Dentaria laciniata	Cut-leaved Toothwort	13.25	13.06	70	89
Dicentra canadensis	Squirrel Corn	21.50	48.33	60	89
Dicentra cucullaria	Dutchman's Breeches	44.25	13.06	90	78
Erythronium americanum	Trout-lily	70.75	74.17	100	100
Summer Green Herbs					
Actaea pachypoda	White baneberry	4.00	19.00	40	90
Aralia nudicalus	Wild Sarsaparilla	1.25	10.00	20	30
Arisaema tripyllum	Jack-in-the-pulpit	14.00	92.00	50	100
Caulophyllum thalictroides	Blue Cohosh	0.00	13.00	0	90
Clintonia borealis	Bead-lily	0.00	0.75	0	10
Dentaria diphylla	Broad-leaved Toothwort	0.00	42.00	0	100
Epipactus helleborine	Helleborine Orchid	3.00	0.50	50	20
Galium lanceolatum	Wild Licorice	0.00	0.50	0	20
Galium triflorum	Sweet-scented Bedstraw	1.25	2.25	30	50
Geranium robertianum	Herb Robert	0.25	4.75	10	50
Hepatica acutiloba	Sharp-lobed Hepatica	5.50	52.50	30	100
Heracleum maximum	Cow Parsnip	0.00	8.75	0	60
Maianthemum canadense	Canada Mayflower	3.00	11.00	60	80
Mitchella repens	Partridge Berry	0.00	4.50	0	50
Mitella diphylla	Two-leaved Miterwort	0.00	5.25	0	60
Osmorhiza claytoni	Sweet Cicely	14.50	70.00	60	90
Phlox divaricata	Blue Phlox	4.00	0.25	20	10
Polygonatum pubescens	Solomon's Seal	2.25	32.75	40	100
Prenanthes alba	White Lettuce	0.00	0.50	0	20
Ranunculus abortivus	Kidneyleaf Buttercup	2.00	0.00	20	0
Sanguinaria canadensis	Bloodroot	0.25	8.75	10	70
Smilacene racemosa	False Solomon's Seal	1.00	15.25	40	90
Smilacene stellaria	Starry False Solomon's Seal	0.00	1.50	0	20
Solidago caesia	Ble-stemmed Goldenrod	0.25	0.25	10	10
Solidago flexicaulis	Zigzag Goldenrod	0.25	12.75	10	90
Streptopus roseus	Rose Twisted -stalk	6.75	11.75	60	100
Thalictrum dioicum	Early Meadow Rue	0.00	3.50	0	60
Trientalis borealis	Starflower	3.00	1.00	20	10
Trillium erectum x *flexipes*	Trillium hybrid	0.00	13.25	0	90
Trillium grandiflorum	Large-flowered Trillium	23.00	27.75	90	100
Uvularia grandiflora	Large-flowered Bellwort	0.25	4.00	10	50
Viola canadensis	Canada Violet	14.25	77.50	60	100
Viola pubescens	Downy Yellow Violet	10.75	33.75	50	90
Ferns					
Adiantum pedatum	Maidenhair Fern	0.00	2.25	0	20
Botrychium virginianum	Rattlesnake Fern	0.00	5.00	0	40
Dryopteris spinulosa	Spinulose Woodfern	5.50	12.75	40	90
Onoclea sensibilis	Sensitive Fern	0.50	0.00	20	0
Grass/sedge	Grass/sedge	11.75	1.50	60	30
Woody Plants					
Acer pennsylvanicum	Striped Maple	1.00	0.00	30	0
Acer saccharrum	Sugar Maple	79.50	25.25	100	100
Acer spicatum	Mountain Maple	0.00	0.25	0	10
Cornus alternafolia	Alternate-leaved Dogwood	0.00	1.50	0	20
Fagus grandifolia	American Beech	52.00	0.50	100	10
Fraxinus americana	White Ash	0.00	5.75	0	90
Ostrya virginiana	Ironwood	3.75	0.00	20	0
Prunus serotina	Black Cherry	16.75	0.25	60	10
Prunus virginiana	Choke Cherry	0.00	11.50	0	70
Quercus rubra	Red Oak	0.25	0.00	10	0
Ribes sp.	Ribes sp.	0.00	1.75	0	50
Rubus sp.	Rubus sp.	0.00	0.25	0	10
Sambucus pubens	Elderberry	0.00	21.00	0	100
Taraxacum officnale	Dandelion	0.25	0.00	10	0
Taxus canadensis	Canada Yew	0.00	1.25	0	30
Tilia americana	American Basswood	0.00	0.50	0	10

Appendix 4. Means ± SE for herbaceous layer percent frequency in northern hardwood forests on North and South Manitou Islands, summarized for 2004 for surveys.

		North Manitou Island			South Manitou Island		
Scientific Name	Common Name	Mean		SE	Mean		SE
Spring Ephemerals							
Allium tricoccum	Wild Leek	1.40	±	0.78	21.18	±	2.38
Claytonia virginica	Spring Beauty	1.58	±	0.40	0.42	±	0.05
Dentaria laciniata	Cut-leaved Toothwort	0.62	±	0.27	0.26	±	0.07
Dicentra canadensis	Squirrel Corn	2.44	±	1.11	7.50	±	2.27
Dicentra cucullaria	Dutchman's Breeches	5.07	±	1.80	2.25	±	0.71
Erythronium americanum	Trout-lily	6.43	±	1.33	2.77	±	0.48
Summer Green Herbs							
Actaea pachypoda	White baneberry	0.18	±	0.09	1.12	±	0.26
Aralia nudicalus	Wild Sarsaparilla	0.13	±	0.11	1.95	±	1.79
Arisaema tripyllum	Jack-in-the-pulpit	0.33	±	0.24	9.78	±	1.46
Caulophyllum thalictroides	Blue Cohosh	0.00	±	0.00	0.22	±	0.06
Clintonia borealis	Bead-lily	0.00	±	0.00	0.05	±	0.05
Dentaria diphylla	Broad-leaved Toothwort	0.00	±	0.00	2.10	±	0.66
Epipactus helleborine	Helleborine Orchid	0.20	±	0.14	0.01	±	0.01
Galium lanceolatum	Wild Licorice	0.00	±	0.00	0.01	±	0.00
Galium triflorum	Sweet-scented Bedstraw	0.13	±	0.11	0.04	±	0.02
Geranium robertianum	Herb Robert	0.04	±	0.04	0.36	±	0.32
Hepatica acutiloba	Sharp-lobed Hepatica	0.43	±	0.24	1.67	±	0.27
Heracleum maximum	Cow Parsnip	0.00	±	0.00	1.90	±	1.34
Maianthemum canadense	Canada Mayflower	0.06	±	0.02	0.37	±	0.10
Mitchella repens	Partridge Berry	0.00	±	0.00	0.30	±	0.16
Mitella diphylla	Two-leaved Miterwort	0.00	±	0.00	0.07	±	0.03
Osmorhiza claytoni	Sweet Cicely	0.52	±	0.33	5.25	±	0.86
Phlox divaricata	Blue Phlox	0.16	±	0.10	0.00	±	0.00
Polygonatum pubescens	Solomon's Seal	0.02	±	0.01	0.91	±	0.26
Prenanthes alba	White Lettuce	0.00	±	0.00	0.01	±	0.01
Ranunculus abortivus	Kidneyleaf Buttercup	0.22	±	0.22	0.00	±	0.00
Sanguinaria canadensis	Bloodroot	0.06	±	0.06	0.24	±	0.07
Smilacene racemosa	False Solomon's Seal	0.01	±	0.01	1.23	±	0.63
Smilacene stellaria	Starry False Solomon's Seal	0.00	±	0.00	0.15	±	0.15
Solidago caesia	Ble-stemmed Goldenrod	0.05	±	0.05	0.00	±	0.00
Solidago flexicaulis	Zigzag Goldenrod	0.05	±	0.05	0.69	±	0.27
Streptopus roseus	Rose Twisted -stalk	0.20	±	0.12	1.81	±	0.97
Thalictrum dioicum	Early Meadow Rue	0.00	±	0.00	0.43	±	0.16
Trientalis borealis	Starflower	0.04	±	0.04	0.02	±	0.02
Trillium erectum x *flexipes*	Trillium hybrid	0.00	±	0.00	0.64	±	0.15
Trillium grandiflorum	Large-flowered Trillium	1.76	±	0.83	2.28	±	0.54
Uvularia grandiflora	Large-flowered Bellwort	0.00	±	0.00	0.26	±	0.10
Viola canadensis	Canada Violet	0.37	±	0.17	4.09	±	0.49
Viola pubescens	Downy Yellow Violet	0.30	±	0.17	1.52	±	0.48
Ferns							
Adiantum pedatum	Maidenhair Fern	0.00	±	0.00	0.30	±	0.25
Botrychium virginianum	Rattlesnake Fern	0.00	±	0.00	0.14	±	0.09
Dryopteris spinulosa	Spinulose Woodfern	0.93	±	0.65	1.72	±	0.59
Onoclea sensibilis	Sensitive Fern	0.01	±	0.01	0.00	±	0.00
Grass/sedge	Grass/sedge	0.35	±	0.16	0.06	±	0.04
Woody Plants							
Acer pennsylvanicum	Striped Maple	0.08	±	0.04	0.00	±	0.00
Acer saccharrum	Sugar Maple	7.86	±	1.93	1.10	±	0.31
Acer spicatum	Mountain Maple	0.00	±	0.00	0.00	±	0.00
Cornus alternafolia	Alternate-leaved Dogwood	0.00	±	0.00	0.27	±	0.22
Fagus grandifolia	American Beech	4.87	±	1.38	0.01	±	0.01
Fraxinus americana	White Ash	0.00	±	0.00	0.26	±	0.08
Ostrya virginiana	Ironwood	0.22	±	0.15	0.00	±	0.00
Prunus serotina	Black Cherry	0.29	±	0.12	0.00	±	0.00
Prunus virginiana	Choke Cherry	0.00	±	0.00	1.00	±	0.39
Quercus rubra	Red Oak	0.00	±	0.00	0.00	±	0.00
Ribes sp.	Ribes sp.	0.00	±	0.00	0.10	±	0.06
Rubus sp.	Rubus sp.	0.00	±	0.00	0.01	±	0.01
Sambucus pubens	Elderberry	0.00	±	0.00	1.28	±	0.29
Taraxacum officnale	Dandelion	0.00	±	0.00	0.00	±	0.00
Taxus canadensis	Canada Yew	0.00	±	0.00	0.43	±	0.30
Tilia americana	American Basswood	0.00	±	0.00	0.04	±	0.04

Appendix 5. Green's coefficient of dispersion for herbaceous layer species on North and South Manitou Islands.

Scientific Name	Common Name	Transects		Quadrats within transects	
		NMI	SMI	NMI	SMI
Spring Ephemerals					
Allium tricoccum	Wild Leek	0.309	0.014	0.409	0.035
Claytonia virginica	Spring Beauty	0.062	0.009	0.236	-0.026
Dentaria laciniata	Cut-leaved Toothwort	0.193	0.078	0.257	0.414
Dicentra canadensis	Squirrel Corn	0.207	0.102	0.194	0.093
Dicentra cucullaria	Dutchman's Breeches	0.125	0.111	0.298	0.384
Erythronium americanum	Trout-lily	0.043	0.033	0.092	0.043
Summer Green Herbs					
Actaea pachypoda	White baneberry	0.247	0.040	0.426	0.193
Aralia nudicalus	Wild Sarsaparilla	0.796	0.791	0.779	0.326
Arisaema tripyllum	Jack-in-the-pulpit	0.508	0.022	0.093	0.030
Caulophyllum thalictroides	Blue Cohosh	--	0.042	--	0.385
Clintonia borealis	Bead-lily	--	--	--	0.883
Dentaria diphylla	Broad-leaved Toothwort	--	0.097	--	0.193
Epipactus helleborine	Helleborine Orchid	0.495	--	0.605	--
Galium triflorum	Sweet-scented Bedstraw	0.731	0.072	0.825	0.759
Geranium robertianum	Herb Robert	--	0.768	--	0.475
Hepatica acutiloba	Sharp-lobed Hepatica	0.304	0.025	0.377	0.079
Heracleum maximum	Cow Parsnip	--	0.457	--	0.623
Maianthemum canadense	Canada Mayflower	0.126	0.036	0.737	0.540
Mitella diphylla	Two-leaved Miterwort	--	0.077	--	0.411
Mitchella repens	Partridge Berry	--	0.165	--	0.556
Osmorhiza claytoni	Sweet Cicely	0.396	0.014	0.436	0.072
Phlox divaricata	Blue Phlox	0.438	--	0.213	--
Polygonatum pubescens	Solomon's Seal	0.146	0.082	-0.172	0.147
Ranunculus abortivus	Kidneyleaf Buttercup	0.975	--	0.461	--
Sanguinaria canadensis	Bloodroot	1.000	0.033	1.000	0.305
Smilacene racemosa	False Solomon's Seal	0.000	0.252	1.000	0.452
Smilacene stellaria	Starry False Solomon's Seal	--	0.934	--	0.348
Solidago flexicaulis	Zigzag Goldenrod	--	0.143	--	0.554
Streptopus roseus	Rose Twisted -stalk	0.323	0.284	0.448	0.494
Thalictrum dioicum	Early Meadow Rue	--	0.069	--	0.813
Trientalis borealis	Starflower	0.761	--	0.622	0.228
Trillium erectum x *flexipes*	Trillium hybrid	--	0.042	--	0.463
Trillium grandiflorum	Large-flowered Trillium	0.224	0.054	0.327	0.227
Uvularia grandiflora	Large-flowered Bellwort	--	0.042	--	0.687
Viola canadensis	Canada Violet	0.204	0.014	0.370	0.043
Viola pubescens	Downy Yellow Violet	0.303	0.087	0.076	0.221
Ferns					
Adiantum pedatum	Maidenhair Fern	--	0.396	--	0.448
Botrychium virginianum	Rattlesnake Fern	--	0.287	--	0.653
Dryopteris spinulosa	Spinulose Woodfern	0.493	0.105	0.648	0.397
Onoclea sensibilis	Sensitive Fern	0.333	--	1.000	--
Woody Plants					
Acer pennsylvanicum	Striped Maple	0.282	--	0.820	--
Acer saccharrum	Sugar Maple	0.060	0.077	0.077	0.323
Cornus alternafolia	Alternate-leaved Dogwood	--	0.439	--	0.462
Fagus grandifolia	American Beech	0.080	--	0.216	--
Fraxinus americana	White Ash	--	0.075	--	0.620
Ostrya virginiana	Ironwood	0.468	--	0.279	--
Prunus serotina	Black Cherry	0.164	--	0.198	--
Prunus virginiana	Choke Cherry	--	0.109	--	0.455
Ribes sp.	Ribes sp.	--	0.255	--	0.979
Sambucus pubens	Elderberry	--	0.052	--	0.447
Taxus canadensis	Canada Yew	--	0.315	--	1.000

In Our Opinion: Are Michigan Deer Hunters Satisfied Stewards or Coerced Conservationists?

R. Ben Peyton[1,3] and Peter Bull[2,3]
Michigan State University
Department of Fisheries & Wildlife

[1]*R. Ben Peyton, Professor Email: peyton@msu.edu*
[2]*Peter Bull, Research Associate Email: bullpe@msu.edu*
[3]*Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan 48824*

Abstract: *There can be no doubt that hunters and anglers in the U.S. have played a major role in North American conservation efforts. They have contributed political leadership and support and engaged in habitat improvement projects. A significant contribution has been the financial base provided through license sales and excise taxes. The "great North American Conservation Model" partnership has traditionally justified hunting and trapping as effective "management tools" and extolled hunters and trappers as "conservationists", indispensable for wildlife management.*

The hunting community has unarguably been an enthusiastic steward of scarce game species and critical habitat. But that partnership is being tested in a new era of game species abundance. Every state with white-tailed deer has experienced the difficulty of getting hunter cooperation in achieving agency management goals for deer. The wildlife management community is increasingly examining whether or not consumptive wildlife use can serve as an effective management tool in the control of these abundant wildlife populations. This presentation focuses on Michigan deer hunters as partners in deer management.

Certainly some deer hunters have become active stewards with concerns for social and ecological impacts of deer as well as deer hunting quality for hunters. Some hunting organizations remain staunch advocates of responsible deer management and support state agencies. However, considerable resistance to efforts to lower deer numbers have also surfaced in the state's hunting community for a plethora of reasons. Efforts to optimize deer management in the state cannot succeed if a substantial portion of deer hunters refuse to cooperate in harvest goals – or worse – present strong political opposition to those goals. The presentation draws on a decade of research as well as existing literature and theory. Specifically, we explore the influence that hunters' motivations, satisfaction, attitudes, and behaviors may exert on the potential role of hunters as stewards not only of deer, but of the social and ecological values impacted by deer.

There can be no doubt that hunters and anglers in the U.S. have played a major role in the bulk of conservation efforts in North America. In times of wildlife scarcity, they have contributed political leadership and support and engaged in habitat improvement projects. A critical contribution has been the financial base for conservation provided through license sales and excise taxes. The partnership between consumptive recreational wildlife users and the management agencies has been lauded as the "North American Conservation Model" (Muth and Jamison 2000). The partnership has traditionally extolled hunters and trappers as "conservationists" and justified hunting and trapping as indispensable wildlife "management tools".

The partnership has been successful in bringing many game species back to abundance. There is no question that hunters have been enthusiastic stewards of scarce game species and critical habitat. But the partnership has experienced some limitations such as when confronted with today's challenge to manage overabundant game species. Today the wildlife management community is examining whether or not consumptive wildlife use is equally effective as a management tool in the control of these abundant wildlife populations (see The Wildlife Society Bulletin, 2000, Vol. 28, #4 for a number of articles exploring this relationship). The discussion presented in this paper focuses on the partnership role of Michigan deer hunters in achieving deer management goals. Specifically, we address the implications of hunters' attitudes and behaviors for their role as stewards not only of deer, but of the social and ecological values impacted by deer.

Our discussion of Michigan hunter attitudes, intentions and behaviors is based on the following quantitative surveys and, to a lesser extent, qualitative focus groups associated with these and other investigations of Michigan deer hunters. These studies are briefly annotated here because many are unpublished.

Bull and Peyton 1999: A mail survey of landowners and hunters in Deer Management Unit 015 (Menominee County, MI). Survey was sent to all landowners in the DMU and to deer hunters contacted in the field during the 1998 deer season (adjusted response rate was 62% with 688 useable returns). The study was done as part of the "Quality Hunting Ecology" project of the Sand Co. Foundation.

Bull et al 2004: Michigan deer hunters (N = 4000; randomly drawn statewide from license data) were surveyed regarding their attitudes towards, use of and success with bait for deer hunting during the 2001 season (response rate = 60.4%; n = 2320 usable returns).

Bull et al 2005: In 2003, a study of hunter mobility and the impact of bovine TB on hunter choice of hunting area involved two different surveys. One was sent to a statewide random sample of license holders (response rate = 67%; n = 1919 usable returns). The other survey involved a sample of hunters who had hunted in the northeastern TB counties in 1997 and a control sample who hunted in non-affected nearby counties in 1997 (both had a response rate = 77%; total usable surveys = 1894) .

Holsman and Peyton 2003: Users of state game areas in the Maple River watershed were surveyed to assess their attitudes about the benefits of ecosystem management compared to traditional game species management. Surveys were mailed to hunters (adjusted response rate = 78%; n = 764 usable returns), as well as members of Sierra Club, Audubon Club and area residents.

Minnis 1996: A study of hunter and farmer attitudes regarding crop depredation by deer and the associated management problems was conducted in 1995. Surveys were mailed to 1257 deer hunters (adjusted response rate = 65%; n = 792 usable returns) who hunted in counties selected for the study based on the levels of crop losses in those areas.

Minnis and Peyton 1994: A mail survey was used to investigate hunter attitudes towards baiting, motivations for baiting and to explore whether use of bait created problems among hunters. A sample of 4000 deer hunter was drawn from the 1992 license data base (adjusted response rate = 71%; n = 2788 useable returns).

Peyton and Bull 2001: A study of Michigan deer hunters' attitudes and behaviors regarding quality deer management (QDM) issues. A survey mailed to 9423 randomly selected Michigan deer license holders in 2001 (adjusted response rate = 60.4%; n = 5470 usable returns). The survey was also sent to all (439) current members of the QDM Association (adjusted response rate = 82%; n = 350 usable returns). Responses from the statewide sample and the QDMA membership were not combined for analysis so that QDMA members could provide a comparison for QDM attitudes and behaviors among the statewide sample.

Wallmo et al. 2004. A public choice study regarding trade-offs associated with various deer management outcomes (e.g., auto accident rates, prevalence of deer disease, availability of wildlife viewing and hunting benefits, etc.) was completed in 2003. Multiple survey versions were used in an experimental design to compare the values placed on these attributes. Versions of the survey were sent to a sample of licensed hunters (N = 1980, response rate = 66%) and the general public (N = 2970; response rate = 62%). The general public sample was drawn from state driver's license data.

Are Deer Hunters a "Single Species"?

Marketing experts have made lucrative careers using the "market segmentation" concept. Auto manufacturers do not make cars for "the average" car consumer, they make cars for distinct car consumer types (market segments), each representing a unique market to be developed. The concept of "segmentation" works equally well when trying to understand the preferences, behaviors, expectations, etc. of hunters. In this paper, "segment" implies a grouping that is useful in understanding or influencing hunter responses to management goals. To illustrate, we have found that deer hunters who prefer bowhunting are measurably different in important ways from those who prefer firearm hunting. The two segments differ from the segment that enjoys both hunting methods equally. Deer hunters who own recreational land and hunters who use primarily public land show important differences in attitudes and behaviors. Some attitudes differ among segments based on age. All of these are functional means of segmenting deer hunters when considering important management implications. Knowledge of the stewardship attitudes and behaviors of deer hunter segments holds more potential for improving deer hunter cooperation with agency harvest goals than notions about the "average" deer hunter. Although it is sometimes useful to report characteristics of "general deer hunters" it must be remembered that the "average" deer hunter does not exist as a "single species" and it is often more productive to think in terms of hunter segments when selecting management approaches. Unfortunately, space permits only a few references to hunter segments here. More detailed discussions of deer hunter segments have been discussed in Peyton and Bull 2001.

What Do Social Science Theories Offer to Understand Hunter Choices?

Some social theories offer a place to begin. For our limited discussion here, we illustrate with application of the Theory of Reasoned Action, recently revised to the Theory of Planned Behavior (TPB) (Fishbein and Ajzen 1975; Hrubes et al 2001). This is a popular model using attitudes to predict intentions and behavior. One critical element posed by this theory is whether an individual believes that positive consequences would result from some behavior such as lowering deer densities. A deer hunter who does not agree that excessive levels of crop damage are being inflicted and/or disagrees that reduction in deer numbers would be a reasonable means of reducing the economic impact on farmers is less likely to harvest antlerless deer for the purpose of lowering the deer herd. We have found evidence that a broad range of beliefs exist to influence deer hunters' positions on acceptable deer densities. To illustrate, some deer hunters believe that the consequences of deer densities could be avoided by actions other than reducing deer numbers (e.g., fencing out deer). Some argue that high rates of deer-auto accidents is not a function of deer density but of driver behavior; therefore, lowering deer densities would have little effect on lowering accident rates.

The TPB also suggests that another precursor required for hunter acceptance of fewer deer is that they place a value on the accumulated gain in positive consequences that is greater than the value placed on any lost hunting benefits they believe would result. I.e., the total value they place on reducing accident rates, lowering crop losses, etc., has to be greater than the value they place on benefits of high deer densities such as numbers of deer sighted, harvest rates, etc.

The Theory of Planned Behavior poses other factors that play a role in hunter support or opposition regarding goals to manage deer within social carrying capacity. But certainly the hunters' beliefs about what positive and negative consequences will occur if deer densities are changed and the values they hold for those consequences are major contributors.

Do Hunters have Holistic Stewardship Attitudes?

It is appropriate to ask: "stewards of what?" We have established that hunters have traditionally led in the conservation of the resources needed for their recreation. They demand protection for any game species from over-harvest when they believe it is in decline and they guard critical habitat needed by a valued game species. But the question here is, how much are hunters concerned about a broader range of environmental attributes and social values, especially those impacted by the abundance of deer we are experiencing today in many areas? A holistic definition of stewardship extends beyond deer to ecological and social systems. As holistic stewards, we would expect hunters to support a deer management program that balances an interest in available deer for harvest with a need to avoid unacceptably high impacts of deer on biodiversity, public safety, habitat, and agricultural crops, for example (see Holsman and Peyton 2003). The management question of importance is whether a substantial portion of deer hunters in Michigan is willing to trade off hunting benefits dependent on high deer densities in order to avoid environmental and social costs of having "too many deer". I.e., is their conservation ethic restricted to deer and deer habitat or do they advocate – or at least accept – a broader stewardship approach?

Case Study: Hunter support for ecosystem-based management

Resource management is moving towards a more integrated "ecosystem-based management" approach. The trend is to address the ecosystem at larger spatial scales, over longer periods of time and to be more concerned with attributes such as native biodiversity than what is most often associated with traditional "featured species management". It could be argued that support for ecosystem-based management would be consistent with a holistic stewardship attitude. In the study regarding ecosystem management goals (Holsman and Peyton 2003) hunters who used the state game areas and refuge in the Maple River watershed valued biodiversity as much as did environmental groups who were surveyed (e.g., non-hunting Sierra Club members). Would area hunters then accept a shift to ecosystem management that might produce more biodiversity even at the cost of lower game surplus for harvest in the area? Unfortunately, they would not. Although the two groups placed the same value on such benefits, they differed in their beliefs regarding whether more was needed (i.e., their perceptions of consequences differed). Hunters generally reported there were sufficient numbers of native non-game species (biodiversity); environmental respondents reported there were too few. The good news is the hunters reported that they placed importance on values that would support stewardship choices. The bad news is that their beliefs regarding biodiversity would not support a shift to ecosystem-based management.

Case Studies: Deer numbers versus a reduction in social and ecological costs of deer

The real test of the stewardship attitude is to see if stewardship values dominate in choices when hunters are aware of the consequences. In the QDM survey (Peyton and Bull 2001), we inferred levels of stewardship among respondents by examining the relationships between their desires for more or fewer deer and their awareness of deer-related problems (deer-auto accidents, crop damage, and overbrowsing of forests). Our assumption was that a steward who recognized deer-related impacts would prefer fewer deer to reduce the problems.

Many respondents were undecided about the level of deer-related problems in the area where they hunted. Few agreed that either crop (20%) or forest damage (12%) was a problem in their hunting area; however, 44% agreed that car-deer collisions were too high (ranging from 48% of upper and southern lower peninsula hunters to 39% of northern lower peninsula hunters). Overall, 49% did not see any deer-related problems, 31% identified one problem, 13% two problems and 6% saw all three as problems. Respondents were more likely to agree that hunting-related problems existed in their area. For example, 42% agreed that the deer harvest rate was too low in their area and 66% agreed that the buck to doe ratio was too low.

Respondents were also asked how many deer would be a reasonable goal for their hunting area compared to the present population. Only 11% wanted fewer deer, 22% were satisfied with the current number, 47% wanted more deer (11% wanted twice as many) and 20% were not sure. Those hunting only public land (where deer densities tend to be lower) were most likely to prefer more deer. However, the majority of those who spent at least part of their effort on private land also preferred more. A desire for more deer was expressed by more Northern Lower Peninsula (NLP) hunters (62%) than Upper Peninsula (U.P.) (54%) or Southern Lower Peninsula (S.L.) hunters (58%) (19.3, df=4, p<0.001).

We cannot determine the accuracy of a respondent's perceptions about either the number of deer or the severity of the three deer-related problems in their hunting area. However, we can infer whether their perceptions of deer problems are related to the number of deer they preferred; i.e., how many hunters would desire a reduction of the herd if they were persuaded that serious problems existed for agriculture, automobile drivers and/or forest ecosystems? Most (65%, n=2091) of the respondents who agreed that one or none of the three problems existed in their hunting areas wanted more deer. Among respondents who acknowledged that two or all three of the listed problems existed at excessive levels in their hunting area (n = 742), 34% wanted more deer and only 36% wanted a reduction in deer numbers; i.e., well over half wanted to maintain or increase deer numbers even though they reported two or more excessive problem levels. Of the respondents who reported two or more deer-related problems, those who hunted land they owned were more likely to prefer a reduction in deer numbers (43% versus 31%). Certainly, our measure of stewardship attitude was not precise, but the pattern that emerged is not encouraging. A substantial portion of our respondents placed more value on hunting opportunity than on costs of deer-related impacts they acknowledged to exist.

Although the precise questions and context varied somewhat, we have probed this stewardship question on several surveys with Michigan deer hunters that produced similar results. In the survey on crop damage (Minnis 1996), 83% of deer hunters believed crop losses ought to be considered in setting deer density goals but they rated the importance of crop losses in setting deer goals as significantly less important than providing for hunting benefits. In a study which asked respondents to make choices among trade-offs associated with deer, both hunters and non-hunters valued the presence of deer (Wallmo et al. 2004). But hunters chose scenarios that presented higher levels of deer-vehicle accidents, deer health problems and forest over-browsing in order to maintain or increase deer numbers. When the choice involved increased numbers of "bucks", hunters (but not non-hunting respondents) were willing to accept even higher levels of problems (e.g., crop damage, deer-auto accidents) than when increased numbers of deer in general were offered.

The conflict that hunters experience in choosing between deer and social/ecological costs were clearly displayed in the results of a small survey of Menominee County deer hunters and landowners (Bull and Peyton 1999). About 45% agreed that deer management should minimize crop losses and prevent impacts on natural ecosystems and two-thirds agreed that over-browsing of new forest growth and high rates of car-deer accidents should be prevented. Those are encouraging attitudes. However, 58% agreed that deer management should maintain the highest possible success rate for hunters and over 70% wanted management to produce as many large-antlered bucks as possible. When they were asked to assign priorities to those kinds of outcomes, "large antlered bucks" was ranked most important, prevention of over-browsing new forest growth was second and maintaining the highest possible harvest success was number three. Maintaining low car-deer accidents rates was ranked as the number one management priority by non-hunting landowners; but was ranked lowest by hunting respondents.

Case Studies Implications

Results of our studies suggest that as a group, deer hunters place values on the costs of maintaining high deer numbers that are similar to those expressed by the non-hunting public. However, many hunters often opposed – or at least failed to cooperate in – efforts to lower deer densities because (1) they hold high competing values for the benefits of those high deer numbers and because (2) they hold conflicting beliefs regarding the actual impacts of deer densities and the consequences of various management options.

Enck and Brown (2001) reported findings that support our inferences. In a study of Pennsylvania deer hunters, they found that although 94% of respondents held positive attitudes towards the land ethic, only 2/3 of them believed it was the hunters' responsibility to help lower deer numbers when the population was "out of balance". When asked to evaluate the quality of the habitat in their hunting area, most hunters believed it was in good shape, without serious problems. Most hunters, even those who acknowledged some habitat problems, did not associate moderate or great deer herbivory with decreased condition of the Land Community. As with our Michigan studies, this Pennsylvania study revealed small segments of hunters who did acknowledge deer impacts and held associated stewardship attitudes regarding hunter responsibility. Generally Pennsylvania hunters were similar to many Michigan hunters. They had positive stewardship values (e.g., supported the land ethic), but failed to accept the extent of problems created by deer and/or the stewardship role of deer harvesters towards a quality ecosystem.

Is Deer Hunter Satisfaction Incompatible with Michigan's Needs for Stewardship?

The criterion for evaluating management success shifted from the "game bagged" to "multiple satisfaction models" in the 1970's (Hendee 1972). Since then, researchers have attempted to measure the importance hunters place on various motivations and events in order to identify the factors that influence hunter satisfaction. The assumption has been that deer managers can achieve their goal of hunter satisfaction by using these factors as guidelines. Although a fairly rich body of research has addressed deer hunter motivations and satisfactions, only a few are selectively discussed here to illustrate certain points.

Some clear patterns emerge regarding the factors that consistently play some role in motivating hunters. For example, research supports grouping many motivations for hunting into three categories: achievement (related to getting game, using equipment, obtaining a trophy, etc.), appreciative (motivated by enjoying nature, practicing hunting skills, relaxation and escape from routine) and affiliative (social benefits such as spending time with family and/or friends) (Decker and Connelly 1989).

Given the importance that hunters placed on increased number of bucks in our studies, satisfaction would be expected to increase if that goal to produce available bucks for harvest was achieved. However, although the motivation to harvest a buck is prevalent among deer hunters, it is not always the most important factor determining choice. In the northeastern Lower Peninsula hunter mobility survey (Bull et al 2005), 18% of hunters rated "the number of mature bucks (2.5 years or older) as a "very important" reason for selecting the area they hunt most. However, for the entire group of respondents this factor ranked as number 11 based on the importance they assigned to the 13 choices we provided. "Seeing many deer" had a higher importance score (scored number 5 among the 13) and was rated as "very important" by 31%. When asked to identify the first or second most important reasons for choosing their hunting area, "seeing many deer" was identified as the second most important reason by 16% of respondents. The number of mature bucks was selected as either a first or second most important reason by only 6% of hunters. "Having a traditional camp in the area" was identified as either first or second most important reason by 16%.

Although harvest of a deer is not always the <u>most</u> important motivation for hunting – and therefore, not always the most important determination of hunting satisfaction – it certainly cannot be described as <u>unimportant</u>. Further, harvests of bucks are clearly preferred rather than antlerless deer and that makes it more difficult to achieve desired control of the deer herd through antlerless harvest. In the QDM study (Peyton and Bull 2001), we asked under what conditions hunters would shoot a doe. About 10% would never harvest a doe, 31% would harvest does only as a last resort to get venison. However, 27% would harvest a doe regularly to get venison. About 28% would shoot does to balance the buck to doe ratio and 30% would shoot does if convinced the herd needed to be reduced. Respondents were able to check more than one condition; however, 52% checked one or both of the latter reasons for shooting does. This probably represents the most reliable pool of cooperators among our respondents. However, even this group must be convinced there is a need to control the herd as a prerequisite to their cooperation. As discussed elsewhere in this paper, that presents a major challenge to achieving the desired antlerless harvest. This study had a 61% response rate and our non-response follow-up showed that hunters using a mixture of public and private land for deer hunting were under-represented among respondents (23% versus 43% among non-respondents). Given that public land hunters in our studies have been more inclined to believe deer numbers are already low, the percent of potential cooperators among the statewide population of deer hunters is likely well below 52%.

One way to achieve desired doe harvest levels is to exploit hunter interests in tagging a buck by requiring them to harvest an antlerless deer in order to validate their buck tag ("earn-a-buck"). Wisconsin achieved some harvest success with this, but the approach was not acceptable to many deer hunters in that state and a strong lobby against the strategy was exerted recently. In our QDM study, 70% of respondents agreed there were too few mature bucks for harvest in their hunting area but none of the options we presented for addressing that problem were acceptable to a large portion of hunters. In other words, most agreed they wanted more big bucks, but they were strongly divided on the way they wanted to achieve that goal. The "earn-a-buck" option was one of the least acceptable. It was strongly opposed by 28% and strongly approved by only 16%. Similarly, respondents were strongly polarized on all options presented to them for achieving a higher ratio of mature bucks to does. Satisfaction would be increased for many hunters if the chance of harvesting a mature buck increased, but the regulations required to achieve that goal could decrease the satisfaction to produce a no-win gain, at least in the short term.

Deer sightings also play an important role in determining hunter satisfaction. In a study of hunters on the state's Shiawassee Refuge in 1985 (unpublished data) unsuccessful hunters rated the quality of the hunt as "good" if they had sighted large numbers of deer, in fact, unsuccessful hunters who saw large numbers of bucks rated the hunt similarly to successful hunters. However, the satisfaction of unsuccessful hunters who saw even more bucks was significantly lowered, likely due to the frustration of not being able to harvest at least one when so many were seen. Langenau (1980) found that Michigan deer hunters preferred some level of hunter crowding because associated deer movement resulted in higher levels of deer sightings. The sighting of deer and other wildlife can also add enjoyment to the use of bait for hunting deer. In the statewide mobility study (Bull et al. 2005), 36% of respondents reported that the ability to bait for deer was at least somewhat important as a reason for selecting a hunting area. Nearly all (95%) of this group also indicated that seeing deer was at least somewhat important as a reason for choosing a hunting area. If baiting was banned in their hunting area, 30% of our statewide respondents said they would stop hunting there (50% would continue and 20% were uncertain). In another statewide survey on baiting (Minnis and Peyton 1994) 39% of respondents agreed that hunting with bait was more satisfying or at least as satisfying as hunting without bait; 41% disagreed and 20% were undecided. Of those who used bait, 52% rated as a "very important" reason for baiting that it "... is more exciting because I can watch more deer and other wildlife...". About 43% rated "a better chance to harvest a deer..." as a very important reason for baiting.

Frawley (2002) reported that the baiting ban in the northeastern Lower Peninsula caused a reduction in the number of archery hunters in the area. About 50% of the archers in the northeast Lower Peninsula (excluding Deer Management Unit 452) hunted less because of the baiting ban, while 31% of people hunting in the regular firearm season hunted less. However, when the Natural Resource Commission temporarily lifted the archery season baiting ban for one year, the action failed to produce an increase in antlerless deer harvest.,

Surveys have consistently shown that baiting is not strongly related to success rates. Based on a more recent deer hunter survey on baiting practices (Bull et al. 2004), 20% of the state's deer hunters always hunted with bait. Bait was never used by 53% and occasionally used by 27% of respondents. Harvest efficiency of bait (total deer harvested/ total days hunted with bait) was higher in the archery seasons, while hunting without bait was more efficient in the firearm and muzzle loader seasons. Deer were harvested more efficiently (fewer reported days effort per deer) without bait. When only successful hunters are considered, there is no real difference between deer harvested with bait per successful hunter (1.34) and those without bait (1.39). Overall, bait appears to be less important to statewide harvest effectiveness than other hunting behaviors. Because hunters report they see more deer over bait it would seem antlerless harvest might be increased by its use. However, that was true only for the archery season where slightly more antlerless deer were taken with bait (47% with bait, 53% without). When all seasons are combined, fewer antlerless deer were taken over bait.

The prevalence of deer baiting in the past two decades has most likely played a role in determining deer sightings and hunter perception of deer numbers. Baiting has enabled hunters to use increasingly smaller units of private land because they can attract deer to a small portion of their home range. Bait piles can shift movement patterns of deer and greatly influence the number of deer sighted by a sedentary hunter near a bait pile. On the other hand, if a large portion of hunters use bait, fewer hunters moving around to displace and move deer, further reduces sighting. Hunters are inclined to equate these reduced sightings to inadequate deer densities. Those hunters whose satisfaction remains dependent on deer harvest or sightings, present managers with a no-win challenge of managing deer numbers.

Understanding hunter satisfaction and the implications for deer management is a complex endeavor, in part because deer hunter satisfaction is a moving target. One reason is that the factors that bring about satisfaction for hunters vary in importance depending on whether they are measured before, during or after the season. Jackson and Anderson (1985) found significant shifts on pre-season, season, and post-season surveys among Wisconsin deer hunters in the importance of the time spent with friends and family, the rewards of getting a trophy, and the use of equipment. In our April 1999 survey of Menominee County (Michigan Upper Peninsula) deer hunters, “spending time with family and friends” was a “very important” reason for hunting for two thirds of the respondents. “Getting close to nature”, “escaping stresses of life” and “seeing many kinds of wildlife” were each “very important” to about 55% of respondents. The motivations described as “very important” by the fewest number of respondents were “using hunting equipment” (15%), “using hunting skills” (22%), and “getting venison” (23%). Had this survey been conducted before the season the previous fall, Jackson’s study suggests the latter three motivations would have been considerably more important. More research into the temporal nature of hunter expectations and satisfactions would provide some utility to managers striving to optimize hunter benefits.

Age and experience also introduce variability into the importance placed on various motivations for deer hunting. Researchers in New York found that hunters who placed more importance on use of equipment and harvesting a deer (achievement oriented hunters) were younger than those who placed more importance on enjoying the natural experience (appreciative hunters) or those who placed most importance on being with friends and family (affiliative hunters) (Decker and Connelly 1989). Although achievement hunters were more motivated to harvest deer, appreciative hunters had a higher success rate. Many appreciative hunters purchased antlerless tags but they contributed little to achieving deer goals because they used the tags as a means of continuing to participate in the hunt and did not harvest substantially more deer.

An individual’s motivations for hunting and related satisfaction also appear to develop over time. Jackson and Norton (1980) proposed developmental stages for hunters. They suggested that beginning hunters were first motivated to use equipment and develop skills (e.g., shooting stage), then moved on to successive stages that focused on harvesting a limit of game, getting a trophy, using more challenging methods, and finally a sportsperson stage. Although the progression of stages is not infallible, evidence exists that some pattern of motivation shifts do occur among hunters. Developmental stages have also been proposed for anglers (Bryan 1977). To the extent that deer hunters experience these stages, shifts in hunting demographics could have more implications for deer hunter abilities to control deer numbers. In the New York study (Decker and Connelly 1989), the three segments exhibited the same relationship; with increasing age and experience there was a trend to shift importance from “getting game” to enjoyment of non-harvest related benefits. We have found a relationship between increasing age and decreasing importance of deer hunting (Bull et al. 2005). Respondents to the hunter mobility survey who said deer hunting was their most important recreational activity had an average age of 44. Average age increased from the identification of hunting as “one of the more important activities” (48 years) to “less important than most activities” (50 years) and finally to “not at all important” (55 years). A similar distribution was found in the QDM survey results (Peyton and Bull 2001).

Unfortunately, a shift in motivation for hunting with diminished interest in harvest may mean that the older and potentially more effective deer hunters may not harvest at desired rates. An analysis of age demographics in Michigan revealed that participation generally began to decline among males when they were 45-54 years old, although the decline has become less apparent since 1980 (Frawley 2004a). The mean number of deer harvested per hunter in 2002 peaked among hunters at 25-44 years of age and declined steadily among hunters older than 50 years of age. Frawley inferred that hunting success among older hunters declined because of fewer days spent hunting. He projected that the lower antlerless harvest among older hunters will cause antlerless harvest rates to lag behind the harvest of antlered deer.

Not only is there a tendency for hunter motivations and participation to shift developmentally with age and experience, but there is also a tendency towards recreational specialization that further complicates the matter of hunter satisfaction (Ditton et al. 1992). Theories of recreational specialization are still being debated in the literature (e.g., Scott and Shafer 2001; Salz et al. 2001) but essentially it involves an individual placing an increasing importance and emphasis on some recreation. Hunters may specialize on some attribute of the experience such as a method (e.g., archery), a species (e.g., deer), a place or some combination of those attributes. The phenomenon is proposed to be more than just an increased interest in a favorite past time, it takes on the attributes of a social subworld – a cultural entity (Ditton et al. 1992). The theory predicts that increased recreational specialization will be associated with mediated communication (e.g., regular readers of deer hunting magazines), group-defined standards of behavior (ethics), membership in related organizations, investments in equipment or hunting areas and leadership in the activity. For a recreational specialist, the activity (e.g., deer hunting) plays a highly central role in their life (centrality). The motivations of specialists usually broaden from activity-specific benefits such as harvesting “a deer” towards benefits such as nature appreciation and affiliation with family and friends. This does not imply that deer-hunting related benefits necessarily become unimportant, simply that other benefits become more important.

Recreational specialists are not excluded from being members of more than one sub-world. A specialist in archery deer hunting may also specialize in fly fishing or some other sub-world. They may participate in a number of other forms of hunting such as upland birds or waterfowl, but at a more casual level and without reaching the same level of membership in those sub-worlds. Conversely, someone who hunts only for deer and not other types of game may not actually be a specialist unless deer hunting meets the other criteria of intensity, e.g., exhibits centrality in their life style and membership in the social sub-world. Frawley (2004a) found that 62% of those who purchased a deer license in 2000, 2001 and/or 2003, did not purchase any other type of hunting license. Some, but not all of this group are likely to be deer hunting specialists. The most highly specialized deer hunters are likely contained within the 23% of respondents to the QDM survey who reported that deer hunting was “my most important recreational activity” (Peyton and Bull 2001).

A common characteristic of hunting specialists is that they become dedicated stewards of their recreation-dependent resources. Wetland conservation would not have happened without the support of waterfowl hunting specialists who not only supported, but led in the political battles to create special funding sources for wetland protection. Hunting specialists become more effective at influencing the management system because of their “social subworld” status (e.g., mediated communication and organization). Specialist subworlds learn the agency management system and find ways to “capture” its attention and resources for their own brand of resource-dependency (Langenau 1982). One means of doing this is to lobby for license fees to become restricted funds that can be spent only on the species of interest (e.g., Michigan’s turkey license fees, Deer Range Improvement Program fees). Highly specialized deer hunters can be extremely demanding and vocal protectionists of the resource they depend on for recreation. This protection can sometimes occur at the expense of more holistic management goals such as maintaining deer within a biological or social carrying capacity.

But specialist groups are not always self-serving and many reflect stewardship ethics. Many specialist organizations and individuals recognize that conservation goals must extend beyond their own resource-dependent recreation. Some hunting organizations have exhibited real interest in stewardship concerns beyond their species of interest. Individuals may gravitate towards organizations such as Michigan United Conservation Clubs or Safari Club International that have agendas to work for broader environmental improvement, including a reduction of deer numbers where they surpass habitat or social carrying capacity. Many hunting specialists become leaders who are passionate and well informed about natural resources. As such they make potential allies in working to gain support to achieve deer population goals. However, managers must recognize that these deer hunting specialists do not reflect the same pattern of motivations, preferences, value priorities, beliefs and behaviors as do less specialized participants that comprise a plurality if not a majority of deer hunters. The involvement of specialists cannot be accepted as representative of the views of the deer hunting community.

Exploring options

Responsible deer management must approach deer as a key component of both ecological and social systems. The conundrum is how to optimize (versus maximize) the benefits and costs of deer among a diversity of stakeholders and within the limits posed by biological carrying capacity. A compounding element is the fact that, for multiple reasons, deer management must strive to achieve reasonable levels of deer hunter satisfaction. If harvest rate or numbers of deer sighted remain the over-riding criterion of success for achieving the latter goal, conflict between this and an equally important goal of maintaining deer within biological and social carrying capacities is unavoidable. In some areas of Michigan and many other states, management needs to address deer over-abundance through hunter harvest. New York models projected that even if antlerless permits were unlimited, there were too few hunters in the state willing to harvest antlerless deer to achieve the desired level of control (Brown et al 2000). That lack of willingness appears to be a factor in at least some regions of Michigan as well. Our studies suggest that the solution will require a shifting of priorities and beliefs on the part of hunters; a goal fraught with inter-related barriers.

Addressing hunter values as barriers

A majority of hunters appear to place value on the ecological and social attributes that can be impacted by deer populations (e.g., public safety, biodiversity). This is fortunate because there is little we can do to bring about changes in values held by individuals. Personal values change over time slowly through life experience, if at all. The changes in hunter motivations over time we described earlier illustrate the individualized, intrinsic nature of value development. We can expose hunters to new experiences (e.g., lower deer densities), but we cannot ensure that values and motivations will shift to accommodate those experiences. However, we can keep hunters aware of the range of values that are involved (e.g., ecological integrity as well as hunting satisfaction) and encourage them to examine and reconsider their own priorities in the light of consequences of deer management; i.e., maintain a saliency of these tradeoffs among hunters. For any real shifts in perspective and evaluations to take place, hunters must be accurately informed of the consequences for those values. The latter falls into the realm of addressing beliefs which is not an easy task, but is easier than addressing values.

Addressing hunter beliefs as barriers

Failure to consider the range of consequences can be attributed to a lack of awareness, understanding, and/or acceptance of those consequences. Many hunters are not at all aware of the actual or potential impact of deer on biodiversity, for example. The dynamics and functions of biodiversity are subtle and not easily understood, so many who are aware of the arguments may not be persuaded by them. Even those who come to understand the arguments may not accept them and may choose to challenge the credibility of the sources instead. Of course, there is the risk that some well informed deer hunters will place a higher value on the benefits of high deer densities than on the losses, e.g., biodiversity, crop damage. Perhaps the most contentious category of these beliefs relate to the need for and consequences of lowering deer population in a region.

Very often deer hunters disagree with the proposition that deer densities are high in the first place. That poses an obvious barrier to getting them to accept proposals to lower deer densities. A large portion of Michigan deer hunters spend limited time in the field observing and studying deer – few of us qualify as a wood-wise Natty Bumpo. Although it varies by age segments and regions, the average number of days Michigan hunters spent deer hunting was about 14 (Frawley 2004b). Respondents to our statewide mobility survey (Bull et al. 2005) spent an average of 8 days in off-season scouting and building blinds, but the median was 3 days. About 40% of those who hunted less than 50 miles from their home reported no days were spent in scouting, blind construction, etc. Half of the rest of that group spent 5 days or less. Those who hunted more than 50 miles from their home tended to spend even less time afield. Zero days were reported by 54% and the median days spent by the other 46% was 3 days. Certainly, some hunters spend considerable time in the field observing deer and habitat, but it appears to be a small proportion. In addition, half of the respondents to the QDM survey who used private lands reported they hunted 80 acres or less, so their observations are not only limited temporally, but spatially as well.

We projected from our 2001 deer baiting survey that at least 47% of hunters used bait to hunt deer; 20% hunted only with bait (Bull et al 2004). A substantial portion of hunter observations during hunting season is limited to animals responding to bait. If baiting is used to attract deer to small parcels with marginal habitat, reliability of observations is vulnerable to slight decreases in regional deer density and to local competing food sources. Considering the basic home range size of Michigan deer and the variability of factors that influence seasonal and daily movements, the majority of deer hunters in Michigan appear to have an unreliable basis for determining deer densities through direct observation.

One very insightful paper recently hypothesized why deer hunter observations may not produce reliable estimate of deer numbers. Van Deelen and Etter (2003) used predator/prey models to examine deer hunters' response to changes in deer densities. Although grossly simplified here, modeling relationships between prey densities, predator effort and success suggested that the relationship between the number of deer observed by hunters (exerting a constant effort) is not linearly related to changes in deer densities. If an agency reduces deer density by 10% the reduction in observed deer by local hunters will be considerably greater than 10%. When even small decreases in density create large reductions in deer sightings, there is stronger hunter resistance to continued reduction of deer numbers.

The phenomenon described by Van Deelen and Etter is confounded by the limited nature of hunters' observations in time and space and many other factors already mentioned. A large (often vocal) portion of dedicated deer hunters use their own observations and inferences to reject science-based estimates of population trends. The prevalent view among deer hunters in any state seems to be that deer number estimates by professional deer managers are wrong. Similarly, many deer hunters remain unconvinced that impacts on forests or agricultural crops are high enough to warrant a reduction in deer, which they already believe are too few.

Credibility of management agencies gets drawn into this dilemma. There are two parts to this; 1) do the constituents trust the agency to fairly consider their own interests, and 2) do constituents believe the agency is competent and skilled. Hunter perception of agency credibility varies with the issue, sometimes doubting the agency trustworthiness, sometimes questioning the agency competence and sometimes both. Agency credibility among deer hunters can also differ from the credibility they place on professional biologists in the agency. In our crop damage study, for example, many farmers with crop damage trusted the local biologists, but not the "Lansing staff" (Minnis 1996). In a survey of Michigan public, Mertig and Koval (2001) found the general public tended to believe the Michigan DNR was credible; she observed that it was the agency constituents (e.g., hunters) who worked most closely with the DNR who questioned the agency credibility most.

In part, credibility contributes to the hunter belief problems. Hunters are immediately skeptical of deer population estimates provided by an agency judged as lacking credibility. But credibility is also a victim of human nature to trust our observations and judgments. Hunters are reluctant to accept management conclusions that differ so obviously from what their own experiences tell them and so agency/biologist credibility further suffers.

Entangled with our agency credibility problems is credibility of our wildlife science. Our society in general has been ineffective in creating scientific literacy among our citizens. The deficiency is compounded in Michigan because the Department of Natural Resources lost an effective Information and Education Division to the political environment of the 1970s and 1980s. Whether or not there is a political support for the idea that a natural resource agency is an educational as well as a regulatory agency, available financial resources make it unlikely that a return of a comprehensive Information and Education program is possible any time soon. In its absence, the mass media has emerged to fill the void of agency sponsored wildlife education. Deer hunters supplement their own observation-based conclusions with information from outdoor writers and television hosts.

Wildlife science is a complex process and the associated body of information is still burdened by a degree of uncertainty. It is not likely we could ever educate most hunters to understand, for example, the modeling and conclusions provided by Van Deelen and Etter (2003) and expect them to accept the implications of that. However, if hunters perceived the agency and its professionals to be credible, perhaps they would be more willing to fairly consider if not immediately accept uncomfortable management proposals. It seems prudent to consider a lack of credibility in our managers and our management science as considerably more than a slight inconvenience. Credibility is an absolutely critical tool in the deer management process and it cannot be established and nurtured without effective communication.

Is QDM a Movement Towards Stewardship in Michigan?

There has emerged in states with white-tailed deer, groups of specialized hunters who advocate a management approach known as Quality Deer Management (QDM). The emergence of this movement illustrates the attributes of hunter specialization discussed earlier. Among the principles advanced by some QDM proponents is the notion that this practice could contribute to shifting deer hunters toward more responsible, stewardship-based choices.

As a concept, "Quality Deer Management" (QDM) does offer some potential stewardship benefits. Goals of QDM address the need to manage deer herds within their biological and social carrying capacity. They also advocate a "natural" buck to doe ratio and older age distribution of bucks. Fundamentally, QDM is not advanced as a "trophy" deer management program, although one of the benefits is to produce more large antlered bucks in a herd. A comprehensive and successful QDM approach requires the hunter to collect and interpret biological harvest data, monitor population trends, understand deer biology and ecology, prescribe and implement harvest goals for does and bucks and to actively manage habitat where needed. Often it involves a higher participation with neighboring landowners and may create a greater awareness of social carrying capacity problems (e.g., crop damage). Unfortunately, application of QDM in Michigan has not realized this stewardship potential.

There is a risk that broader stewardship goals can be lost as some farming practices associated with "QDM" programs take on a mission of their own. "Artificial" feeding is becoming increasingly incriminated in wildlife disease problems, however 29% of the QDMA members reported using artificial feeding to support and/or attract larger deer numbers. Issues of the QDMA magazine have included advertisements of feeding equipment. Indeed, 19% of Michigan QDMA members believed artificial feeding was an accepted QDM practice. Use of food plots to enhance natural deer habitat was reported by 43% of landowners and 79% of Quality Deer Management Association (QDMA) Michigan members who responded to our 2001 QDM survey. A third of the landowner respondents and 69% of QDMA members improved habitat by fertilizing and/or mowing fields or patches. Used as part of a comprehensive program that does not seek to increase deer numbers beyond local natural habitat or social carrying capacities, food enhancement efforts such as fertilizing deer browse or producing food plots can contribute to the physical health of deer. However, without a judicious harvest system, such enhancements can simply become effective strategies for attracting and holding large numbers of deer to private property with negative impacts on surrounding natural habitat and potential disease implications. In its early adoption stages in Michigan, fencing was incorporated into some versions of "QDM" practice, although this is now heavily restricted by the state due to the presence of Bovine Tuberculosis and the risk of Chronic Wasting Disease. However, in some other states, QDM practices are associated with the "privately owned" or "captive" cervid approach to game farming.

The strategy advocated by the QDMA has been to recruit voluntary supporters through education and by demonstration of the outcomes of the process. Given time to work in this fashion, true QDM has the potential to influence the thinking and stewardship attitudes of at least those hunters with access to manage private lands in Michigan. Although non-response bias may be inflating the estimate, about 63% of our respondents on the QDM survey indicated they hunted either private land only or both public and private lands and also reported they implemented at least one of the QDM practices listed. Over a third of respondents owned the land where they deer hunted. Private lands offer the greatest challenge to achieving agency population goals and a clear understanding and acceptance of the stewardship elements in QDM philosophy among this substantial portion of the state's hunters would be an asset. Over time, if successfully marketed as a stewardship-based deer management philosophy, voluntary adoption of QDM goals in Michigan has the potential to improve hunter understanding of wildlife science, provide better relationships with agency professionals, and begin to make inroads into the barriers posed by credibility issues and lack of understanding of science based management.

Unfortunately, the voluntary, holistic practice of QDM has become redirected for most Michigan hunters as mandatory "antler point restrictions" (APR). With APR, the focus has shifted from the holistic stewardship goals described earlier to production of older aged buck classes and antler production. Since the adoption process was initiated in 1999, about ten proposals have been submitted to the Michigan Natural Resource Commission requesting that specific deer units be classified as "QDM" units with antler point restrictions on buck harvest. Although doe harvest is mentioned in these proposals, the primary interest of supporters appears not to be maintaining deer within biological and social carrying capacity, but restriction of other hunters from shooting young bucks that would otherwise mature to become large antlered deer. One advertisement advocating for a U.P. "QDM" proposal urged hunters who wanted to prevent the DNR from "shooting all our does" to support the proposed antler restrictions. Not only do these APR proposals fail to address the larger stewardship needs for maintaining deer within biological and social carrying capacity, they have done much to cloud the QDM stewardship goals and to polarize a portion of the state's hunters against the concept.

An alternative and much less popular program known as Quality Hunting Ecology (QHE) has been developed and advocated by the Sand County Foundation (*www.sandcounty.net*). QHE sets a priority on the management of deer within the constraints both biological and social carrying capacity. The Foundation has supported projects to research and/or encourage stewardship choices among deer hunters in the Great Lakes states, including the Pennsylvania project (Enck and Brown 2001). The QHE has met with mixed results regarding measurable shifts in hunter perceptions. But it is encouraging that this type of thinking is emerging and it certainly provides a model of stewardship concern among hunters.

Conclusion

Many of the problems associated with managing white-tailed deer and deer hunters are related to two needs; (1) hunter cooperation in making recreational harvest an effective management tool; and (2) reduced negative behaviors that exacerbate management problems with deer. The first is tied primarily to achieving a sufficient harvest of antlerless deer to keep deer numbers within regional biological and social carrying capacities. The second implies cooperation with other prescribed management strategies such as reduced baiting and feeding practices. There are important groups of deer hunters who are providing the desired cooperation. The challenge is to influence the much larger majority.

The barriers to achieving these needs are many and difficult to address. A majority of deer hunters are passionate about this recreation. They rate deer hunting as their most important recreation or at least "more important than most other forms of recreation". Most value the benefits of holistic stewardship, but many place priority on competing, recreation-related values. They justify their preferences with inadequate belief systems regarding the causal relationships between deer numbers and the impacts of deer; with the lack of credibility they attribute to management science and agencies; and with their own "proven" observations and intuition. These are tough barriers in part because of their resilient nature and in part because the state lacks effective information and education tools to address them.

It would be a mistake to treat all deer hunters as one. As we search for ways to bring about change, identification of segments of hunters promises the greatest reward. It is more effective to diagnose the attitudes, preferences, and behaviors of a segment (e.g., private land hunters) and target that group to meet the unique opportunities to bring about change. The casual hunter who buys a license only two out of three years offers a different market challenge than the landowner specialist who hunts all archery and firearm seasons and practices his/her own version of deer management twelve months a year.

Fortunately, most deer hunter segments are motivated to hunt by a range of benefits and expectations and this may offer creative opportunities to appeal to a wider set of those motivations than simply “deer sighted” and buck harvest rate. Most deer hunting specialists have found ways to extend their enjoyment of deer hunting well past the fall hunting season. Specialists are avid students of deer and deer hunting technology. They participate in habitat management, develop their natural history skills and knowledge, and spend time scouting throughout the year. Often they are keen users of innovations such as remote sensing digital cameras that monitor deer movements and locate trophies. All of this broadens the source of satisfaction from the traditional deer season and heightens the rewards of non-harvest benefits.

Unfortunately, a large portion of hunters do not share all of these opportunities. Consider the hunters who are wedded to a 20 or 40 acre parcel of land and dependent on bait to bring deer to their pre-selected hunting site. It presents a challenge to encourage this group to develop their skills at studying and understanding the natural history of an animal whose home range may be a square mile or more. Yet, perhaps the specialists offer us a model that would suggest management strategies.

The satisfaction of deer hunters will be influenced by their expectations. We can argue about whether deer numbers actually were at or above two million in the past two decades, but there is no doubt that most hunters today have enjoyed the peak in white-tailed deer abundance in this state and that resistance to deer population decreases are tied to that experience. Their best years have become the norm against which all other years are to be judged. However, if we can manage to reduce deer to social and biological carrying capacities in regions where it is needed, the dynamic nature of hunter satisfaction and motivations may become an asset in bringing about some new expectations. Perhaps a decade or two with a less abundant deer population would result in lower expectations among young hunters (new recruits) and that status would become accepted by older participants to create a new level of satisfaction. Of course, a risk also exists that recruitment and retention of hunters may both be diminished by lower deer numbers, with serious impacts on deer control and agency funding. In either case, the decade or two of adjustment would likely be miserable for wildlife managers.

We are asking much of deer hunters to accept the burden of stewardship as part of their recreational choice. Yet, society and our laws remind us that hunting is a privilege and not a constitutional right. Stewardship is the primary redeeming value that hunting has to offer society in exchange for the privilege. If hunters do not voluntarily and adequately fulfill the role of holistic stewards, our privilege and the potential utility of hunting as an effective management tool will eventually be at risk.

Literature Cited

Brown, T.L., D.J. Decker, S.J. Riley, J.W. Enck, T.B. Lauber, P.D. Curtis, and G.F. Mattfield. 2000. The future of hunting as a mechanism to control white-tailed deer populations. Wildlife Society Bulletin 28(4):797-807.

Bryan, H. 1977. Leisure value systems and recreational specialization: the case of trout fishermen. Journal of Leisure Research 174-187.

Bull, Peter and R.B. Peyton. 1999. Stakeholder preferences for deer management in DMU 15. Report to the Sand County Foundation and Michigan Wildlife Bureau. 24 pp; appendices.

Bull, P., R.B. Peyton and F. Lupi. 2005. Unpublished data. (Ongoing study of hunter mobility, choice of hunting area, and attitudes regarding deer diseases.)

Bull, P., R.B. Peyton, and S. Winterstein. 2004. An Investigation of Michigan Deer Hunter’s Baiting Behaviors During the 2001 Deer Hunting Season. Unpublished report to Michigan State University Bovine TB Research Project: Deer Ecology; June 2004. 62 pp.

Decker, D.J. and N. Connelly. 1989. Motivations for deer hunting: implications for antlerless deer harvest as a management tool. Wildlife Society Bulletin 17(4):455-463.

Ditton, R.B., D.K. Loomis, and S. Choi. 1992. Recreation Specialization: Re-conceptualization from a Social Worlds Perspective. Journal of Leisure Research. Vol. 24, No. 1, pp. 33-51.

Enck, J.W. and T. Brown. 2001. Hunter Participation in Quality Hunting Ecology in Pennsylvania: Baseline Research. 51 pp. www.dnr.cornell.edu/hdru/PUBS/HDRUReport01-1b.pdf

Frawley, B.J. 2002. Deer Baiting in the Northeast Lower Peninsula of Michigan, Department of Natural Resources Wildlife Division Report No. 3372. 13 pp.

Frawley, B.J. 2004a. Demographics, Recruitment, and Retention of Michigan Hunters. Michigan Department of Natural Resources Wildlife Division Report No. 3426. 42 pp.

Frawley, B.J. 2004b. Changes in Deer Hunting Participation and Harvest Related to Hunter's Age. Michigan Department of Natural Resources Wildlife Division Report No. 3426. 42 pp.

Fishbein, M., and I. Ajzen. (1975). Belief, attitude, intention, and behavior: An introduction to theory and research. Reading, MA: Addison-Wesley.

Hendee, J.C. 1972. Management of wildlife for human benefits. Proceedings Annual Conference Western Association of State Game Fish Commissions. 52:175-181.

Holsman, R.H. and R.B. Peyton. 2003. Stakeholder attitudes towards ecosystem management in southern Michigan. Wildlife Society Bulletin 31(2): 340-361.

Hrubes, D., I. Ajzen, and J. Daigle. 2001. Predicting Hunting Intentions and Behavior: An Application of the Theory of Planned Behavior. Leisure Sciences, 23:165–178.

Jackson, R.M., R. Anderson. 1985. The deer hunting experience: its satisfaction and expectations. Deer and Deer Hunting (April): 9-18.

Jackson, R.M. and R. Norton. 1980. "Phases" The personal evolution of the sport hunter. Wisconsin Sportsman 9(6):17-59.

Langenau, E.E. Jr. 1980. Deer hunting success: skill or luck? Michigan Department of Natural Resources Wildlife Division Report 2873. 12pp.

Langenau, E.E. Jr. 1982. Bureaucracy and wildlife: a historical overview. International Journal Stud. Animal Prob. 3(2):140-157.

Mertig, A. and M. Koval. 2001. Attitudes Toward Natural Resources and Their Management; A Report on the "2000 Resource Attitudes in Michigan Survey". Report to the Michigan Department of Natural Resources Wildlife Division. 175 pp.

Minnis, D. and R.B. Peyton. 1994. 1993 Michigan Deer Hunter Survey: Deer Baiting. Unpublished report to Wildlife Division, Michigan Department of Natural Resources. 18 pp and appendices.

Muth, R. and W.V. Jamison. 2000. On the destiny of deer camps and duck blinds: the rise of the animal rights movement and the future of wildlife conservation. Wildlife Society Bulletin 28(4): 841- 851.

Peyton, R.B. and P. Bull. 2001. An assessment of possible antler restrictions and quality deer management by Michigan deer hunters. Project report submitted to Wildlife Division, MDNR. Wildlife Conservation and Restoration Act Pittman-Robertson Project Number W-127-R. 146 pp.

Salz, R.J., D.K. Loomis, and K. Finn. 2001. Development and validation of a specialization index and testing of specialization theory. Human Dimensions of Wildlife. 6(4): 239-258.

Scott, D. and C. Scott Shafer. 2001 Recreational Specialization: A Critical Look at the Construct. Journal of Leisure Research. 33(3): 319-343.

Van Deelen, T. and D. Etter. 2003 Effort and the Functional Response of Deer Hunters. Human Dimensions of Wildlife. 8(2): 97-108.

Wallmo, K., F. Lupi, R.B. Peyton, and P. Bull. 2004. "Public and Hunter Tradeoffs Between Deer Populations and the External Effects of Deer," in Benefits and Costs of Resource Policies Affecting Public and Private Land, (D. McLeod), Western Regional Research Publication, p. 291-311.

Chronic Regeneration Failure in Northern Hardwood Stands: A Liability to Certified Forest Landowners

Gary Donovan[1]
Manager of Wildlife Programs
International Paper

[1]*International Paper, Forest Resources, P. O. Box 885, Bucksport, ME 04416*
Email: gary.donovan@ipaper.com

Abstract: *Long-term overpopulation of white-tailed deer (Odociléus virginianus) and a ubiquitous ground cover of Pennsylvania sedge (Carex pennsylvanica) have dramatically reduced or eliminated regeneration of commercially important northern hardwood species on approximately 35,000 acres of forestland owned by International Paper Company (IP) located in the southern Upper Peninsula of Michigan and northern Wisconsin. Silvicultural guidelines used for dense hardwood cover types are implemented to create all-aged stands. IP forestlands are certified to the International Organization for Standardization (ISO 14001) and the Sustainable Forestry Initiative® (SFI) Standard. During a 2004 third-party audit on IP lands, it was noted that natural regeneration was not established within five years of a harvest in accordance with SFI Performance Measure 2.1. IP will explore other land management options on the impacted acreage to ensure future compliance with these environmental certification programs.*

Keywords: *Hardwood regeneration failure; White-tailed deer; Pennsylvania sedge; Environmental certification*

Introduction

During the week of September 27, 2004, an environmental performance audit was conducted on the forest ownership of International Paper Company (IP) in Michigan and Wisconsin. Auditors became concerned that certain tracts did not have adequate natural regeneration of northern hardwood species present within five years of timber harvest. The observation made on an IP management block commonly referred to as the Vega tract located in Dickinson and Menominee Counties, Michigan will have an impact on IP's preferred method of managing dense northern hardwood stands.

Background

International Paper, the world's largest paper and forest-products company, owns 444,328 acres in the Upper Peninsula of Michigan and 69,038 acres in northern Wisconsin, known as the Lakes States Region. IP's objective is to manage this forestland sustainably and profitably while conserving cultural sites and sensitive natural resources. Nearly all of the acres are enrolled under either Michigan's Commercial Forest Act (CFA) or Wisconsin's Managed Forest Law. Approximately 85 percent of these forestlands can be generally characterized as northern hardwood types. Management goals for the dense hardwood cover types are to achieve regulated all-aged sawlog quality stands. This is accomplished using marked selection harvests initiated on a 10 to 15 year cutting cycle. Post-harvest basal areas are approximately 70-80 ft^2. Pulpwood grade products help support fiber supply needs at the IP paper mill at Quinnesec, Michigan. Other products generated (e.g. bolts, sawlogs, veneer) provide income to the Company.

All of IP's ownership is certified under the International Organization for Standardization addressing environmental management systems, specifically ISO 14001 and the Sustainable

Forestry Initiative Standard (SFIS, 2004). Increasingly, customers of IP are demanding that their magazines and catalogs be manufactured from green certified fiber. Maintaining environmental certifications on its forest ownership is important to International Paper and the customers that use its products.

SFI certified landowners demonstrate that they manage their forestland in conformance with the Principles, Objectives, Performance Measures and Indicators of the Sustainable Forestry Initiative® Program. Most relevant to the lack of regeneration issue is SFI Objective 2 which states "…*to insure long-term forest productivity and conservation of forest resources through prompt reforestation, soil conservation, afforestation, and other measures*". The mandatory Performance Measure 2.1 for this objective further stipulates that within five years after final harvest, the treated area must be regenerated when using natural regeneration methods. In this instance, the managing forester prepared a silvicultural plan noting that the area was to be managed as an all-aged high quality northern hardwood stand. Natural regeneration was to be established within five years of the marked harvest. The auditor, while reviewing the harvest area, noted that the regeneration and sapling component of the stand was absent sufficient numbers of commercially important species to satisfy Performance Measure 2.1.

The Problem

Approximately 35,000 acres of IP's northern hardwood tracts in Menominee, Dickinson, and Iron Counties in Michigan; and Florence and Marinette Counties in Wisconsin have inadequate regeneration and a flourishing ground cover of Pennsylvania sedge (*Carex pennsylvanica)*. The sedge and regeneration concern was first documented in 1978 and 1979 during a stand level forest inventory conducted by Champion International Corporation (prior owner to IP). Anecdotal file notes indicated concern over the occurrence of sedge as early as 1970.

A company deer browse survey was conducted at the 14,000 acre Vega Block during the summer of 1987. The Vega Block is located in northern Menominee and eastern Dickinson Counties. The report referenced Michigan Department of Natural Resources (MDNR) information that this region of NE-SW oriented drumlins is well documented as a historic deer yard with an estimated 200 deer / mi^2 during restrictive wintering conditions (Lee, 1988). Recently, the supervising MDNR biologist for the Western UP District characterized this region as the most important deer wintering area in the Upper Peninsula of Michigan. The Champion International Corporation report further characterized the hardwood stands as park-like with regeneration of commercial tree species heavily browsed or absent (Ibid.). Five miles south of the Vega Block in Menominee County is the IP owned Faithorn tract. At this location, Michigan State researchers have established that the deer population is >31 deer/mi^2 (Randall, 2005). A map titled "Relative Density of Deer for 2004 Deer Management Units" developed by the MDNR, Wildlife Division illustrates that Menominee, southern Dickinson and southern Iron Counties have relatively high deer populations. Recent data from Deer Management Units 022 and 255 indicated that deer populations exceeded 40 deer/mi^2 (Doepker, 2005).

IP foresters, as did their predecessors, recognized the potential of these tracts to grow commercially valuable northern hardwood species. They responded by applying tried and true uneven-aged management prescriptions developed over the past century that were being successfully employed throughout the majority of the quality northern hardwood stands in the Lake States Region (LSR Silvicultural Guidelines, 2004). The preferred management methods are no match to the primary and secondary consequences of a deer population that has far exceeded its carrying capacity for thirty or more years. The reality is that if we continue to manage these tracts by current IP silvicultural guidelines, without a dramatic reduction in deer numbers or proactive control of the sedge, we will be at risk of being issued a **nonconformance** by external auditors. When a nonconformance is found to be warranted, certification is at risk of being withheld until corrective action is implemented and results verified (SFIS, 2004).

Need vs. Perception

Both the State of Michigan and IP have options to remedy the long-term hardwood regeneration failures. First, MDNR can implement a strategy to reduce the deer population to a level below carrying capacity. Habitat recovery in this region of drumlins will be complicated because deer that winter here traditionally travel from a much larger area of the western UP. In short, deer numbers substantially increase in the winter (Doepker, 2005).

MDNR is facing a daunting task. Most hunters want more deer not less. A 1998 hunter survey conducted by Michigan State University in Menominee County found that many hunters believed that deer numbers were at a low level (5 deer/mi^2) on the IP tracts (Bull, 1999). When told that the estimate was >30 deer/mi^2, they were incredulous. Support for doe reduction programs was also questioned for many believe that "*you can't have too many does because they produce the bucks*" (Ibid.). It is clear that the Wildlife Division staff of MDNR has a significant public education job ahead of them to change the long standing beliefs of most hunters. Current initiatives to address the problems associated with high deer populations include support for the voluntary implementation of Quality Deer Management (QDM) practices in a Deer Management Unit provided that two-thirds of the hunters and landowners surveyed support the program. A 2004 proposal to implement QDM in the entire UP failed to receive the necessary threshold of support (MDNR, 2005). Currently, there are experimental QDM regulations in four small DMUs in the vicinity of Dickinson and Menominee Counties. Complaints to Wildlife Division staff of low deer numbers indicate that continuing this initiative in these DMUs is uncertain. Early antlerless seasons have been offered only on private land in southern Menominee County. CFA land is treated as public and DMU allocations of any deer permits for use on public and CFA enrolled lands have not resulted in noticeable improvements to regeneration on the IP tracts.

A study of hardwood forest development under four deer densities (10, 20, 38, and 64/mi^2) by the U.S. Forest Service in Allegheny Northern Hardwoods of Pennsylvania indicated that when a deer population exceeds 20 deer/mi^2 negative impacts to vegetation in a landscape will likely occur (Horsley, et. al., 2003). At population of 10 deer/mi^2, adequate hardwood regeneration became established in clearcuts. Regeneration was also evident in thinned and uncut areas as well (Ibid.). Conversations with a Wildlife Habitat Ecologist at the Forest Sciences Laboratory, US Forest Service, Durham, NH, stated that deer populations needed to be 10 deer/mi^2 or less to successfully regenerate northern hardwoods in the White Mountain National Forest (Yamasaki, 2005). New York Department of Environmental Conservation Biologists issue antlerless permits through the Deer Management Assistance Program to maintain the deer populations ~ 15 deer/mi^2 on forested ownerships and 10 deer/mi^2 when the objective is to re-establish hardwood regeneration (Reed, 2005). In neighboring Wisconsin, the Department of Natural Resources has established deer density goals at 50 to 70% of carrying capacity across northern deer management units in an effort to reduce a population estimated at 25 deer/mi^2 (Rooney et al., 2003). Seventy percent carrying capacity of Wisconsin's northern forest equates to 18 deer/mi^2 (WDNR, 1998). They also report that herbaceous plants may be reduced in abundance and species richness when deer exceed 12-15/mi^2 and abundance of trees and shrubs change with reduced regeneration when deer numbers exceed 20-25/mi^2 (Ibid). Therefore, this research and expert opinion would suggest that an existing deer population estimated to exceed 30 or 40 deer/mi^2 would need to be reduced to allow natural regeneration to become established, not withstanding the need for sedge control.

IP Options

In addition to reducing deer densities, the second option is for IP to make decisions to bring this acreage, as it exists today with deer and sedge challenges, into meeting ISO 14001 and SFI compliance standards.

Feasible strategies within the control of IP include-

- Continue with an uneven-aged strategy with herbicide treatments to control the sedge to support establishment of regeneration.

- Allow basal area to increase and canopy to close in an effort to reduce the sedge population before continuing with an uneven-aged strategy.
- Change to even-aged management system via shelterwood or clearcut with herbicide treatments to control the sedge.
- Convert the sites from current northern hardwood types to conifer plantations.
- Sell the affected acreage.

The IP Manager of Silviculture/Technical Services for Lake States Region has been focusing on finding a silvicultural solution to the regeneration problem over the last five years. Herbicide trials will be initiated in 2005 as a first step to determine the most effective way to sustainably manage northern hardwood stands that have been impacted by overpopulations of deer and site competition by the Pennsylvania sedge. The silvicultural system that will be used on these acres has yet to be determined. The supervising wildlife biologist of the Western UP District has suggested a meeting with the MDNR Wildlife Division staff and landowners (public and private) in the area of this large historic deer wintering area to discuss techniques to remediate the impacts of high winter concentrations of deer on the forest ecosystem. This type of forum would provide an opportunity for information exchange and may eventually result in a program to disperse winter concentrations of deer.

Discussion

The review of the literature adequately documents that long-term over population of white-tailed deer has a dramatic effect on a forest ecosystem. The mission of the MDNR, Wildlife Division is "*To enhance, restore, and conserve wildlife resources, natural communities, and ecosystems for the benefit of Michigan's citizens, visitors, and future generations*". Hunters may want to see more deer but the MDNR must continue efforts to bring the state's deer numbers to a level below carrying capacity. To do otherwise, is contrary to its mission; and a disservice to the deer resource that they are mandated to manage for the people of Michigan, the landowners whose forestland has been degraded by chronic overpopulation, and the prospect of attaining healthy functioning forest ecosystems in this region of the UP. Until then, IP will need to consider alternate methods over the preferred all-aged silvicultural system to manage impacted northern hardwood stands. One thing is clear; losing our ISO 14001 and SFI certifications is not an acceptable option for IP.

Bibliography

Bull, P. 1999. Report on Hunter Interviews and Postcard Distribution in Deer Management Unit 15 During the 1998 Deer Hunting Season. Unpublished. Michigan State University Department of Fisheries and Wildlife, East Lansing, Michigan. 9 p.

Doepker, R. 2005. Personal communication. Michigan Department of Natural Resources, Wildlife Division. Norway, Michigan.

Horsley, E. B., S. L. Stout and D. S. deCalesta. 2003. White-tailed Deer Impact on the Vegetation Dynamics of a Northern Hardwood Forest. Ecological Applications. 13(1):98-118.

International Paper. 2004. Lake States Region Silvicultural Guidelines. Forest Resources Environmental Management System. Memphis, Tennessee.

Lee, R. 1988. Vega Block – Deer Browse Survey. Company report. Champion International Corporation. Norway, Michigan.

MDNR. 2005. Upper Peninsula Quality Deer Management Proposal Results News release. Michigan Department of Natural Resources. Lansing, Michigan.

Randall, J. 2005. Personal communication. Michigan State University Department of Forestry. East Lansing, Michigan.

Reed, E. R. 2005. Personal communication. New York Deer Management Assistance Program, New York State Department of Environmental Conservation. Ray Brook, New York.

Rooney, T. P. and D. W. Waller. 2003. Direct and Indirect Effects of White-tailed Deer in Forest Ecosystems. Forest Ecology and Management 181:165-176.

WDNR. 1998. Deer Management Program: The Issues Involved in Decision Making, second edition. Publication 55-031-09. Wisconsin Department of Natural Resources. Madison, Wisconsin.

Yamasaki, M. 2005. Personal communication. Forest Science Laboratory, U. S. Forest Service. Durham, New Hampshire.

Certifying Sustainable Forestry: The Deer Factor

David deCalesta[1]
Wildlife Analyses Consulting

[1]*Retired USDA Forest Service Northeastern Research Station*
Wildlife Analysis Consulting, Box 621 Hammondsport NY 14840 USA
Email: wildana@earthlink.net

Abstract: *The process developed by the Forest Stewardship Council for certifying that forest management operations sustain local and regional ecologies, economies, and cultures is a performance-based evaluation of ten principle components. Four of these components deal with forest regeneration, ecological diversity, local economies, and conservation of threatened and endangered plant and animal species, and each may be negatively affected by browsing by overabundant deer herds. Browsing by white-tailed deer was identified as the most important biological impediment to sustainable forestry on a majority of 16 certification assessments conducted in the northeastern United States. On some of these assessments, conditions were issued that required reduction of deer impact to maintain certification. With few exceptions, the operation seeking certification had few if any effective options for proactive management to reduce deer abundance, as regulation of deer abundance by hunting regulations was controlled by a separate state agency. This circumstance made it difficult for certifying agencies to develop realistic conditions that could be met for reducing deer impact, and made it equally difficult for operations being certified to affect meaningful reduction in deer impact. However, Pennsylvania provides an example of how proactive management by a state agency and certified operations, in concert with a series of harsh winters, may have resulted in reductions of deer abundance sufficient to satisfy conditional maintenance of certification.*

Introduction

Green certification is a process designed to assess, quantitatively, whether forest management operations are conducted in a way that sustainability is retained and enhanced. Two entities exist for certification: The Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI). Both bodies use similar processes to ascertain sustainability. The FSC process is a structured process that determines whether operations are conducted in a manner that sustains local ecosystems, local economies, and local cultures and heritages.

Assessments are conducted by teams, usually including a silviculturalist, a forest ecologist, and sometimes economists and/or sociologists. The teams utilize standards of sustainability developed by committees comprised of local experts: standards are divided into 10 principles, each with supporting criteria and indicators. Assessment teams evaluate operations based on their evaluations of performances related to the principles, criteria, and indicators. This process includes review of written documents, office visits to check compliance with administrative requirements, and field visits to evaluate compliance with management criteria and indicators. Responses are scored on a 5-point scale with 1 being non-compliance and 5 being exceptional compliance. Composite scores are assembled to determine whether candidate operations are deemed operating sustainably. Generally, a passing score must be awarded for each of the 10 principles for operations to be successful. Failure to make the grade results in preconditions (corrective actions that must be satisfied prior to being certified), and/or conditions (corrective actions that must be satisfied within a designated time period). Observations may also be made by the assessment team and are a part of the written report, but they are simply suggestions for improvement and are not binding. Additionally, interviews with stakeholders are conducted as part of the process and are part of the written report.

Annual audits are required as checks to determine progress towards meeting conditions as well as to observe any new field operations. At 5 year intervals, operations must undergo a full re-assessment to maintain their status as operating sustainably.

Certification is not for everyone, and usually not for owners of small woodlots. Consultants with pools of individual landowners, large public and private forest landowners, educational institutions, and partnerships (e.g. The Nature Conservancy and a private timber company) form the bulk of certified operations.

Many reasons exist for becoming certified: certification is good public relations (and sometimes demanded by clients of wood-producing companies), it may provide the “silver bullet” for protection against lawsuits lodged by environmental activist groups, it is often perceived as “doing the right thing” and is recognized as a way of confirming good management practices. The major advantage often cited is economic incentive, but to date certified wood does not bring the premium price needed to offset the cost of certification.

How Deer Affect Certification

Several of the 10 principles assessed in certifications are affected by overabundant deer herds and their impact on forest resources. ***Principle 5, Benefits from the Forest*** requires that forest management operations shall encourage the efficient use of the forest’s multiple resources and services to ensure economic viability and a wide range of environmental and social benefits. Specifically, sustainability of harvest levels is based on documented data on successful regeneration of tree species after harvest. On many managed forests in the Northeast, browsing by overabundant deer herds has eliminated or greatly reduced the abundance and type of tree seedlings required to regenerate forests after timber harvest. Lack of such regeneration prior to harvest is sufficient to result in failure and a failing score on assessments. Additionally, the principle requires that management diversifies forest uses and practices while maintaining forest composition, structure, and functions. Numerous scientific studies have demonstrated that browsing by overabundant deer herds eliminates or greatly reduces species composition of understory plants, including tree seedlings, simplifies structural (vertical) diversity, and negatively affects functions such as regeneration and nutrient cycling. Almost all assessments conducted by the author over the last five years included conditions and/or observations assessed for reducing the impact of overabundant deer herds.

The 6th principle deals with ***Environmental Impact*** and requires that forest management shall conserve biological diversity and its associated values …. and maintain ecological functions and integrity of the forest. Specifically, the principle requires that safeguards exist to protect rare, threatened, and endangered species and their habitats, that ecological values and functions shall be maintained intact, enhanced, or restored, including forest regeneration and succession. A diversity of habitats for native species is to be protected, maintained, and/or enhanced, including vertical and horizontal structural complexity. Additionally, uneven-age silviculture is to be employed to avoid high grading and or diameter limit cutting. Management systems are to promote development and adoption of environmentally friendly non-chemical methods of pest management and … avoid use of chemical pesticides.

Again, numerous studied have documented that overabundant deer herds reduce diversity and negatively affect ecological functions, including regeneration, structural complexity, and integrity of the forest. Many assessments note negative impacts on diversity, ecological functions and integrity, and of these, almost all are exclusively a result of deer browsing. Uneven-age management is not an option where there are overabundant deer herds, as the deer are attracted to the limited amounts of forage found in small areas harvested under uneven-age management and regeneration always fails on these sites. Often, use of chemical pesticides is the only way to eliminate ferns, grasses, and other interfering plants that are not eaten by deer and which crowd out desirable shrub, tree, and herb species.

Principle 8, ***Monitoring and Assessment***, requires that monitoring is conducted to assess the condition of the forest, management activities … and environmental impacts. Forest management is to include research and data collection to monitor … regeneration and composition and … observed changes in flora and fauna.

Few management operations monitor environmental impacts such as deer browsing or deer density, nor do they monitor changes in flora and fauna resulting from impacts of deer browsing. Indeed, such monitoring is expensive, extensive, and little documented or described by either forest or wildlife professions. Many operations receive conditions relative to monitoring of deer impacts on flora an fauna – it's too expensive and cost-effective technology is unknown.

Finally, the 9th principle, ***Maintenance of High Conservation Value Forests***, requires that management activities in high conservation value forests (such as old-growth, or unique and rare plant communities) shall maintain or enhance the attributes which define such forests (including habitats for threatened or endangered species).

Most of the attributes that define high conservation value forests (unique plant species, unique vertical or horizontal structure) tend to be negatively affected by overabundant deer herds, sometimes in remote or inaccessible areas that land managers are not aware of. Again, conditions often are assessed for failure to protect high conservation value forests from the negative impact of deer browsing.

Thus it may be deduced that many forest operations fail, or receive conditions for improvement, in one or more principles solely as a result of deer browsing. The inherent problem in addressing such failures of management is that control of regulations designed to reduce overabundant deer herds by liberalizing hunting regulations rests not within the operations being certified but rather within state or federal game-managing agencies which are under tremendous political pressure by hunters to increase rather than decrease deer population abundance. Indeed, in > 70% of 20+ different management operations assessed by the author, conditions or pre-conditions were issued that required reducing the impact of browsing by overabundant deer herds. The list of affected operations includes individual state forest management agencies, large private timber companies, partnerships between environmental organizations and timber companies, consultants managing pools of smaller forest landholdings.

Problems with Certifications and Deer Impacts

The overriding difficulty in resolving deer-caused certification failures or problems is that while landowners being certified manage the vegetation, separate, often non-interested state game managing agencies control the legislation and other means by which regulations may be changed to allow higher harvest of deer. Given this political impasse, it is difficult to write conditions related to reducing deer impact that affected landowners can realistically meet, given their almost total lack of control over deer harvest. Additionally, it is hard to measure compliance with conditions written to force reduction of deer impact when affected landowners often cannot do anything to affect reduction in deer density.

The biggest challenge to, and perhaps responsibility of, assessing entities, is to how to force change in regulations affecting deer harvest and abundance that are totally within the purview of non-interested wildlife management agencies. An often-heard solution is to consolidate separate wildlife and forest managing state agencies into a single natural resource agency wherein resolution of forestry and wildlife issues may be forced by executives who not responsible to only one resource.

Problems

- Landowners control the vegetation, separate state agency controls deer herd management
- How to write conditions that address deer impact which landowners can actually achieve
- How to evaluate compliance with conditions
- How to engage state agencies to affect change in deer herd within large and small scale landscapes

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

Susan Stout[1]
USDA Forest Service Northeast Research Station

[1]Research Forester and Project Leader, USDA Forest Service, Northeastern Research Station, Forestry Sciences Laboratory, P.O. Box 267, Irvine, PA 16329 Email: sstout@fs.fed.us

---

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.

Stand type	Food production (lbs/acre)	PROPORTION OF AREA IN REGENERATION OPENINGS			
		5%		10%	
		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

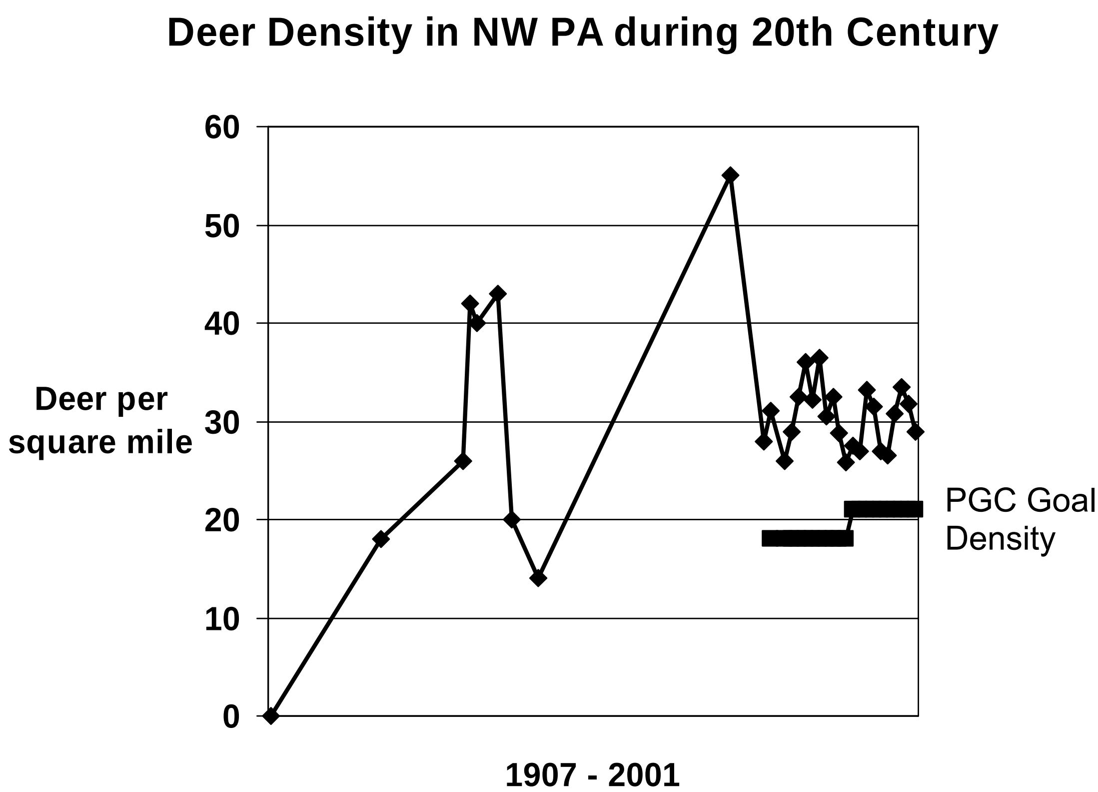


***Figure 1**. Estimated deer density in northwestern Pennsylvania during the 20th century.*

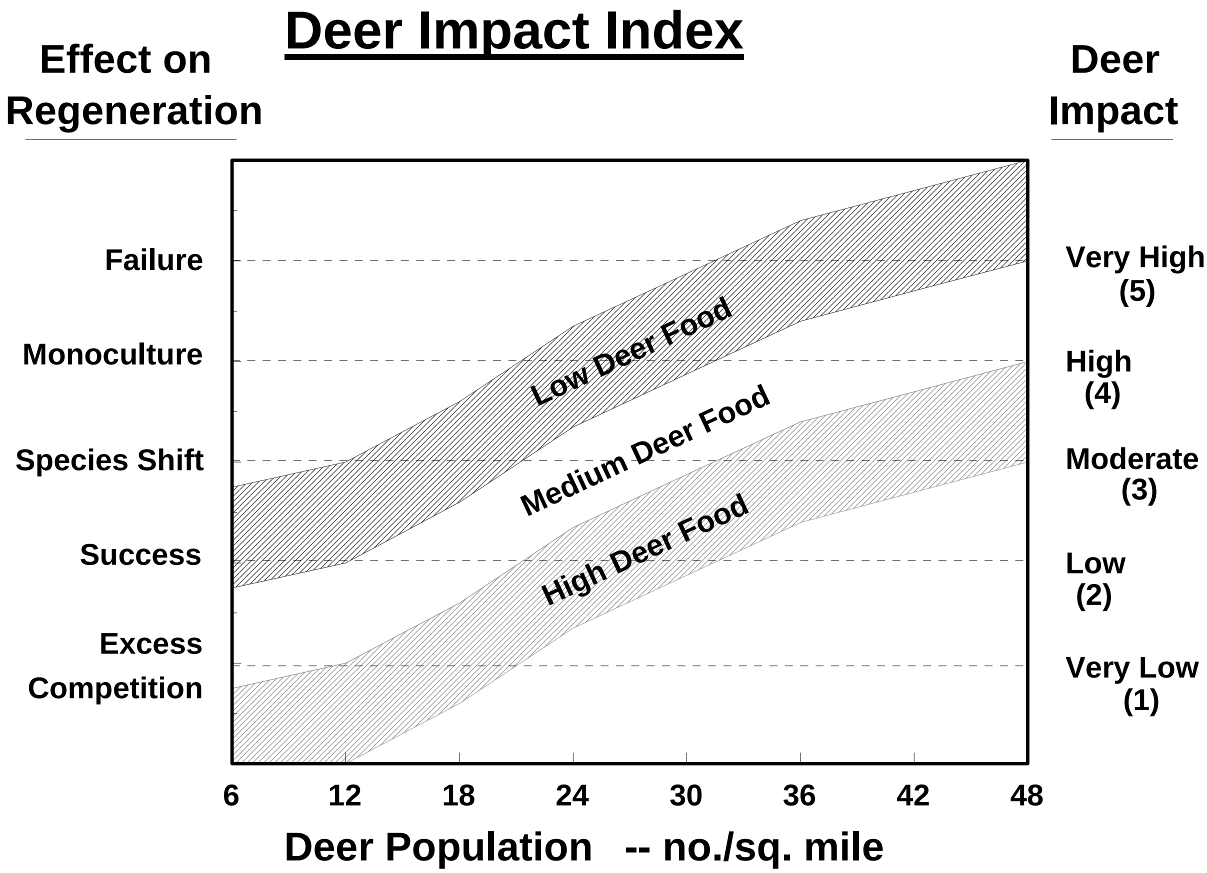


Figure 2. *Deer Impact Index is a way of visually displaying the fact that the impact of deer on forests is a function of both their density and the amount of forage found within the landscape.*

Literature Cited

Alverson, W. S., and D. M. Waller. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests. Pages 280-297 *in* W. J. McShea, H. B. Underwood, and J. H. Rappole, editors. The science of overabundance: deer ecology and population management. Smithsonian Institution Press, Washington, D.C., USA.

Brenneman, Ron. 1987. Movements of deer into hardwood clearcuts in Pennsylvania. In Cochran, Roe S., chair. Proc. Symp.; Deer, Forestry and Agriculture: Interactions and strategies for management. Warren, PA: 1987 June 15-17. Erie, PA: Plateau and Northern Hardwood Chapters, Society of American Foresters. 87 pp.

deCalesta, D.S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. J. Wildl. Manage 58: 711-718.

deCalesta, David S.; Stout, Susan L. 1997. Relative deer density and sustainability: a conceptual framework for integrating deer management with ecosystem management. Wildlife Society Bulletin 25: 252-258.

Grisez, Ted J. 1960. Slash helps protect seedlings from deer browsing. J. For. 58: 385-387.

Horsley, Stephen B.; Stout, Susan L.; deCalesta, David S. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecol. App. 13: 98-118.

Hough, A.F. 1965. A twenty-year record of understory vegetation change in a virgin Pennsylvania forest. Ecology 46: 370-373.

Long, R. P., S.B. Horsley, and P. R. Lilja. 1997. Impact of forest liming on growth and crown vigor of sugar maple and associated hardwoods. Canadian Journal of Forest Research 27: 1560-1573.

Marquis, David A. 1981a. The effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. USDA Forest Service Research Paper NE-475. 10 p.

Marquis, David A. 1981b. Management of Allegheny hardwoods for timber and wildlife. In Proceedings, 17th IUFRO World Congress: Division 1. Forest environment and silviculture. Kyoto, Japan, 1981 September 6-17. Kyoto, Japan. Japan IUFRO Cong. Comm. 17: 369-380.

Marquis, David A.; Bjorkbom, John C. 1982. Guidelines for evaluating regeneration before and after clearcutting Allegheny hardwoods. Res. Note NE-307. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 4 p.

Marquis, David A.; Brenneman, Ronnie. 1981. The impact of deer on forest vegetation in Pennsylvania. U.S. Department of Agriculture, Forest Service. General Technical Report NE-65. Broomall, PA: Northeastern Research Station. 7 p.

Marquis, David A.; Ernst, Richard L.; Stout, Susan L. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). General Technical Report NE-96. Radnor, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 101 p.

McGuinness, Barbara J. 1996. Deer and forest resources: Not just a Pennsylvania problem. PAEE Journal 4(3):14.

Society of American Foresters. 1994. Silviculture terminology with appendix of draft ecosystem management terms. Bethesda, MD. Society of American Foresters. 14 p.

Stout, S.L.; deCalesta, D.S.; DeMarco, L. 1987. Can silviculture change deer impact? In Proceedings of the 1995 Society of American Foresters Convention. Portland, ME. 1995 October 28 - November 1. Bethesda, MD: Society of American Foresters. 437-438.

Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal Wildlife Management 53: 524-532.

Adaptive Management for Deer: A Case Study from Pennsylvania

David deCalesta[1]
Wildlife Analyses Consulting

[1]*Retired USDA Forest Service Northeastern Research Station*
P.O. Box 621, Hammondsport, NY 14840-9712 Email: wildana@earthlink.net

---

Abstract: *The Sand County Foundation, working with local foresters, biologists, researchers, hunters, and community leaders, developed an adaptive management program (Quality Hunting Ecology) to reduce the ecological impact of deer damage on a 74,000 acre demonstration area in north central Pennsylvania. Program goals were simple: produce healthy forests, healthy deer, happy foresters, and happy hunters. Tools (with helpful assists from the Pennsylvania Game Commission) included: 1) education - providing hunters and other interested publics information on deer quality, biology, and impacts with workshops and news releases; 2) access - providing better access and increasing awareness of access to hunting areas; 3) hunting regulations tweaking regulations to improve antler characteristics and increase antlerless harvest; 4) incentives - rewarding hunters for harvesting deer; and, 5) luck unforeseen assists from weather in the form of 3 successive harsh winters. Monitoring included: 1) spring deer density and impact (on forest vegetation) counts; 2) pre-hunt roadside counts of herd sex and age composition; 3) check station operations for harvest characteristics; and 4) evaluation of hunter success and satisfaction. Prior to the program, overwinter population was 40% higher than recommended by the state game commission, impact on forest vegetation was high, and deer were small with poor racks. Over the last three years, deer density and impact on vegetation have declined by approximately 50% and deer body weight and antler characteristics have increased significantly. The biggest challenge will be keeping hunters happy and actively participating (continuing to harvest antlerless deer) as numbers of deer decline and stay low.*

In Pennsylvania, as in other eastern states, deer have increased in abundance since the 1920's. Likewise, negative deer impact has increased on tree regeneration, and on shrub and herbaceous vegetation survival. The solution to these problems, reducing deer abundance by increasing antlerless deer harvest, has been thwarted by conservative harvest regulations, poor access, low hunter turnout and success rates, and reluctance of hunters to harvest antlerless deer. Enlightened management in deer in Pennsylvania, as in other eastern states, seemingly, could be enhanced by an adaptive management approach to the issue.

Adaptive management, as a paradigm for proactive management of wildlife species and communities, requires vision, including definitive goal statements, flexibility in tools and the ability to use them, and comprehensive monitoring to determine progress towards goal achievement and potential need for adjustments in management activities. Adaptive management is an established concept (Holling 1978, Walters 1986): recently Walters (1997) defined it as a

". . . structured process of learning by doing that involves more than ecological monitoring and response to unexpected management impacts."

More specifically, Walters stated that adaptive management should integrate existing interdisciplinary experience (in our case forestry and wildlife) and scientific information into dynamic modeling to make predictions about the impacts of alternative (management) policies. Further, the modeling is to serve three functions: (1) problem clarification and enhanced communication among scientists, managers, and other stakeholders; (2) policy screening to eliminate options that are most likely incapable of doing much good, because of inadequate scale or type of impact; and (3) identification of key knowledge gaps that make model predictions suspect.

The British Columbia Ministry of Forests and Range (2000) more practically defines Adaptive Management and includes a diagram depicting a cycle of activity (Fig. 1):

"Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form active adaptive management employs management programs that are designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed."

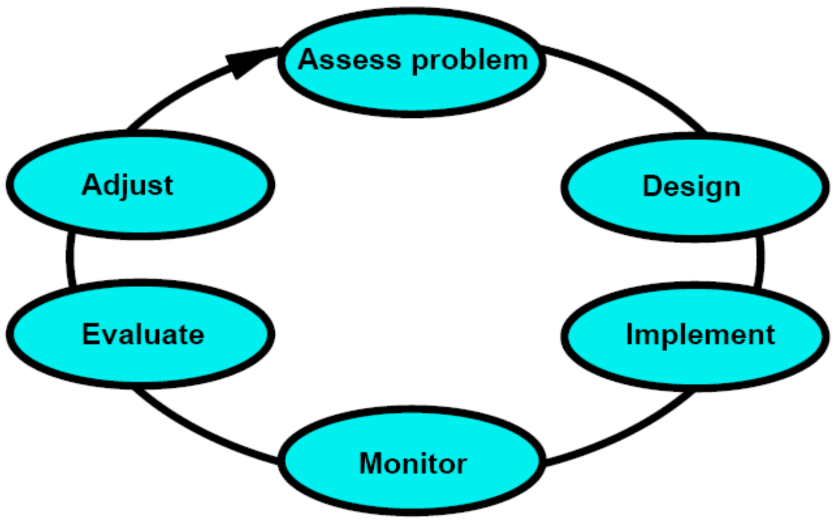


***Figure 1**. Six step cycle of adaptive management (BC Ministry of Forests and Range).*

The deer herd in Pennsylvania was perceived by wildlife managers to be causing negative impact on understory vegetation as early as the 1920s. The management strategy at that time was to allow hunters to harvest doe deer in an attempt to reduce reproduction, and herd density, below the (undefined) point where damage to understory vegetation was acceptable (also undefined). Antlerless tags were issued to hunters thereafter without monitoring of the result, excepting that in 1940 a harsh winter, coupled with liberal antlerless deer tags, resulted in a large crash in the deer population. Ever since, hunters were reluctant to harvest antlerless deer and lobbied to reduce doe hunting. Another population crash following a series of harsh winters (1978-79) was followed by an additional management step to increase doe harvest by management authorities (Pennsylvania Game Commission, hereafter referred to as PGC) in the late 1980s: hunters were allowed to apply for unused antlerless tags as bonus tags. The bonus system succeeded in stabilizing the state-wide deer herd at approximately 27 deer per square mile, but this density exceeded that necessary to permit successful regeneration of tree species and a diversity of structure and species of understory vegetation.

By 2000 it was well-established that deer density of approximately 27 deer per square mile state-wide, with a herd heavily weighted to females and yearling bucks continued to be associated with understory regeneration failures and poor quality deer across Pennsylvania. Accordingly, the PGC initiated an aggressive program of hunter education in a new management strategy: enlightened hunters would see the need for reducing the deer herd and would aggressively hunt and harvest antlerless deer. A further management step was added in 2002 to increase antler quality: a 3 point regulation whereby hunters could only harvest deer with at least 3 antler points on either side, the idea being to spare yearling bucks from harvest, allowing them to grow into 2 ½ year and older deer with larger antler characteristics. Finally, in 2004 a last management strategy was instituted: a Deer Management Assistance Program (DMAP) whereby forest and farm landowners could receive additional antlerless tags to distribute to hunters to reduce deer density and impacts in selected areas.

All of these steps initiated by the PGC could be construed as *ad hoc* adaptive management. However, the PGC did not develop comprehensive and inclusive indicators for success in this program, as the primary indicators utilized were deer density and number of yearling bucks in the harvest. There was no monitoring of hunter satisfaction or education, nor was there monitoring of responses of understory vegetation (wildlife habitat).

In 2000 the Sand County Foundation (a not for profit organization), working with scientists, managers, and stakeholders (foresters, biologists, researchers, hunters, and community leaders), developed an adaptive management program (Kinzua Quality Deer Cooperative hereafter referred to as KQDC) on a 74,000 acre demonstration area in north central Pennsylvania. The program is administered by a Leadership Team comprised of scientists, managers, foresters, hunters, and representatives for the Sand County Foundation and local recreational and economic interests.

The KQDC Leadership Team enhanced the definition and accompanying graphic to include a statement of goals, a list of indicators of success for reaching goals, and quantitative enumeration and evaluation of the indicators (Fig. 2).

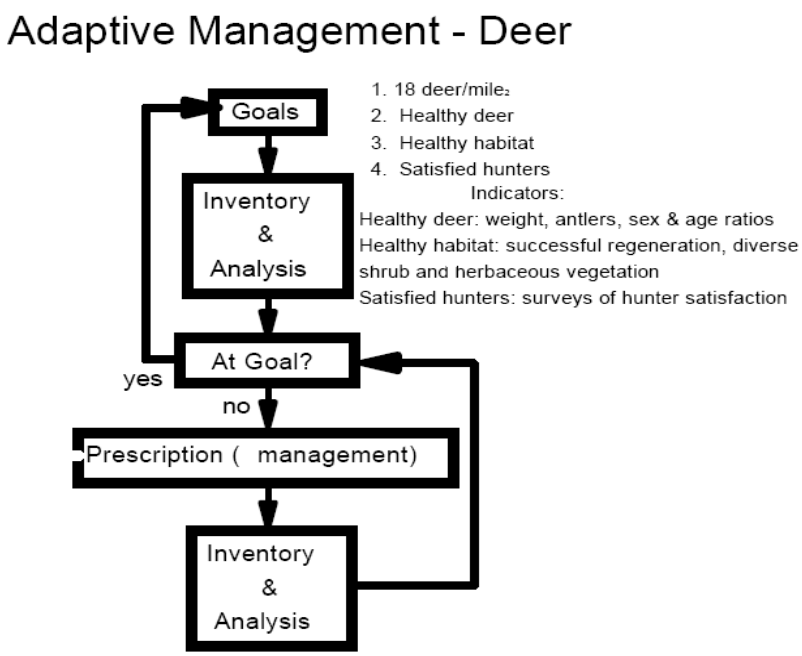


***Figure 2**. KQDC adaptive management illustration including goals and indicators.*

Goals were simple: drive deer density from an existing 28.7 deer per square mile to 18 deer per square mile (density associated with successful regeneration of tree species); produce healthy deer, and healthy habitat. Methods employed to achieve the goals were: launch an aggressive educational program for hunters; and lobby the PGC for additional regulations to increase harvest of antlerless deer and improve deer herd health. Part of the educational program involved incentives: hunters bringing deer to checking stations were issued tickets to a hunter appreciation banquet after the season. The tickets doubled as raffle tickets. Hunters were rewarded for harvesting antlerless deer by being issued two raffle tickets (hunters harvesting antlered deer received only one raffle ticket). Prizes raffled off at the banquet included hunting rifles and other hunting equipment as well as certificates for weekend get-aways.

Indicators for healthy deer were field dressed body weights of harvested deer (> 150 pounds for adult males, > 110 pounds for adult females, > 70 pounds for fawns), antler characteristics of harvested deer (sum of right and left antler averaging > 8 points, antler spread averaging > 16 inches; average beam diameter averaging > 30mm), and defined sex and age ratios of the pre-hunt deer herd (buck:doe ratio ~ 1:3-4; fawn:doe ratio > 1:2). The low goal ratio for fawns:does related to the finding that in Pennsylvania, bear, coyotes, and other predators reduce fawn abundance by approximately 50% prior to the hunting season.

Indicators for healthy habitat were successful regeneration of a diversity of tree species, and presence of a diverse structural and species rich understory of shrubs and herbs. Indicators evaluated by this study were impact levels on six selected indicator tree species (goal level = light), and % of field plots exhibiting no deer browsing impact (goal level > 50%), and % field plots exhibiting no regeneration of any tree or shrub species (goal level < 20). A separate study evaluated more comprehensive indicators of deer impact on regeneration, shrubs, and herbaceous vegetation.

Indicators of satisfied hunters were to be included in a hunter satisfaction survey that has yet to be completed.

The KQDC demonstration project was conducted on a 74,000 acre demonstration area in north central Pennsylvania and included lands of 5 cooperating agencies: two public landowners (the USDA Forest Service Allegheny National Forest and Bradford Water Authority); and three private timber-managing companies (Collins Pine, Forest Investment Associates, and RAMCO)(Fig. 3).

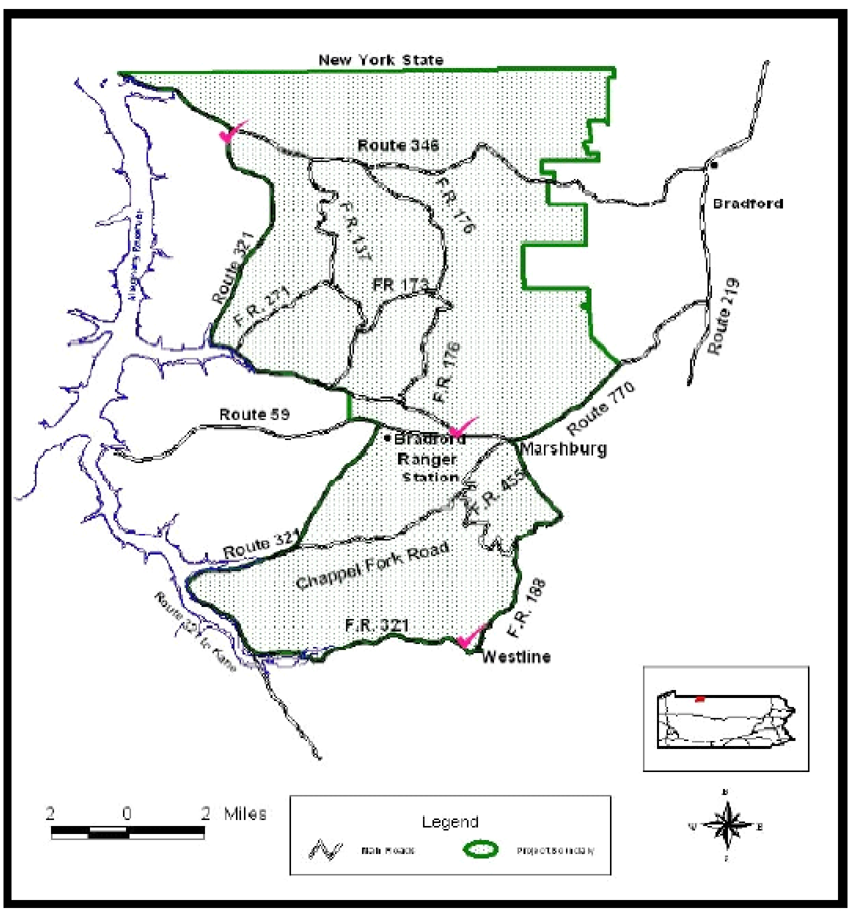


***Figure 3**. KQDC demonstration area.*

Monitoring

Monitoring consisted of three phases: springtime estimation of deer density and impact on selected indicator seedling species; pre-hunt estimation of sex and age ratios of the herd; and check stations to evaluate herd health, including antler characteristics. Data are presented for 2001-2004 when information was comprehensive and complete.

Deer density and impact. - Data for estimating overwinter deer density and deer impact on indicator plant species were collected from plots spaced 100 apart on five transects 5,280 long spaced 1,000 apart. Twenty-four grids of five transect lines were randomly located within the KQDC demonstration area; the figure below portrays a typical grid of five transect lines.

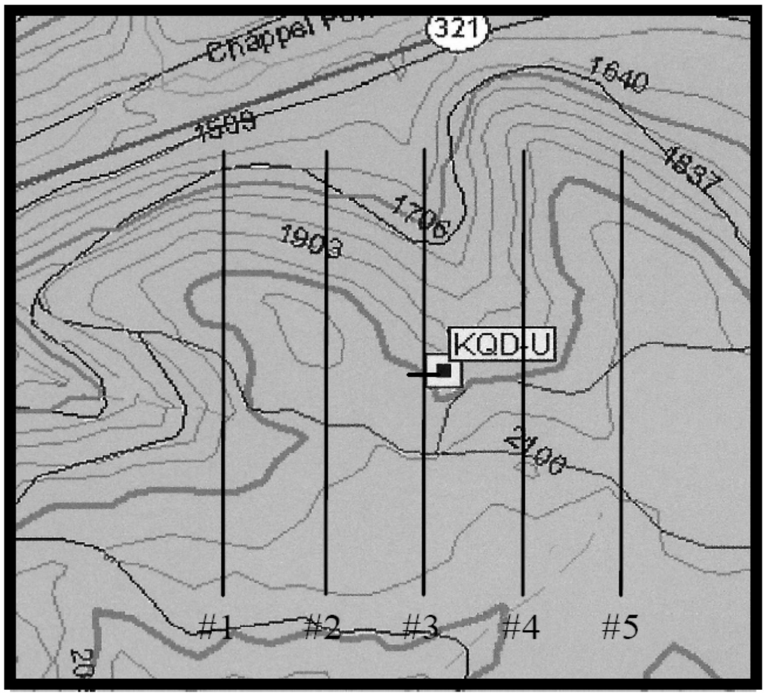


***Figure 4**. Typical deer density and impact grid.*

The middle transect line (line #3) runs through the center point of each randomly located grid. Deer density data (counts of deer pellet groups) were collected on every plot; impact data (five impact levels on five indicator plant species as well as number of plots with no regeneration and percent of plots with no impact) were collected on every other plot.

Density and impact data were collected by volunteers after the snow melted (to reveal presence of pellet groups) and prior to green-up of ground vegetation (after which pellet groups are covered by ground vegetation such as ferns and club mosses)(generally April 1 May 10). An annual workshop for training volunteers and other interested publics, including hunters, was conducted at one 24 of the KQDC grids (grid M).

The five transect lines at each of the 24 locations were each treated as replicates: for estimates of deer density and impact there were thus five replicate samples. Each replicate sample of 24 transect lines was derived by randomly assigning the numbers 1-5 to each transect line at each location. The first replicate sample was comprised of all transect lines randomly selected as # 1, the second replicate sample was comprised of all transect lines randomly selected as #2 and so on.

Sex and age ratios. - Data for estimating pre-hunt deer sex and age characteristics and ratios were collected from six roadside routes located throughout the KQDC demonstration area (Fig. 5). Routes are run two hours before sunset and two hours after dawn, August 1 September 15 by volunteer crews.

Deer herd health. - Check stations were located at the north, middle, and southern portions of the KQDC Demonstration Area. Check stations operated from 10am in the morning to 7 pm at night. All were open the first two days of the season (November 29th and 30th). Two of the check stations were open the first Saturday of the season, and one was open the last Saturday of the season. A paid worker supervised work at each check station, and an additional 10 unpaid volunteers helped collect data at the check stations. Data collected from deer brought to check stations included sex, weight, age, girth, antler characteristics (number points both sides and in aggregate, spread in inches, diameter in mm of right and left beam), location where deer was harvested, day of season deer was harvested, time of day deer was harvested, and time of day deer was brought to the check station.

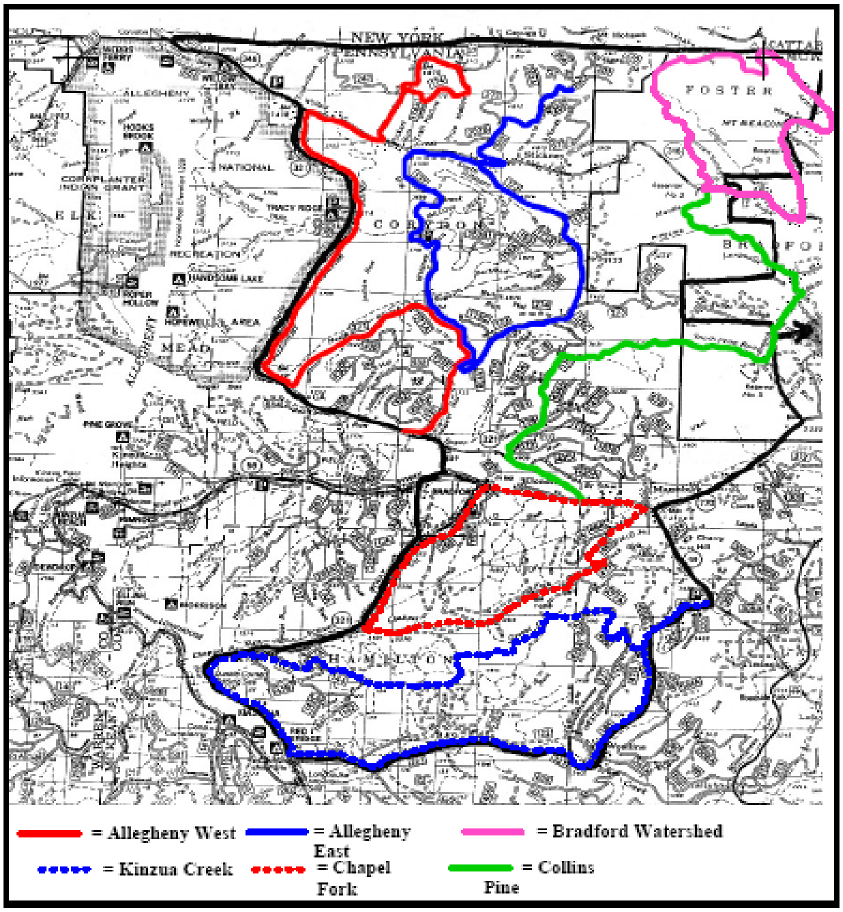


***Figure 5**. Deer roadside count routes within the KQDC demonstration area.*

Response to Adaptive Management

Deer density and impact. - Deer density and impacts were analyzed separately for the northern and southern halves of the KQDC demonstration area. Density declined on the southern half 2002-2004 as did impact: both declined after 2003, the year DMAP was initiated (Fig. 6). Of all PGC wildlife management areas in Pennsylvania (26) only two evidenced reduction in deer density following initiation of the DMAP program and the KQDC demonstration area was one of the two. Seemingly, the DMAP program, initiated in 2003, and perhaps the raffle-incentive programs, resulted in a significant decline in deer density and impact on both halves of the demonstration area. However, density and impacts are still high: the planned adaptive management strategy on the KQDC for 2005 was to provide hunters with maps indicating hot spots of high density, noting access roads into these areas, and encouraging hunters to focus their hunting efforts there. The practice of inviting hunters to participate in density and impact workshops seemed to work as informal surveys after the conclusion of the workshops, wherein hunters collected density and impact data, and participated in the analysis and interpretation, indicated support for lower deer density and higher levels of harvest, including antlerless deer.

Deer sex and age ratios. - Ratio of fawn:antlerless deer has steadily increased since 2001, meaning that for every year since 2001 it took more does every year to produce one fawn that survived to fall (Table 1). Each doe should produce 1-2 fawns every year, but on the KQDC it took approximately 2 does to produce one fawn in 2001, and by 2004 the rate increased to 3 does required to produce one fawn. Similarly, recruitment (percent increase of herd due to fawn production and survival) has steadily decreased since 2001. In 2001 the deer herd increased by

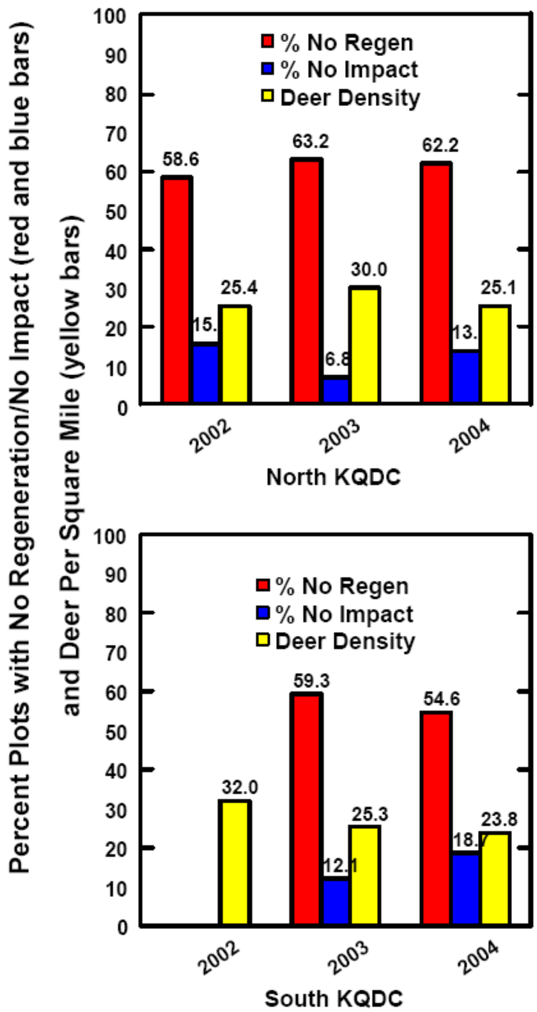


***Figure 6.** Deer density and impact on north and south halves of KQDC.*

47% from spring to fall; by 2004 the increase (recruitment) was nearly halved, falling to 25%. Recent research conducted in Pennsylvania by the Pennsylvania Game Commission and Pennsylvania State University suggests that predators (primarily black bear and coyotes) kill about half of the fawns prior to fall; it is reasonable to assume that the same predation rate exists on the KQDC where bears and coyotes are plentiful.

Buck:doe ratios did not improve 2001-2004 despite attempts by the PGC and KQDC to encourage hunters to harvest antlerless deer. Likewise, fawn:doe ratios got worse instead of better. Additionally, fawn pre-hunt recruitment dropped almost by half in 2004. The general interpretation of these data is that three harsh winters in a row resulted in poor fawn birth and survival rates, especially in 2004.

Table 1. Ratios of fawns:antlerless deer; older bucks: antlerless deer; recruitment rates.

Year	Fawns:Antlerless	Recuitment	Older Bucks:Antleress
2001	1:1.8	47%	1:8.2
2002	1:1.9	41%	1:6.3
2003	1:2.2	40%	1:11.8
2004	1:3.3	25%	1:9.5

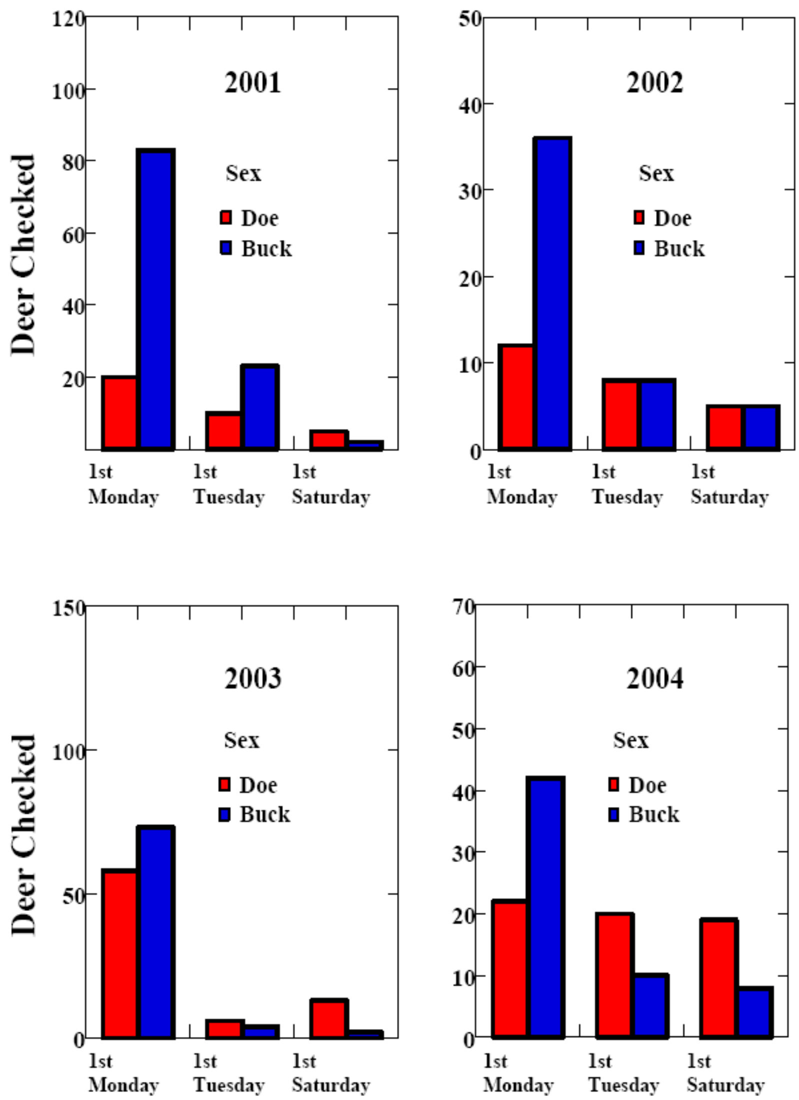


Figure 7*. Numbers of adult bucks and does brought to check stations 2001-2004.*

The PGC had no additional management initiates to increase harvest of antlerless deer, indeed intense political pressure by hunters resulted in no changes in hunting regulations and antlerless tag regulations. The KQDC has no political leverage over the PGC to increase harvest of antlerless deer save requesting a similar number of DMAP tags for 2004 as it did in 2003.

Deer herd health. - Number of does harvested relative to bucks improved in 2003 the year DMAP was initiated. Bucks continued to be harvested in greater numbers that does on opening day, but after that number of does brought to checking stations was higher than the number of bucks (Fig. 6). In this regard, the DMAP program appeared to be working.

Weight of buck fawn weights increased significantly between 2001-2004; 2002-2004; and 2003-2004: female fawn weights increased slightly 2001-2004 but were not significantly different from year to year (Fig. 7). Adult buck weights increased significantly over time for bucks between 2001and 2003; 2001 and 2004; and 2002 and 2004. Forage quality/quantity affect fawns and adult bucks more than other deer. Fawns are balancing demands of growing and storing fat for survival during winter and adult bucks deplete fat reserves during the rut. Increases in adult buck and fawn weights, especially in 2004, may reflect a response to the slight increase in overwinter forage in 2004.

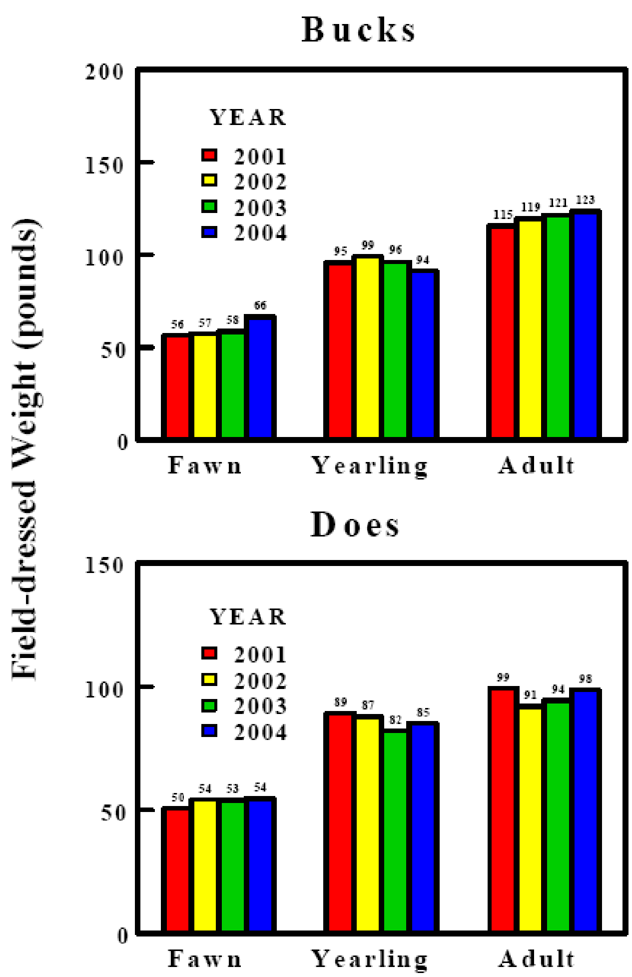


***Figure 8**. Field-dressed weights of deer brought to check stations.*

All measured antler characteristics (spread, total points, right and left beam diameters) were significantly greater between 2001 and the following years (Fig. 8) but did not increase after 2002. Increase in antler characteristics ceased after 2002 because hunters were shifting harvest from yearling deer to 2 ½ year old deer. Thus, the initial strategy by PGC to increase antler characteristics was successful initially, but failed to improve after 2002 because hunters continued to harvest young deer (primarily 2 ½ year old bucks).

Herd health characteristics suggest that strategies employed by the PGC to reduce herd density and improve herd health and antler characteristics met with initial success but need to be followed up with additional changes in hunting regulations/opportunities to further reduce deer density and improve deer weight and antler characteristics. KQDC is mulling a request to the PGC increase antler point restrictions to 4 points on either side on the KQDC demonstration area in an attempt to increase the age of harvested bucks.

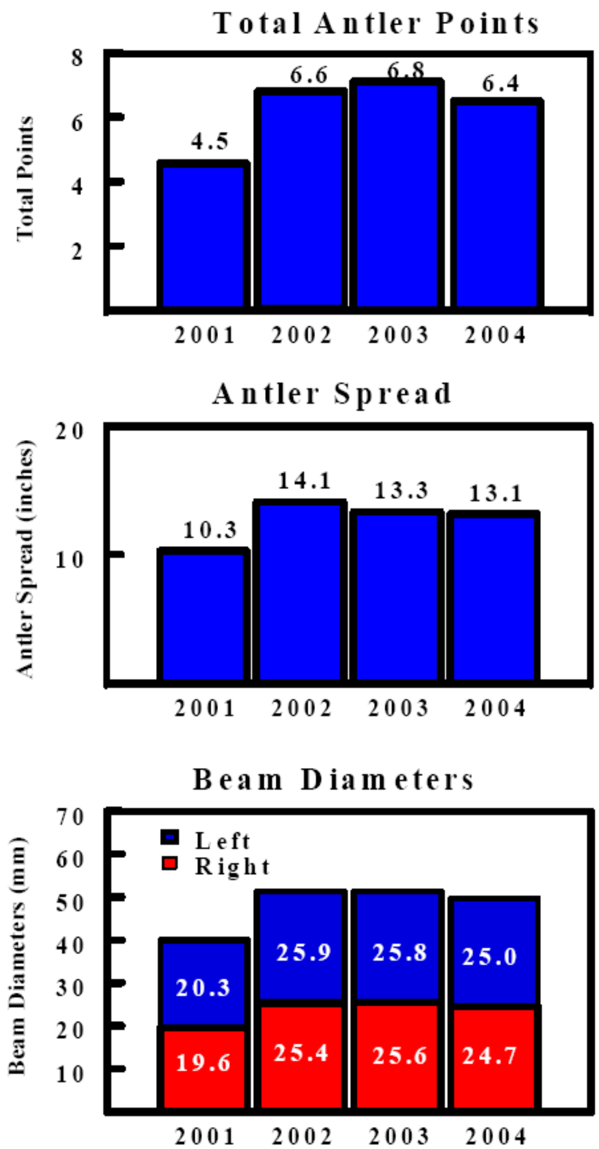


Figure 9. *Antler characteristics of harvested bucks.*

Summary

The KQDC leadership team was limited in adaptive management strategies for reducing deer density and impact and for improving deer and forest health. All regulations (DMAP program, antler point restriction) for improving deer and forest management were effected by the PGC. The KQDC leadership team merely enhanced these two programs by educational and incentive efforts. However, based on monitoring, the KQDC leadership team was able to demonstrate quantitative progress toward some goals, and had the information needed to support continuation of the DMAP program to make further advances toward goals.

Literature Cited

British Columbia Ministry of Forests and Range. 2000. Definitions of adaptive management. *www.for.gov.bc.ca/hfp/amhome/Amdefs.htm*.

Holling, C.S., editor. 1978. *Adaptive Environmental Assessment and Management.* John Wiley & Sons., New York.

Walters, C. 1986. *Adaptive Management of Renewable Resources.* Macmillan, New York.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Cons. Ecol.1(2)1-17.

Deer and Sedge: Bottlenecks to Seedling Regeneration in Northern Hardwood Forests and Potential Restoration Techniques Aimed at Reversing the Effects

Jesse Randall
Michigan State University Department of Forestry

Jesse A. Randall[1] and Michael B. Walters[2]

[1]Doctoral Candidate, Department of Forestry, Michigan State University, 126 Natural Resources, East Lansing, Michigan, 48824-1222, randal35@msu.edu
[2]Associate Professor, Department of Forestry, Michigan State University, 126 Natural Resources, East Lansing, Michigan, 48824-1222, mwalters@msu.edu

---

Abstract: *High white-tailed deer densities lead to tree recruitment failure, decreased vertical structure complexity, and shifts in composition to species such as sedge (e.g. Carex pensylvanica) in Great Lakes northern hardwood ecosystems. We tested various treatments to identify mechanisms by which deer and competing vegetation interact with tree seedlings to reduce survival, seedling height, and stem biomass using a field study in mesic northern hardwood stands in the Upper Peninsula of Michigan, USA. We used three sedge removal treatments (varying in severity) plus a control in deer exclosures and paired open areas in an attempt to increase seedling regeneration into and through the zone of deer herbivory (0.25m – 1.5m) while maintaining herb layer richness. After four years, sedge biomass was still significantly lower in the three treatments relative to the controls, while herb biomass, which rebounded within two years, was at or above control levels. Planted sugar maple seedling survival, total height, and stem biomass were significantly greater in deer exclosures (68% survival, 23.6 cm height, 1.05 g stem biomass) compared to open areas (25% survival, 13.1 cm height, 0.5 g stem biomass). Of the surviving planted sugar maple seedlings, 82% were damaged in areas open to deer. Within deer exclosures we found an interaction between sedge and light; higher light levels increased the negative effects of sedge on seedling height and biomass. Recruitment into higher height classes was completely suppressed in areas open to deer irrespective of treatment. In contrast, deer exclusion areas had seedlings in higher height classes with greater numbers in sedge removal areas. Our data revealed that sedge did impact seedling height and biomass especially in high light environments, but that the main bottleneck to seedling survival and recruitment into higher height classes was the effect of deer.*

In another experiment we tested operationally feasible treatments (summer vs. fall glyphosate applications) and their effects on sedge and non-target vegetation. We found that: 1) sedge was controlled almost as thoroughly in fall treatment areas as in summer treatment areas, 2) there was very little effect on non-target species with fall application, while large negative effects were evident with summer spraying, and 3) more sugar maple seedlings germinated and had higher survival in fall treatment areas than in summer or control areas. It is important to note that we did find increasing deer damage to surviving seedlings in treated areas, especially those in summer application areas. Thus long term growth and survival may still be compromised in high deer density areas.

Land use and deer management practices in Michigan have caused unprecedented high deer densities. Intense deer browsing has strong negative impacts on forest herbs, tree recruitment, and forest vertical structure. There are some species, however, that are avoided as browse. One of these, Pennsylvania sedge (*Carex pennsylvanica*), has increased dramatically. Even if deer are completely removed it is believed that established sedge maintains dominance by out-competing reestablishing tree seedlings and herbs. Thus, tree seedling regeneration and forest herbs can be negatively impacted by deer directly via browse, and indirectly via competition from high sedge densities. However, the relative effects of deer vs. sedge on tree regeneration and herbs are unknown. It is possible that if sedge effects are strong, reducing sedge densities with management interventions such as herbicides could increase tree, shrub, and herb establishment even in the presence of deer browse pressure. In a series of experiments we examined the effects of deer and sedge removal on vegetation, and evaluated the effectiveness of practical sedge removal treatments on tree regeneration.

Effects of Sedge and Deer Removal: Trees

Our preliminary analyses indicate that at high deer densities (>31 deer/mi^2 outside our deer exclosures) maple seedlings greater than 25 cm tall were very rare (Figure 1a), leaving virtually no potential for future sapling-sized trees. At high deer densities with sedge *removed*, seedling densities were higher than without sedge removed, but still there was no recruitment to larger size classes (Figure 1a). In contrast, four years after deer removal (using exclosures), sugar maples grew into larger size classes both with and without sedge removal, but recruitment into taller height classes was much greater with sedge removed (Figure 1b). Thus, both deer and high sedge densities negatively impact height growth and survival of tree seedlings. Removing sedge alone may not be adequate to get sufficient tree recruitment in areas with very high deer density. Removing *all* vegetation with a broad spectrum herbicide applied in summer killed nearly all advance regeneration, resulting in low densities of young seedlings. No recruit sized individuals existed 4 years after spraying (Fig 1a).

Effects of Sedge and Deer Removal: Herbaceous Vegetation

In addition to killing advance tree regeneration, using broad-spectrum herbicides in summer to control sedge also kills non-target species, such as forest herbs. Surprisingly, in exclosures four years after complete vegetation removal with non-selective herbicide we found a 20% increase in the number of herb species present (i.e., species richness). However, this increase was largely due to an increase in “weedy” species such as mullein, mustard, and Linaria spp., rather than native forest herbs. Removing sedge alone should be an improvement over broad-spectrum herbicide in maintaining forest herbs, but we found that sedge removal and high deer densities decreased herb species richness. The remaining vegetation may be more nutritional and/or more visible to deer. This result must be interpreted carefully since the small size of each treatment area (10x10m) may have contributed to herbaceous species declines by creating a small “oasis” of high quality browse that contrasted sharply with the sedge-dominated landscape surrounding it. If sedge were removed over a much larger area, herbs and tree regeneration may be able to overcome browse pressure by saturating deer with high quality food.

Timing Broad-Spectrum Herbicide Application to Control Sedge and Minimize Unwanted Impacts

Over larger (1/2 acre) study plots than used in our first experiment and without exclosures (deer ~ 30/mi^2), we compared the effects of summer (July 15th) vs. fall (Nov 1st) spraying of a broad-spectrum herbicide on sedge and other vegetation. We found that both summer and fall applications decreased sedge biomass two years after application (figure 1c), but the early fall application had little impact on non-target species. In fact, fall application increased the plant species richness compared to areas not sprayed (in contrast to our results from 10 x 10 m plots, above), whereas summer application reduced species richness (Fig.1d). Fall and summer treatment areas had 14 and 9 species, respectively, which were absent in non-sprayed areas. Of these, 43% and 78% respectively were weedy species. Thus, fall spraying resulted in increased species richness and decreased invasion of weeds compared to summer spraying.

Management Recommendations

Our results suggest that summer application of broad-spectrum herbicide has too many negative impacts on potential tree recruits and herbaceous vegetation to be useful for controlling sedge in most situations. Also, selective sedge removal may not increase tree seedling recruitment and plant diversity in small treatment areas with very high deer densities. However, in areas with lower deer densities, and/or possibly if applied over large areas, selective sedge removal may enhance the growth rates and survival of tree seedlings and maintain/increase non-target plant diversity. In summary, for northern hardwood stands that have been or will soon be partially (e.g. selection) harvested within two years:

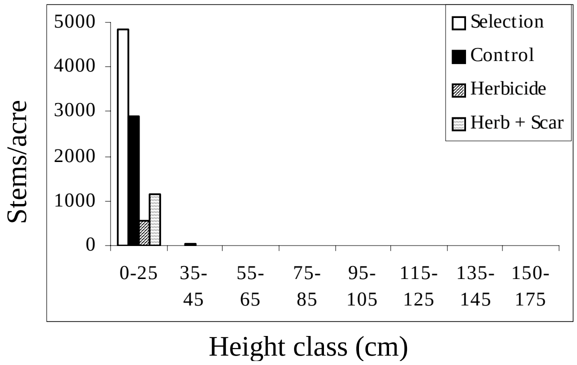
1) Apply broad-spectrum herbicide just after leaf off in autumn. At this time sedge and some grasses are the predominant photosynthetically active (and thus herbicide sensitive) plants. In special cases, summer treatment may be desirable if the understory has high densities of undesirable advanced regeneration such as ironwood.

2) Apply herbicide to relatively large areas (i.e., several acres). This may be especially effective in areas where deer densities are moderated by factors such as distance to winter thermal cover and increased snow depth (for further details see LeBouton et al.). The increased browse quantity and quality resulting from spraying are more likely to saturate and thus overcome local deer browse pressure if these effects occur over a larger area.

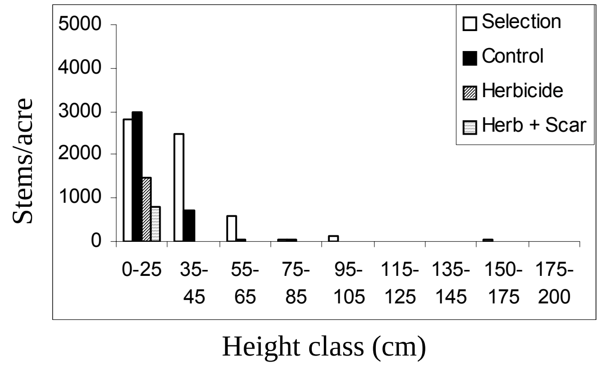
3) Consider reducing basal area to lower levels (50-60ft^2/acre) than those typically used for partial cutting to open the canopy for aerial spraying and to promote rapid growth of seedlings into and through the zone of deer foraging.

4) Factors other than deer and sedge may be limiting tree seedling recruitment. These factors include a) seed limitations that could result from insufficient densities of large seed producing trees, and b) stand structure. For example, self-thinning closed canopy forests transmit little light to the forest floor resulting in low seedling densities.

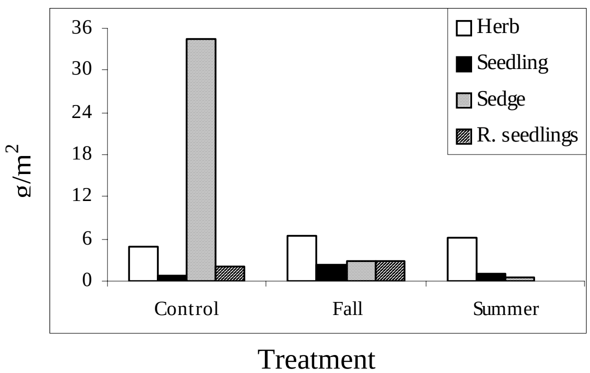
Sugar maple seedling stems/acre – Open to deer



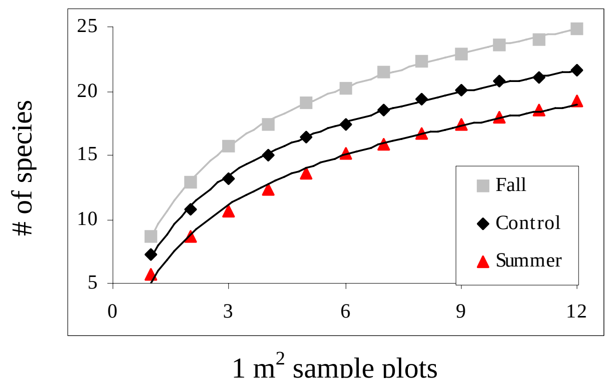
Sugar maple seedling stems/acre – Excluding deer



Harvest biomass (summer 2004)



Species / Area curves (summer 2004)



Strategies in Changing Deer Management Policy in Pennsylvania, 1999-2004

Gary Alt
Wildlife Consultant
Retired Pennsylvania Game Commissioner

Retired Supervisor of Deer Management Section, Pennsylvania Game Commission
2530 Reservoir Road, Madison Township, PA 18444 Email: garyalt@echoes.net

---

Abstract: *The most sweeping policy changes in Pennsylvania deer management history occurred between 1999 and 2004. Pennsylvania's traditional rifle deer seasons consisted of a two-week "buck" (antlered only) season followed by a three-day "doe" (antlerless only) season, which typically produced antlerless harvests inadequate to balance deer populations with their forest habitat, resulting in undesirably low survival of antlered bucks. To rectify the underharvest of antlerless deer, antlerless allocations and sales were increased from about 600,000, to over a million; hunters were allowed to buy up to three antlerless licenses, instead of just one; the two-week "bucks only" season was converted to an either-sex season; an October antlerless season was created and a Deer Management Assistance Program (DMAP) was created. To increase survival of antlered bucks, antler restrictions were changed in 2002 from a spike, three or more inches in length, to requiring three or more points on ones side in much of Pennsylvania, and four or more points on one side in the areas of best habitat. These changes resulted in their intended effect with an increase in average antlerless harvests by about 100,000 and a reduction in the buck harvest by roughly 50,000. Political climate and public attitudes were important in determining when and how much policy could be changed. Selecting of a competent team of scientists and providing them with a stimulating and safe meeting environment to evaluate existing programs, design research, and make policy change recommendations were critical. An intense and large-scale outreach campaign, during the public comment period, was one of the most critical actions to successfully change policy.*

The agricultural paradigm of "traditional" deer management, attempting to maximize the number of deer for hunter satisfaction, has had major negative impacts on the health and sustainability of our forest ecosystems in Pennsylvania and a number of other eastern states. For decades hunters have successfully applied social and political pressures on wildlife agencies to attempt to raise more deer than the land could sustain, resulting in severe overbrowsing and loss of biodiversity. Ironically, these attempts to maximize the number of deer have often had the exact opposite effect, leading to population declines due to habitat destruction. If we are to successfully balance deer populations with forests, we will need to change our style of deer management from an agricultural paradigm to a more ecosystem-friendly approach. This article describes our experiences implementing this approach in Pennsylvania.

Political climate and public attitudes were important in determining when and how much policy could be changed. It was the complaints of disgruntled sportsmen during the Governor's 1998 re-election campaign that stimulated political support and agency commitment to start an active era of policy changes to improve deer management in Pennsylvania.

Selection of a competent team of scientists who were dedicated to improving deer management was a critical step in setting the stage for changing policy. The "deer team" was made up of wildlife research and management biologists from within the Pennsylvania Game Commission, an academic biologist/statistician from the Pennsylvania State University and an independent wildlife management consultant. Most deer team meetings were held at an offsite retreat location, providing a stimulating and safe environment for members to discuss and debate sensitive and controversial management alternatives. Premature release of this type of information to the press, without adequate explanation, could have limited alternatives and the team's effectiveness.

The primary function of the deer team was to evaluate the current deer management program, design and carry out research projects to supply needed information, and to make policy change recommendations. Because it was not politically possible to make all the changes at once, the team prioritized the chronological order of changes that needed to occur.

The team's recommendations for hunting seasons and bag limits were presented to senior staff each December. After consideration by the senior staff and the executive director, then they were placed on a formal written agenda for vote by the Board of Game Commissioners on as proposed seasons and bag limits for that year at their January commission meeting. A 90-day minimum comment period was required before the commission could finalize its proposed seasons and bag limits. This always occurred during their April Commission meeting.

An intense and large-scale outreach campaign during the public comment period was one of the most critical actions to successfully change policy. This was designed to win support for our proposed changes and ensure confirmation at the April Commission Meeting. Each year, during the public comment period, between 50 and 75 public meetings were held throughout the state. Attempts were made to schedule meetings within 20 miles of nearly every Pennsylvanian. High school and university auditoriums and other large public buildings were the most common locations used. Audience size averaged about 550 per location but crowds in excess of 1,000 were not uncommon. At some events, once the auditorium was filled, a video feed would be run to a nearby cafeteria or gymnasium where the overflow of people could watch a display of the lecture and meeting discussions on a large screen. The consumption of alcoholic beverages at these events was prohibited.

Many of the meetings were co-sponsored by local legislators, individual Game Commissioners, or conservation organizations. Meetings would begin with the introduction of the supervisor of the deer management section of the Game Commission who would then present a slide presentation giving an in-depth discussion of the natural history and management of deer and, near the end of the program, provide a detailed description of what policy changes were proposed and why it made sense to take these actions. A question and answer session would follow the presentation until all questions were answered, often lasting for three or more hours. Each night the biologist, at the end of his program, would ask for a show of hands of how many would be willing to give these proposed policy changes a chance to work. Typically 80 percent, or more, would raise their hands, which sent a powerful message to legislators, administrators, and policy-makers and set the stage for new policy adoption. Virtually all proposed policy changes were accepted during the years that intense public outreach programs were in effect.

Most meetings were preceded with a press conference providing local television, radio, and newspaper reporters an opportunity to interview a deer biologist and learn what changes in policy were under consideration and why this was necessary to improve deer management in Pennsylvania. The Pennsylvania Game Commission would typically have a display booth set up at the entrance of the auditorium, at each event, dispensing brochures, press releases and answering questions. Between January and April of 2002, 35,000 copies of a video describing the need and justification of proposed changes were distributed, for free, to nearly everyone who attended these public meetings. These videos appeared to be very effective at winning support for policy changes.

As the ability of the deer team to successfully change policy grew, so did its ability to raise money for studies. Studies were conducted on the causes of fawn mortality (212 radio-collared fawns); over 3,000 fawn conception dates were determined, statewide, yielding information on the timing of the rut and the birthing period; a variety of human dimensions studies were contracted out to learn more about the attitudes of hunters and landowners; movement patterns of hunters were studied by equipping hundreds of them with GPS units that tracked where they went, and over 550 bucks were radio-collared and followed to evaluate the effectiveness of antler restriction policy changes on their survival. The results of these studies provided fantastic material to share with the press and people attending public meetings, increasing the credibility and acceptance necessary for policy changes to improve deer management in Pennsylvania.

Primarily, there were two goals that guided the team's decisions on recommendations for policy change. The primary goal was to balance the deer herd with its habitat, which required increasing the antlerless harvest, because the fecundity of the deer herd is a function of the number of breeding does. The secondary goal, and on a much lower priority, was to establish a more natural breeding ecology by reducing the buck kill, allowing more bucks to live to at least 2 ½ years of age.

Pennsylvania's primary traditional deer seasons consisted of a two-week "buck" (antlered only) rifle season followed by a three-day "doe" (antlerless only) season. Each hunter who bought a general hunting license was entitled to a single antlered deer but only hunters who purchased an additional antlerless license were entitled to take antlerless deer. There were roughly a million deer hunters of which only about 600,000 would buy antlerless licenses. In 1999, when the deer team started its evaluations, a hunter was only allowed to buy a single antlerless license annually.

The problems with these traditional deer seasons were that they almost always resulted in an underharvest of antlerless deer, making it impossible to balance the herd with its forested habitat, and an over-harvest of antlered deer with relatively few bucks surviving the hunting season. In much of Pennsylvania, over 80 percent of the buck harvest consisted of yearlings, while more accessible areas exceeded 90 percent yearlings.

The changes in deer seasons and bag limits that occurred between 2000 and 2004 were the most dramatic in the history of Pennsylvania wildlife management and were designed to increase antlerless harvests and decrease buck harvests in line with the goals of the deer team. To increase antlerless harvests, antlerless license allocations and sales were increased from about 600,000, to over a million; hunters were allowed to buy up to three antlerless licenses, instead of just one; the two-week "bucks only" season was converted to an either-sex season; an October antlerless season was created (rifle for junior and senior hunters, muzzleloader for all hunters with an antlerless license) and a Deer Management Assistance Program (DMAP) was created, allowing landowners to take additional antlerless deer on their property with DMAP permits. To decrease the buck harvest, antler restrictions were changed in 2002 from a spike, three or more inches in length, to requiring three or more points on one side in much of Pennsylvania, and four or more points on one side in the areas of best habitat.

The results of these policy changes were dramatic on deer harvests. The five largest antlerless harvests in the recorded history of Pennsylvania occurred during the past five years. Antlerless harvests increased by nearly 100,000 (48%) for the period 2000-2004 compared to the five previous years (Mean = 308,758 for 2000-04 compared to 209,305 for 1995-99). Antlered harvests dropped by an average of about 56,000 (28%) for the three years after antler restrictions went into effect (2002-04) compared to the three previous years (Mean = 200,280 for 1999-2001 compared to 144,032 for 2002-04). The number of antlerless deer harvested per antlered buck more than doubled (2.23 compared to 1.07) when comparing a three-year period after antler restrictions went into effect (2002-04) to the last three years before policies started to change in 2000 (1997-99). Antlered bucks aged two and older increased in the harvest, and for the first time, made up more than fifty percent of the total antlered buck kill, reflecting greater survival of bucks to maturity.

Though Pennsylvania's deer harvests were dramatically altered in the intended directions by these policy changes, the extent of their actual impacts on deer populations and forest ecosystem health and sustainability in the long term is less clear. Of great concern is that the Game Commission in 2005 reduced statewide antlerless allocations by 160,000, cutting allocations almost in half in some of the wildlife management units with the greatest problems of overbrowsing and forest regeneration. This occurred in response to political pressures, as it has repeatedly over the past 75 years, from hunters who demanded more deer at any cost. If this reversal of policy continues in the long term, preventing a balance from occurring between deer populations and their forest ecosystems, it is likely to have negative consequences for the Pennsylvania Game Commission and the future of sport hunting.

Michigan SAF Spring Conference Agenda

Forests & Whitetails-Striving for Balance

9-10 June 2005, St. Ignace, Little Bear Conference Center

	Thursday, 9 June, 2005	
8:00	*Registration, coffee & tea available*	
915	Welcome & Introduction	Don Dickmann
930	Keynote Address–Challenges of deer management from an ecosystem perspective	Gary Alt
1030	*Break*	
11:00	Population biology, abundance, and management history of Michigan white-tailed deer	Brent Rudolph
12:00	*SAF Chapter Meetings, other groups may meet in the main conference room as desired*	
12:30	*Lunch, provided*	
1:30	Forests for dinner: Exploring a model of how deer affect advance regeneration at stand and landscape scales.	Joe LeBouton
2:00	Cost-Share Programs, Deer Habitat Enhancement, and PNIF Implications	Tom Ward
2:30	Ecological impacts of deer overabundance on temperate and boreal forests	Jean-Pierre Tremblay
3:00	*Break*	
3:30	An assessment of long-term biodiversity recovery from intense and sustained deer browse on North Manitou Island, Sleeping Bear Dunes National Lakeshore	Dave Flaspohler
4:00	Michigan Deer Hunters: Satisfied Stewards or Coerced Conservationists?	Ben Peyton
4:30	Question & Answer Session	The day's speakers
5:00	*SAF State Business Meeting* *In the conference room, immediately following the Q & A Session*	
6:00	*Beach Banquet, SAF Awards, Foresters Fund* *Located at the Harbour Pointe Lakeshore Motel*	
Friday, 10 June, 2005		
8:00	Chronic regeneration failure in northern hardwood stands: A liability to certified forest landowners	Walt Arnold for Gary Donovan
8:30	Certifying sustainable forestry: The deer factor	
9:00	Even-aged silviculture as an approach to regeneration of forests with high deer	Dave deCalesta
9:30	densities	Susan Stout
	Adaptive management for deer: A case study from Pennsylvania	Dave deCalesta
10:00	*Break*	
10:30	Deer and sedge : Bottlenecks to seedling regeneration in northern hardwood forests and potential restoration techniques aimed at reversing the effects	Jesse Randall
11:00	Developing effective management strategies for white-tailed deer in Michigan	Bill Moritz
11:30	Strategies in changing deer management policy in Pennsylvania, 1999-2004	Gary Alt
12:00	Question & Answer Session	The day's speakers

A special thank-you to the following organizations that provided financial support for this conference: The Forestland Group, Grossman Forestry Company, Michigan State University Extension, Michigan Association of Timbermen, NewPage Corporation (formerly MeadWestvaco), Weyerhaeuser

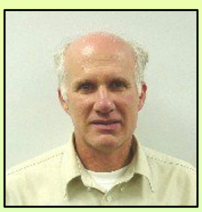
Conference Speakers

Forests & Whitetails-Striving for Balance, 9-10 June, 2005

Dr. Gary Alt
Retired Pennsylvania Game Commissioner
Currently a Wildlife Consultant
2530 Reservoir Road
Moscow, PA 18444
570-842-1797
garyalt@echoes.net

Brent Rudolph
Wildlife Research Specialist
Michigan DNR
PO Box 30444
Lansing, MI 48909-7944
517-373-9565
rudolphb@michigan.gov

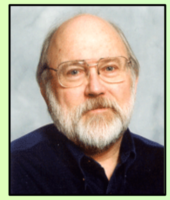
Joe LeBouton
PhD Candidate
Department of Forestry
Michigan State University
210 Natural Resources
East Lansing, MI 48824-1222
517-374-7241
lebouton@msu.edu



Tom Ward
Michigan State Forester
USDA Natural Resource Conservation Service
3001 Coolidge Road, Suite 250
East Lansing, MI 48823
517-324-5234
tom.ward@mi.usda.gov

Jean-Pierre Tremblay
PhD Candidate
NSERC Anticosti Forest Products
Industrial Research Chair & Nordic
Studies Center
Department of Biology
Laval University Quebec
Quebec, G1K 7P4
418-656-2131 x8152
Jean-Pierre.Tremblay@bio.ulaval.ca

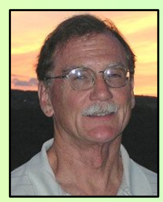
Dr. David Flaspohler
Michigan Technological University
School of Forest Resources and
Environmental Science
1400 Townsend Drive
Houghton, MI 49931-1295
906-487-3608
djflaspo@mtu.edu



Dr. R. Ben Peyton
Department of Fisheries & Wildlife
Michigan State University
165 Natural Resources
East Lansing, MI 48824-1222
517-353-3236
peyton@msu.edu

Walt Arnold
Manager, Forest Operations
Speaking for Gary Donovan
International Paper
W6582 US Highway 2, PO BOX 39
Norway, Michigan 49870
906-563-7526
walter.arnold@ipaper.com

Gary Donovan
Manager of Wildlife Programs
International Paper
P.O. Box 885
Bucksport, ME 04416
207-469-1578
gary.donovan@ipaper.com



Dr. David deCalesta
Retired US Forest Service Biologist
Wildlife Analyses Consulting
P.O. Box 621
Hammondsport, NY 14840-9712
607-292-6078
wildana@earthlink.net

Dr. Susan Stout
US Forest Service Silviculturist
Northeastern Research Station
P.O. Box 267
Irvine, PA 16329-0267
814-563-1040
sstout@fs.fed.us

Jesse Randall
PhD Candidate
Department of Forestry
Michigan State University
210 Natural Resources
East Lansing, MI 48824-1222
517-374-7241
randal35@msu.edu

Dr. Bill Moritz
Wildlife Division Chief
Michigan DNR
PO Box 30444
Lansing, MI 48909-7944
517-373-1234
moritzw@michigan.gov

Speaker Biographies
Michigan Society of American Foresters
"Forests & Whitetails-Striving for Balance"
9-10 June, 2005

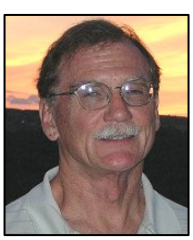
GARY ALT – 1) Keynote: Challenges of deer management from an ecosystem perspective, and 2) Strategies in Changing Management Paradigms and Policy
2530 Reservoir Road, Madison Township, PA 18444
570-842-1797, *garyalt@echoes.net*

Dr. Gary Alt worked as a wildlife research biologist for the Pennsylvania Game Commission for over 27 years: 22 running their black bear and 5 running their deer research and management programs. During his tenure, Gary was responsible for launching some of the largest field studies in the country on black bears and deer and made some of the most sweeping changes to bear and deer management in the history of Pennsylvania. He and Hal Korber produced a video on black bears that generated over $1.5 million for the Pennsylvania Game Commission and won 5 awards at an International Wildlife Film Festival. They teamed up again and produced over 35,000 deer management videos that were distributed to the general public and were instrumental in an educational campaign to win support for major policy changes. Gary has been very active in public education presenting over 1,500 lectures to approximately 300,000 people during his career.

Gary's work has been published in a variety of professional journals and featured in People Magazine, National Geographic World, Sports Illustrated, Readers Digest, National Wildlife, the Wall Street Journal, USA Today, New York Times, Philadelphia Inquirer, Washington Post and hundreds of other magazines and newspapers. In addition, Dr. Alt's work has been given national television coverage by Good Morning America, CBS Sunday Morning News, National Geographic Explorer, PM Magazine, Evening Magazine, and repeatedly on the national news.

In terms of professional training, Gary received an associate degree in Wildlife Technology from the DuBois Campus of the Pennsylvania State University in 1972, a Bachelor of Science in Wildlife Science from Utah State University in 1974, a Master of Science in Wildlife Management from the Pennsylvania State University in 1977, and a Ph.D. in Forest Resources Science from West Virginia University in 1989. Since retiring from the Game Commission, six months ago, Gary has established a wildlife consulting business and also leads photographic and natural history trips worldwide.

DAVID DECALESTA – 1) Certifying Sustainable Forestry: The Deer Factor and Adaptive, and 2) Management for Deer: A Case Study from Pennsylvania
Wildlife Analysis Consulting, P.O. Box 621, Hammondsport, NY 14840-9712
607-292-6078, *wildana@earthlink.net*



Education: AB Dartmouth College, psychology 1964; M.S. Colorado State University, wildlife ecology 1971; Ph.D. Colorado State University, wildlife ecology 1973.

Experience: Assistant and Associate Professor, Forest Science, Zoology, and Wildlife Ecology departments, North Carolina State University and Oregon State University 1973-1988; Research Wildlife Biologist, Northeast Research Station, USDA Forest Service 1988-2001; Adjunct Professor of Forestry, SUNY-ESF 2002-present; Wildlife Consultant, Wildlife Analysis inc. 2001-present.

Research and management subjects: wildlife habitat relationships and forestry – deer, elk, mountain lion, black bear, coyotes, bobcats, small mammal and bird communities; control of animal damages to forestry and agriculture – deer, coyotes, bobcats, small mammals and birds. Certified Wildlife Biologist

GARY DONOVAN - Chronic regeneration failure in northern hardwood stands: A liability to certified forest landowners

Manager of Wildlife Programs, P.O. Box 885, 14 Bagley Avenue, Bucksport, ME 04416
207-469-1578 or 207-469-1300, *gary.donovan@ipaper.com*

Gary Donovan is a Certified Wildlife Biologist with 36 years of professional experience. In 1995, he retired from the Maine Department of Inland Fisheries and Wildlife where he held a variety of field and supervisory positions including the position of Wildlife Division Director for the last eight years of his 26+ year career with the agency.

Gary has worked for the forest industry (Champion International Corporation and International Paper) since leaving state service and is currently Manager of Wildlife Programs for IP's Lake States and Northeast Regions. He provides leadership and oversight for the conservation of non-timber resources and management of public-uses on approximately 785,000 acres of forestlands in Maine, New York, Wisconsin, and Michigan.

Professional recognitions include the *Distinguished Wildlife Alumnus*, University of Maine, College of Natural Sciences, Forestry and Agriculture (1998); *Award of Professional Achievement*, Maine Chapter of The Wildlife Society (1999); and *National Wetlands Award (Land Stewardship and Development*), co-sponsored by the Environmental Law Institute, the U.S Environmental Protection Agency, the Natural Resource Conservation Service, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service, Washington, D.C. (1999).

Gary was unable to attend this conference at the last moment due to a family emergency. Walt Arnold spoke in his place.

DAVID JAMES FLASPOHLER - An assessment of long-term biodiversity recovery from intense and sustained deer browse on North Manitou Island, Sleeping Bear Dunes National Lakeshore

Associate Professor, School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931
906-487-3608, *djflaspo@mtu.edu*, *http://forest.mtu.edu/faculty/flaspohler*

Dr. David Flaspohler is an Associate Professor in the School of Forest Resources and Environmental Science, Michigan Technological University in Houghton, Michigan. His research interests include conservation biology, forest fragmentation, maintaining viable populations in managed forest landscapes, island ecology, applications of conservation biology to management, avian ecology, evolution of nest site selection and breeding strategies, and effects of nest predators and parasites on breeding strategies. He received his appointment at MTU in 1998 and currently teaches courses in conservation biology and ornithology. Dr. Flaspohler earned his Ph.D. and Master of Science degrees from the University of Wisconsin-Madison, and a Bachelor of Science from the University of Michigan. He is a member of several professional organizations and has authored many articles in professional journals.

JOSEPH LEBOUTON - White-tailed deer herbivory reduces vertical canopy structure in northern hardwood forests

Department of Forestry, Michigan State University, 210 Natural Resources, East Lansing, MI 48824   517-374-7241, *lebouton@msu.edu*

Joseph LeBouton is from northern Wisconsin. He graduated with a Bachelor of Science in botany from the University of Wisconsin, Madison in 1996. He worked as a botanist at Colorado State University's Center for Ecological Management of Military Lands, as a Community Environmental Educator in the Peace Corps in Nicaragua, and as a GIS Projects Manager with Clark Forestry in Wisconsin. He began his graduate studies with Professor Michael Walters at Michigan State University in 2000 and is scheduled to defend his dissertation in December, 2005. Joseph is presently working with SAF-certified tropical hardwoods in Bolivia, and is a consultant with Sylvania Forestry, LLC in Land O Lakes, Wisconsin.

BILL MORITZ - Developing effective management strategies for white-tailed deer in Michigan

Wildlife Division Chief, Michigan DNR, PO Box 30444, Lansing, MI 48909-7944
517-373-1234, *moritzw@michigan.gov*

William E. Moritz was named chief of the Wildlife Division of the Michigan Department of Natural Resources December 9, 2004, leaving the position of assistant chief where he had served since February of 2002. Moritz is responsible for the administration and direction of the division, which has 175 employees and a $26 million budget that supports programs for wildlife management.

Moritz holds three degrees in wildlife management, a bachelor's degree in Fish and Wildlife Biology from Iowa State University, a master's degree in Fish and Wildlife Management from Montana State University, and a doctorate in Zoology from Southern Illinois University at Carbondale.

Moritz began his career in wildlife management working for the Iowa Conservation Commission (now Iowa Department of Natural Resources). He left Iowa to continue graduate-level education, completing his masters and doctoral degrees. He was hired by the Michigan DNR Wildlife Division in 1993 as a research biologist conducting surveys of hunter efforts and attitudes. He served in this capacity until 1998, when his duties were directed to deer research activities. After a leave of absence in 2002, he returned to the role of assistant chief in February 2003.

Moritz and his wife live on a small farm in Shiawassee County, where they raise cattle and hay.

R. BEN PEYTON - Michigan deer hunters: satisfied stewards or coerced conservationists?

Professor, Department of Fisheries and Wildlife, Michigan State University, E. Lansing, MI 48824
517-353-3236, *peyton@msu.edu*

Dr. R. Ben Peyton is a full professor in the Department of Fisheries and Wildlife, Michigan State University where he has been employed since 1978. His research, teaching and service activities focus on the human dimensions of management. Most of his research is designed to assist in the management of wildlife resource issues. For example, he has researched and published on catch and release fishing controversies, bear hunting issues, deer crop damage problems, issues associated with bovine tuberculosis in Michigan's deer herd and the difficulty of shifting management from single species to ecosystem management goals. He developed a model of social carrying capacity that has been applied to deer and black bear in

Michigan and is currently being used in planning for wolf management in the state. He conducted an extensive survey regarding deer hunter attitudes about quality deer management (QDM) and reviewed the process being used by the Natural Resource Commission to evaluate proposals for QDM or antler point restrictions in management units. A study to examine the factors influencing hunting area selection by Michigan deer hunters and their response to the presence of bovine TB is in progress.

Examples of professional activities include president of the former Human Dimensions in Wildlife Study Group, associate editor of the Wildlife Society Bulletin, member of the Board of Technical Experts (Great Lakes Fisheries Commission) and a member of the Professional Wildlife Management Committee (advisory to the American Archery Council and Archery Manufacturers Association). Dr. Peyton served as special editor for an issue of the Wildlife Society Bulletin that was devoted to examining the future relationship of consumptive wildlife use (e.g., hunting, trapping) and professional wildlife management. In 2000, he was recognized by the Pope and Young Club for his professional contributions to management of bow hunting issues. As a faculty member in the Partners in Ecological Research and Management program (PERM), a portion of Dr. Peyton's time is assigned to the Wildlife Division of the Michigan DNR. He provides input on various projects ranging from strategic planning to conducting research projects.

JESSE RANDALL - Deer and sedge : Bottlenecks to seedling regeneration in northern hardwood forests and potential restoration techniques aimed at reversing the effects

Department of Forestry, Michigan State University, 210 Natural Resources, East Lansing, MI 48824-1222 517-374-7241, *randal35@msu.edu*

Jesse Randall is currently a Ph.D. candidate in the Department of Forestry at Michigan State University. He is the past recipient of a two year MSU plant science fellowship, and is currently an MSU land policy graduate research scholar. Randall's thesis work focuses on understanding deer and forest vegetation interactions with an emphasis on identifying operationally feasible silvicultural methods for restoring the vertical structure and composition of ecologically and economically valuable northern hardwood forests. Prior to beginning his dissertation at MSU, Jesse obtained a B.S. degree from Cornell University's Department of Natural Resources. His interest in forestry stems from his family's 180 year old history of forest management and maple syrup production. Jesse hopes to continue research on northern hardwood systems including silvicultural practices which promote and sustain both the ecological and economical attributes that northern forests provide.

BRENT RUDOLPH - Population biology, abundance, and management history of Michigan white-tailed deer

Wildlife Research Specialist, Michigan DNR, PO Box 30444, Lansing, MI 48909-7944
517-373-9565, *rudolphb@michigan.gov*

Brent Rudolph is a wildlife research specialist with the Michigan Department of Natural Resources, where he coordinates the Wildlife Division's deer research program. Brent holds a Master's of Science in environmental and forest biology from the College of Environmental Science and Forestry at Syracuse, and a Bachelor's of Science in biology from Ohio Northern University. Prior to working in his research position, Brent was a habitat biologist with the Wildlife Division for several years, and served briefly as visiting instructor of wildlife ecology at the New York State Ranger School. His professional interests focus on addressing the ecological and sociological challenges to managing wildlife on increasingly human-dominated landscapes.

SUSAN STOUT - Even-aged silviculture as an approach to regeneration of forests with high deer densities

Research Forester and Project Leader, USDA Forest Service, Northeastern Research Station, Forestry Sciences Laboratory, P.O. Box 267, Irvine, PA 16329
814-563-1040, sstout@fs.fed.us

Dr. Stout has been employed as a research forester with the United States Forest Service Research Project located in Warren, PA since 1981. In 1991, she was named leader of the research team at that location. Her research interests include measuring crowding and diversity in forests, deer impact on forests, silvicultural systems, and translating the concepts of ecosystem management to practical guidelines for Pennsylvania's forests and beyond. Dr. Stout serves as coordinator of the Northeastern Research Station's Science Based Technology Applications Program, and on the Pennsylvania State Bureau of Forestry Ecosystem Management Advisory Council, and has served on the planning committee for several local, regional, and national meetings of the Society of American Foresters, and in leadership positions in its Silviculture Working Group. She was educated at Radcliffe College of Harvard University (A.B. 1972), the State University of New York (M.S. Silviculture 1983), and Yale University (D.F. 1994).

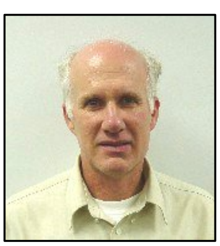
JEAN-PIERRE TREMBLAY - Ecological impacts of deer overabundance on temperate and boreal forest

Phd Candidate, NSERC Anticosti Forest Products Industrial Research Chair & Nordic Studies Center
Department of Biology, Laval University Quebec, Quebec, G1K 7P4
418-656-2131 x8152, Jean-Pierre.Tremblay@bio.ulaval.ca

Jean-Pierre's dissertation title is; "*Regeneration dynamics of low diversity forest stands at high herbivore densities*". He comes with over ten years of wildlife ecology research and experience and has co-authored a number of benchmark papers on the topic of forest/deer ecological impacts. His research interests include natural resources management, plant-herbivore interactions, forest ecology, population dynamics, and ecological modeling. He received his Master of Science and Bachelor of Science degrees from Laval University.

TOM WARD – Cost-share programs, deer habitat enhancement, and PNIF implications

State Forester , Michigan Natural Resource Conservation Service, 3001 Coolidge Road, Suite 250, East Lansing, MI 48823 517-324-5234, Tom.Ward@mi.usda.gov



Tom transferred to the Michigan NRCS State Office in East Lansing in August, 2004 after serving in the Illinois NRCS State Office in Champaign for 8 ½ years as Forester on the Ecological Sciences staff. Previous to Illinois he served as staff Forester for NRCS in Anchorage, Alaska for 13 years. Before beginning his career with NRCS Tom served in the Peace Corps on the West Indian island of St. Lucia. He received a bachelor's degree in forestry from Humboldt State University in California and a Masters Degree in forest pest management from Simon Fraser University in Vancouver, British Columbia, Canada.

Annotated Bibliography

Michigan Society of American Foresters
Forests & Whitetails-Striving for Balance Conference

Bill Cook
Forester/Biologist

Michigan State University Extension, U.P. Tree Improvement Center, 6005 J Road, Escanaba, MI 49829   Email: cookwi@msu.edu

This bibliography has been assembled for those wishing to learn more about ungulate impacts on forest ecosystems. The Conference organized by the Michigan Society of American Foresters highlighted only some of the major themes related to the conference topic, due to time constraints. The depth and breadth of research goes far beyond what was presented during the conference. The papers annotated herein have been sorted into four categories for ease of reference (listed below). A few papers are listed in more than one category. This bibliography is not intended to be a comprehensive list of the vast amount of research addressing the issues involved with forests and ungulate impacts. Rather, an attempt has been made to catalogue representative papers, benchmark papers, and those often cited in ongoing research.

1. Natural Resource Impacts
2. Methodologies to Address Deer "Overabundance"
3. Ungulate Population Biology/Ecology
4. Other Topics or Mixed Topics

Natural Resource Impacts

Alverson, W.S., D.M. Waller, and S.L. Solheim. 1988. Forests too deer: Edge effects in northern Wisconsin. Conservation Biology 2: 348-358. [*www.botany.wisc.edu/waller/deer/Foreststoodeer.pdf*]

A classic study demonstrating loss of hemlock and yew reproduction and recruitment across northern Wisconsin and the Upper Peninsula of Michigan. Deer densities as low as 4/km^2 (10/mi^2) may prevent regeneration of hemlock, yew, and northern white cedar. States deer densities of 8/km^2 (21/mi^2) is far too high to maintain full diversity, and tentatively recommended densities below 4/km^2 (10/mi^2).

Alverson W.S. and D.M. Waller. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests. pp. 280-297 in W. McShea and J. Rappole, eds., The Science of Overabundance: Deer ecology and population management, Smithsonian Inst. Press, Washington, DC. *[www.botany.wisc.edu/waller/deer]*

A classic case study in browse impact. Challenged, in part, by Mladenoff & Stearns (1993). However, Rooney and others have done subsequent research reinforcing the negative role of deer browsing on hemlock, and other species.

Brandner. T.A., R.O. Peterson, and K.L. Risenhoover. 1990. Balsam fir on Isle Royale: Effects of moose herbivory and population density. Ecology 71: 155-164.

Low fir densities, heavy height suppression by moose. High fir densities recruited during periods of moose lows. Peak moose numbers in the 1920s. Also see Risenhoover & Maass (1986).

Case, D.J. and D.R. McCullough. 1987. The white-tailed deer of North Manitou Island. Hilgardia 55 (9): 1-57.
A population dynamics study of introduced deer onto the island (part of Sleeping Bear Dunes N.P.). The irruptions did not follow the classical pattern described by A. Leopold. Of odd note, the second irruption was partially supported by deer feeding on alewives washed-up along the shores of the island. Demonstrated high rate of increase despite poor range conditions. Definite changes in habitat quality. Includes herbaceous data. No "balance" predicted. Dave Flaspohler (MTU) is doing current work on the island.

Cote S.D., T.P. Rooney, J.P. Tremblay, C. Dussault & D.M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology Evolution and Systematics 35: 113-147. (preprint). [*www.botany.wisc.edu/waller/deer*]
An excellent comprehensive review of economic losses, ecological impacts (vegetation structure, composition, diversity, indirect/cascading effects, nutrient/water cycling, successional shifts, alternative stable states, vegetation recovery potential, etc.), research needs, management needs (including adaptive management, hunting, social values, etc.), and other topics. Very good citation list. Also see Healy, deCalesta, & Stout (1997).

deCalesta, D.S. 1992. Impact of deer on species diversity of Allegheny hardwood stands. Proceedings of the Northeastern Weed Science Society Abstracts 46: 135.

deCalesta, D.S. 1994. Impact of white-tailed deer on songbirds within managed forest in Pennsylvania. J. Wildlife Mngt. 58: 771-718.
A classic enclosure study about "cascading" or "indirect" effects of herbivory across several habitat conditions and deer densities. Species abundance more sensitive than species richness. Four deer densities, 3 silvicultural treatments, 10 years of browsing. Often cited. See Tilghman (1989).

DeGraaf, R.M., W.M. Healy, and R.T. Brooks. 1991. Effects of thinning and deer browsing on breeding birds in New England oak woodlands. Forest Ecology and Mngt. 41: 179-191.
Impacts of thinning & deer browsing on bird populations at the Quabbin Reservoir in Massachusetts. Three oak stands in each of four treatments. Thinned stands with more birds. Six (out of 65) species differed among treatments (hermit thrush, rufous-sided towhee, American redstart, red-eyed vireo, ovenbird, veery). Thinning has more impact on bird populations than high deer densities.

Frelich. L.E. and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in Michigan, USA. Biological Conservation 34: 99-120.
Study at Porcupine Mountains State Park, where browsing seems to be major cause of hemlock regeneration decline and not seedbed conditions or changing climate. Mixed results across study areas. Developed a "sugar maple deer browse index" to help assess local level of browsing pressure, used by other researchers. Effect and relative importance of deer browse pressure challenged by Mladenoff & Stearns (1993).

Healy, W.M., D.S. deCalesta, and S.B. Stout. 1997. A research perspective on white-tailed deer overabundance in the northeastern United States. Wildlife Society Bulletin 25:259-263.
Speaks about value judgment bases, large body of literature, direct & indirect effects of overbrowsing, hunters/hunting, ecosystem emphasis, stand level impacts, adaptive management, research/management merger, etc. Cites 4 research areas. Complements Cote, etal, 2004.

Healy, W.M. 1997. Influence of deer on the structure and composition of oak forests in central Massachusetts. *in* McShea, et al. 1997. The science of overabundance. Smithsonian Institution. pp. 249-266.
*An interesting study of the protected Quabbin Reservoir compared to hunted lands around the preserve. Demonstrates significant browse effects of de*er. See DeGraaf, et al. (1991).

Jones, S.B., D.S. deCalesta, and S.B. Chunko. 1993. Whitetails are changing our woodlands. American Forests 99: 20-25, 53-54.
A good popular press article that brings many of the issues to print.

Marquis, D.A. and R. Brenneman. 1981. The impact of deer on forest vegetation in Pennsylvania. U.S. Forest Service General Technical Bulletin NE-65.
One of the first early comprehensive reports of deer impacts supported by research. Primarily a timber & silvicultural perspective. Marquis was a key contributor to forest management techniques and recommendations for northeastern forests.

Marquis, D.A. and T.J. Grisez. 1978. The effect of deer exclosures on the recovery of vegetation in failed clearcuts on the Allegheny Plateau. U.S. Forest Service Research Note NE-270.
Regeneration failure in these clearcuts was a driving factor in developing management recommendations for forest with high deer densities, and as evidence for the need to reduce deer density goals. See Marquis, Ernst, & Stout (1992).

Millers I., D.S. Shriner, and D. Rizzo. 1989. History of hardwood decline in the eastern United States. U.S. Forest Service General Technical Bulletin NE-197.
A comprehensive review of hundreds of documents and reports regarding declines of major hardwood species with numerous maps and tables. While not related to deer damage, the impact of non-deer factors in forest declines is certainly evident and is well-documented in this report. Includes oaks, maples, birches, ashes, beech, aspens, cottonwood, lack cherry, shagbark hickory, sweetgum, yellow-poplar, and eastern white pine. The report also talks about the early forest and various abiotic causes of decline and pre-disposition towards decline (stress factors, mortality factors, atmospheric deposition, etc.

Mladenoff, D.J. and F. Stearns. 1993. Eastern hemlock regeneration and deer browsing in the Northern Great Lakes Region: A re-examination and model simulation. Conservation Biology 7: 889-900.
Revisits hemlock regeneration issues, especially Alverson, Waller, & Solheim (1988), and challenges some of the underlying reasons for regeneration/recruitment failure. Modeling suggests other factors more responsible. Advocates ecosystem approach to management, rather than single species management. See also Anderson & Katz (1993) and Rooney, et al. (2004).

Porter. W.F. 1991. White-tailed deer in eastern ecosystems: Implications for management and research in national parks. Natural Resources Report NPS/NRSUNY/NRR-91/05, Denver, Colorado
Porter has many publications about deer impacts on protected resources in National Parks and in other protected areas. One of the major forest-deer issues involves the role of deer on endangered and threatened species reserves, and the management/intervention role in National Parks (and parks with similar objectives). Gettysburg, Eisenhower, Saratoga, Shenandoah, Smokey Mtns. are examples where studies are available.

Porter, W.F., M.C. Coffey, and J. Hadidian. 1994. In search of a litmus test: Wildlife management on the U.S. national parks. Wildlife Society Bulletin 22: 301-306.
Deer browsing has seriously compromised eastern park objectives regarding preservation or maintenance of natural ecosystems (often remnant pieces). Policy dilemma. Political barriers to deer control and lack of specific local indicators based on research. An example of the body of research illustrating deer browse problems in parks and natural reserves.

Risenhoover, K.L. and S.A. Maass. 1986. The influence of moose on the composition and structure of Isle Royale forests. Canadian J. of Forest Research 17: 357-364.
Very high moose populations on Isle Royale have had major impacts on the vegetation, including balsam fir. Exclosure study, four exclosures from 1949/50, three forest types. Stem densities grazed to short, dense condition. Variable results by species, woody species only. Moose slow succession. Reduced vertical structure. Also see Brandner, et al. (1990).

Rooney T.P., S.L. Solheim, and D.M. Waller. 2002. Factors influencing the regeneration of northern white cedar in lowland forests of the Upper Great Lakes region, USA. Forest Ecology and Management 163: 119-130. *[www.botany.wisc.edu/waller/deer]*
Study from the western U.P. and northern Wisconsin. 77 stands, regional scale, multiple deer densities, two survey years. Takes 30 years to recruit to 3 meters (above deer reach). Regeneration density and deer browse were major factors in regeneration and recruitment. Browsing was demonstrated to be a regional factor in depressing regeneration.

Rooney, T.P., S.M. Wiegmann, D.A. Rogers, and D.M. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. Conservation Biology 18: 787-798.
Demonstrated the ability of deer to remove browse-sensitive species from forests, indirectly promote generalist species less preferred by deer, resulting in a loss of biodiversity across a landscape. Concept of "biotic homogenization". Revisited selected Curtis' plots from 1959. Considers hunting pressure in browse abatement. Eliminated succession as a cause. Greatest loss in "protected" areas where hunting does not occur. See also Alverson, et al. (1988), Mladenoff & Stearns (1993), and Anderson & Katz (1993).

Rooney, T.P. and D.M. Waller. 2003. Direct and indirect effects of deer in forest ecosystems. For. Ecol. Manage. 181: 165-176. [*www.botany.wisc.edu/waller/deer/Davos.pdf*]
Direct effects (e.g. tree regeneration, understory flora) and indirect/cascading effects (e.g. food chains, change in plant interactions such as sedge & hay-scented fern, habitat changes, nutrient cycling, etc.). Poses several good questions for future directions/study. Many examples cited. Excellent reference list.

Sage, R. W., W. F. Porter, and H. B. Underwood. 2003. Windows of opportunity: white-tailed deer and the dynamics of northern hardwood forests of the northeastern US. Journal for Nature Conservation 10:213220.

Tilghman, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. J. Wildlife Mngt. 53: 524-532.
An excellent and often cited paper because the project used controlled and variable deer density impacts across a range of habitat or forest types, 5 deer densities across 3 silvicultural treatments, 5 years. Deer are major cause of regeneration failure. Related to deCalesta 1994. Recommends deer densities <18/mi^2.

Methodologies to Address Deer "Overabundance"

Behrend, D.F., G.F. Mattfeld, W.C. Tierson, and J.E. Wiley III. 1970. Deer density control for comprehensive forest management. J. Forestry 68: 695-700.
The use of public hunting on a private ownership to reduce deer densities and facilitate tree regeneration. The Archer & Anna Huntington Wildlife Forest Station (15,000 acres) in the Adirondack Mountains. Objective was to reduce deer densities from ~27/mi^2 to 13-14/ mi^2. Private ownership and limited hunting pressure represents one of the barriers to meeting regional or landscape deer density goals. Substantial reductions in deer density in some areas did not immediately "back-fill" from deer migration (elimination of maternal groups). An interesting case study. See also Mathews & Porter (1993).

deCalesta, D.S. and S.L. Stout. 1997. Relative deer density and sustainability: A conceptual framework for integrating deer management with ecosystem management. Wildlife Soc. Bull. 25: 252-258.
Well articulated paper regarding relative deer density to set population management goals using ecosystem parameters. There are multiple levels at which deer densities can be managed with varying impacts to diversity, timber production, and sustained deer yield. Absolute population goals will vary with habitat quality. See also Healy, et al. (1997) and Cote, et al. (2004).

Dessecker, D.R. and R.H. Yahner. 1987. Breeding bird communities associated with Pennsylvania northern hardwood clearcut stands. Proceedings Pennsylvania Academy Science 61: 170-173.

Frawley, Brian. 2004. Michigan Deer Harvest Survey Report 2003 Seasons. Michigan DNR Wildlife Report 3418. *[www.michigan.gov/documents/deer_03harvest_93353_7.pdf]*
Deer hunter survey. 743,000 hunters, similar to 2002. About 500,000 deer harvested, up 5% from 2002. Hunter success was 45%. No mention of deer populations or management goals.

Healy, M.H., D.S. deCalesta, and S.L. Stout. 1997. A research perspective on white-tailed deer overabundance in the northeastern United States. Wildlife Society Bulletin 25(2): 259-263.
A brief research perspective article. Four research approaches; 1) modeling deer impacts on the ecosystem components, 2) better estimates of deer impact at the stand level, 3) methods of regulating deer populations, and 4) better understanding of the human dimensions. Proponent of adaptive management. See also Cote et al. (2004), deCalesta & Stout (1997), Sinclair (1991), MacNab (1983), and others.

Latham, R.E., J. Beyea, M. Brenner, C.A. Dunn, M.A. Fajvan, R.R. Freed, M. Grund, S.B. Horsely, A.F. Rhoads, and B.P. Shissler. 2005. Managing white-tailed deer in forest habitat from an ecosystem perspective: Pennsylvania Case Study. Report by the Deer Management Forum for Audubon Pennsylvania and Pennsylvania Habitat Alliance, Harrisburg. xix + 340 pp. *[http://pa.audubon.org/ExecutiveSummary.pdf]*
A controversial benchmark document (executive summary) of some of the paradigm-changing work spearheaded by Dr. Gary Alt; whose team has done much to overcome some of the socio-political challenges in managing deer populations in Pennsylvania. Pennsylvania forest-deer management is a showcase for the rest of the eastern USA.

Marquis, David A. 1981. Management of Allegheny hardwoods for timber and wildlife. In Proceedings, 17th IUFRO World Congress: Division 1. Forest environment and silviculture. Kyoto, Japan, 1981 September 6-17. Kyoto, Japan. Japan IUFRO Cong. Comm. 17: 369-380.
Outlines fundamental strategies in regenerating commercial tree species under heavy browsing pressue. Strategy is to overwhelm deer with advanced regeneration in excess of 100,000 seedlings/hectare. Better sites and larger proportions of harvest area result in greater success. Even-aged management is standard. Recognized high deer densities should be a temporary phenomenon that must be reduced through better agency cooperation.

Marquis, D.A., R.L. Ernst, and S.L. Stout. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). U.S. Forest Service General Technical Report NE-96. 102 pp.
The result of ~25 years of silvicultural research in the northeast on how to regeneration commercial tree species under browse pressure from overabundant deer. Many of the commercial species of the NE are earlier in a successional path than many commercial species in the Lake States, especially sugar maple. The silviculture involves site assessments, clearcutting, and a "forage saturation" concept. Differences of Lake States forests, traditional silviculture, and social acceptance will present challenges.

MacNab, J. 1983. Wildlife management as scientific experimentation. Wildlife Society bulletin 11: 397-401.
An "adaptive management" concept where wildlife management is designed using an experimental framework to test ecosystem/landscape hypotheses and gather landscape level data for management direction. See also Cote et al. (2004), Healy et al. (1997), deCalesta & Stout (1997), Sinclair (1991), others.

Martin, J and C. Baltzinger. 2002. Interaction among deer browsing, hunting, and tree regeneration. Canadian J. Forest Resources 32: 1254-1264.
Demonstrates a link between hunting pressure and commercial tree regeneration, although the example is with black-tailed deer and western red-cedar, sitka spruce, & western hemlock in the Queen Charlotte Islands of British Columbia. Suggests that actual kill-count may be less important than the "fear factor" in affecting deer behavior.

Miller, R.O. 2004. Regeneration in a heavily browsed northern hardwood stand twelve years after scarification and fencing. Michigan State University Upper Peninsula Tree Improvement Center Research Report. [*www.maes.msu.edu/uptic*]
A multiple treatment exclosure study in a 35-acre northern hardwood stand. Results show fencing increased density, richness, and diversity of herbaceous and woody plants. Electric fencing used costs $2.00 per linear foot.

Rooney T.P. and D.M. Waller. 2001. How experimental defoliation and leaf height affect growth and reproduction in Trillium grandiflorum. Journal of the Torrey Botanical Society 128: 393-399. [*www.botany.wisc.edu/waller/deer/RooneyWaller01.pdf*]
A possible "indicator" species to better assess specific site impacts of deer herbivory. Clintonia borealis has also been suggested (Balgooyen & Waller, 1995).

Sinclair. A.R.E. 1991. Science and the practice of wildlife management. J.Wildlife Mngt. 55: 767-772.
An earlier advocacy of "adaptive management" or applying scientific methodology to designed management practices at the landscape level. Use wildlife management as scientific experimentation to further understand complex landscape scale dynamics. Complements Cote et al. (2004), Healy et al. (1997), deCalesta & Stout (1997), MacNab (1983), others.

Welsh, C.J.E. and W.M. Healy. 1993. Effect of even-aged timber management on bird species diversity and composition in northern hardwoods of New Hampshire. Wildlife Society Bulletin 21: 143-154.
Response/emphasis on recommendations by Marquis & Stout (area effects). Compared managed and unmanaged forests, more from the silvicultural impacts on bird presence, than the effects of deer browsing.. Species richness lower in reserved areas (where herbivory effects more pronounced). Species abundance differences not observable.

Wisconsin DNR. 1995. Deer populations goals and harvest management environmental assessment. Eds. W. Vander Zouwen and K. Warnke.
A benchmark EA that identifies the range of factors in considering forest affects of deer densities. Illustrates a range of research and data acquisition needs. An excellent framework for further work.

Ungulate Population Biology/Ecology

Davidson, W.R. and G.L. Doster. 1997. Health Characteristics and white-tailed deer population density in the southeastern United States. *in* McShea, W.J., H.B. Underwood, and J.H. Rappole. 1997. The science of overabundance; deer ecology and population management. Smithsonian Book. pp. 164-184.
A review that illustrates the many variables involving the density-dependence of disease prevalence in deer populations across a wide range. Not all relationships are intuitive.

Halls, L.K. 1984. White-tailed deer: Ecology and management. Stackpole Books.
An often-cited text with a collection of papers about deer.

Leopold, A. 1943. Deer irruptions. Wisconsin Conservation Bulletin 8 (8): 3-11.
An early classic in describing irruptive behaviors of ungulates. The spike-crash-stabilization model has been challenged (see McCullough's George Reserve papers, Case & McCullough(1987), May (1977), and other non-Leopold models in the literature, too).

Leopold, A. 1933. Game Management. Charles Scribner's Sons. 481 pp.
A classic text on game management that has tremendous influence on wildlife management philosophy in the USA. Some of the components of Leopold's work have been challenged and/or modified over the decades.

Lubow. B.C. and B.L. Smith. 2004. Population dynamics of the Jackson Elk Herd. J. Wildlife Mngt. 68 (4): 810-829.
The Jackson Elk Herd (Yellowstone National Park) is a classic subject of population studies. Suggests that increased cow harvest is necessary to maintain herd size with current management policies.

Mathews, N.E. and W.F. Porter. 1993. Effect of social structure on genetic structure of free-ranging white-tailed deer in the Adirondack Mountains. J. Mammalogy 74: 33-43.
An example of a study relating genetic lineage with social behavior of deer. Although breeding occurs on summer ranges, winter range populations have similar genetics. The authors suggest this is due to social structure centering on females. Application to deer density may include the notion that removal of matrilineal group may not result in immediate deer density recovery, thus allowing an opportunity for range recover (but the sufficient number of recovery years needed remain elusive). See Behrend, et al (1970).

May, R.M. 1977. Thresholds and breakpoints in ecosystems with a multiplicity of stable states. Nature 269: 471-477.
"Stable" populations may have more than one population level, contrary to some of the classic ideas about carrying capacity and population stability. Deer may be an example of a species that can demonstrate multiple stable population levels, at least in some situations. See also deCalesta & Stout (1997), Healy, et al. (1997) and Cote, et al. (2004).

McCullough, D.R. 1979. The George Reserve deer herd: Population ecology of a K-selected species. University of Michigan Press, Ann Arbor.
The George Reserve is located in southern Michigan and was the experimental site of deer population studies. Six deer in 1928, 222 in 1935, reduction to 10 by 1975, 212 by 1981. Results are often cited in research papers. An excellent captive heard case study. Many papers came out of the George Reserve research.

McCullough, D.R. 1982. Population growth rate of the George Reserve deer herd. J.Wildlife Mngt. 46: 1079-1083.
The George Reserve studies are benchmarks in the field of understanding population dynamics of white-tail deer. Six deer in 1928, 222 in 1935, reduction to 10 by 1975, 212 by 1981. Data show two irruptions with little suggestion of stabilization. Apparent vegetation recovery between spikes, in terms of forage quantity (no diversity assessments). Often cited. Also see Van Ballenberghe (1987).

McCullough, D.R. 1983. Rate of increase of white-tailed deer on the George Reserve: A response. J.Wildlife Mngt. 47: 1248-1250.
A response to Van Ballenberghe's challenge to McCullough's 1982 article, an arithmetic error, but defended concepts the study demonstrated. See McCullough (1982) and Van Ballenberghe (1983).

MacNab, J. 1985. Carrying capacity and related slippery shibboleths. Wildlife Society Bulletin 13: 403-410.
MacNab (several authors) helps define and challenge terms commonly used in population dynamics, such as carrying capacity, overpopulation, overharvesting, and overgrazing. With deer, carrying capacity is a moving target defined by a range of variables, and might best be applied in particular applications, rather than across broad landscapes. See also Decker, et al. (1987), Garrot,t et al. (1993), and Decker, et al. (1991).

Ozoga, J., L.J. Verme, and C.S. Bienz. 1982. Partuition behavior and territoriality in white-tailed deer: Impact on neonatal mortality. J. Wildlife Mngt. 46: 1-11.
John Ozoga and Lou Verme's work at Cusino is often referenced in studies of deer population dynamics and social structure. The results of many papers have been used in the development of deer population management and, more recently, in Quality Deer Management efforts. K. Miller is another noted authority in deer socio-biology. A good set of references on the topic can found in chapter 9 in the text McShea, Underwood, and Rappole (1997).

Ozoga, J.J. and L.J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. J. Wildlife Mngt. 46: 281-301.
Cusino enclosure study, population rose from 23 to 159 deer. Progressively more feed was eaten and summer forage decreased. Better antler development, increased natality. Fawn mortality increased. Doe territoriality and limited fawning space lowered maternal success. Concludes supplemental feeding a viable option for herd and range.

Schmitz, O.J. 1990. Management implications of foraging theory: Evaluating deer supplemental feeding. J. Wildlife Mngt. 54: 522-532.
Compared foraging behavior of naturally wintering and supplementary fed deer. Concluded that supplemental feeding programs are likely inefficient.

Skogland, T. 1991. What are the effects of predators on large ungulate populations? Oikos 61: 401-411.
Thick reading. Generally, there is little evidence that predators can regulate populations. However, predators can limit populations under certain circumstances. "Regulation" and "limiting" are different population effects. Most cases, predators are limited by territoriality. Birth synchrony does not appear to a strategy correlated to predation. Based largely on boreal and African research.

Van Ballenberghe, V. 1983. Rate of increase of white-tailed deer on the George Reserve: A re-evaluation. J. Wildlife Mngt. 47: 1245-1247.
Challenges the outcomes of McCullough (1982). Mostly a methodological error. However, a pair of r-values differ. Also see McCullough (1982, (1983)).

Van Deelen, T.R., H. Campa III, J.B. Haufler, and P. Thompson. 1997. Mortality patterns of white-tailed deer in Michigan's Upper Peninsula. Journal of Wildlife Management 61:903-910.
Patterns in the herds that utilize the Whitefish and Stonington deer yards. 58 of 95 radio-collared deer died from 1992 to 1995, 45% from shooting. 12 of the 58 died from predation (1 wolf kill). Hunting mortality was strongly male-biased. Other mortality didn't differ between sexes. Populations were severely skewed towards females and younger age classes. Looked at age, sex, season, etc. Complements next paper.

Van Deelen, T.R., H. Campa III, M. Hamady, and J.B. Haufler. 1998. Migration and seasonal range dynamics of deer using adjacent deeryards in northern Michigan. Journal of Wildlife Management 62:205–213.
Tracks 95 radio-collared deer for three years. Involves the Whitefish and Stonington deer yards and related to movement between winter and summer ranges. Relates to sex, age, migratory propensity, and socio-behavior. Management implications. Complements previous paper.

Other Topics or Mixed Topics

Anderson, R.C. and A.J. Katz. 1993. Recovery of browse sensitive species following release from white-tailed deer *Odocoileus viginianus* Zimmerman browsing pressure. Biological Conservation. 63: 203-208.
Looked at recovery of hemlock when protected from deer using 12 and 27 year exclosures in northern Wisconsin, and plots on the Menominee Indian Reservation. Only three exclosures. Challenges models done by Mladenoff & Stearns (1993). See also Alverson, et al. (1988), Frelich & Lorimer (1985), and Rooney, et al. (2004).

Balgooyen, C.P. and D.W. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in Northern Wisconsin. Natural Areas Journal 15: 308-318.
A possible answer to the need to find a metric to assess stand-level impacts of deer (Cote et al., 2004, deCalesta & Stout, 1997). Trillium height has also been considered (Rooney & Waller, 2001 and Rooney & Gross, 2003).

Decker, D.J., and T.A. Gavin. 1987 Public attitudes toward a suburban deer herd. Wildlife Society Bulletin 15: 173-180.
Survey of residents in a Long Island, New York community. Emphasized need to understand public attitudes prior to developing education and management programs. Attitudes demonstrated desire to maintain or increase deer numbers, despite increasing car crashes and problems with garden herbivory and Lyme disease. Also, in suburban areas, management practices must be modified from those used in rural areas.

Decker, D.J., R.E. Shanks, L.A. Nielsen, and G.R. Parsons. 1991. Ethical and scientific judgments in management: Beware of blurred distinctions. Wildlife Society Bulletin 19: 523-527.
Threats from animal rights (anti-hunting) advocates. Caution to managers about confusing ethical perspectives with science-based judgments. Also see chapter 4 by Allen Rutberg in McShea, Underwood, & Rappole (1997).

Finley, F.C. and S.B. Jones (eds.). 1993. Penn's woods – change and challenge. Proceedings of the Penn State Forest Resources Issues.

Frawley, Brian J. 2004. Demographics, Recruitment, and Retention of Michigan Hunters. Michigan Department of Natural Resources, Wildlife Division Report No. 3426. 42 pp. *[www.michigan.gov/documents/michigan_hunter_demographics_104984_7.pdf]*
Census of hunting licenses 2000-2002. Looks at age, game type, hunter retention, gender, Michigan region. Many tables & graphs. About 868,000 licenses (not just deer) purchased annually. Hunter numbers down during period, but higher than in 1960s. Michigan hunting is middle-aged male sport, 90% southern Lower Peninsula residents. Deer licenses increasingly dominate purchases.

Garrott, R.A., P.J. White, and C.A. Vanderbilt White. 1993. Overabundance: An issue for conservation biologists? Conservation Biology 7: 946-949.
Well-written and evocative article articulating conservation issues; deer as a native invasive species, anthropogenic change favors generalists (e.g. deer), defining "overabundance" is problematic, control by killing is unpopular, human-altered systems provide justification for management. Numerous examples/illustrations cited.

McShea, W.J., H.B. Underwood, and J.H. Rappole. 1997. The science of overabundance; deer ecology and population management. Smithsonian Book. 402 p.
A very good review of "overabundance" issues and research. 23 chapters written by many outstanding experts, covering a wide range of topics. About $20 from Amazon.com.

Michigan Natural Resources Council. 1960. Relationship of timber and game in forest land management. Annual meeting of the Michigan Natural Resources Council, Civic Center, Lansing, Michigan. 63 pp.
An intriguing historical view of forests & deer from several perspectives; wood production, hunting economics, ecology, sportsmen, industrial forestry, and coordination of efforts. Addresses social, economic, and scientific values associated with deer/forest issues in Michigan and Wisconsin. Shows that these debates are at least 50 years old.

Redding, J.A. 1995. History of deer population trends and forest cutting on the Allegheny National Forest. Pages 214-224 *in* Proceedings of the 10th Northcentral Hardwoods Conference. U.S. Forest Service General Technical Report NE-197.
Evaluates 70 years of selected browsing. Severe impacts. Suggests increased & sustained deer harvest and increased forage production through timber harvest. Four major changes; 1) dramatic increase in deer densities, 2) composition change in overstory & understory, 3) lower diversity, and 4) seedbed conditions. Begins with pre-settlement conditions.

Waller D.M. and W.S. Alverson. 1997. The white-tailed deer: A keystone herbivore. Wildlife Society Bulletin 25: 217-226. *[www.botany.wisc.edu/waller/deer]*
A "keystone" species is one which has major influence on the functions of ecosystems (e.g. succession, water/nutrient cycling, decomposition, etc.). The authors argue that deer are a keystone species in forested landscapes and further research is needed.

Website URLs of Reference

- Tom Rooney and Don Waller Deer Research: *www.botany.wisc.edu/waller/deer*
- Don Waller Faculty Biography: *www.botany.wisc.edu/waller/bio.htm*
- Steeve Cote Research: *www.cen.ulaval.ca/english/scote.html*
- Proceedings of the Conference on the Impact of Deer on the Biodiversity and Economy of the State of Pennsylvania, 1999: *www.audubon.org/chapter/pa/pa/DCP.htm*
- Michigan Deer Management: *www.michigan.gov/dnr/0,1607,7-153-10319-28543--,00.html*
- Pennsylvania Game Commission Deer Management Plan: *www.wpconline.org/dailyphotos/pa_game_commission_deer_mgt.pdf* (56 pp.)
- Environmental Assessment by APHIS, Deer Damage Management in Pennsylvania: *www.aphis.usda.gov/ws/nepa/PAalldeer.pdf* (51 pp.)
- EA by APHIS, Deer Damage Management in the Commonwealth of Virgina: *www.aphis.usda.gov/ws/nepa/VAdeer.pdf* (52 pp.)
- Bemidji State University Conference "White-tailed Deer and the Landscape: An Expanding Relationship?" 2 Dec 2002 (PowerPoint presentations): *www.cri-bsu.org/deerWorkshop.html*
- Managing white-tailed deer in forest habitat from an ecosystem perspective: Pennsylvania Case Study. Report by the Deer Management Forum for Audubon Pennsylvania and Pennsylvania Habitat Alliance, Harrisburg. *http://pa.audubon.org/ExecutiveSummary.pdf* (340 pp.)
- Kinzua Quality Deer Cooperative (Pennsylvania): *www.allegheny-vacation.com/kqdc.html* (44 pp.)
- Kinzua Quality Deer Cooperative Management Plan, August 2002: *www.fs.fed.us/r9/allegheny/forest_management/wildlife/kqdc/KQDC2002mgmt_plan.pdf* (44 pp.)
- Sand County Foundation: *www.sandcounty.net*
- Michigan Deer Management: *www.michigan.gov/dnr/0,1607,7-153-10319-28543--,00.html*
- Michigan DNR Wildlife Division: *www.michigan.gov/dnr/0,1607,7-153-10370---,00.html*
- Michigan DNR Organizational Chart: *www.michigan.gov/documents/currentorg_112205_7.pdf*
- Michigan DNR Mission Statement: *www.michigan.gov/dnr/0,1607,7-153-10366-85266--,00.html* *"The Michigan Department of Natural Resources is committed to the conservation, protection, management, use and enjoyment of the State's natural resources for current and future generations."*
- Michigan DNR "Relative Density of Deer" by Deer Management Unit: *www.michigan.gov/images/deer_density_85395_7.jpg* (map)

Note: These URLs worked at the time of publication.

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Rex Ainslie
MDNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
ainslier@michigan.gov

Steve Alguire
JS Alguire For. Con. Ser. Inc.
3800 S. Lier Point Road
Suttons Bay, MI 49682
231-271-6620
salguire@aol.com

Gary Alt - Speaker
2530 Reservoir Road
Moscow, PA 18444
570-373-9565
garyalt@echoes.net

Joyce Angel-Ling
DNR Forestry
2550 Murmur
Naubinway, MI 49762
989-732-3541
angellij@michigan.gov

Walter Arnold, CF
International Paper
1200 Walker Street
Iron Mountain, MI 49801
906-563-7526
walter.arnold@Ipaper.com

Mike Bailey
MDNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
baileyme@michigan.gov

Bruce Barlow
MDNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
barlowb@michigan.gov

Ben Bartlett
MSU Extension
PO Box 70
Cheboygan, MI 49721

Debbie Begalle
DNR Forestry
20 Arrowhead Drive
Marquette, MI 49855
906-249-3009
begalled@michigan.gov

Brad Bender
U.P. Tree Improvement Center
Michigan State University
6005 J Road
Escanaba, MI 49829
906-786-1575
benderb@msu.edu

Dale Betcher
Grossman Forestry Company
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Rebecca Bieneman
Muskegan Conservation District
1001 E. Wesley Avenue, Room 6
Muskegon, MI 49442
231-773-0008
rebecca.bieneman@macd.org

Mark Boersen
MDNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1234
boersenm@michigan.gov

Ben Boric
Grossman For. Company - MTU
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Dave Bostick
MDNR Wildlife Division

Cara Boucher, CF
DNR Forestry
4844 Smith Road
Dimondale, MI 48821
517-646-7179
boucherc@michigan.gov

Kevin Bryers
Louisiana-Pacific
PO Box 80
Newberry, MI 49868
9062938402
kevin.bryers@lpcorp.com

Peter Bull
Dept. of Fisheries & Wildlife
Michigan State University
165 Natural Resources
East Lansing, MI 48824
517-353-3236
bullpe@msu.edu

Larry Burcz
Canada Creek Ranch Association
23500 Ranch House Trail
Atlanta, MI 49709
989-785-4201

Chris Burnett
Marquette Conservation District
1030 Wright Street
Marquette, MI 49855
906-226-2461
chris.burnett@macd.org

Collin Burnett
Michigan Forest Association
2684 Lone Oak Drive
Ann Arbor, MI 48103
734-604-4278
ckburnett1@netzero.com

Bob Burnham
DNR Forestry
14791 LL Road
Wetmore, MI 49895
906-341-8463
burnharg@michigan.gov

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Elaine Carlson
MDNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
carlsone@michigan.gov

Gary Carr
USFS Retired
N4071 Traders Mine Road
Iron Mountain, MI 49801
906-774-9244

Guenther Castillon
USDA Forest Service
5761 N. Skeel Avenue
Oscoda, MI 48750
989-739-0728 Ext 3030
gcastillon@fs.fed.us

Ned Caveney
1313 Wiltse Road
Lapton, MI 48635
989-473-3439
ncaveney@m33access.com

Steve Chadwick
DNR Wildlife Division

Rod Clute
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909-7944
517-373-9565

Bill Cook, CF
MSU Extension
6005 J Road
Escanaba, MI 49829
906.786.1575

Ken Cramer
Canada Creek Ranch Association
23500 Ranch House Trail
Atlanta, MI 49709
989-785-4201
cramerken@hotmail.com

Terry DeBlaay
Fahl Forest Products
1200 Vermeersch Road
Cental Lake, MI 49622-9433

Dave deCalesta-Speaker
Wildlife Analyses Consulting
P.O Box 621
Hammondsport, NY 14840-9712
607-292-6078
wildana@earthlink.net

Chris D'Hulster
Grossman For. Company - MTU
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Don Dickmann, CF
Dept of Forestry, Emeritus
Michigan State University
6299 Doyle Road
Laingsburg, MI 48848
517-353-5199
dickman1@msu.edu

Bob Doepker
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
906-228-6561
doepkerb@michigan.gov

Mike Donovan
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
donovanm@michigan.gov

Amy Douglass, CF
DNR Forestry
16968 County Road 458
Newberry, MI 49868-9802
906-477-6048

Paul Drysdale, CF
Drysdale Forestry & Consulting

Andrea Durham
Ottawa National Forest
4810 E. M-28
Kenton, MI 49967
906-852-3500
adurham@fs.fed.us

Rich Earle
DNR Wildlife Division

Tyson Edwards
DNR Wildlife Division

Dale Ekdom, CF
DNR Forestry
6390 N Roscommon Road
Roscommon, MI 48653
989-275-5056
ekdomd@michigan.gov

Carl Eklund
Fahl Forest Products
1200 Vermeersch Road
Central Lake, MI 49622-9433

Mike Elenz
Elenz, Inc.
7620 Olmstead Street
Gaylord, MI 49735
989-732-7233
mikeelenz@hotmail.com

Eric Epstein
Wisconsin DNR

DeWayne Evans
Hiawatha Sportsman's Club
N7269 Lake Boulevard
Engadine, MI 49827
906-477-6592
hiawatha@sault.com

Sam Fahl
Fahl Forest Products
1200 Vermeersch Road
Central Lake, MI 49622-9433
231-587-5388

Chad Fate
Forest Resource Services

Dave Fehringer
The Forestland Group
26298 E. Grosse Pte Shores Road
Hancock, MI 49930
906-288-3380
dave@forestlandgroup.com

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Jim Ferris, CF
DNR Forestry
6 Oakridge Drive
Marquette, MI 49855
906-249-3667
ferrisj@michigan.gov

Kerry Fitzpatrick
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
fitzpak@michigan.gov

David Flaspohler-Speaker
Michigan Technological Univ.
School of Forest Resources &
Environmental Science
1400 Townsend Drive
Houghton, MI 49931-1295
906-487-3608
djflaspo@mtu.edu

Ken Ford
Lake States Forestry
1191 120th Avenue
Hersey, MI 49639-8742
231-734-2841

Lora Freer
Oscoda Conservation District
PO Box 820
Mio, MI 48647
989-826-8824
lora-freer@macd.org

Robert Froese
Michigan Technological Univ.
1400 Townsend Drive
Houghton, MI 49931
906-487-2723
froese@mtu.edu

Jeff Greene
DNR Wildlife Division

Steve Griffith
DNR
PO Box 30444
Lansing, MI 48909
517-373-1234

Gerald Grossman, CF
Grossman Forestry Company
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Shawn Hagan, CF
The Forestland Group
33687 Lake Gerald Road
Toivola, MI 49965
906-288-3380
shawn@forestlandgroup.com

Patrick Hallfrisch
DNR-Forestry
4255 Riverside
Sault Ste Marie, MI 49783
906-632-4704

John Hamel, CF
DNR Forestry
1990 S US-41
Marquette, MI 49855
906-228-6561
hameljm@michigan.gov

Christine Hanaburgh
DNR Wildlife Division

Jason Hartman
DNR
111 Burrows Avenue
Roscommon, MI 48653
989-390-0279
hartmajp@michigan.gov

Bill Hasse
International Paper
W6582 Hwy US 2
PO Box 39
Norway, MI 49870
906-563-7541

Eric Henderson
Hiawatha National Forest

Chad Hiltunen
Grossman Forestry Company
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Les Homan
DNR-Forestry
15318 Co Road 402
Newberry, MI 49868
906-293-8348
lhoman@up.net

Ernie Houghton
DNR Forestry
414 Montana Avenue
Gladstone, MI 49837
906-428-9838

Don Howlett, CF
Hiawatha National Forest
7766 Summit 19.55 Drive
Gladstone, MI 49837
906-428-4192
dhowlett@fs.fed.us

Jeremy Hubbard
US Forest Service
2727 N. Lincoln Road
Escanaba, MI 49829
906-789-3374

Bernie HubbaRoad, CF
DNR Forestry, Retired
215 W. Avenue D
Newberry, MI 49868
906-293-5627
forestmeister@sbcglobal.net

John Huff
Wisconsin DNR
PO Box 208
715-582-5047
john.huff@dnr.state.wi.us

Ryan Issacson
George Banzhaf
260 Hagerman Lake Road
Iron River, MI 49935
906-265-2451

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Tom Jacques
Huron Consulting
1251 Sparton Road
Tawas City, MI 48763
989-362-6245
tjactree@hotmail.com

Mark Janke
Menasha Packaging Company
320 N. Farmer Street
Ostego, MI 49078
269-692-6867

Scott Jones
Ontario Ministry of Natural Resources
1235 Queen Street East
Saulte Ste Marie, Ontario, Canada
P6A2E5
705-946-7442
scott.jones@mnr.gov.on.ca

Boyd Kahler, CF
Sappi
3343 20 Mile Road
Kent City, MI 49330
616-675-4648
boyd.kahler@sappi.com

Nik Kalejs
DNR Wildlife Division

Craig Kasmer
DNR
2319 Sonnen-Schein Drive
Gaylord, MI 49735
989-348-2537
kasmere@michigan.gov

Daniel Keathley
Department of Forestry
Michigan State University
126 Natural Resources
East Lansing, MI 48824
517-355-0093
keathley@msu.edu

Randy Keen
Fahl Forest Products

Russell Kidd
MSU Extension
PO Box 507
Roscommon, MI 48653
989-275-4670
kidd@msu.edu

Andy Klein
Packaging Corporation of America
766 Filer Street
Filer City, MI 49634
231-499-1346

Pete Klink
Progressive Forest Mgmt.
PO Box 521
Coldwater, MI 49036-0521
517-238-4048

Don Krejcarek, CF
Sunrise Forestry
PO Box 16
Harrisville, MI 48740-0016
989-724-6165

Randy Kuipers
Menasha Packaging Co
320 N. Farmer Street
Ostego, MI 49078
269-692-6867

Russ LaBeau
402 Rolling Hills
Petoskey, MI 49770
231-347-5682

Greg Lake
International Paper
W6582 Hwy US 2
PO Box 39
Norway, MI 49870
906-563-7541

Jerry Lambert
Forest Resource Services

Joseph LeBouton-Speaker
Department of Forestry
Michigan State University
210 Natural Resources
East Lansing, MI 48824-1222
517-374-7241
lebouton@msu.edu

Pat Lederle
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
lederlep@michigan.gov

Doug Lee
Lee Forestry Services
404 John K Drive
Auburn, MI 48611
989-662-4561
forester@gix.net

Larry Leefers
Department of Forestry
Michigan State University
126 Natural Resources
East Lansing, MI 48824
517-355-0097
leefers@msu.edu

Kelly Levely
Delta Conversation District
2003 Minneapolis Avenue
Gladstone, MI 49837
906-428-9469

Lester Livermore
Hiawatha Sportsman's Club
N7269 Lake Boulevard
Engadine, MI 49827
9064776592
hiawatha@sault.com

Rick Lucas, CF
Mecosta Conservation District
18260 Northland Drive
Big Rapids, MI 49307
231-832-2950
rick.lucas@mi.nacdnet.net

Robert MacGregor
Ottawa National Forest
500 N Moore Street
Bessemer, MI 49911
906-932-1330
rmacgregor@fs.fed.us

Mark MacKay
DNR
W8860 Wescher Drive
906-869-3229
mackaym@michigan.gov

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Bill Mahalak
Retired DNR Forestry
9222 Snapper
Port Charlotte, FL 33981
989-821-5332

Kevin Makuck
George Banzhaf
HC 2 Box 635
L'Anse, MI 49946
906-524-5500
kevinm@gband.co.com

Jim Malloy
Michigan State University
900 Long Boulevard #231
Lansing, MI 48911
5172680208
malloyja@msu.edu

Terry Manty
Grossman Forestry Company
1013 S Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Lloyd Martindale, CF
Grossman Forestry Company
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Glen Matthews
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
matthewsg@michigan.gov

Rory Mattson
Delta Conversation District
2003 Minneapolis Avenue
Gladstone, MI 49837
906-428-9469

Josh McDonald
Weyerhaeuser
4111 E 4 Mile Road
Grayling, MI 49738
989-370-6290
joshua.mcdonald@weyerhaeuser

Terry McFadden
DNR Wildlife Division
Marquette, MI 49855

Sherry McKinnon
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263

Quentin McNichols
Huron-Manistee National Forest
4635 Clark Road
Harrisville, MI 48740
989-724-6624
qmcnichols@fs.fed.us

Penney Melchoir
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1234
melchoip@michigan.gov

Ray Miller
U.P. Tree Improvement Center
Michigan State University
6005 J Road
Escanaba, MI 49829
906-786-1575

Todd Miller, CF
Grossman Forestry Company
1013 S. Newberry Avenue
PO Box 426
Newberry, MI 49868
906-293-8707
gfco@up.net

Terry Minzey
DNR Wildlife Division

Jason Mittlestat
DNR Forestry
HCR 2 Box 729
Baraga, MI 49908
mittlesj@michigan.gov

Burt Moeke
Fahl Forest Products
1200 Vermeersch Road
Central Lake, MI 49622-9433

Jerry Mohlman, CF
DNR Forestry
PO Box 86
Gwinn, MI 49841
906-346-9201 Ext 21
mohlmang@michigan.gov

Dan Moore
DNR Forestry
5100 M-123
Newberry, MI 49868
906-293-5131 Ext 4045
mooredw@michigan.gov

Michael Moore
Moore & Associate
817 Pepperwood Drive
Lansing, MI 48917
517-323-7685
mdmoore817@aol.com

Bill Moritz-Speaker
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909-7944
517-373-1234
nelsonc@michigan.gov

Dan Morris
Packaging Corporation of America
766 Filer Street
Filer City, MI 49634
231-499-1346

Richard A. Myrick
Iosco Conservation District
USDA Service Center
190 M-55
Tawas City, MI 48763
989-362-2591
rick.myrick@macd.org

Dave Neumann
DNR Forestry
4571 W. Barnes
Mason, MI 48854
517-490-7640
neumannd@michigan.gov

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Dennis Nezich
DNR Forestry
135 Edgewood
Marquette, MI 49855
906-249-3572
nezichd@michigan.gov

Bob & Adeline Ojala, CF
221 Fairland
Mio, MI 48647
989-826-3138

David Olson
12082 S. Elk Bridge Drive
Trarverse City, MI 49684
231-933-9137
olsonde@aol.com

Charles Olson
3327 Yellowstone Drive
Ann Arbor, MI 48105
734-665-2387

Eunice Padley
Wisconsin DNR
PO Box 7921, FR/4
Madison, WI 53707
608-261-6459
eunice.padley@dnr.state.wi.us

Mike Paluda
DNR Forestry
1990 US 41 S
Marquette, MI 49855
906-228-6561
paludam@michigan.gov

Mark Parkinson
Mid-Forest Lodge
40 MFL
Prudenville, MI 48651
989-366-5191
ecomgmt@centurytel.net

Larry Pedersen
DNR Forestry
1992 Riveria
East Lansing, MI 48823-1425
517-335-3330
pedersen@msu.edu

Jack Penegor
Penegor Forestry Services
6117 Woodland P.1 Avenue
Gladstone, MI 49837
906-428-4735
forester@chartermi.net

John Penfold
Fahl Forest Products
1200 Vermeersch Road
Central Lake, MI 49622-9433

Todd Penrose
SAPPI
505 County Road GMA
Ishpeming, MI 49849
906-486-4099
todd.penrose@sappi.com

Jean Perkins
Superior National Forest
8901 Grand Avenue Place
Duluth, MN 55808
2186264385
jeperkins@fs.fed.us

Georgia Peterson
DNR Forestry
5946 N. Hagadorn
E. Lansing, MI 48823
517-335-7383
petersog@msu.edu

Adam Petrelius
DNR Forestry
608 Park Avenue
Manistique, MI 49854
906-341-7771
petrelia@michigan.gov

Ben Peyton-Speaker
Dept. Fisheries & Wildlife
Michigan State University
165 Natural Resources
East Lansing, MI 48824-1222
517-353-3236
peyton@msu.edu

Kirk Piehler
US Forest Service
2727 N. Lincoln Road
Escanaba, MI 49829
906-789-3374
kpiehler@fs.fed.us

John Pilon
DNR Forestry
1732 W M-32
GayloRoad, MI 49735
989-732-3541 x5042
pilonj@michigan.gov

Fred Prince
Forests for the Future
37069 Charter Oaks
Clinton Twp, MI 48036
586-469-3364

Dan Racine
DNR Forestry
292 Abrahams Road
Escanaba, MI 49829
906-786-2354
racined@michigan.gov

Chad Radka
Louisiana-Pacific
PO Box 80
Newberry, MI 49868
906-293-8402
chad.radka@lpcorp.com

Jesse Randall-Speaker
Department of Forestry
Michigan State University
210 Natural Resources
East Lansing, MI 48824-1222
517-374-7241
randal35@msu.edu

Doug Reeves
DNR Wildlife Division

Dean Reid, CF
D&S Forestry Services Co.
483 Gros Cap Road
St. Ignace, MI 49781
906-643-7515
reiddi46@sault.com

Matt Rintamaki, CF
U.P. Timber Company
2 Robin Street
Ishpeming, MI 49849
906-235-6011

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Jim Rivard
Houghton-Keweenaw Con. Dist.
600 East Lakeshore Drive
Suite #2
Houghton, MI 49931
906-482-0214
jerivaRoad@charter.net

Bill Rockwell, CF
Strategic Resource Systems
700 S. Oakland
St Johns, MI 48879
989-224-4600
rockwell@mich.com

Karen Rodock, CF
DNR Forestry
PO Box 433
Naubinway, MI 49762
906-477-6048
rodockk@michigan.gov

Brent Rudolph-Speaker
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909-7944
517-373-9565
rudolphb@michigan.gov

Patrick Ruppen
DNR Forestry
4280 North Ridge Drive
Traverse City, MI 49684
231-935-4007
ruppenp@michigan.gov

James Rutledge
Hiawatha Sportsman's Club
N7269 Lake Boulevard
Engadine, MI 49827
9064776592
hiawatha@sault.com

Byron Sailor
DNR Forestry, Retired
105 Wadaga Road
Baraga, MI 49908
906-353-6980
landlkr@up.net

Ken Salo
Route 1, Box 338
Republic, MI 49879
906-376-2132
kensalo@up.net

Sara Schafer
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
schaefsm@michigan.gov

Dan Schillinger
Grand Traverse Cons. District
1222 Veterans Drive
231-941-0960
dschillinger@gtcd.org

Jim Schmierer
Michigan Technological Univ.
1400 Townsend Drive
Houghton, MI 49931
906-487-2963
jmschmie@mtu.edu

Jim Schules
8141 Hogstrom Lane
Cadillac, MI 49601
231-775-9476
schules8141@charter.net

Jan Schultz
Hiawatha National Forest
1030 Wright Street
Marquette, MI 49855
906-228-8491
jschultz@fs.fed.us

John Schultz
8846 Green Briar Road
Lake Ann, MI 49650-9532
231-275-6735
nwwodpc@chartermi.net

Ron Scott, CF
ARC Consulting Services
711 E. Chapin Street
Cadillac, MI 49601
231-775-6334
arcwoods@charter.net

Tom Seablom
DNR Forestry
HCR 2 Box 721
L'Anse, MI 49946
906-524-5507
tjseablo@up.net

Sean Sexton
Quality Hardwoods
10 N. Monroe
Rockford, MI 49341
616-460-5152
spsexton@aol.com

Dick Shellenbarger
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
shellenr@michigan.gov

Martha Sjogren
Hiawatha National Forest
1017 S. State Street
St. Ignace, MI 49781
906-643-9763

Mac Smith
Michigan Forest Association
1558 Barrington
Ann Arbor, MI 48103-5603
734-665-8279
mfa@i-star.com

Pete Squibb
Wildlife Solutions
7068 Fhaner Hwy
Potterville, MI 48876
517-285-0026
squibbp@aol.com

Jeff Stampfly, CF
DNR Forestry
N7234 Connors Road
Munising, MI 49862
906-387-5440
stampflj@michigan.gov

Dave Steffensen
Ottawa National Forest
1209 Rockland Road
Ontonagon, MI 49953
906-884-2411
dsteffensen@fs.fed.us

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Jeff Steinkraus, CF
Wakeland Forestry
18623 Marcellus Hwy
Marcellus, MI 49067
269-646-7306
jjs@locallink.net

Jason Stephens
DNR Forestry
14277 Butwell Road
Bear Lake, MI 49614
231-631-8591
stephenj@michigan.gov

Bill Sterrett
DNR Forestry
512 Indiana
Manton, MI 49663
231-775-9727
sterrettw@michigan.gov

Mark Stormzand
Weyehaeuser
9880 Richardson
Cheboygan, MI 49721
231-627-6066

Susan Stout-Speaker
USFS NE Research Station
P.O. Box 267
Irvine, PA 16329-0267
814-563-1040
sstout@fs.fed.us

Warren Suchovsky
Suchovsky Logging
N9677 County Road 577
Stephenson, MI 49887
906-753-6666
warrensuchovsky@fastmail.fm

Linda Swartz
US Forest Service
2727 N. Lincoln Road
Escanaba, MI 49829
906-789-3374

Randy Swaty
The Nature Conservancy
125 W. Washington Street
Marquette, MI 49855
906-225-0399

Phillip Sworden
Conservation District
3344 Lakeshore
Sanford, MI 48657
989-687-9760
phil.sworden@macd.org

Melissa Taylor
Fink Forestry
HC 1 Box 266B
Marquette, MI 49855
906-345-0137
treesr4me@hotmail.com

Jerry Thiede
DNR Forestry
307 Kenway Drive
Lansing, MI 48917
517-323-9112

Eric Thompson
DNR Forestry
1520 Wisconsin Avenue
Gladstone, MI 49837
906-428-3870
thompsoe@michigan.gov

Jason Tokar, CF
DNR Forestry
PO Box 307
Naubinway, MI 49762
906-293-3293 x4742
tokarj@michigan.gov

Glen Tolksdorf, CF
Tolksdorf Forestry
52943 Hwy US-41
Calumet, MI 49913-9224
906-482-9366
glent@direcway.com

Don Tracey
Donald Tracey Forestry
6772 Indian Trail Road
Cheboygan, MI 49721
231-627-4610
dtracey@straitsarea.com

Jean-Pierre Tremblay
Laval University
Research Chair & Nordic Studies Ctr.
Dept. of Biology, Laval Univ.
Quebec, QUE G1K7P4
418-656-2131 x8152
Jean-Pierre.Tremblay@bio.ulaval.ca

Jessica Turino, CF
Weyerhaeuser
3593 N 45.5 Road
Manton, MI 49663
231-631-9233
jessica.turino@weyerhaeuser.com

Tim VanDeelen
University of Wisconsin-Madison
226 Russell Labs
1630 Linden Drive
Madison, WI 53707
608-265-3280
trvandeelea@Wisc.edu

Larry Visser
DNR Wildlife Division
PO Box 30444
Lansing, MI 48909
517-373-1263
visserl@michigan.gov

Tom Ward-Speaker
Michigan NRCS
3001 Coolidge Road, Suite 250
East Lansing, MI 48823
517-324-5234
tom.ward@mi.usda.gov

Craig Weatherby
Adrian College
Biology Department
110 S. Madison Street
Adrian, MI 49221-2575
734-649-7084
cweatherby@aDriveian.edu

Chris Webster
Michigan Technological Univ.
1400 Townsend Drive
Houghton, MI 49931
906-487-3618
cwebster@mtu.edu

LIST OF REGISTERED CONFERENCE PARTICIPANTS

Dean Wilson
DNR Forestry
1985 US 41 West
Ishpeming, MI 49849
906-485-1031 x305
wilsonde@michigan.gov

John Wilson
USDA Forest Service
4793 Forestry Drive
Rhinelander, WI
715-528-4464
jgwilson@fs.fed.us

Dave Wilson
Wilson Forestry Services
1118 E. Park Road
Rothbury, MI 49452
231-861-8549
wilsonforestry@glis.net

Joe Woodruff
Clinton Conservation District
2343 N. US-27
989-224-3720 x3
joe.woodruff@mi.nacdnet.net

Dennis Worst
560 E. State Road
Coldwater, MI 49036
231-766-2711

Carol Young
Ottawa National Forest
1209 Rockland Road
Ontonagon, MI 49953
906-884-2411
cayoung@fs.fed.us

Kile Zuidema
U.P. Tree Improvement Center
Michigan State University
6005 J Road
Escanaba, MI 49829
906-786-1575

Supporting Papers Recommended by Presenters

Frawley, B.J. 2005. Michigan Deer Harvest Survey Report: 2004 Seasons. Michigan Department of Natural Resources, Wildlife Division Report No. 3444. 38 pp.

> See *www.michigan.gov/documents/report3444_135086_7.pdf* or *Frawley-2004-Harvest.pdf* on the Proceedings CD-ROM, Michigan Society of American Foresters "Forests & Whitetails-Striving for Balance" Conference, 9-10 June 2005 in St. Ignace, Michigan.

Frawley, B.J. 2004. Demographics, Recruitment, and Retention of Michigan Hunters. Michigan Department of Natural Resources, Wildlife Division Report No. 3426. 42 pp.

> See *www.michigan.gov/documents/michigan_hunter_demographics_104984_7.pdf* or *Frawley-Hunters.pdf* on the Proceedings CD-ROM, Michigan Society of American Foresters "Forests & Whitetails-Striving for Balance" Conference, 9-10 June 2005 in St. Ignace, Michigan.

LeBouton, Joseph P., M.B. Walters, J. Liu, F. Lupi, E.J. Laurent, and L. Racevskis. 2005. White-tailed deer and landscape effects on forest structure and species composition [DRAFT]. Michigan State University Extension Bulletion E-xxxx, East Lansing, Michigan.

Randall, Jesse A. and M.B. Walters. 2005. Deer and sedge impact tree regeneration in working forests: Possible restoration treatments [DRAFT]. Michigan State University Extension Bulletion E-xxxx, East Lansing, Michigan.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Wildlife Report No. 3444
August 2005

Printed by Authority of: P.A. 451 of 1994
Total Number of Copies Printed: 85
Cost per Copy: $2.66
Total Cost: $226.10
Michigan Department of Natural Resources

MICHIGAN DEER HARVEST SURVEY REPORT 2004 SEASONS

Brian J. Frawley

ABSTRACT

A survey of deer hunters was conducted following the 2004 hunting seasons to estimate hunter participation, harvest, and hunting effort. In 2004, an estimated 713,000 hunters spent 10,183,000 days afield. Statewide, the number of people hunting deer declined by about 4% and hunting effort declined by about 2% since 2003. Hunters harvested nearly 456,000 deer, a decrease of nearly 9% from the number taken in 2003. Statewide, 45% of hunters harvested a deer. About 24% of the hunters took an antlerless deer and 30% took an antlered buck. About 15% of deer hunters harvested two or more deer.

INTRODUCTION

The Michigan Department of Natural Resources (DNR) has the authority and responsibility to protect and manage the wildlife resources of the State of Michigan. Harvest surveys are one of the primary management tools used by the DNR to accomplish its statutory responsibility. Estimating hunter participation, harvest, and hunting effort are the primary objectives of these surveys. Estimates derived from harvest surveys as well as information from deer harvest check stations, deer pellet group surveys, reports of automobile accidents involving deer, and population modeling are some of the methods used to monitor deer populations and establish harvest regulations.

During 2004, white-tailed deer (*Odocoileus virginianus*) could be harvested primarily during the following hunting seasons: youth, archery, early antlerless, early antlerless in Deer Management Unit (DMU) 055, regular firearm, muzzleloader, and late antlerless. In order to harvest a deer, hunters had to possess a hunting license (firearm, archery, combination, or antlerless license) (Table 1).

A harvest tag was issued as part of the hunting license. Hunters could purchase a maximum of two harvest tags for taking an antlered deer (either one combination license or both a firearm and an archery license). Archery and firearm licenses included one harvest tag, while the combination license had two harvest tags. A firearm license allowed a person to take one deer with at least one antler three inches or longer (Table 1). An archery license allowed an individual to take one deer of either sex. A person with a combination license could take two deer of either sex during the archery season or two antlered deer during the firearm season (Table 1). If two antlered deer were taken, one of these deer needed to have at least one antler with four or more points (qualifying points must be at least one inch).

A contribution of Federal Aid in Wildlife Restoration, Michigan Project W-147-R

IC2390-11 (08/10/2005)

Antlerless licenses could be purchased in addition to archery, firearm, or combination licenses. Antlerless deer licenses allowed hunters to take deer without antlers or with antlers shorter than 3 inches during any season with equipment appropriate for the season. Use of each antlerless license was restricted to a single DMU designated at the time of purchase. Antlerless licenses were available for most of the state except in portions of the Upper Peninsula (UP). Antlerless licenses were valid for either public or private lands. Public land antlerless licenses were not available in all DMUs. The number of licenses available in DMUs open to antlerless deer hunting was established by quota.

Antlerless licenses for use on public lands were allocated among people that applied for these licenses using a random drawing. In contrast, antlerless licenses for private lands could be purchased directly from a license vendor on a first-come, first-served basis. Hunters could purchase one antlerless license for private lands per day until the license quota had been met.

Deer Management Assistance (DMA) permits were special antlerless permits issued to landowners where the number of antlerless licenses was insufficient to meet the objective of specific landowners (i.e., controlling disease or the deer population). These permits allowed hunters to take an antlerless deer per permit during any deer season on the land where issued or adjacent private lands with the landowner's permission. To use these permits, the hunter must also have purchased a firearm, archery, combination, or antlerless deer license for the season in which they were hunting.

The youth season was held during September 25-26 on public and private lands statewide. Youths 12-16 years of age could take one deer using either a firearm license, combination license, antlerless license, or DMA permit. Youths participating during this season had to be accompanied by an adult at least 18 years old. All youths 12 and 13 years of age were restricted to archery-only hunting. Youth hunters could take no more than one deer during the season.

The archery season occurred statewide on public and private lands. This season was divided into an early and late season (i.e., October 1 to November 14 and December 1, 2004, to January 2, 2005). Archery licenses, antlerless licenses, combination licenses, and DMA permits could be used to take deer during the archery seasons using archery equipment.

The statewide regular firearm season occurred November 15-30. The muzzleloader season was held December 3-12 in the Upper Peninsula (UP) and December 10-19 in the Lower Peninsula (LP). Hunters were allowed to take deer on both public and private lands with firearm and combination deer hunting licenses during the regular firearm and muzzleloader seasons. Antlerless licenses (including DMA permits) also could be used during the firearm seasons.

The late antlerless firearm season occurred from December 20, 2004, through January 2, 2005. Hunters pursuing deer during this season had to possess an unused antlerless license (including DMA permits) and were limited to hunting on private land. The area open to hunting during the late antlerless season was limited to 19 counties in the LP.

There was an early antlerless firearm deer season in DMU 055 in the UP during September 16-22. In eight special regulation DMUs in the northeastern Lower Peninsula (within Alcona, Alpena, Crawford, Montmorency, Oscoda, Otsego, and Presque Isle counties), an early firearm season for antlerless deer also was held October 9-17. Hunters participating during these early antlerless seasons had to possess an unused antlerless license (including DMA permits), and hunting was restricted to private lands only.

Deer could also be taken on private lands during the special disabled firearm hunt (October 16-17, 2004). Only hunters that were issued a permit to hunt from a standing vehicle could participate in this season, and this study did not attempt to estimate harvest or participation during this limited hunt.

METHODS

Following the 2004 deer hunting seasons, a questionnaire was sent to 52,357 randomly selected individuals who had purchased a hunting license (firearm, archery, antlerless, or combination deer hunting licenses). Hunters receiving the questionnaire were asked to report seasons in which they pursued deer, number of days spent afield, and number of deer harvested. Hunters were instructed not to report hunting effort and harvest associated with DMA permits because landowners obtaining these permits already were required to report the number of deer harvested to the DNR.

Estimates were based on information collected from random samples of hunting license buyers. Thus, these estimates were subject to sampling errors (Cochran 1977). Estimates were calculated using a stratified random sampling design (Cochran 1977) and were presented along with their 95% confidence limit (CL). In theory, this confidence limit can be added and subtracted from the estimate to calculate the 95% confidence interval. The confidence interval is a measure of the precision associated with the estimate and implies the true value would be within this interval 95 times out of 100. Unfortunately, there are several other possible sources of error in surveys that are probably more serious than theoretical calculations of sampling error. They include failure of participants to provide answers (nonresponse bias), question wording, and question order. It is very difficult to measure these biases.

License buyers were assigned to one of four groups (strata). The first stratum consisted of people eligible only for the archery, regular firearm, and muzzleloader hunting seasons (N = 611,802). The second stratum consisted of people eligible to hunt during archery, regular firearm, muzzleloader, early antlerless, and late antlerless seasons (N = 114,628). Hunters in the third stratum were eligible to hunt during archery, regular firearm, muzzleloader, early antlerless, and late antlerless seasons, as well as the special early antlerless season in DMU 055 (N = 2,503). The fourth stratum consisted of people eligible to hunt during archery, regular firearm, muzzleloader, early antlerless, late antlerless, and youth seasons (N = 26,997). The random sample consisted of 37,121 people from the first stratum and 6,786 people from the second stratum. An additional 2,468 people were included from the third stratum, and 5,982 people were from the fourth stratum. The stratified sampling design accounted for the varying probabilities of being selected from the four strata so estimates could be reliably extrapolated from the sample to all license buyers.

Estimates were calculated separately by the area where the hunt occurred. The state was divided into eight areas that closely matched the DNR's wildlife management administrative units (Figure 1). The state was also divided into three ecological regions (UP, northern LP, and southern LP). These regions generally matched major ecoregions, except in the UP where two ecoregions were combined (Albert 1995). Ecoregions are regions having similar soils, vegetation, climate, geology, and physiography. Estimates were also calculated for each DMU (Figure 2, Appendix A). Deer harvested from unknown locations were allocated among areas in proportion to the known harvest.

Questionnaires were initially mailed during mid-January 2005, and two follow-up questionnaires were mailed to nonrespondents. To increase the number of questionnaires returned, everybody that returned their questionnaire promptly was eligible to win a prize (i.e., firearm or bow). Although 52,357 people were sent the questionnaire, 1,201 surveys were undeliverable resulting in an adjusted sample size of 51,156. Questionnaires were returned by 35,394 of people receiving the questionnaire (69% response rate).

Estimates of harvest, hunting effort, and hunter participation are affected by the willingness of people to complete and return their questionnaires. This problem can confound comparisons of estimates made between years if response rates vary greatly. The percentage of people returning their questionnaire this year was lower than previous years. To reduce bias caused by this lower response rate, an adjustment was made on the 2004 estimates to make them comparable to the

2003 estimates (74% response rate). Estimates of harvest, hunting effort, and hunter numbers were reduced by 1.2, 1.2, and 0.5%, respectively, to make estimates comparable to 2003. These reductions reflected the average decline noted between estimates calculated when 68 and 74% of the responses were used in 2000 and 2001 surveys.

RESULTS

In 2004, 755,930 people purchased a license to hunt deer in Michigan. The number of people buying a license in 2004 declined 4% from 2003 (787,935 people purchased a license in 2003) but was similar to the number of licensees in 1995 (764,938). Most of the people buying a license were male (92%). The average age of the license buyers was 41 years (Figure 3). Nearly 7.5% (56,603) of the license buyers were younger than 17 years old.

The number of 2004 deer harvest tags sold for all license types combined decreased 4.5% since 2003 (Table 2). License buyers were issued an average of 2.3 harvest tags. About 88% of the license buyers obtained three or fewer harvest tags, and 98% had five or fewer harvest tags (Figure 4). Hunters most frequently obtained antlerless and combination harvest tags (Figure 5). About 51% of the license buyers purchased at least one antlerless license (388,076 people), and 96% of antlerless license buyers purchased three or fewer antlerless licenses (Figure 6).

The number of hunting licenses sold decreased by 3%, while the number of harvest tags issued decreased 4.5% between 2003 and 2004 (Table 2). The decrease in harvest tags issued was larger than the decline in license sales because some 2003 antlerless licenses included two harvest tags, but no antlerless licenses had two harvest tags in 2004.

About 94.3 ± 0.1% (712,894 hunters) of the people buying a license in 2004 actually spent time hunting deer (Table 3). Most hunters (652,798) pursued deer during the regular firearm season (Figure 7). Statewide, the number of people hunting deer during all seasons combined declined 4.1%. Hunter numbers declined about 5.5% in the UP, 6.4% in the northern LP, while the number of hunters in the southern LP was nearly unchanged between 2003 and 2004.

Hunter participation declined by about 5% in the regular firearm season. The number of people hunting in the archery, early antlerless firearm season in northeast LP, late antlerless firearm season, and early antlerless in DMU 055 seasons was statistically unchanged between 2003 and 2004 (Figure 8, Table 3). In contrast, greater numbers of people hunted during the youth (8%) and muzzleloader (7%) seasons.

About 46% of the days hunters spent pursuing deer throughout the state occurred in the archery season (Figure 9). About 44% of the hunting effort occurred during the regular firearm season. Nearly 10% of the hunting effort occurred in the muzzleloader and late antlerless seasons. Statewide, hunters devoted an average of 14.5 days afield hunting deer during all seasons combined (Table 4). Archers had the greatest number of days available to hunt deer (78 days) and devoted the greatest number of days afield ($\bar{x}$ 7 = 14.7 days/hunter) (Figure 10, Table 4).

For all seasons, hunting effort statewide was virtually unchanged between 2003 and 2004 (Table 3). Hunting effort increased during the early antlerless season in DMU 055 and in the youth season but declined during the regular firearm season. Hunting effort during the archery, muzzleloader, early antlerless, and late antlerless seasons was similar to levels reported in 2003.

Nearly 456,000 deer were harvested in 2004, a decrease of nearly 9% from the number taken in 2003 (Figure 11, Tables 5-6). Statewide, the harvest of antlered bucks decreased 10%, and the antlerless deer harvest decreased 8% from last year (Table 5). Between 2003 and 2004, deer harvest decreased 14% during the regular firearm season. Harvest in the other seasons did not change significantly between 2003 and 2004.

About 59% of the animals harvested (sexes combined) in 2004 were taken during the regular firearm season (Figure 13). Most of the antlerless deer (53%) and antlered bucks (64%) were harvested in the regular firearm season. Hunters took 28% of the harvested deer (sexes combined) during archery season. During the archery season, hunters took 26% of the antlerless deer and 29% of the antlered bucks harvested. Few antlered bucks (5%) were taken in the muzzleloader season. The muzzleloader and antlerless seasons accounted for about 20% of the antlerless deer harvested.

About 87% of the animals harvested (sexes combined) in 2004 were taken on private lands (Table 7). Statewide, most of the antlerless deer (90%) and antlered bucks (84%) were harvested on private lands. Overall, harvest decreased 16% and 8% between 2003 and 2004 on public and private lands, respectively.

Statewide, 43% of the deer hunters harvested at least one deer (all deer seasons and sexes combined) in 2004 (Figure 14, Table 8). About 23% of the hunters took an antlerless deer, and 28% took an antlered buck. About 14% of deer hunters harvested two or more deer.

Hunters were most successful in taking a deer during the early antlerless season in DMU 055 (Figure 15, Table 9); 63% of the hunters in this early antlerless season took a deer. Hunter success was lowest in the muzzleloader season (19% successful). Hunter success ranged from 27 to 34% for the other seasons.

About 34% of the hunters harvested a deer (sexes combined) during the regular firearm season (Table 9). Nearly 22% of the hunters took an antlered buck and 16% harvested an antlerless deer during the regular firearm season.

Acknowledgements

I thank all the deer hunters that provided information. Holly Campbell, Theresa Riebow and Becky Walker completed data entry. Mike Bailey, Rod Clute, Valerie Frawley, Pat Lederle, Penney Melchoir, Bill Moritz, Cheryl Nelson-Fliearman, and Brent Rudolph reviewed a previous version of this report.

Literature Cited

Albert, D. A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification. General Technical Report NC-178. U.S. Department of Agriculture, Forest Service, North Central Forest Experimental Station, St. Paul, Minnesota, USA.

Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons, New York, USA

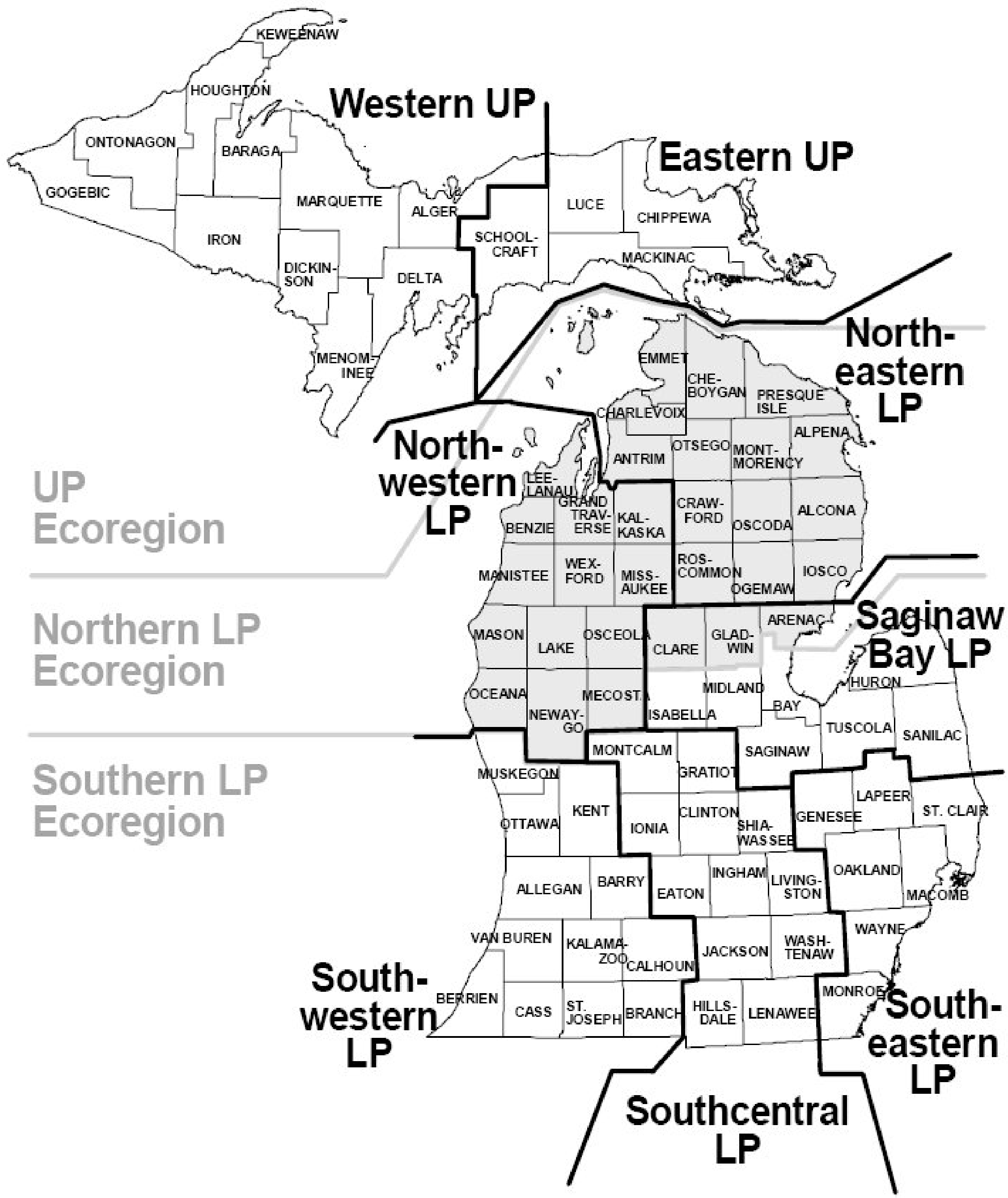


Figure 1 Areas used to summarize deer harvest in Michigan for the 2004 hunting seasons.

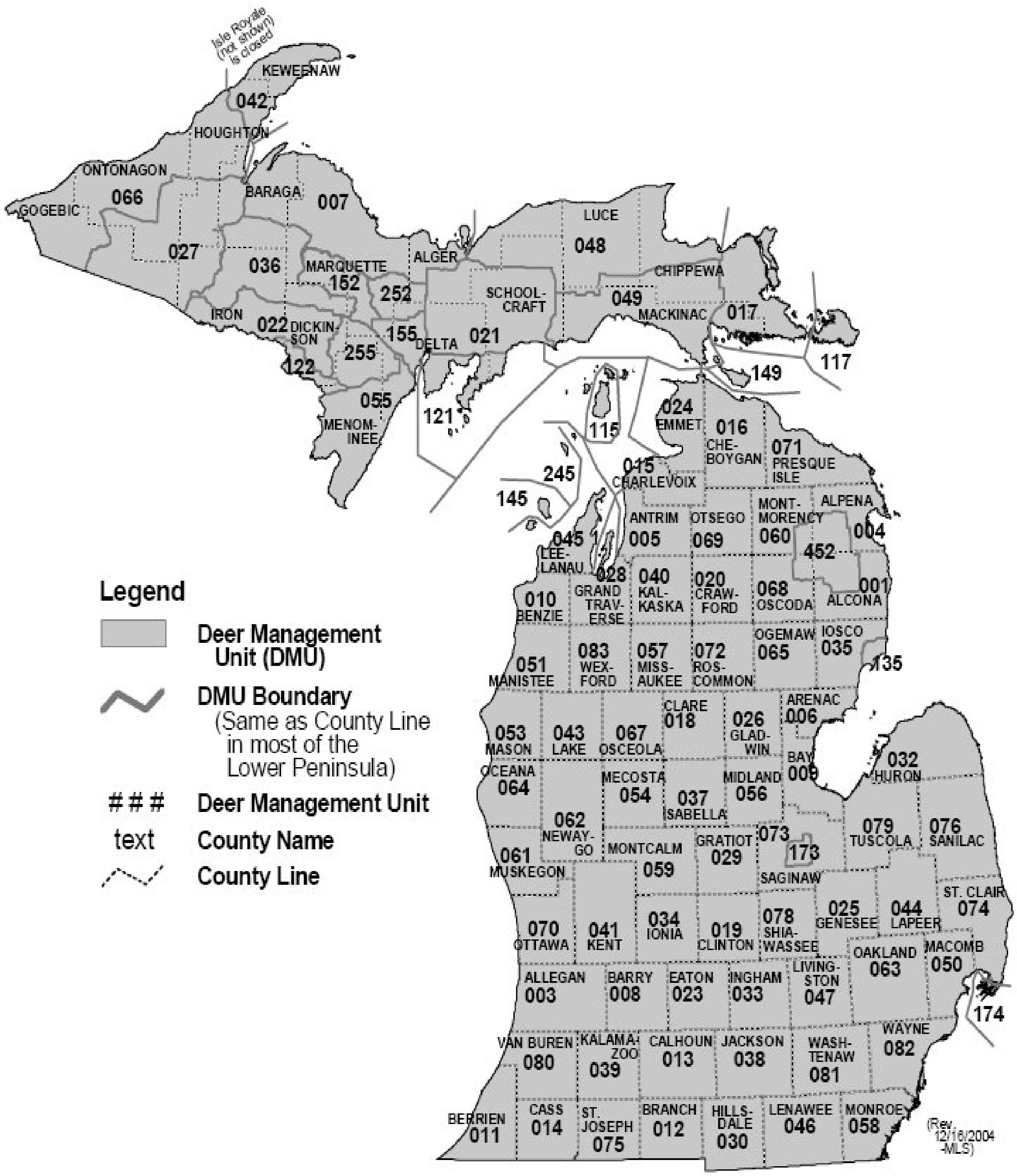


Figure 2. Deer Management Units in Michigan for the 2004 hunting seasons.

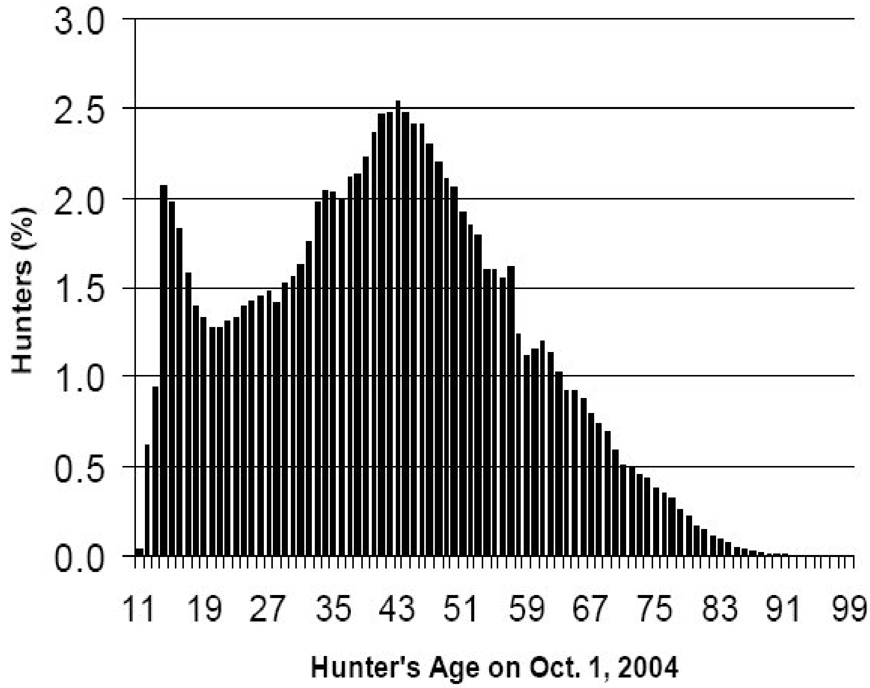


Figure 3. Age of people that purchased a deer hunting license in Michgian for the 2004 hunting seasons (x = 41 years).

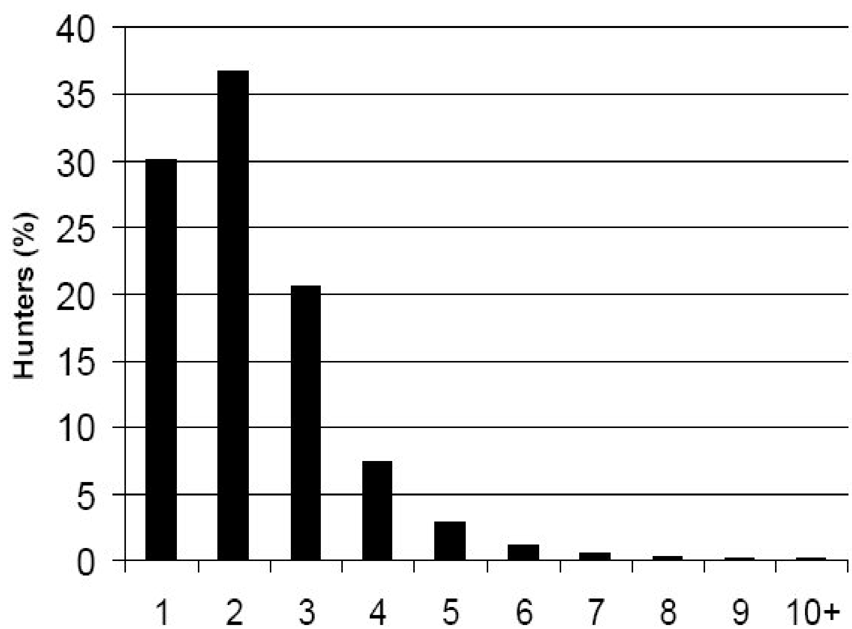


Figure 4. Number of harvest tags (all license and tag types) issued per person for hunting deer in Michigan during the 2004 huntings seasons (x = 2.3 tags). Licenses were purchased by 755,930 people.

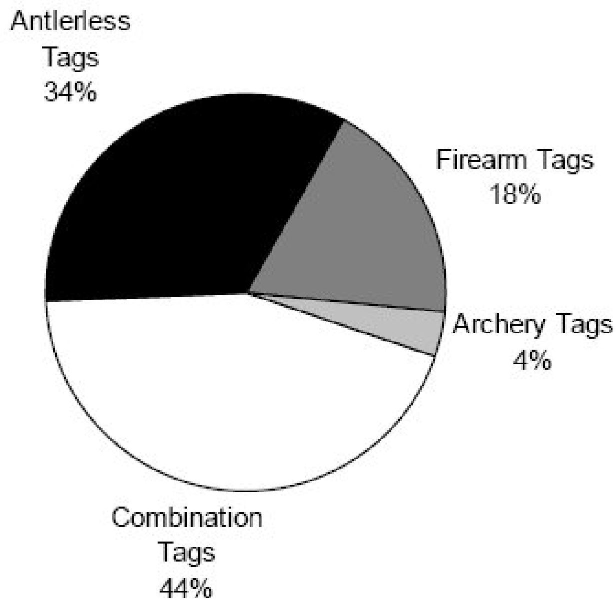


Figure 5. Types of harvest tags issued for deer hunting in Michigan during the 2004 hunting seasons.

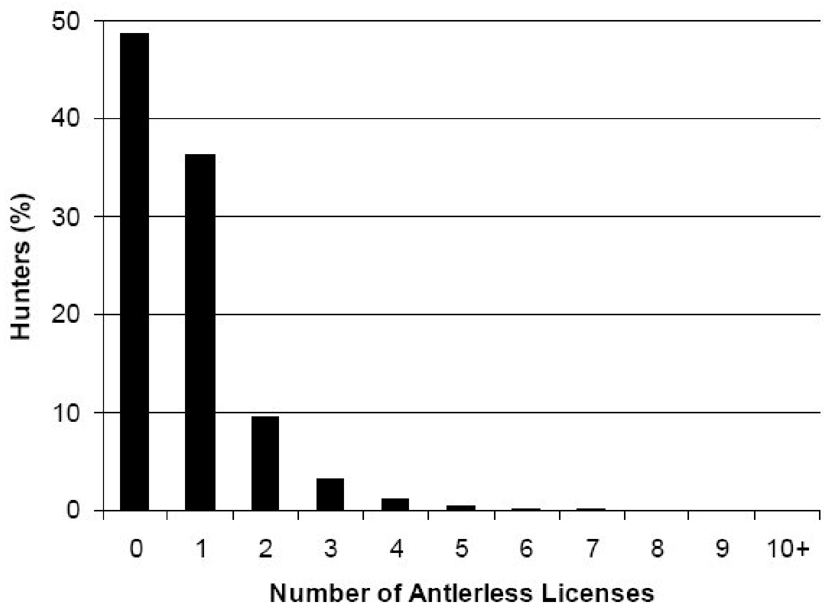


Figure 6. Percentage of deer hunting license buyers (all license types) purchasing an antlerless license in Michigan, 2004. Antlerless licenses were purchased by 388,076 of 755,930 people (51%) buying deer hunting licenses.

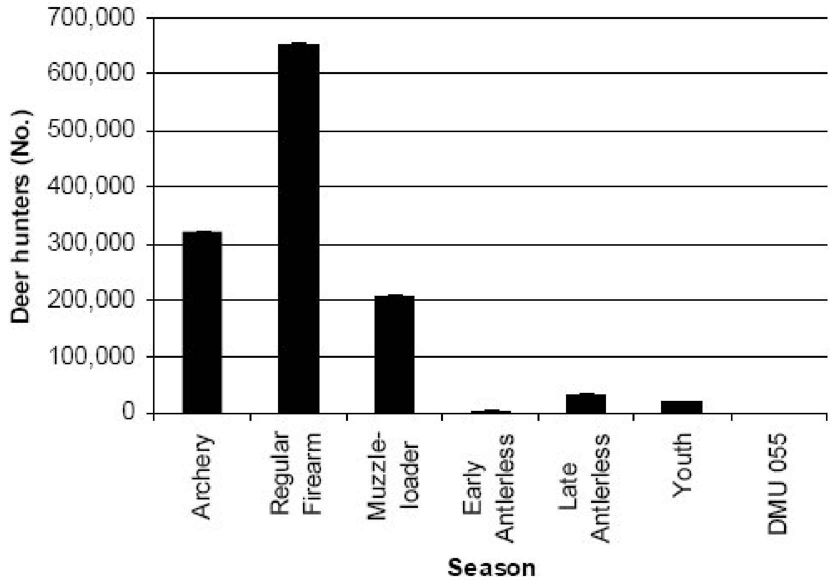


Figure 7. Number of people hunting deer in Michigan during the 2004 hunting seasons. Error bars represent the 95% confidence limits.

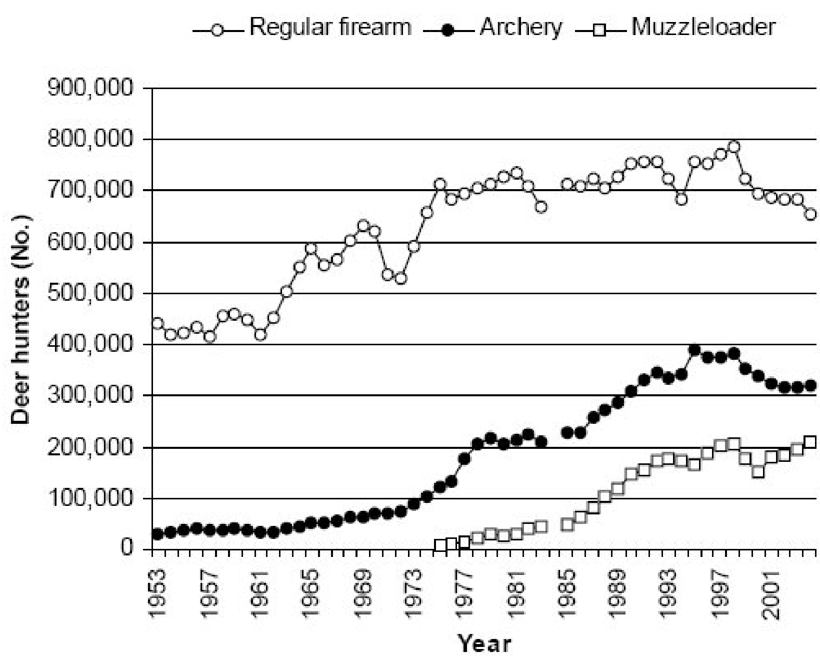


Figure 8. Number of people hunting deer in Michigan during the regular firearm, archery, and muzzleloader seasons, 1953-2004.

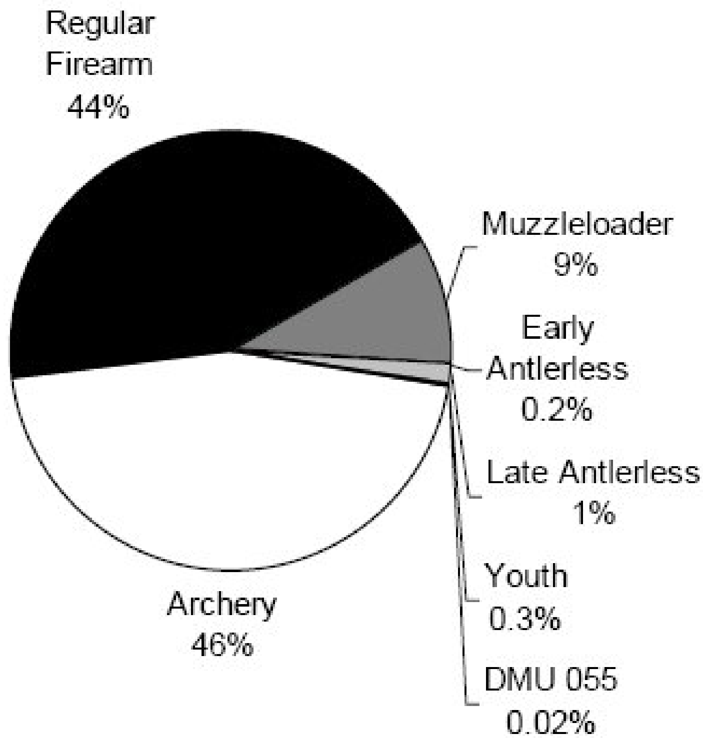


Figure 9. Distribution of hunting effort among deer hunting seasons in Michigan, 2004.

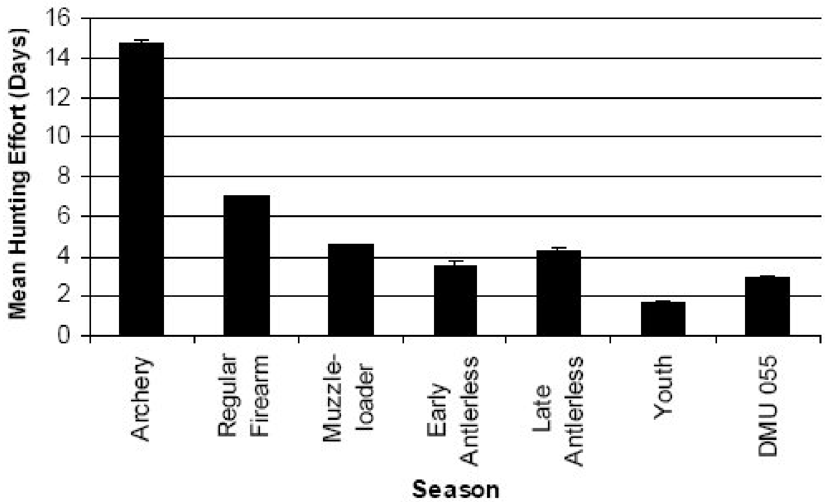


Figure 10. Mean number of days spent hunting deer in Michigan during the 2004 hunting seasons. Error bars represent the 95% confidence limits.

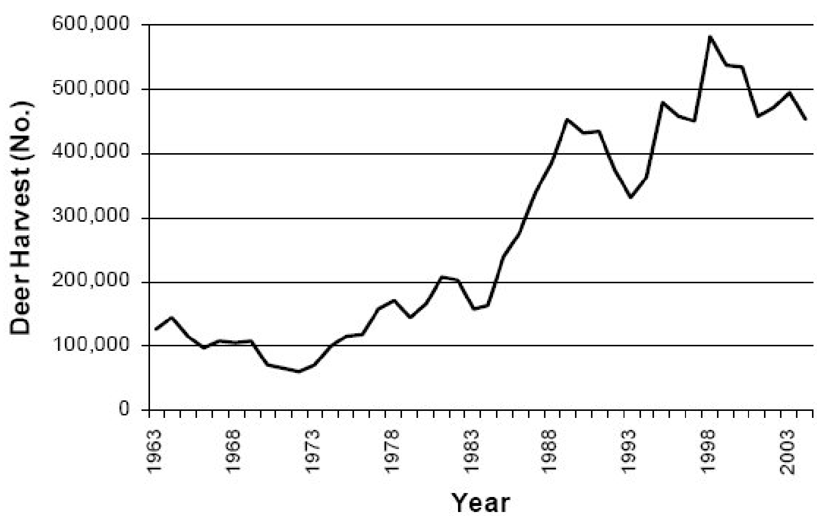


Figure 11. Number of deer harvested in Michigan's hunting seasons, 1963-2004. Harvest from all seasons and for all deer sexes was combined.

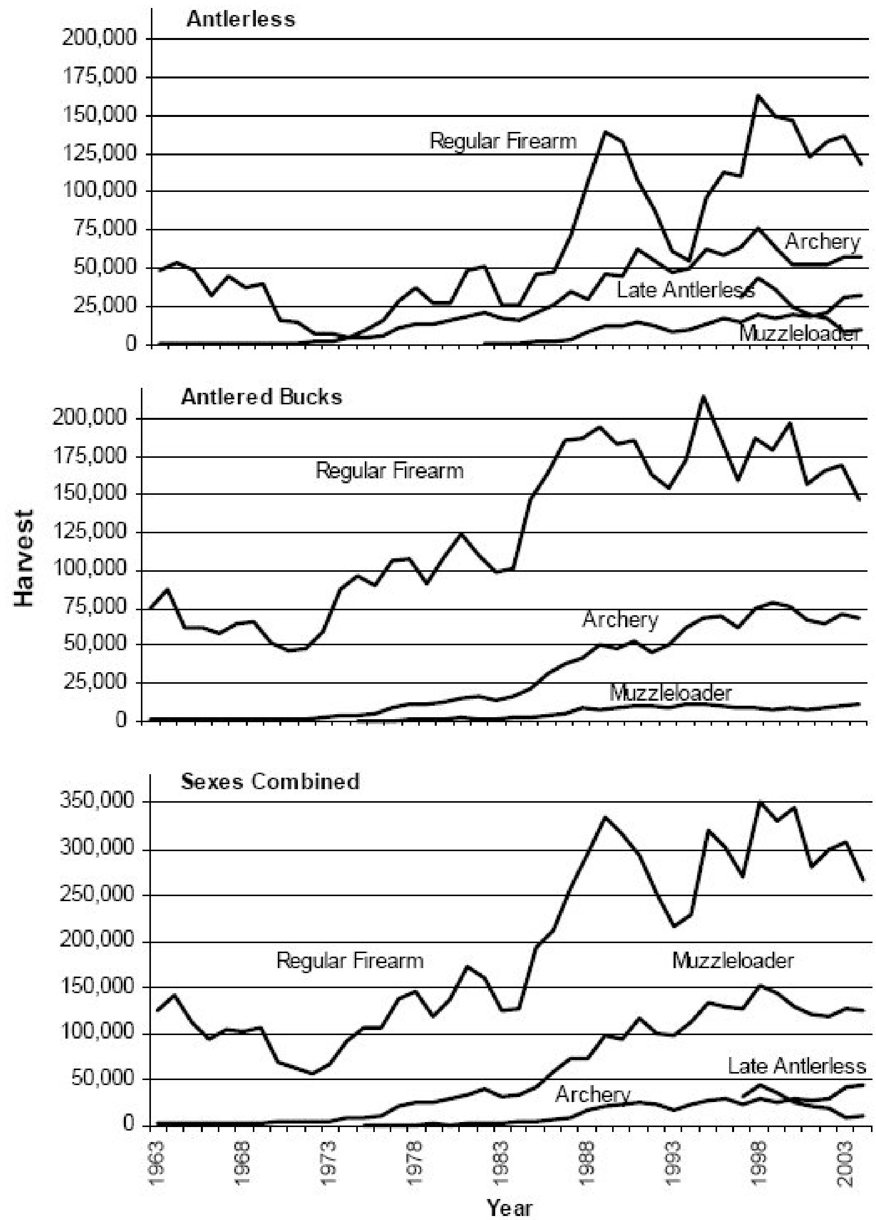


Figure 12. Number of deer harvested in Michigan's hunting seasons, 1963-2004. Harvests for early antlerless, early antlerless in DMR 055, and youth seasons were not shown.

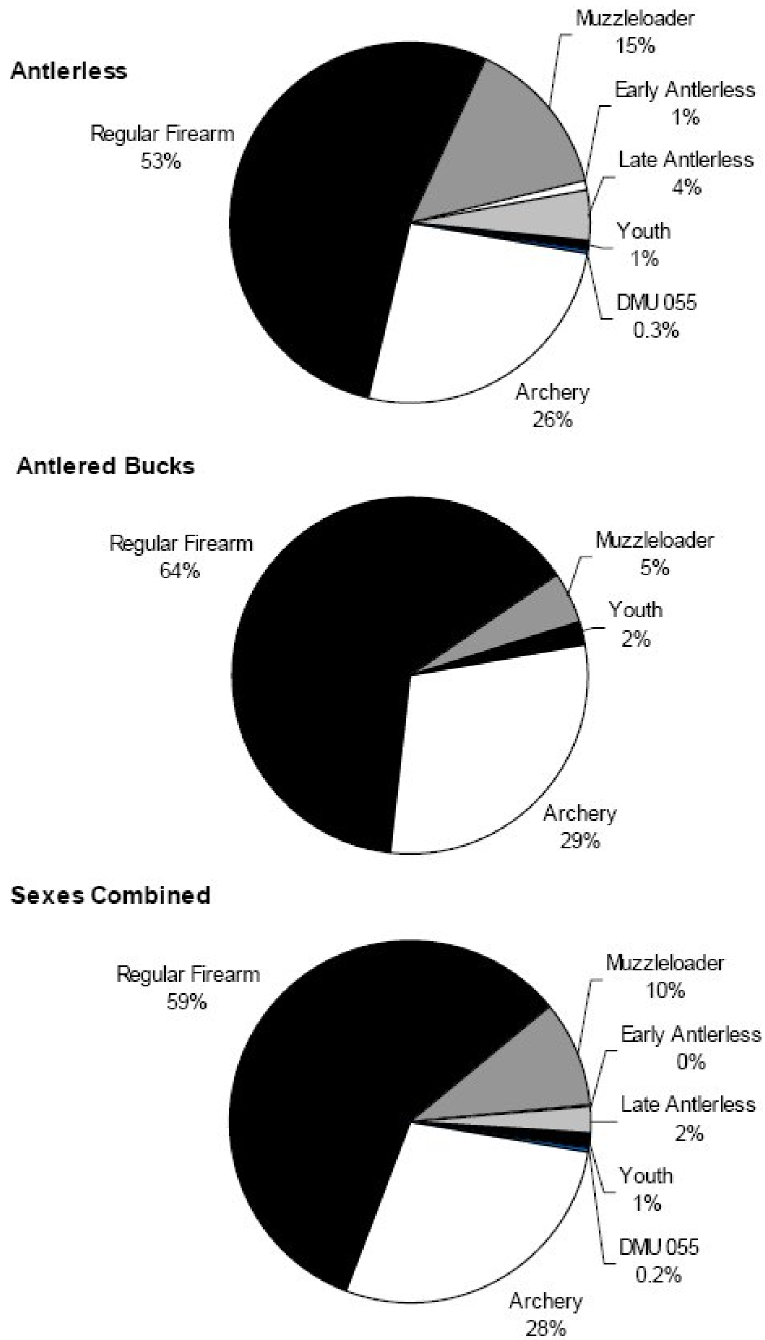


Figure 13. Distribution of harvest among deer hunting seasons in Michigan, 2004.

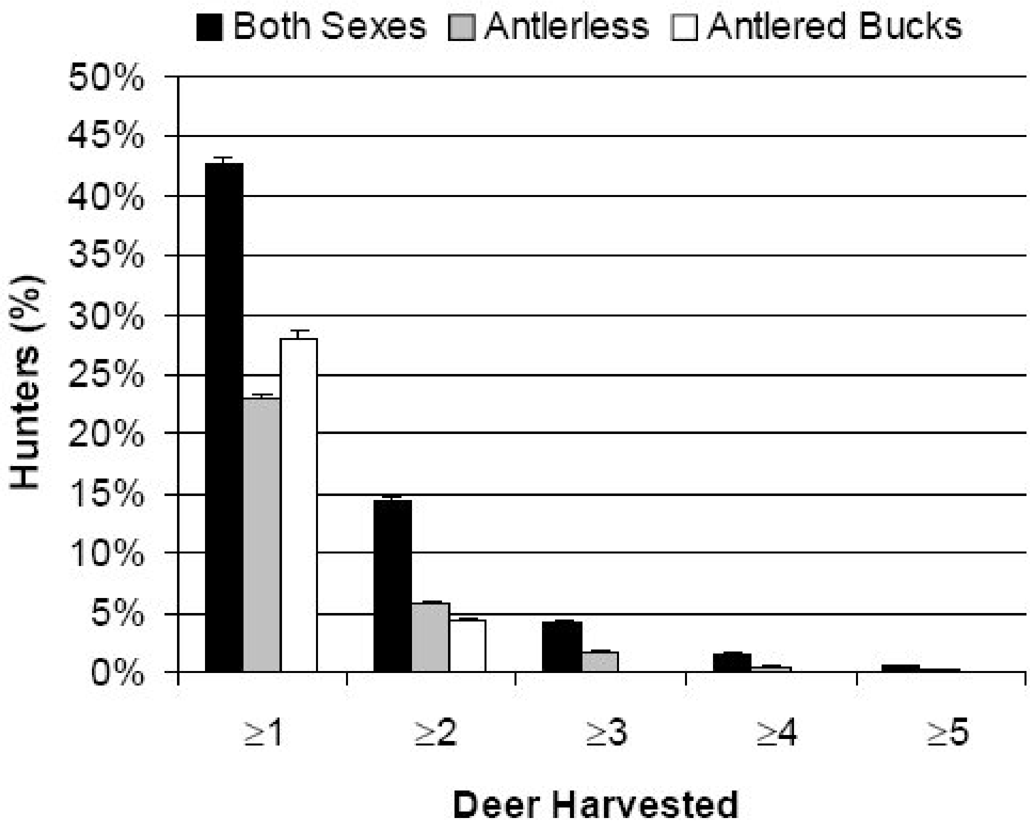


Figure 14. Percentage of hunters harvesting a deer in Michigan, 2004. Error bars represent the 95% confidence limits.

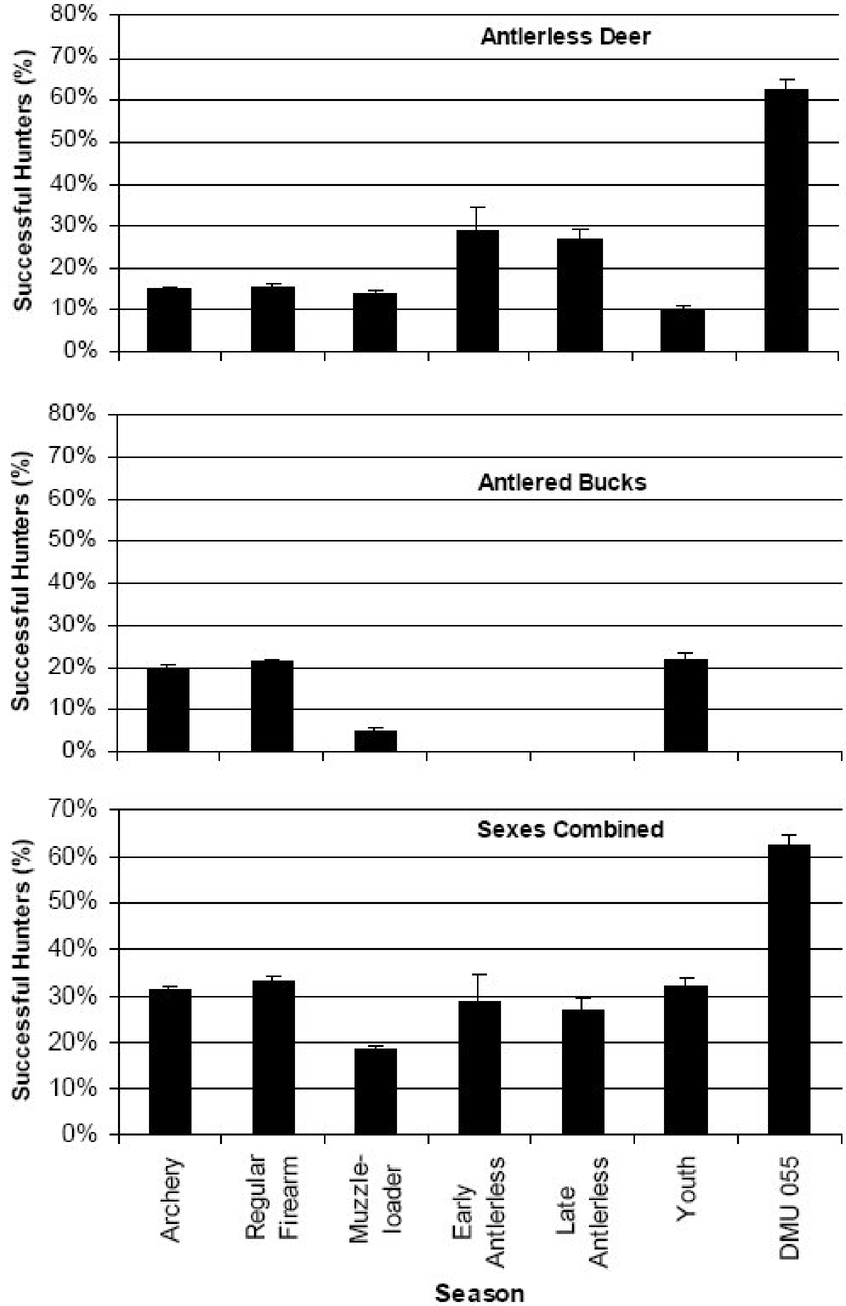


Figure 15. Percentage of hunters harvesting a deer in Michigan's deer hunting seasons, 2004. Error bars represent the 95% confidence limits.

Table 1. Kind of deer that could be taken during the 2004 Michigan deer hunting seasons for each combination of season and hunting license.

Type of license (harvest tag) or permit	Season	Kind of deer that could be harvested[a]
Archery License	Archery seasons	Antlerless or antlered deer[b]
Firearm License	Regular Firearm, Youth[c], or Muzzleloading seasons	Antlered deer only[b]
Combination License[d] (Regular harvest tag)	Archery season	Antlerless or antlered deer
Combination License[d] (Regular harvest tag)	Regular Firearm, Youth, or Muzzleloading seasons	Antlered deer only
Combination License[d] (Restricted harvest tag)	Archery seasons	Antlerless deer or a deer that has at least 1 antler with 4 or more antler points, 1 or more inches in length
Combination License[d] (Restricted harvest tag)	Regular Firearm, Youth, or Muzzleloading seasons	A deer that has at least 1 antler with 4 or more antler points, 1 or more inches in length
Antlerless License	All seasons	Antlerless deer only
Deer Management Assistance (DMA) permit[e]	All seasons	Antlerless deer only

[a]Antlered deer had antlers at least 3 inches in length; antlerless deer included deer without antlers and deer with antlers less than 3 inches in length. Hunters could harvest a maximum of 2 antlered deer per year (all seasons combined); maximum antlerless limit varied by region of the state.

[b]If a person took 2 antlered deer during all seasons combined, one of the antlered deer must have had at least 1 antler with 4 or more antler points, 1 or more inches in length.

[c]All youths 12 and 13 years of age were restricted to archery-only hunting. Hunters could harvest only 1 deer in the youth season.

[d]Combination licenses included two harvest tags (i.e., regular and restricted harvest tags).

[e]Permits issued to landowners in areas where the number of antlerless licenses was insufficient to meet the objective of specific landowners (i.e., controlling disease or the deer population). To use these permits, the hunter must also have purchased a firearm, archery, combination, or antlerless deer license for the season in which they were hunting.

Table 2. Number of Michigan deer licenses purchased and harvest tags issued, 2002-2004.

Licenses or Harvest Tags	Number Purchased or Issued 2002	2003	2004	Change Between 2003 and 2004 (%)
Firearm Licenses				
Resident	304,294	296,570	267,661	-9.7
Non-resident	14,772	14,791	13,229	-10.6
Senior	32,461	32,719	32,638	-0.2
Military	24	27	444	1544.4
Subtotal	351,551	344,107	313,972	-8.8
Archery Licenses				
Resident	54,136	51,724	47,984	-7.2
Non-resident	3,228	3,122	2,840	-9.0
Junior	9,254	8,946	8,337	-6.8
Senior	2,962	3,182	3,166	-0.5
Military	29	19	135	610.5
Subtotal	69,609	66,993	62,462	-6.8
Combination Licenses[a]				
Resident	299,140	309,319	307,592	-0.6
Non-resident	1,603	1,688	1,738	3.0
Junior	30,852	33,040	33,895	2.6
Senior	25,813	27,650	29,074	5.2
Military	137	157	356	126.8
Subtotal	357,545	371,854	372,655	0.2
Antlerless Licenses[b]				
Resident	597,721	575,077	568,138	-1.2
Non-resident	5,312	4,930	4,824	-2.2
Junior	4,890	4,941	4,667	-5.5
Military		23	266	1056.5
Deer Management Assistance	6,312	6,434	6,728	4.6
Subtotal	614,235	591,405	584,623	-1.1
Total Licenses Sold	1,392,940	1,374,359	1,333,712	-3.0
Harvest Tags Issued				
Firearm	351,551	344,107	313,972	-8.8
Archery	69,609	66,993	62,462	-6.8
Combination	715,090	743,708	745,310	0.2
Antlerless	653,446	631,734	584,623	-7.5
Total Harvest Tags	1,789,696	1,786,542	1,706,367	-4.5

[a]Combination licenses included two harvest tags. Other license types had one harvest tag.

[b]In 2003, two harvest tags were issued with 40,329 antlerless licenses sold for eight management units in northeast LP.

Table 3. Number of deer hunters and hunting effort in Michigan by hunting season, 2003-2004.

	Number of hunters[a]				Hunting effort (days)			
Season and Area	2003	2004	95% CL[b]	Change from 2003 to 2004 (%)	2003	2004	95% CL[b]	Change from 2003 to 2004 (%)
Archery								
West UP	24,034	23,496	1,386	-2.2	272,535	261,903	20,732	-3.9
East UP	8,309	9,612	911	15.7	83,977	94,942	12,828	13.1
NE LP	48,205	49,372	2,011	2.4	480,367	502,677	28,189	4.6
NW LP	66,731	63,253	2,229	-5.2	811,884	759,157	37,048	-6.5
Sag. Bay	57,399	56,803	2,129	-1.0	744,319	718,878	36,503	-3.4
SW LP	52,156	57,171	2,125	9.6	782,368	799,367	39,308	2.2
SC LP	63,965	67,073	2,295	4.9	949,983	929,624	42,395	-2.1
SE LP	35,403	37,537	1,761	6.0	473,737	512,910	32,503	8.3
UP	32,124	32,899	2,772	2.4	356,512	356,844	24,380	0.1
NLP	131,308	129,047	3,898	-1.7	1,509,844	1,505,356	51,024	-0.3
SLP	181,889	189,839	3,869	4.4	2,732,815	2,717,256	72,767	-0.6
Statewide[c]	314,961	318,161	3,990	1.0	4,599,171	4,579,457	92,324	-0.4
Regular Firearm								
West UP	82,208	78,293	2,439	-4.8	606,131	588,690	21,739	-2.9
East UP	29,940	27,673	1,528	-7.6	203,292	189,923	12,130	-6.6
NE LP	130,686	121,369	2,988	-7.1	791,349	732,052	22,838	-7.5
NW LP	141,433	129,837	3,025	-8.2	852,111	772,457	23,090	-9.3
Sag. Bay	101,181	101,342	2,761	0.2	614,456	618,802	21,175	0.7
SW LP	100,577	97,750	2,667	-2.8	679,481	633,793	21,694	-6.7
SC LP	117,566	116,149	2,909	-1.2	752,159	708,498	22,609	-5.8
SE LP	44,589	43,555	1,893	-2.3	262,128	250,649	13,285	-4.4
UP	111,412	105,292	1,637	-5.5	809,423	778,613	24,894	-3.8
NLP	300,924	281,152	3,044	-6.6	1,839,867	1,715,448	34,703	-6.8
SLP	319,370	313,003	3,476	-2.0	2,111,817	2,000,802	38,172	-5.3
Statewide[c]	683,951	652,798	2,696	-4.6	4,761,106	4,494,864	57,523	-5.6

[a]Excludes people that did not hunt during the season.
[b]95% confidence limit for the 2004 estimate.
[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one area.

Table 3 (continued). Number of deer hunters and hunting effort in Michigan by hunting season, 2003-2004.

	Number of hunters[a]				Hunting effort (days)			
Season and Area	2003	2004	95% CL[b]	Change from 2003 to 2004 (%)	2003	2004	95% CL[b]	Change from 2003 to 2004 (%)
Muzzleloader								
West UP	17,193	18,543	1,235	7.9	85,599	92,537	6,930	8.1
East UP	6,958	7,125	787	2.4	32,901	34,430	4,289	4.6
NE LP	24,378	26,165	1,495	7.3	99,301	110,184	7,259	11.0
NW LP	30,244	29,965	1,582	-0.9	126,433	118,038	7,243	-6.6
Sag. Bay	32,188	35,175	1,715	9.3	130,007	143,953	8,242	10.7
SW LP	36,867	39,852	1,806	8.1	166,745	170,073	8,971	2.0
SC LP	41,161	43,574	1,892	5.9	174,643	179,314	9,074	2.7
SE LP	17,988	19,724	1,302	9.7	74,450	79,932	6,150	7.4
UP	23,966	25,537	1,449	6.6	118,500	126,968	8,150	7.1
NLP	62,505	66,015	2,298	5.6	260,039	271,024	11,155	4.2
SLP	115,922	124,191	2,979	7.1	511,540	530,469	15,789	3.7
Statewide[c]	194,809	207,666	3,613	6.6	890,079	928,461	21,061	4.3
Early Antlerless								
West UP	0	0	0		0	0	0	
East UP	0	0	0		0	0	0	
NE LP	5,944	4,835	647	-18.7	20,062	16,684	2,605	-16.8
NW LP	0	0	0		0	0	0	
Sag. Bay	0	0	0		0	0	0	
SW LP	0	0	0		0	0	0	
SC LP	0	0	0		0	0	0	
SE LP	0	0	0		0	0	0	
UP	0	0	0		0	0	0	
NLP	5,944	4,835	647	-18.7	20,062	16,684	2,605	-16.8
SLP	0	0	0		0	0	0	
Statewide[c]	5,944	4,835	647	-18.7	20,062	16,684	2,625	-16.8

[a]Excludes people that did not hunt during the season.
[b]95% confidence limit for the 2004 estimate.
[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one area.

Table 3 (continued). Number of deer hunters and hunting effort in Michigan by hunting season, 2003-2004.

	Number of hunters[a]				Hunting effort (days)			
Season and Area	2003	2004	95% CL[b]	Change from 2003 to 2004 (%)	2003	2004	95% CL[b]	Change from 2003 to 2004 (%)
Late Antlerless								
West UP	0	0	0		0	0	0	
East UP	0	0	0		0	0	0	
NE LP	4,893	3,848	579	-21.3	17,110	14,927	2,764	-12.8
NW LP	0	0	0		0	0	0	
Sag. Bay	1,927	2,412	456	25.2	6,446	10,327	2,472	60.2
SW LP	13,781	12,955	1,013	-6.0	50,729	53,216	5,241	4.9
SC LP	9,489	9,752	892	2.8	34,421	38,866	4,518	12.9
SE LP	2,682	2,844	495	6.0	9,557	10,960	2,331	14.7
UP	0	0	0		0	0	0	
NLP	4,893	3,848	579	-21.3	17,110	14,927	2,764	-12.8
SLP	27,667	27,619	1,375	-0.2	101,153	113,368	7,709	12.1
Statewide[c]	32,799	31,898	1,444	-2.7	118,263	128,295	8,248	8.5
Youth								
West UP	848	676	125	-20.3	1,435	1,158	222	-19.3
East UP	224	273	80	21.6	355	474	143	33.4
NE LP	2,009	1,823	201	-9.3	3,499	3,230	376	-7.7
NW LP	3,810	4,034	285	5.9	6,138	6,890	538	12.2
Sag. Bay	3,526	4,077	287	15.6	5,845	6,775	531	15.9
SW LP	3,010	3,194	259	6.1	4,944	5,239	463	6.0
SC LP	3,978	4,327	300	8.8	6,472	6,929	541	7.1
SE LP	1,275	1,654	196	29.7	1,999	2,708	335	35.5
UP	1,072	934	146	-12.8	1,790	1,632	264	-8.8
NLP	6,716	7,035	351	4.7	11,127	12,172	720	9.4
SLP	10,830	11,960	405	10.4	17,770	19,599	902	10.3
Statewide[c]	18,520	19,947	363	7.7	30,687	33,402	1,188	8.8

[a]Excludes people that did not hunt during the season.
[b]95% confidence limit for the 2004 estimate.
[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one area.

Table 3 (continued). Number of deer hunters and hunting effort in Michigan by hunting season, 2003-2004.

Season and Area	Number of hunters[a] 2003	2004	95% CL[b]	Change from 2003 to 2004 (%)	Hunting effort (days) 2003	2004	95% CL[b]	Change from 2003 to 2004 (%)
Early Antlerless in DMU 055								
West UP	753	771	28	2.4	1,841	2,050	85	11.3
East UP	0	0	0		0	0	0	
NE LP	0	0	0		0	0	0	
NW LP	0	0	0		0	0	0	
Sag. Bay	0	0	0		0	0	0	
SW LP	0	0	0		0	0	0	
SC LP	0	0	0		0	0	0	
SE LP	0	0	0		0	0	0	
UP	753	771	28	2.4	1,841	2,050	85	11.3
NLP	0	0	0		0	0	0	
SLP	0	0	0		0	0	0	
Statewide[c]	753	771	28	2.4	1,841	2,050	85	11.3
All Seasons								
West UP	92,096	87,490	2,559	-5.0	967,185	945,779	38,876	-2.2
East UP	34,533	31,885	1,633	-7.7	320,400	319,633	23,615	-0.2
NE LP	147,547	137,084	3,129	-7.1	1,411,342	1,379,058	48,735	-2.3
NW LP	161,860	149,424	3,186	-7.7	1,796,642	1,656,773	56,119	-7.8
Sag. Bay	120,383	120,310	2,952	-0.1	1,501,249	1,499,002	55,756	-0.1
SW LP	115,295	116,544	2,859	1.1	1,684,378	1,661,775	60,839	-1.3
SC LP	137,504	137,266	3,103	-0.2	1,917,917	1,863,553	64,226	-2.8
SE LP	61,456	61,379	2,211	-0.1	822,096	857,641	44,961	4.3
UP	125,118	118,192	2,904	-5.5	1,287,585	1,265,412	45,486	-1.7
NLP	339,398	317,687	3,975	-6.4	3,657,823	3,535,268	80,704	-3.4
SLP	374,973	372,108	3,925	-0.8	5,475,801	5,382,533	109,397	-1.7
Statewide[c]	743,471	712,894	1,806	-4.1	10,421,209	10,183,213	143,729	-2.3

[a]Excludes people that did not hunt during the season.
[b]95% confidence limit for the 2004 estimate.
[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one area.

Table 4. Mean number of days hunters spent hunting deer ($\bar{x}$ hunting effort) in Michigan by hunting season, 2004.[a]

	Season															
	Archery		Regular Firearm		Muzzle-loader		Early Antlerless		Late Antlerless		Youth		Early Antlerless in DMU 055		All Seasons	
Area	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]	$\bar{x}$ days	95% CL[b]
West UP	11.3	0.6	7.5	0.1	5.0	0.2	0.0	0.0	0.0	0.0	1.7	0.1	2.9	0.1	10.8	0.3
East UP	10.0	1.0	6.9	0.2	4.9	0.3	0.0	0.0	0.0	0.0	1.7	0.1	0.0	0.0	10.0	0.5
NE LP	10.3	0.4	6.1	0.1	4.3	0.1	3.5	0.3	4.0	0.4	1.8	0.0	0.0	0.0	10.1	0.3
NW LP	12.1	0.4	6.0	0.1	4.0	0.1	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	11.1	0.3
Sag. Bay	12.9	0.4	6.2	0.1	4.2	0.1	0.0	0.0	4.7	0.6	1.7	0.0	0.0	0.0	12.6	0.3
SW LP	14.2	0.5	6.5	0.1	4.3	0.1	0.0	0.0	4.3	0.2	1.6	0.0	0.0	0.0	14.4	0.4
SC LP	14.1	0.4	6.2	0.1	4.2	0.1	0.0	0.0	4.2	0.3	1.6	0.0	0.0	0.0	13.8	0.4
SE LP	13.9	0.6	5.8	0.2	4.1	0.2	0.0	0.0	4.0	0.5	1.6	0.1	0.0	0.0	14.1	0.5
UP	11.0	0.5	7.4	0.1	5.0	0.2	0.0	0.0	0.0	0.0	1.7	0.1	2.9	0.1	10.7	0.3
NLP	11.8	0.3	6.1	0.1	4.2	0.1	3.5	0.3	4.0	0.4	1.7	0.0	0.0	0.0	11.2	0.2
SLP	14.6	0.3	6.5	0.1	4.4	0.1	0.0	0.0	4.3	0.2	1.6	0.0	0.0	0.0	14.6	0.2
Statewide	14.7	0.2	7.0	0.0	4.6	0.1	3.4	0.3	4.3	0.2	1.7	0.0	2.9	0.1	14.5	0.2

[a]Excludes people that did not hunt during the season.
[b]95% confidence limit.

Table 5. Number of deer harvested in Michigan, 2002-2004.

Season or permit	Type of deer	2002	2003	2004	Change from 2003 to 2004 (%)
Season					
Archery	Antlerless	53,258	57,299	57,658	0.6
	Antlered bucks	64,517	70,292	67,719	-3.7
	Sexes combined	117,775	127,592	125,377	-1.7
Regular firearm	Antlerless	133,524	136,625	118,028	-13.6
	Antlered bucks	165,412	169,720	146,793	-13.5
	Sexes combined	298,936	306,345	264,821	-13.6
Muzzleloader	Antlerless	20,792	31,684	32,215	1.7
	Antlered bucks	8,233	10,589	10,793	1.9
	Sexes combined	29,026	42,273	43,008	1.7
Early antlerless	Antlerless	2,307	2,875	1,640	-43.0
Late antlerless	Antlerless	17,876	9,165	9,905	8.1
Youth	Antlerless	2,004	2,325	1,991	-14.4
	Antlered bucks	3,142	3,872	4,350	12.4
	Sexes combined	5,146	6,197	6,341	2.3
DMU 055	Antlerless	811	798	713	-10.6
Special permits[a]	Antlerless	4,338	4,502	4,617	2.6
Grand Total	Antlerless	234,911	245,274	226,768	-7.5
	Antlered bucks	241,304	254,473	229,654	-9.8
	Sexes combined	476,215	499,747	456,422	-8.7

[a]Includes deer harvested with DMA permits. These permits could be used during any deer hunting season.

Table 6. Number of deer harvested in Michigan by hunting season, 2003-2004.[a]

Season and Area	Antlerless				Antlered Bucks				Sexes Combined			
	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004 (%)	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004 (%)	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004 (%)
Archery												
West UP	5,812	5,184	822	-10.8	4,482	2,948	515	-34.2	10,286	8,130	1,026	-21.0
East UP	1,645	1,336	368	-18.8	1,048	1,026	300	-2.1	2,690	2,362	525	-12.2
NE LP	6,848	5,560	769	-18.8	5,952	4,994	673	-16.1	12,792	10,553	1,088	-17.5
NW LP	8,884	8,276	1,016	-6.8	10,055	9,546	943	-5.1	18,937	17,822	1,498	-5.9
Sag. Bay	10,049	9,429	1,009	-6.2	12,311	11,160	1,040	-9.4	22,360	20,588	1,577	-7.9
SW LP	7,939	10,006	1,160	26.0	12,490	13,172	1,154	5.5	20,438	23,179	1,802	13.4
SC LP	10,243	11,485	1,209	12.1	16,828	17,524	1,319	4.1	27,084	29,011	1,972	7.1
SE LP	5,879	6,381	875	8.5	7,126	7,350	842	3.1	13,005	13,731	1,332	5.6
UP	7,457	6,520	901	-12.6	5,530	3,974	596	-28.1	12,976	10,492	1,152	-19.1
NLP	19,397	17,258	1,408	-11.0	19,268	17,268	1,261	-10.4	38,651	34,525	2,038	-10.7
SLP	30,445	33,879	2,057	11.3	45,495	46,477	2,148	2.2	75,965	80,360	3,266	5.8
Statewide	57,299	57,658	2,657	0.6	70,292	67,719	2,570	-3.7	127,592	125,377	4,030	-1.7
Regular Firearm												
West UP	11,206	8,858	945	-21.0	23,434	19,287	1,318	-17.7	34,639	28,151	1,718	-18.7
East UP	2,210	1,386	370	-37.3	5,552	4,821	646	-13.2	7,762	6,210	778	-20.0
NE LP	18,956	13,595	1,187	-28.3	26,078	20,306	1,381	-22.1	45,034	33,904	1,911	-24.7
NW LP	23,075	16,832	1,342	-27.1	25,443	21,550	1,407	-15.3	48,518	38,382	2,088	-20.9
Sag. Bay	21,434	20,379	1,520	-4.9	26,122	22,884	1,474	-12.4	47,557	43,261	2,291	-9.0
SW LP	24,488	22,697	1,623	-7.3	22,926	22,017	1,454	-4.0	47,414	44,710	2,406	-5.7
SC LP	29,119	27,521	1,791	-5.5	31,280	29,726	1,698	-5.0	60,399	57,243	2,693	-5.2
SE LP	6,135	6,760	842	10.2	8,886	6,201	758	-30.2	15,021	12,959	1,189	-13.7
UP	13,416	10,244	1,015	-23.6	28,986	24,108	1,468	-16.8	42,401	34,360	1,886	-19.0
NLP	47,675	36,429	1,969	-23.6	58,852	48,320	2,124	-17.9	106,528	84,751	3,081	-20.4
SLP	75,533	71,355	2,863	-5.5	81,882	74,365	2,669	-9.2	157,416	145,709	4,269	-7.4
Statewide	136,625	118,028	3,635	-13.6	169,720	146,793	3,726	-13.5	306,345	264,821	5,612	-13.6

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.
[b]95% confidence limit for the 2004 estimate.

Table 6 (continued). Number of deer harvested in Michigan by hunting season, 2003-2004.[a]

Season and Area	Antlerless 2003 Harvest	Antlerless 2004 Harvest	Antlerless 95% CL[b]	Antlerless Change from 2003 to 2004 (%)	Antlered Bucks 2003 Harvest	Antlered Bucks 2004 Harvest	Antlered Bucks 95% CL[b]	Antlered Bucks Change from 2003 to 2004	Sexes Combined 2003 Harvest	Sexes Combined 2004 Harvest	Sexes Combined 95% CL[b]	Sexes Combined Change from 2003 to 2004
Muzzleloader												
West UP	3,086	2,548	485	-17.4	1,449	1,114	310	-23.1	4,535	3,661	605	-19.3
East UP	754	710	355	-5.8	451	562	231	24.5	1,205	1,270	429	5.4
NE LP	3,168	2,623	526	-17.2	981	962	290	-1.9	4,150	3,585	612	-13.6
NW LP	4,151	2,855	550	-31.2	1,006	937	283	-6.9	5,157	3,791	626	-26.5
Sag. Bay	5,257	6,482	808	23.3	1,700	1,622	380	-4.6	6,957	8,105	914	16.5
SW LP	6,083	6,151	819	1.1	2,277	2,338	451	2.7	8,361	8,488	969	1.5
SC LP	7,236	8,531	984	17.9	1,933	2,149	433	11.2	9,169	10,682	1,109	16.5
SE LP	1,949	2,316	461	18.9	791	1,108	310	40.1	2,740	3,424	571	25.0
UP	3,839	3,257	601	-15.2	1,900	1,676	387	-11.8	5,740	4,932	741	-14.1
NLP	8,580	7,402	881	-13.7	2,549	2,190	436	-14.1	11,129	9,593	994	-13.8
SLP	19,265	21,556	1,519	11.9	6,139	6,926	778	12.8	25,404	28,483	1,763	12.1
Statewide	31,684	32,215	1,861	1.7	10,589	10,793	977	1.9	42,273	43,008	2,162	1.7
Early Antlerless												
West UP	0	0	0		0	0	0		0	0	0	
East UP	0	0	0		0	0	0		0	0	0	
NE LP	2,875	1,640	429	-43.0	0	0	0		2,875	1,640	429	-43.0
NW LP	0	0	0		0	0	0		0	0	0	
Sag. Bay	0	0	0		0	0	0		0	0	0	
SW LP	0	0	0		0	0	0		0	0	0	
SC LP	0	0	0		0	0	0		0	0	0	
SE LP	0	0	0		0	0	0		0	0	0	
UP	0	0	0		0	0	0		0	0	0	
NLP	2,875	1,640	429	-43.0	0	0	0		2,875	1,640	429	-43.0
SLP	0	0	0		0	0	0		0	0	0	
Statewide	2,875	1,640	429	-43.0	0	0	0		2,875	1,640	429	-43.0

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.

[b]95% confidence limit for the 2004 estimate.

Table 6 (continued). Number of deer harvested in Michigan by hunting season, 2003-2004.[a]

Season and Area	Antlerless				Antlered Bucks				Sexes Combined			
	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004
Late Antlerless												
West UP	0	0	0		0	0	0		0	0	0	
East UP	0	0	0		0	0	0		0	0	0	
NE LP	1,793	1,110	343	-38.1	0	0	0		1,793	1,110	343	-38.1
NW LP	0	0	0		0	0	0		0	0	0	
Sag. Bay	657	515	243	-21.6	0	0	0		657	515	243	-21.6
SW LP	3,704	4,347	719	17.4	0	0	0		3,704	4,347	719	17.4
SC LP	2,262	2,890	596	27.8	0	0	0		2,262	2,890	596	27.8
SE LP	750	1,043	346	39.2	0	0	0		750	1,043	346	39.2
UP	0	0	0		0	0	0		0	0	0	
NLP	1,793	1,110	343	-38.1	0	0	0		1,793	1,110	343	-38.1
SLP	7,372	8,795	1,025	19.3	0	0	0		7,372	8,795	1,025	19.3
Statewide	9,165	9,905	1,085	8.1	0	0	0		9,165	9,905	1,085	8.1
Youth												
West UP	104	44	32	-57.6	147	101	49	-31.4	251	145	58	-42.3
East UP	35	43	32	23.7	56	50	34	-9.9	91	93	47	3.0
NE LP	361	243	76	-32.6	361	288	82	-20.4	723	531	112	-26.5
NW LP	457	429	100	-5.9	796	870	142	9.3	1,253	1,300	174	3.8
Sag. Bay	486	401	97	-17.6	880	1,007	153	14.4	1,366	1,407	181	3.0
SW LP	250	322	87	28.8	440	582	117	32.4	690	905	145	31.1
SC LP	472	394	96	-16.7	913	1,165	165	27.6	1,385	1,558	190	12.5
SE LP	160	115	52	-28.3	279	288	82	3.0	439	402	97	-8.4
UP	139	87	45	-37.3	203	151	59	-25.4	341	238	74	-30.2
NLP	971	809	138	-16.7	1,381	1,431	183	3.6	2,352	2,240	229	-4.7
SLP	1,216	1,095	160	-9.9	2,289	2,768	254	21.0	3,504	3,863	300	10.3
Statewide	2,325	1,991	217	-14.4	3,872	4,350	320	12.4	6,197	6,341	386	2.3

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.

[b]95% confidence limit for the 2004 estimate.

Table 6 (continued). Number of deer harvested in Michigan by hunting season, 2003-2004.[a]

Season and Area	Antlerless 2003 Harvest	Antlerless 2004 Harvest	Antlerless 95% CL[b]	Antlerless Change from 2003 to 2004 (%)	Antlered Bucks 2003 Harvest	Antlered Bucks 2004 Harvest	Antlered Bucks 95% CL[b]	Antlered Bucks Change from 2003 to 2004 (%)	Sexes Combined 2003 Harvest	Sexes Combined 2004 Harvest	Sexes Combined 95% CL[b]	Sexes Combined Change from 2003 to 2004 (%)
Early Antlerless in DMU 055												
West UP	798	713	42	-10.6	0	0	0		798	713	42	-10.6
East UP	0	0	0		0	0	0		0	0	0	
NE LP	0	0	0		0	0	0		0	0	0	
NW LP	0	0	0		0	0	0		0	0	0	
Sag. Bay	0	0	0		0	0	0		0	0	0	
SW LP	0	0	0		0	0	0		0	0	0	
SC LP	0	0	0		0	0	0		0	0	0	
SE LP	0	0	0		0	0	0		0	0	0	
UP	798	713	42	-10.6	0	0	0		798	713	42	-10.6
NLP	0	0	0		0	0	0		0	0	0	
SLP	0	0	0		0	0	0		0	0	0	
Statewide	798	713	42	-10.6	0	0	0		798	713	42	-10.6
All Seasons												
West UP	20,994	17,312	1,432	-17.5	29,496	23,445	1,478	-20.5	50,496	40,760	2,242	-19.3
East UP	4,642	3,478	668	-25.1	7,103	6,457	778	-9.1	11,748	9,937	1,105	-15.4
NE LP	34,006	24,762	1,749	-27.2	33,359	26,547	1,628	-20.4	67,362	51,310	2,622	-23.8
NW LP	36,573	28,401	1,900	-22.3	37,300	32,903	1,803	-11.8	73,872	61,307	2,905	-17.0
Sag. Bay	37,884	37,219	2,219	-1.8	41,019	36,673	1,951	-10.6	78,903	73,891	3,340	-6.4
SW LP	42,468	43,525	2,691	2.5	38,140	38,111	2,052	-0.1	80,602	81,632	3,870	1.3
SC LP	49,339	50,831	2,872	3.0	50,965	50,568	2,348	-0.8	100,303	101,398	4,256	1.1
SE LP	14,867	16,623	1,537	11.8	17,092	14,949	1,246	-12.5	31,960	31,570	2,221	-1.2
UP	25,636	20,789	1,581	-18.9	36,599	29,903	1,670	-18.3	62,244	50,697	2,500	-18.6
NLP	81,299	64,653	2,850	-20.5	82,037	69,207	2,622	-15.6	163,333	133,862	4,282	-18.0
SLP	133,837	136,708	4,618	2.1	135,837	130,544	3,756	-3.9	269,669	267,246	6,794	-0.9
Statewide	240,772	222,151	5,672	-7.7	254,473	229,654	4,891	-9.8	495,245	451,805	8,438	-8.8

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.
[b]95% confidence limit for the 2004 estimate.

Table 7. Number of deer harvested on public and private lands during all seasons combined in Michigan by management region, 2003-2004.[a]

Season and Area	Antlerless				Antlered Bucks				Sexes Combined			
	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004 (%)	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004 (%)	2003 Harvest	2004 Harvest	95% CL[b]	Change from 2003 to 2004 (%)
Public Lands												
West UP	4,839	4,426	629	-8.5	10,468	8,550	888	-18.3	15,314	12,977	1,149	-15.3
East UP	678	639	235	-5.8	2,715	2,703	484	-0.4	3,397	3,344	557	-1.6
NE LP	7,564	4,982	693	-34.1	9,496	7,304	834	-23.1	17,056	12,285	1,167	-28.0
NW LP	4,007	2,333	460	-41.8	7,848	7,176	834	-8.6	11,859	9,513	981	-19.8
Sag. Bay	3,740	4,408	650	17.9	4,796	4,196	636	-12.5	8,534	8,601	983	0.8
SW LP	2,771	2,487	495	-10.3	2,692	2,359	468	-12.4	5,460	4,844	722	-11.3
SC LP	3,018	2,835	536	-6.1	3,095	2,957	531	-4.5	6,110	5,791	828	-5.2
SE LP	1,579	907	301	-42.6	1,426	968	297	-32.1	3,003	1,874	442	-37.6
UP	5,518	5,065	672	-8.2	13,183	11,253	1,011	-14.6	18,711	16,321	1,277	-12.8
NLP	12,856	9,038	920	-29.7	19,437	16,168	1,247	-16.8	32,293	25,208	1,641	-21.9
SLP	9,823	8,913	943	-9.3	9,916	8,793	911	-11.3	19,728	17,700	1,415	-10.3
Statewide	28,197	23,016	1,488	-18.4	42,535	36,213	1,853	-14.9	70,732	59,229	2,527	-16.3
Private Lands												
West UP	16,165	12,895	1,262	-20.2	19,033	14,905	1,171	-21.7	35,201	27,801	1,873	-21.0
East UP	3,964	2,840	619	-28.4	4,390	3,758	602	-14.4	8,355	6,598	940	-21.0
NE LP	26,458	19,789	1,583	-25.2	23,866	19,249	1,391	-19.3	50,323	39,038	2,301	-22.4
NW LP	32,565	26,066	1,837	-20.0	29,453	25,731	1,581	-12.6	62,016	51,797	2,695	-16.5
Sag. Bay	34,141	32,813	2,106	-3.9	36,221	32,474	1,835	-10.3	70,363	65,287	3,142	-7.2
SW LP	39,686	41,031	2,622	3.4	35,445	35,745	1,996	0.8	75,128	76,774	3,775	2.2
SC LP	46,308	47,988	2,816	3.6	47,865	47,601	2,284	-0.6	94,174	95,589	4,155	1.5
SE LP	13,287	15,713	1,506	18.3	15,665	13,979	1,207	-10.8	28,954	29,691	2,167	2.5
UP	20,130	15,735	1,406	-21.8	23,423	18,663	1,317	-20.3	43,555	34,399	2,095	-21.0
NLP	68,458	55,623	2,674	-18.7	62,606	53,050	2,289	-15.3	131,060	108,672	3,892	-17.1
SLP	123,987	127,777	4,498	3.1	125,909	121,729	3,635	-3.3	249,898	249,504	6,596	-0.2
Statewide	212,575	199,135	5,437	-6.3	211,938	193,441	4,506	-8.7	424,513	392,576	7,963	-7.5

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.
[b]95% confidence limit for the 2004 estimate.

Table 8. Percentage of deer hunters harvesting deer in Michigan during all seasons, 2004.[a]

Sex and Area	Number of deer harvested									
	≥1 deer		≥2 deer		≥3 deer		≥4 deer		≥5 deer	
	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]
Antlerless										
West UP	15.5	1.1	2.9	0.5	0.8	0.2	0.3	0.1	0.1	0.1
East UP	9.2	1.5	1.1	0.5	0.3	0.3	0.2	0.2	0.1	0.1
NE LP	14.7	0.9	2.6	0.4	0.5	0.2	0.1	0.1	0.1	0.1
NW LP	15.1	0.9	2.8	0.4	0.8	0.2	0.2	0.1	0.0	0.0
Sag. Bay	23.8	1.1	5.5	0.6	1.2	0.3	0.3	0.2	0.0	0.1
SW LP	26.2	1.2	7.0	0.7	2.4	0.4	0.8	0.3	0.4	0.2
SC LP	26.9	1.1	6.6	0.6	2.0	0.4	0.6	0.2	0.3	0.1
SE LP	20.9	1.5	4.4	0.8	1.1	0.4	0.4	0.2	0.2	0.2
UP	13.9	0.9	2.5	0.4	0.6	0.2	0.3	0.1	0.1	0.1
NLP	16.2	0.6	3.1	0.3	0.7	0.1	0.2	0.1	0.0	0.0
SLP	26.4	0.7	6.8	0.4	2.1	0.2	0.6	0.1	0.3	0.1
Statewide	23.0	0.5	5.7	0.3	1.7	0.1	0.5	0.1	0.2	0.0
Antlered Bucks[c]										
West UP	24.9	1.3	1.7	0.4						
East UP	19.1	2.1	1.0	0.5						
NE LP	17.6	1.0	1.6	0.3						
NW LP	19.5	1.0	2.0	0.3						
Sag. Bay	26.0	1.2	3.6	0.5						
SW LP	27.4	1.2	4.9	0.6						
SC LP	30.6	1.2	5.4	0.6						
SE LP	21.1	1.5	2.8	0.6						
UP	23.7	1.1	1.6	0.3						
NLP	19.8	0.7	2.0	0.2						
SLP	29.8	0.7	5.3	0.3						
Statewide	28.1	0.5	4.3	0.2						

[a]Excludes people that did not hunt during the season and deer taken with DMA permits.
[b]95% confidence limit.
[c]The season bag limit for antlered deer was two.

Table 8 (continued). Percentage of deer hunters harvesting deer in Michigan during all seasons, 2004.[a]

Sex and Area	Number of deer harvested									
	≥1 deer		≥2 deer		≥3 deer		≥4 deer		≥5 deer	
	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]
Sexes Combined										
West UP	36.0	1.5	7.6	0.8	1.5	0.3	0.7	0.2	0.2	0.2
East UP	25.8	2.3	4.1	1.0	0.8	0.5	0.2	0.2	0.1	0.1
NE LP	28.7	1.1	6.8	0.6	1.3	0.3	0.4	0.2	0.1	0.1
NW LP	30.5	1.1	7.8	0.6	1.8	0.3	0.6	0.2	0.2	0.2
Sag. Bay	42.5	1.3	13.5	0.9	3.8	0.5	1.1	0.3	0.2	0.2
SW LP	44.3	1.4	16.6	1.0	5.2	0.6	2.3	0.4	0.2	0.2
SC LP	47.3	1.3	17.8	1.0	5.2	0.6	1.7	0.3	0.2	0.2
SE LP	36.4	1.8	10.7	1.2	2.7	0.6	0.9	0.4	0.5	0.5
UP	33.7	1.3	6.8	0.6	1.4	0.3	0.5	0.2	0.1	0.1
NLP	31.4	0.8	8.0	0.4	1.8	0.2	0.6	0.1	0.1	0.1
SLP	46.0	0.8	17.2	0.6	5.2	0.3	1.9	0.2	0.5	0.5
Statewide	42.6	0.5	14.4	0.4	4.2	0.2	1.5	0.1	0.6	0.1

[a]Excludes people that did not hunt during the season and deer taken with DMA permits.
[b]95% confidence limit.
[c]The season bag limit for antlered deer was two.

Table 9. Percentage of deer hunters harvesting at least one deer in Michigan by hunting season, 2004.[a]

Sex and Area	Archery Success	Archery 95% CL[b]	Regular Firearm Success	Regular Firearm 95% CL[b]	Muzzleloader Success	Muzzleloader 95% CL[b]	Early Antlerless Success	Early Antlerless 95% CL[b]	Late Antlerless Success	Late Antlerless 95% CL[b]	Youth Success	Youth 95% CL[b]	Early Antlerless in DMU 055 Success	Early Antlerless in DMU 055 95% CL[b]	All Seasons Success	All Seasons 95% CL[b]
Antlerless																
West UP	17.7	2.3	9.9	1.0	12.5	2.2	0.0	0.0	0.0	0.0	6.6	4.6	62.8	2.0	15.5	1.1
East UP	12.7	3.2	4.6	1.2	8.3	3.1	0.0	0.0	0.0	0.0	15.8	10.8	0.0	0.0	9.2	1.5
NE LP	10.0	1.3	10.1	0.8	8.9	1.7	29.5	6.2	26.8	6.8	13.4	3.9	0.0	0.0	14.7	0.9
NW LP	11.1	1.2	11.3	0.8	8.5	1.5	0.0	0.0	0.0	0.0	10.7	2.4	0.0	0.0	15.1	0.9
Sag. Bay	14.8	1.4	17.2	1.1	17.1	1.9	0.0	0.0	19.2	7.6	9.9	2.3	0.0	0.0	23.8	1.1
SW LP	14.4	1.4	19.7	1.2	14.0	1.6	0.0	0.0	28.4	3.7	10.1	2.6	0.0	0.0	26.2	1.2
SC LP	14.3	1.3	19.9	1.1	17.2	1.7	0.0	0.0	24.8	4.1	9.1	2.1	0.0	0.0	26.9	1.1
SE LP	14.4	1.7	14.1	1.6	11.5	2.1	0.0	0.0	31.9	8.3	6.9	3.1	0.0	0.0	20.9	1.5
UP	16.3	1.9	8.6	0.8	11.4	1.8	0.0	0.0	0.0	0.0	9.4	4.6	62.8	2.0	13.9	0.9
NLP	11.6	0.8	11.4	0.6	10.0	1.1	29.5	6.2	26.8	6.8	11.5	1.9	0.0	0.0	16.2	0.6
SLP	15.0	0.8	19.2	0.7	15.7	1.0	0.0	0.0	27.0	2.5	9.2	1.3	0.0	0.0	26.4	0.7
Statewide	15.3	0.6	15.6	0.4	14.0	0.7	28.6	6.0	27.0	2.4	10.0	1.0	62.6	1.9	23.0	0.5
Antlered Bucks																
West UP	11.9	1.9	23.6	1.4	5.9	1.6	0.0	0.0	0.0	0.0	14.9	6.7	0.0	0.0	24.9	1.3
East UP	10.7	3.0	17.4	2.1	7.5	2.9	0.0	0.0	0.0	0.0	18.4	11.4	0.0	0.0	19.1	2.1
NE LP	9.9	1.3	16.1	1.0	3.7	1.1	0.0	0.0	0.0	0.0	15.7	4.2	0.0	0.0	17.6	1.0
NW LP	14.4	1.3	16.0	1.0	3.1	0.9	0.0	0.0	0.0	0.0	21.5	3.2	0.0	0.0	19.5	1.0
Sag. Bay	18.4	1.5	21.3	1.2	4.5	1.0	0.0	0.0	0.0	0.0	24.6	3.3	0.0	0.0	26.0	1.2
SW LP	21.2	1.6	21.3	1.2	5.8	1.1	0.0	0.0	0.0	0.0	18.2	3.3	0.0	0.0	27.4	1.2
SC LP	24.2	1.5	23.9	1.2	4.9	1.0	0.0	0.0	0.0	0.0	26.9	3.3	0.0	0.0	30.6	1.2
SE LP	18.4	1.9	13.7	1.6	5.6	1.5	0.0	0.0	0.0	0.0	17.4	4.6	0.0	0.0	21.1	1.5
UP	11.6	1.6	22.1	1.2	6.4	1.4	0.0	0.0	0.0	0.0	16.1	5.9	0.0	0.0	23.7	1.1
NLP	12.9	0.9	16.5	0.7	3.3	0.7	0.0	0.0	0.0	0.0	20.3	2.3	0.0	0.0	19.8	0.7
SLP	22.5	0.9	22.4	0.7	5.5	0.6	0.0	0.0	0.0	0.0	23.1	1.9	0.0	0.0	29.8	0.7
Statewide	19.9	0.7	21.5	0.5	5.2	0.5	0.0	0.0	0.0	0.0	22.0	1.4	0.0	0.0	28.1	0.5

[a]Excludes people that did not hunt during the season and deer taken with DMA permits.
[b]95% confidence limit.

Table 9 (continued). Percentage of deer hunters harvesting at least one deer in Michigan by hunting season, 2004.[a]

Sex and Area	Archery		Regular Firearm		Muzzleloader		Early Antlerless		Late Antlerless		Youth		Early Antlerless in DMU 055		All Seasons	
	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]	Success	95% CL[b]
Sexes combined																
West UP	27.3	2.7	31.2	1.5	17.7	2.5	0.0	0.0	0.0	0.0	21.4	7.7	62.8	2.0	36.0	1.5
East UP	20.8	3.9	21.1	2.3	15.4	4.0	0.0	0.0	0.0	0.0	34.2	14.0	0.0	0.0	25.8	2.3
NE LP	18.4	1.6	24.6	1.2	12.3	1.9	29.5	6.2	26.8	6.8	29.1	5.2	0.0	0.0	28.7	1.1
NW LP	23.2	1.6	25.2	1.1	11.5	1.7	0.0	0.0	0.0	0.0	32.2	3.6	0.0	0.0	30.5	1.1
Sag. Bay	30.2	1.8	34.9	1.4	20.9	2.0	0.0	0.0	19.2	7.6	34.5	3.6	0.0	0.0	42.5	1.3
SW LP	32.0	1.8	35.9	1.4	18.9	1.9	0.0	0.0	28.4	3.7	28.3	3.9	0.0	0.0	44.3	1.4
SC LP	34.0	1.7	39.0	1.3	21.2	1.8	0.0	0.0	24.8	4.1	36.0	3.6	0.0	0.0	47.3	1.3
SE LP	29.4	2.2	26.1	2.0	16.6	2.5	0.0	0.0	31.9	8.3	24.3	5.2	0.0	0.0	36.4	1.8
UP	25.6	2.2	28.7	1.3	17.2	2.2	0.0	0.0	0.0	0.0	25.5	6.9	62.8	2.0	33.7	1.3
NLP	22.3	1.1	25.9	0.8	13.2	1.2	29.5	6.2	26.8	6.8	31.8	2.7	0.0	0.0	31.4	0.8
SLP	33.4	1.0	37.0	0.8	20.3	1.1	0.0	0.0	27.0	2.5	32.3	2.1	0.0	0.0	46.0	0.8
Statewide	31.3	0.8	33.5	0.5	18.5	0.8	28.6	6.0	27.0	2.4	32.0	1.6	62.6	1.9	42.6	0.5

[a]Excludes people that did not hunt during the season and deer taken with DMA permits.
[b]95% confidence limit.

Appendix A. Number of deer hunters, hunting effort, and deer harvested in Michigan during 2004, summarized by Deer Management Unit.

	Hunters[b,c]		Hunting effort (days)[b]		Deer harvested (all seasons combined)[a]					
					Antlerless		Antlered bucks		Sexes combined	
DMU[d]	No.	95% CL[e]	No.	95% CL	No.	95% CL	No.	95% CL	No.	95% CL
001	9,033	887	82,064	12,300	1,639	483	1,681	405	3,320	711
003	15,760	1,152	204,086	21,607	4,508	846	3,999	657	8,507	1,221
004	5,290	681	53,944	9,494	1,196	366	1,084	302	2,280	493
005	7,173	787	67,454	10,835	1,246	393	1,313	356	2,559	584
006	9,659	905	113,479	15,287	3,040	634	2,581	504	5,621	910
007	9,892	925	107,826	14,167	584	244	2,161	450	2,745	548
008	15,712	1,146	199,448	20,986	6,715	1,072	5,134	756	11,849	1,478
009	4,599	623	52,703	10,151	893	344	1,148	329	2,040	527
010	5,018	663	51,733	10,122	340	185	1,026	339	1,365	392
011	6,095	726	81,020	13,632	1,117	382	1,689	422	2,806	630
012	8,253	840	105,682	15,743	4,486	892	3,221	612	7,707	1,242
013	13,037	1,046	170,776	19,300	6,022	1,142	4,796	727	10,818	1,571
014	7,114	787	98,186	14,742	2,948	789	2,248	486	5,197	1,062
015	5,472	683	61,845	10,920	1,035	365	1,422	381	2,457	593
016	7,897	829	76,072	11,673	610	232	1,515	391	2,124	478
017	7,096	783	73,482	11,281	903	314	1,480	385	2,383	546
018	18,808	1,260	202,148	19,667	4,411	750	4,001	632	8,413	1,082
019	11,635	995	131,854	15,934	3,180	662	3,284	597	6,463	1,015
020	11,557	1,000	112,183	15,039	1,405	379	1,558	399	2,962	599
021	11,904	1,011	111,632	13,056	646	227	2,959	523	3,604	595
022	12,842	1,050	118,410	13,924	3,325	796	3,233	553	6,558	1,067
023	10,991	971	128,122	15,914	3,293	657	4,056	659	7,349	1,067
024	5,404	683	58,242	10,317	1,069	377	1,663	421	2,732	609
025	11,221	982	153,840	19,350	2,672	571	2,465	498	5,137	865
026	16,969	1,201	184,906	19,202	4,024	699	3,204	569	7,228	1,012
027	8,587	863	71,971	10,148	1,485	387	1,417	362	2,901	572
028	7,514	802	79,336	12,797	423	187	1,281	360	1,705	421
029	8,989	872	102,198	14,150	3,224	675	3,151	581	6,375	1,013
030	11,183	974	142,311	18,170	4,161	764	3,648	645	7,809	1,143
032	11,854	1,003	116,986	14,111	3,099	635	4,443	697	7,542	1,070
033	9,725	911	126,011	16,854	3,263	686	3,500	617	6,763	1,047
034	13,055	1,046	160,121	18,624	5,336	981	5,342	758	10,678	1,399

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.
[b]Column totals for hunting effort and harvest may not equal regional and statewide totals because of rounding errors.
[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one DMU.
[d]See Figure 2 for the locations of DMUs.
[e]95% confidence limit.

Appendix A (continued). Number of deer hunters, hunting effort, and deer harvested in Michigan during 2004, summarized by Deer Management Unit.

					Deer harvested (all seasons combined)[a]					
	Hunters[b,c]		Hunting effort (days)[b]		Antlerless		Antlered bucks		Sexes combined	
DMU[d]	No.	95% CL[e]	No.	95% CL	No.	95% CL	No.	95% CL	No.	95% CL
035	11,097	976	113,285	14,552	2,354	532	2,202	459	4,556	826
036	6,200	732	53,381	8,367	1,260	405	1,514	379	2,774	613
037	11,387	983	131,493	16,819	4,214	769	4,679	723	8,893	1,220
038	17,982	1,225	241,661	23,687	6,877	1,164	6,635	879	13,512	1,734
039	9,159	889	106,311	14,463	2,646	618	2,467	527	5,113	950
040	10,646	959	106,898	14,855	466	196	1,536	382	2,002	439
041	17,430	1,210	211,982	21,102	4,153	752	4,662	716	8,815	1,171
042	3,098	523	37,364	8,237	122	122	614	231	736	261
043	19,907	1,296	177,594	18,113	2,435	526	2,283	470	4,718	779
044	16,848	1,184	228,511	23,027	6,036	987	4,913	729	10,950	1,380
045	4,055	588	46,798	10,342	334	167	844	290	1,178	360
046	9,339	893	120,231	16,152	2,577	557	2,596	527	5,173	858
047	14,705	1,117	191,423	21,473	4,170	704	4,195	644	8,364	1,123
048	6,064	728	57,593	9,817	147	113	929	285	1,076	313
049	9,824	923	98,750	13,546	1,657	517	1,939	420	3,596	727
050	4,120	593	48,443	9,917	1,102	353	746	267	1,849	488
051	12,704	1,040	112,754	14,153	2,266	569	2,029	432	4,294	817
053	12,356	1,024	133,203	15,971	3,194	728	2,963	549	6,157	1,016
054	15,720	1,152	154,157	16,060	4,432	738	4,635	683	9,068	1,128
055	14,447	1,030	148,917	14,098	5,166	614	4,935	643	10,101	992
056	12,685	1,037	173,088	19,844	4,834	845	3,290	580	8,124	1,168
057	11,636	996	116,767	14,495	1,960	486	2,336	496	4,296	751
058	4,901	651	60,460	11,341	426	210	596	224	1,022	323
059	18,948	1,259	227,561	21,942	7,412	1,221	7,356	892	14,768	1,720
060	9,951	931	78,320	10,258	1,418	393	1,444	360	2,862	581
061	9,999	915	138,605	17,643	2,050	451	1,970	439	4,020	700
062	26,359	1,471	290,532	24,191	5,532	844	5,827	758	11,359	1,281
063	12,910	1,049	159,655	19,397	2,995	684	2,889	548	5,884	980
064	10,867	955	119,687	15,022	2,218	540	2,827	522	5,045	849
065	16,491	1,185	164,075	16,645	3,834	713	3,630	636	7,464	1,046
066	12,654	1,045	126,710	13,827	745	275	3,205	558	3,949	635
067	14,044	1,094	134,876	15,451	2,936	576	3,360	570	6,296	897

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.

[b]Column totals for hunting effort and harvest may not equal regional and statewide totals because of rounding errors.

[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one DMU.

[d]See Figure 2 for the locations of DMUs.

[e]95% confidence limit.

Appendix A (continued). Number of deer hunters, hunting effort, and deer harvested in Michigan during 2004, summarized by Deer Management Unit.

					Deer harvested (all seasons combined)[a]					
	Hunters[b,c]		Hunting effort (days)[b]		Antlerless		Antlered bucks		Sexes combined	
DMU[d]	No.	95% CL[e]	No.	95% CL	No.	95% CL	No.	95% CL	No.	95% CL
068	11,450	997	92,221	11,330	1,396	408	1,120	338	2,516	554
069	7,668	819	61,455	9,498	724	276	1,080	328	1,804	459
070	10,596	944	135,802	17,122	2,506	546	2,609	544	5,115	863
071	8,908	883	82,365	10,948	1,919	490	2,071	455	3,990	735
072	16,615	1,190	153,301	16,203	2,232	521	2,206	454	4,437	772
073	9,270	881	127,572	17,473	2,194	532	2,551	506	4,745	819
074	13,318	1,063	186,202	21,514	3,151	628	3,212	580	6,363	958
075	6,410	743	88,020	13,751	3,383	836	2,247	517	5,630	1,157
076	15,730	1,150	170,514	18,356	4,833	815	5,489	747	10,322	1,250
078	10,508	942	139,337	18,393	3,434	779	3,225	613	6,659	1,130
079	16,972	1,190	206,451	21,016	5,151	803	4,814	710	9,966	1,201
080	8,809	868	124,292	17,960	2,934	598	3,089	588	6,023	958
081	12,186	1,019	155,452	18,809	3,839	806	3,608	616	7,447	1,147
082	1,346	341	20,511	7,023	121	103	136	124	257	197
083	14,061	1,096	134,477	15,943	1,827	479	1,950	424	3,777	691
115	628	234	5,348	2,557	291	185	87	105	378	222
117	1,814	400	13,332	3,461	170	122	371	191	540	245
121	3,591	560	37,248	7,893	834	390	666	257	1,500	494
122	1,629	376	21,388	7,465	457	207	652	254	1,109	382
135	645	238	4,551	2,289	170	138	56	67	225	154
145	24	46	170	323	0	0	0	0	0	0
149	494	209	3,866	1,880	147	113	128	104	275	179
152	4,857	651	48,778	9,034	251	185	689	261	941	333
155	5,465	682	54,356	8,567	1,453	403	1,141	321	2,595	570
173	2,147	429	19,604	6,488	429	213	445	203	874	308
174	258	149	1,275	994	97	146	0	0	97	146
245	48	66	218	295	0	0	24	46	24	46
252	3,043	512	32,062	7,351	593	250	650	262	1,243	412
255	3,940	577	36,398	7,469	1,054	343	1,231	337	2,285	523
452	12,747	1,051	115,494	14,421	2,299	537	2,357	477	4,656	773

[a]Harvest estimates do not include deer taken with DMA permits. An additional 4,617 deer were taken with these permits.

[b]Column totals for hunting effort and harvest may not equal regional and statewide totals because of rounding errors.

[c]Number of hunters does not add up to statewide total because hunters can hunt in more than one DMU.

[d]See Figure 2 for the locations of DMUs.

[e]95% confidence limit.

Michigan DNR
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Wildlife Division Report No. 3426
September 2004

Printed by Authority of: P.A. 451 of 1994
Total Number of Copies Printed: 85
Cost per Copy: $2.94
Total Cost: $249.90
Michigan Department of Natural Resources

DEMOGRAPHICS, RECRUITMENT, AND RETENTION OF MICHIGAN HUNTERS

Brian J. Frawley

ABSTRACT

At least 868,000 people purchased Michigan hunting licenses each year during 2000-2002. Hunter numbers have increased slightly since the 1960s when an average of 858,000 people purchased licenses. Although the number of licensees has increased since the 1960s, the percentage of Michigan residents (included all ages) that have purchased a hunting license has declined from an average of 10.1% during the 1960s to 8.7% during 2000-2002. Currently, most hunters reside in the southern Lower Peninsula; however, a higher proportion of residents in the Upper Peninsula purchased hunting licenses. During 2000-2002, about 91% of the license buyers were males, but participation by females has increased since the 1980s. Hunting in Michigan has become increasingly focused on deer hunting; at least 91% of the hunting license buyers purchased a deer hunting license during 2000-2002. The proportion of residents that hunted deer has increased gradually in all regions of the state since the 1960s. The proportion of residents that hunted deer has increased for all age groups and sexes since the 1950s. About 80% of deer license buyers purchased a license during consecutive years, higher than for any other group of hunters. As deer hunting has gained popularity, small game hunting has declined. The proportion of males and females hunting small game in 2002 was among the lowest levels recorded since 1950. Deer hunters in 2002 were more specialized in their pursuit of deer than they were in 1970. In 2002, 62% of the deer hunters only purchased a deer hunting license, while 51% of deer hunters purchased only deer hunting licenses in 1968. In contrast, fewer small game hunters pursued only small game in 2002 than they did in 1968. In 1968, 45% of small game hunters only purchased a small game hunting license, while in 2002, 16% of these small game hunters only purchased a small game hunting license.

INTRODUCTION

Hunting has always been an integral part of modern wildlife conservation programs in North America. Moreover, hunting can be important for promoting stewardship of all natural resources, not just game species (Holsman 2000). Between 1991 and 2001, the number of people hunting in the United States declined 7% from 14.1 million to 13.0 million people (U.S. Department of the Interior 2002a, Aiken 2004). In Michigan, the number of hunters declined 9% from 826,300 to 754,000 during this same period (U.S. Department of the Interior 1993, 2002b). In addition, the proportion of Michigan residents over 16 years of age that hunted in Michigan declined from 11% in 1991 to 10% in 2001. This trend could impact natural resource agencies' ability to provide recreational, management, and stewardship benefits of wildlife conservation programs (e.g. Brown et al. 2000a).

A contribution of Federal Aid in Wildlife Restoration, Michigan Project W-147-R

IC2578-24 (09/24/2004)

Although trends from national surveys indicate that hunting participation may have declined, it was unknown whether similar trends could be documented using independent data collected by the Michigan Department of Natural Resources (DNR). Thus, the major study objectives were to determine demographics (age, sex, and residency), recruitment, and retention of Michigan hunters and compare to previous estimates. Special focus was given to summarizing data from 2000-2002 because data collected prior to that time had been summarized previously (Frawley 2001).

METHODS

Hunters included anybody that purchased a license to hunt or trap bear, deer, elk, furbearers, small game, turkey, or waterfowl in Michigan (Table 1). Most people hunting in Michigan were required to purchase a hunting license. Only owners of farmland and their families that hunted on the property where they lived could hunt small game species without a hunting license. Additionally, any landowner (or their designee) could take raccoons and coyotes throughout the year on their property without a license if these animals were causing damage. Waterfowl hunters were generally required to purchase both a small game hunting license and waterfowl hunting license. Hunters younger than 16 years of age could hunt waterfowl without a waterfowl hunting license; however, they still were required to purchase a small game license.

Michigan currently sells hunting licenses using a statewide automated license sales system (i.e. Retail Sales System). This system allowed the DNR to maintain a central database containing license sales information (e.g. sales transactions and customer profiles). From this database, the sex, birth date, and state and county of residence of each license buyer were determined.

Residency of hunters was categorized by areas within the state that closely matched the DNR's wildlife management administrative units (Figure 1). The state was also divided into three ecological regions (Upper Peninsula [UP], northern Lower Peninsula [NLP], and southern Lower Peninsula [SLP]). These regions closely matched major ecoregions (Albert 1995), except in the Upper Peninsula where two ecoregions were combined. Ecoregions are regions having similar soils, vegetation, climate, geology, and physiography. These ecoregions also matched regions used to report results from previous studies.

The DNR currently uses a random drawing to allocate a limited number of bear, elk, and turkey hunting licenses among applicants. An unlimited number of licenses were available for people hunting small game and hunting or trapping furbearers. An unlimited number of licenses were available for people hunting deer and waterfowl, although random drawings were also used to allocate certain types of deer licenses (e.g. antlerless licenses) and managed waterfowl area hunts among hunters.

The procedures used to award turkey hunting licenses to people that were successful in the drawing differed between 1997 and subsequent years. These differences affect how hunting license sales can be compared among years. In 1997, hunters paid an application fee and a license fee when they applied for a hunt. Hunters that were unsuccessful in the drawing were reimbursed their license fee, while hunters that were successful in the drawing were mailed their hunting license. Starting in 1998, hunters only paid an application fee when they applied for a hunt. People that were successful in the drawing were mailed notification that they were successful in the drawing, and it was their responsibility to purchase a hunting license. Successful applicants did not always purchase a license.

Hunters had to be at least 14 years old before they could purchase a firearm deer hunting license in Michigan. Before 1970, however, there was no minimum age required to hunt deer with archery equipment or to hunt small game species in Michigan (Ryel et al. 1970). Beginning in 1970, hunters had to be at least 12 years old before they could purchase either an archery deer hunting license or small game hunting license.

Starting in 1995, Michigan hunting licenses could be purchased through the Retail Sales System using one of four types of identification: Michigan Driver License, Michigan Identification Card, DNR Sportscard, or DNR Identification Card. Most hunting licenses were purchased using a driver license; however, younger people ($\leq$16 years old) often used a DNR Sportscard because they did not have a driver license.

Hunter retention was the number of people remaining in the hunter population over time and was determined by monitoring a person's license purchases among years. Hunter retention was not estimated for hunters less than 18 years old because these young hunters often use multiple forms of identification to purchase licenses (e.g. DNR Sportscard and driver license). Hunter retention was underestimated for people that use multiple forms of identification to purchase licenses because they can appear as different people buying a license rather than the same person.

Estimates of hunter demographics prior to 1995 were based on information collected from random samples of hunting license buyers. Thus, these estimates were subject to sampling errors (Cochran 1977). The Retail Sales System for selling hunting licenses has allowed the DNR to collect demographic information (sex, age, and residence) from nearly every license buyer. Thus, estimates derived for 1997-2002 were based on nearly complete counts (i.e. census) of hunting license buyers. Even with electronic licensing, a few license purchases were completed without collecting some demographic information. When summarizing data that included missing data, the distribution of hunter demographics among hunters with missing data was assumed to be the same as that for known hunters.

Many hunting participation studies estimate the number of people that actually hunted rather than people that purchased a license. Typically, 5-10% of the license buyers did not hunt. Thus, estimates from this study are not directly comparable to estimates based on actual participation. When calculating the percentage of Michigan residents that hunted, estimates of the population for Michigan were obtained from the U.S. Census Bureau and Michigan Department of Community Health.

RESULTS

At least 868,000 people purchased hunting licenses to hunt in Michigan each year during 2000-2002 (Table 2). Participation declined by 26,938 people (3%) between 2000 and 2002. Most hunters (≥96%) were residents of Michigan and most lived in the SLP (Tables 3-5).

About 92% of the license buyers were males and 8% were females (Table 6). The proportion of female hunters was highest among people buying elk, deer, and bear hunting licenses. A relatively small proportion (<3.5%) of the hunting licenses for furbearers, small game, and waterfowl were sold to females. The mean age of license buyers was 40 years (Table 7). On average, people buying small game and waterfowl licenses were the youngest hunters, while people buying elk and fall turkey hunting licenses were the oldest.

Of the Michigan population 16 years old and older, about 19% of the males and 2% of the females purchased a hunting license in 2000-2002 (Table 8). Hunting participation among Michigan residents younger than 65 years of age during 2000-2002, ranged from a low of 6% for 12-year old residents to a high of about 13% for residents that were in their late 30s or early 40s (Figure 2).

The most commonly hunted species in Michigan was deer. During 2000-2002, at least 91% of the hunting license buyers purchased a deer hunting license (Table 2). For Michigan residents (<65 years of age), deer hunting participation ranged from a low of 3% among 12-year old residents to a high of about 12% for residents that were in their late thirties to early forties (Figure 3). Among Michigan residents that were in their late twenties to their early fifties, hunting participation was greater than 10%.

Small game licenses were the next most commonly purchased licenses (Table 2). About 39% of the license buyers obtained a small game license during 2000-2002. Small game hunting participation for Michigan residents less than 65 years of age ranged from 3% among 18- to 20-year old residents to about 5% for residents that were in their early teens (13-14 years old) and among hunters in their late-thirties to early forties (Figure 4). Participation was generally greater than 4% among Michigan residents that were in their late twenties to their early fifties. Among female hunters, participation peaked when they were 12-14 years old.

About 12% of license buyers purchased a turkey hunting license during 2000-2002 (Table 2). The number of people hunting turkeys has been steadily increasing in recent years. The number of turkey licenses sold increased 11% during 2000-2002. For Michigan residents less than 65 years of age, turkey hunting participation ranged from 0.5% among 18- to 22-year old residents to nearly 2.5% among hunters in their mid-sixties (Figure 5). Participation was generally greater than 2% among Michigan residents that were in their late thirties to their mid-sixties.

About 7% of the licensees purchased a waterfowl hunting license during 2000-2002; however, the number of waterfowl hunting licenses sold declined 2% during this period (Table 2). Nearly 2% of the license buyers in 2000-2002 purchased a license for furbearers, but the number of licensees has increased by 12% during this period. Generally less than 1% of the license buyers purchased either bear or elk hunting licenses during 2000-2002 because these licenses were limited.

Deer hunters were the most specialized group of hunters; about 62% of deer hunters did not buy any other type of hunting license during 2000-2002 (Table 9). The next largest group of specialist was small game hunters; about 17% of small game hunters only purchased a small game license. Most people that purchased a license to hunt species other than deer had purchased more than one hunting license type. Most of the people purchasing multiple hunting license types (≥78%) had also purchased a deer hunting license (Tables 10-12).

Nearly 79% of the hunting license buyers (≥18 years old) purchased hunting licenses during consecutive years (Figures 6 and 7; Table 13). The license types that were allocated using random drawings (i.e. elk, bear, and turkey) had the lowest percentage of repeat license buyers. Nobody purchased an elk license during consecutive years because elk hunters were ineligible to obtain licenses in consecutive years. Among license types that were not restricted (i.e. deer, fur harvester, small game, and waterfowl), hunter retention rates were highest among people buying a deer hunting license (=80%) and about 66% among people buying other unrestricted hunting license types. Hunter retention rates were at least 21% higher among male than female license buyers.

About 69% of license buyers (≥18 years old) purchased hunting licenses each year during 2000-2002 (Figure 8, Table 14). Most males that purchased deer, fur harvesters, small game, or waterfowl hunting licenses in 2000 also purchased these licenses in both 2001 and 2002. Less than 50% of the males that purchased a bear, elk, or turkey hunting license in 2000 also purchased this same type of license each year during 2000-2002. (Hunter retention among bear, elk, and turkey hunters was artificially low because a limited number of licenses were available each year.) Most females (57%) buying licenses in 2000 did not consistently buy a hunting license each year during 2001 and 2002 (Table 14).

DISCUSSION

The number of people purchasing a hunting license has increased 3% from an average of 858,000 in the 1960s, to an average of about 885,000 during 2000-2002 (Figure 9). Although the number of licensees has increased since the 1960s, the percentage of Michigan residents (all ages included) that purchased a hunting license has declined from an average of 10.1% during the 1960s to 8.7% during the last three years.

The US Department of the Interior (2002b) reported 10% of Michigan residents at least 16 years of age had hunted in 2001. They also reported 18% of the males had hunted. These estimates were similar to the level of participation observed based on license sales data (Table 8).

The proportion of Michigan residents that hunted deer has increased gradually in all regions of Michigan since the 1960s. The number of people hunting during the regular firearm deer hunting season (November 15-30) has increased 52% between 1960 and 2002 (Figure 10). The average annual increase during this period has been 1.0% per year. These trends have also been reported nationwide as the number of deer hunters has reached record highs (U.S. Department of the Interior 2002a, Aiken 2004). Deer hunter numbers in Michigan have increased in response to increased deer numbers and expanded hunting opportunity. Nationwide, 79% of hunters pursued deer in 2001 (Aiken 2004). Deer hunting is more common in Michigan than reported nationwide; at least 91% of the Michigan licensees had purchased a deer hunting license during recent years (Table 2).

The proportion of Michigan residents hunting small game has declined 61% between 1960 and 2002 (Figure 10). The average annual decline during this period has been 2.2% per year. Declining numbers of small game hunters has also been noted nationally since the mid-1970s (Enck et al. 2000, U.S. Department of the Interior 2002a, Aiken 2004). The greatest declines among Michigan small game hunters occurred in the SLP where participation declined from 7.0% of the residents in 1964 to 2.5% in 2002. Hawn (1979) speculated that the declining ring-necked pheasant population was the primary reason for the declining small game hunter numbers in Michigan. Pheasants were most common in the SLP, which also was the region experiencing the greatest decline in small game hunters and the highest proportion of Michigan residents. Factors other than declining pheasant numbers were probably responsible for declining small game hunter numbers in Michigan because this decline has also occurred in areas where pheasants do not occur. Other factors may include increased urbanization of the human population, increased competition between hunting and other leisure activities, and loss of wildlife habitat (Brown et al. 2000b).

The number of people hunting turkeys during the spring has increased more than two fold between 1990 and 2002 (Figure 11). The average annual increase during this period has been 10% per year. Participation during the fall season has increased 72% between 1990 and 2002 (average annual increase = 4.6%). Turkey hunter numbers in Michigan have increased in response to increased turkey numbers and expanded hunting opportunity (Frawley 2003b). Increasing numbers of turkey hunters has also been noted nationally since the early 1990s (Aiken 2004).

The number of people hunting waterfowl has declined 19% during 1997-2002 (average annual decline = 4.1%, Figure 10). The number of trappers in 1960 was similar to the number in 2002, although during the interim years numbers have changed markedly (Figure 12). The number of people hunting bear has more than doubled during 1990-2002, and the average annual increase has been 9.8% during this period (Figure 13).

During 1960-2002, most of the deer and small game hunters resided in the SLP (Figure 14). The distribution of deer hunters among geographic regions has remained stable since the 1960s, but the distribution of small game hunters has shifted northward. Although most small game hunters still resided in the SLP in 2002, the proportion of hunters in the SLP has declined steadily since the 1960s (Figure 15).

The proportion of Michigan residents hunting deer and small game was highest among residents of the UP and lowest for residents of the SLP. Duda et al. (1995), Mankin et al. (1999), and U.S. Department of the Interior (2002a) noted that hunting participation was highest among people raised in rural areas. In 2002, 87% of Michigan residents lived in the SLP (U.S. Census Bureau, unpublished data). Thus, the higher rate of participation among Michigan residents in northern Michigan probably reflects their rural origins, although other factors such as greater access to public land in northern Michigan may also affect participation.

During 1960-2002, about 2-4% of deer and small game hunters were nonresidents (e.g. Jamsen 1967, Langenau et al. 1985). The proportion of nonresident hunters has been relatively constant since the 1960s (Figure 14). The U.S. Department of the Interior (2002b) reported that 6% of the state's hunters were nonresidents in 2001 (all types of hunting). This estimate may be flawed because information was collected from relatively few hunters which can lead to imprecise estimates.

As with male hunters, deer is the most frequently hunted species among female hunters (Henderson 2004). The proportion of female deer hunters in Michigan was about 6% during 1960-1980 (Figure 16). Since 1980, participation has generally increased, and during the last three years about 8% of deer hunters were females. Among small game hunters, females comprised about 2.5% of the hunters during 1960-1980. The proportion of small game hunters that were females has increased slightly since 1980. During the last three years, about 3.1% of the small game hunters were females.

Hunter retention rates were at least 20% higher among male than female license buyers. Female hunters also generally take fewer hunting trips, spend fewer days hunting, and spend less money hunting than male hunters (Responsive Management 2003b, Henderson 2004). In addition, female hunters generally have hunted for fewer years than male hunters.

As deer hunting has become more popular, it has attracted a wider variety of individuals. The proportion of residents that hunted deer has increased for all age groups and sexes since the 1950s (Figure 17). Among males, hunting participation has remained constant among 10-19 year-olds since 1970 but has declined for most other age classes in recent years. Participation generally began to decline among males when they were 45-54 years old. Bouchard and Lerg (1977) also reported that in 1975 deer hunting participation started to decline when hunters were about 45 years old. Although deer hunting participation started to decline among males in the 45-54 year-old age class, the decline has become less apparent since 1980. Moreover, deer hunting participation among these older males has remained near all-time highs since 1980. The mean age of deer hunters was 40 years in both 1984 and 1991 (Langenau et al. 1985, Winterstein 1992), while the mean age of deer hunters in 2002 was 41.

Among females, deer hunting participation has generally increased among the youngest and oldest age classes since 1960 (Figure 17). Participation among people aged 20-54 has been declining since 1981. As noted for males, deer hunting participation among females began to decline when they reached 45-54 years of age. Participation among older females (≥55 years old) has increased since 1970 and has remained near all-time highs, similar to the trend for males.

Deer hunters were generally devoted to their pastime. No other form of hunting had as high a percentage of people participating during consecutive years. During the 1960s, about 80% of the people that hunted deer with a firearm reported that they also hunted during the previous year (Ryel 1965a, 1966, 1968, 1969). This percentage increased to nearly 85% of the firearm deer hunters during the early 1980s (Ryel 1982). The increasing trend was consistent with the increased hunting by older hunters (≥55 years old) during this period.

Unlike deer hunting, the proportion of people hunting small game has declined since the 1950s and 1960s (Figure 18). Furthermore, the proportion of males and females hunting small game in 2002 was among the lowest levels recorded since 1950 for most age classes.

Deer hunters in 2002 were more specialized in their pursuit of deer than they were in 1970. Ryel et al. (1970) reported that 51% of deer hunters purchased only deer hunting licenses in 1968. In 2002, 62% of the deer hunters only purchased a deer hunting license. In contrast, fewer small game hunters pursued only small game in 2002 than they did in 1968. In 1968, 45% of small game hunters only purchased a small game hunting license, while in 2002, 16% of these small game hunters only purchased a small game hunting license.

MANAGEMENT IMPLICATIONS

Trends in hunter recruitment and retention reflect the demand for hunting opportunities. These trends also may indicate changes in the number of people supportive of some conservation programs and number of people available to help achieve wildlife management goals. For example, declining hunter numbers may make it more difficult to reduce populations of nuisance or overabundant wildlife species.

Most hunters are initiated into the sport of hunting before age 20 (Responsive Management 2003a). Since the 1980s, the percentage of youths hunting deer (10-19 years olds) has remained at about 6%, and the average age of deer hunters has been relatively constant. Thus, recruitment of youth deer hunters appears to be relatively steady; however, retention has generally declined in older age classes. The net effect has been fewer people purchasing deer hunting licenses since 1998.

As deer numbers have increased in Michigan, hunting has become the primary method used to manage deer populations exceeding desired levels. Moreover, hunting will likely remain the primary mechanism for controlling regional deer populations for the foreseeable future (Brown et al. 2000a). In 1960, about 700,000 deer were present throughout Michigan prior to the hunting seasons (Michigan Wildlife Division, unpublished data), and about 481,000 people purchased a license to hunt deer. In contrast, about 1,800,000 deer existed throughout Michigan in 2002, and about 788,000 people purchased a deer hunting license. Deer hunter numbers have not increased proportionally with deer numbers. Deer numbers increased by 2.5 times between 1960 and 2002, but hunter numbers increased by only 1.6 times. During this same period, wildlife agencies have placed increased emphasis on harvesting antlerless deer to control deer numbers (Brown et al. 2000a). In Michigan, the annual harvest of antlered deer has increased five-fold, while harvest of antlerless deer has increased eight-fold between 1960 and 2002. Although harvest of antlerless deer has increased, a limited number of license buyers are willing to harvest antlerless deer. In 2002, 52% of deer license buyers purchased at least one antlerless license (Frawley 2003a). Thus, controlling deer numbers with hunting has become more difficult and complex (e.g. additional seasons and harvest restrictions) despite increasing hunter numbers and liberalized harvests of antlerless deer (Brown et al. 2000a). In the face of declining deer hunters, controlling deer populations will become increasingly difficult.

In Michigan, deer hunting participation by older hunters has increased since the 1970s. Older hunters generally harvest fewer deer and spend fewer days hunting deer than younger hunters (Frawley 2004). Moreover, older hunters generally hunt during fewer seasons, tending to concentrate their hunting effort during the regular firearm season. Despite the increased participation by older hunters in Michigan, deer population goals may be harder to achieve if Michigan hunters are less willing to harvest deer, particularly antlerless deer.

Although the proportion of youth that hunted deer has been relatively consistent since the 1970s in Michigan, deer hunter recruitment and retention has not kept pace with increased deer numbers. Thus, hunting seasons designed to recruit new hunters of any age may be important to help increase deer harvest. Moreover, the Wildlife Division may need to consider additional strategies to increase harvest of antlerless deer (Brown et al. 2000a, Riley et al. 2003).

As small game hunter numbers have declined, fewer small game species have been harvested. Thus, many small game species have population surpluses that could be harvested if additional hunters participated. The Wildlife Division needs to promote opportunities that increase small game hunting participation.

ACKNOWLEDGEMENTS

I thank Michael Bailey, Cheryl Nelson-Fliearman, Valerie Frawley, Pat Lederle, Barb Lercel, Glen Matthews, William Moritz, Brent Rudolph, Greg Soulliere, and Al Stewart for reviewing a previous version of this report.

LITERATURE CITED

Aiken, R. 2004. Fishing and hunting 1991-2001: avid, casual, and intermediate participation trends. Report 2001-5. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification. General Technical Report NC-178. U.S. Department of Agriculture, Forest Service, North Central Forest Experimental Station, St. Paul, Minnesota, USA.

Bouchard, M.E. and J.M. Lerg. 1977. Sex and age parameters in the population dynamics of Michigan hunters. Wildlife Division Report 2796. Michigan Department of Natural Resources, Lansing, USA.

Brown, T.L., D.J. Decker, S.J. Riley, J.W. Enck, T.B. Lauber, P.D. Curtis, and G.F. Mattfeld. 2000a. The future of hunting as a mechanism to control white-tailed deer populations. Wildlife Society Bulletin 28:797-807.

Brown, T.L., D.J. Decker, W.F. Siemer, and J.W. Enck. 2000b. T rends in hunting participation and implications for management of game species. Pages 145-154 in W.C. Gartner and D.W. Lime, editors. Trends in outdoor recreation, leisure, CAB International, New York, New York, USA.

Cochran, W.G. 1977. Sampling techniques. John Wiley & Sons, New York, USA.

Duda, M.D., S.J. Bissell, and K.C. Young. 1995. Factors related to hunting and fishing participation in the United States. Responsive Management, Harrisonburg, Virginia, USA.

Enck, J.W., D.J. Decker, and T.L. Brown. 2000. Status of hunter recruitment and retention in the United States. Wildlife Society Bulletin 28:817-824.

Frawley, B.J. 2001. Demographics, recruitment, and retention of Michigan hunters. Wildlife Division Report 3332. Michigan Department of Natural Resources, Lansing, USA.

Frawley, B.J. 2003a. Michigan deer harvest survey report, 2002 seasons. Wildlife Division Report 3399. Michigan Department of Natural Resources, Lansing, USA.

Frawley, B.J. 2003b. 2003 Michigan spring turkey hunter survey. Wildlife Division Report 3412. Michigan Department of Natural Resources, Lansing, USA.

Frawley, B.J. 2004. Changes in deer hunting participation and harvest related to hunter's age. Report 3424. Michigan Department of Natural Resources, Lansing, USA.

Hawn, L.J. 1979. Hunting results, Michigan small game seasons, 1978. Surveys and Statistical Services Report 189. Michigan Department of Natural Resources, Lansing, USA.

Henderson, E. 2004. Participation and expenditure patterns of African-American, Hispanic, and female hunters and anglers. Report 2001-4. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Holsman, R.H. 2000. Goodwill hunting? Exploring the role of hunters as ecosystem stewards. Wildlife Society Bulletin 28:808-816.

Jamsen, G.C. 1967. Sex and age structure of licensed hunters, trappers and fishermen in Michigan. Research and Development Report 125. Michigan Department of Conservation, Lansing, USA.

Langenau, E.E., E.J. Flegler, and H.R. Hill. 1985. Deer hunters' opinion survey, 1984. Wildlife Division Report 3012. Michigan Department of Natural Resources, Lansing, USA.

Mankin, P.C., R.E. Warner, and W.L. Anderson. 1999. Wildlife and the Illinois public: a benchmark study of attitudes and perceptions. Wildlife Society Bulletin 27:465-472.

Minnis, D.L. and R.B. Peyton. 1994. 1993 Michigan deer hunter survey: deer baiting. Federal Aid Job Performance Report W-127-R-12, Study 127-82, Job Number 2, Michigan Department of Natural Resources, Lansing, USA.

Responsive Management. 2003a. Factors related to hunting and fishing participation among the nation's youth; phase V: final report. Report prepared under a grant from the U.S. Fish and Wildlife Service, Division of Federal Aid, Sport Fish Restoration Program. Harrisonburg, Virginia Winterstein, S. R. 1992. Michigan hunter opinion surveys. Department of Fisheries and Wildlife, Michigan State University, Lansing, USA.

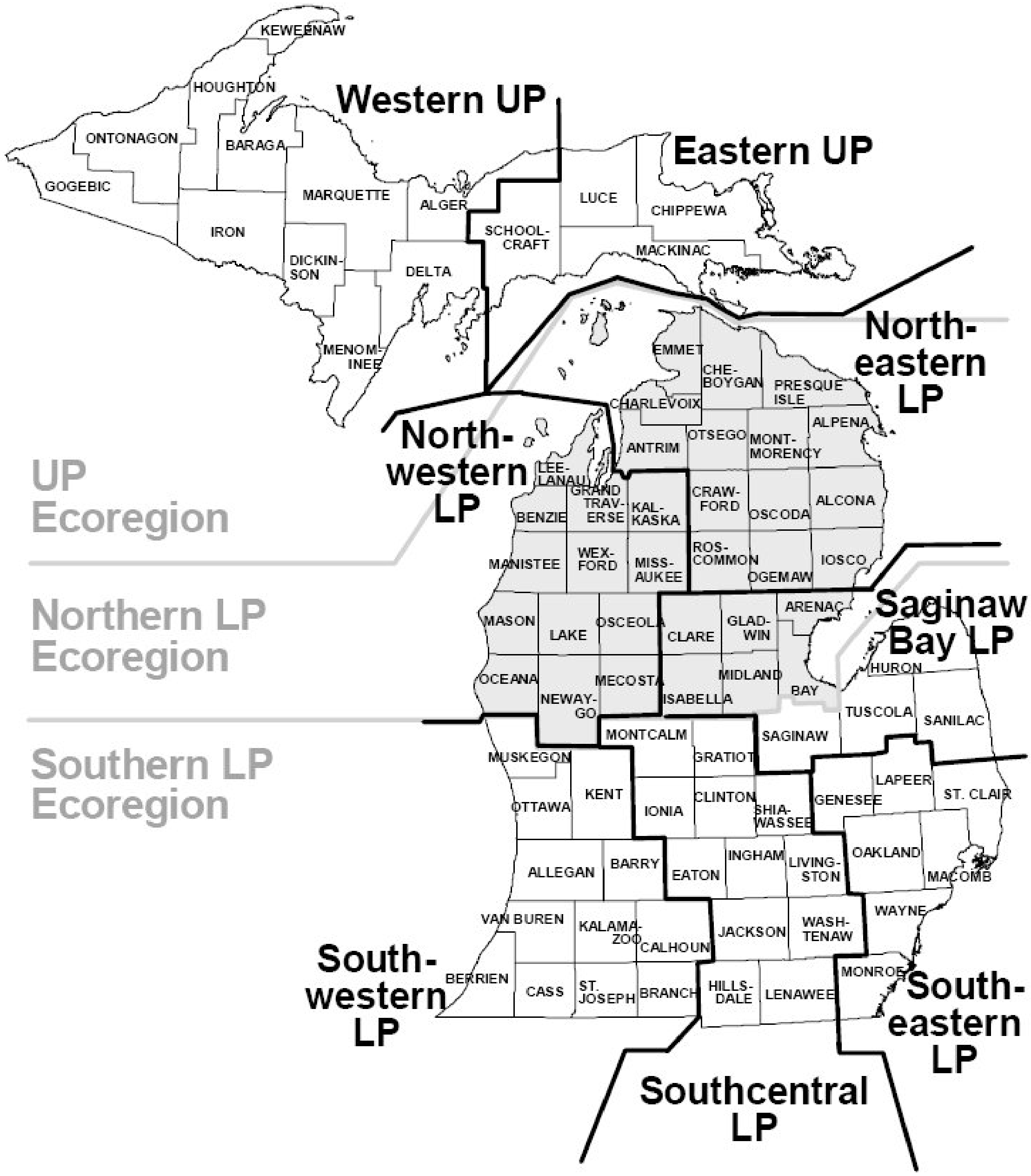


Figure 1. Areas used to summarize regional estimates of hunter demographics in Michigan.

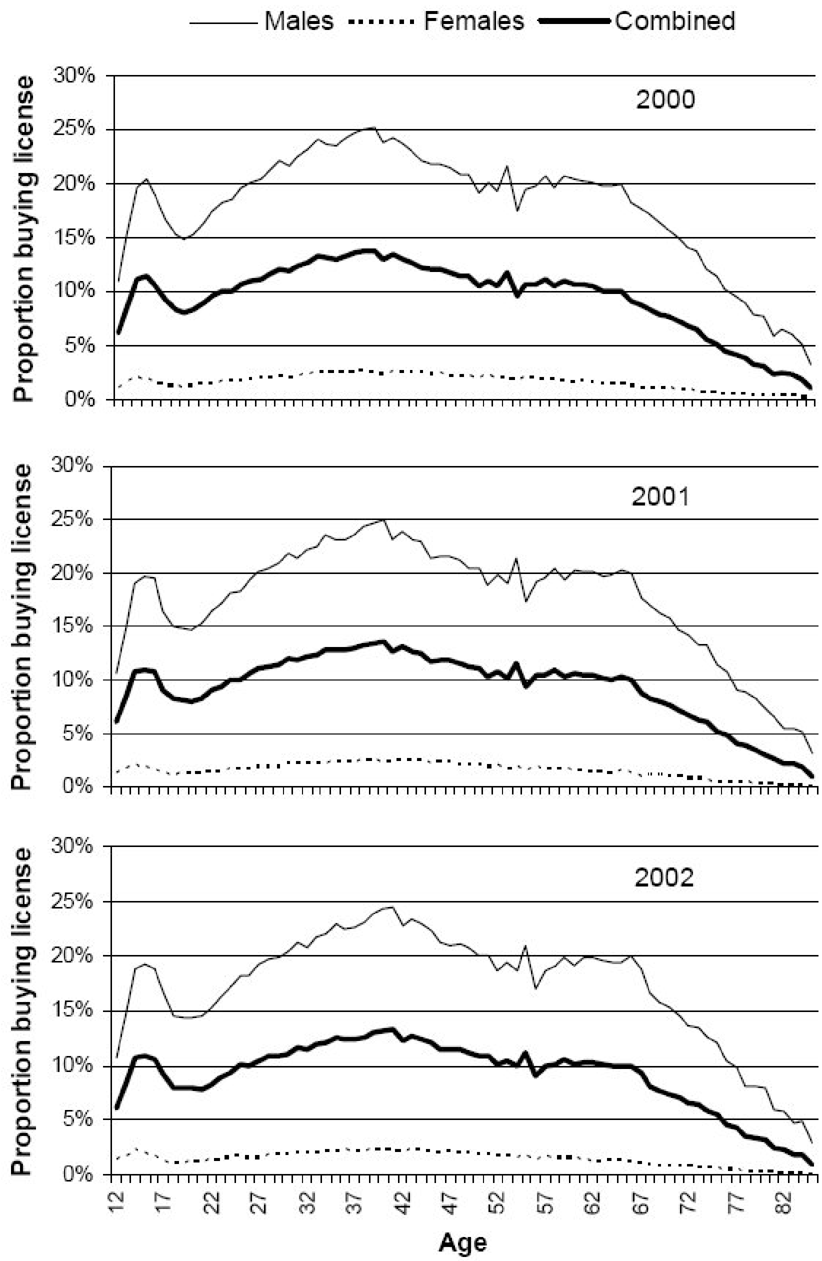


Figure 2. Proportion of Michigan residents that purchased Michigan hunting licenses (all hunting license types) by age, 2000-2002.

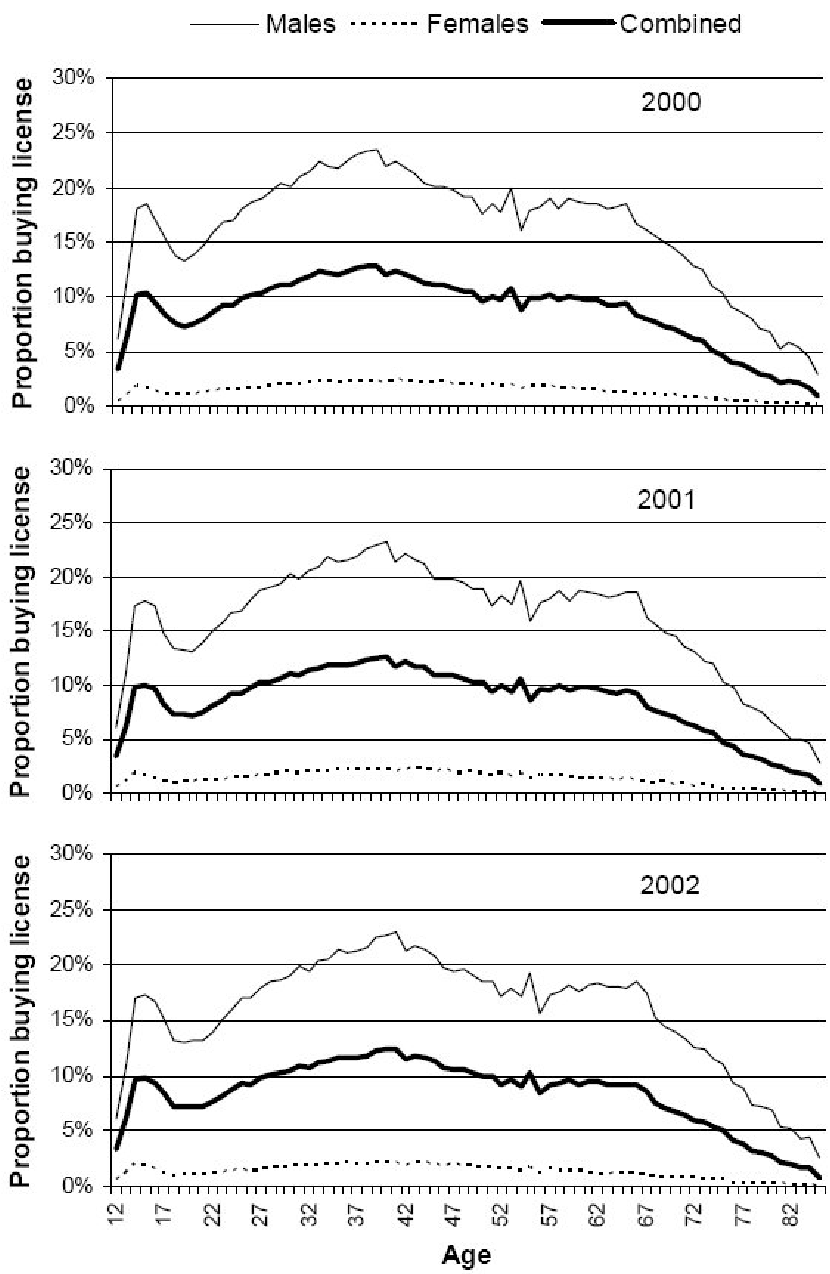


Figure 3. Proportion of Michigan residents that purchased Michigan deer hunting licenses by age, 2000-2002.

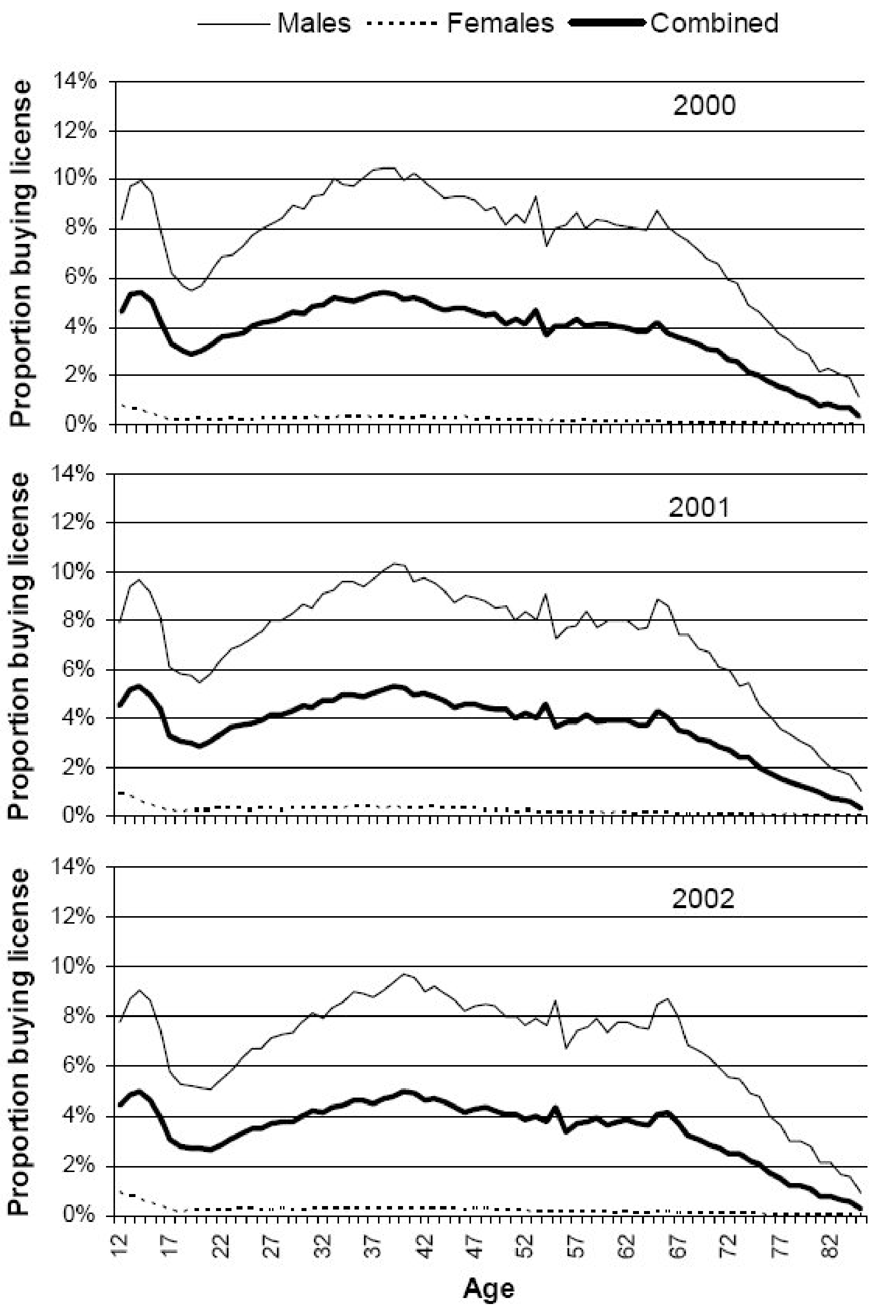


Figure 4. Proportion of Michigan residents that purchased Michigan small game hunting licenses by age, 2000-2002.

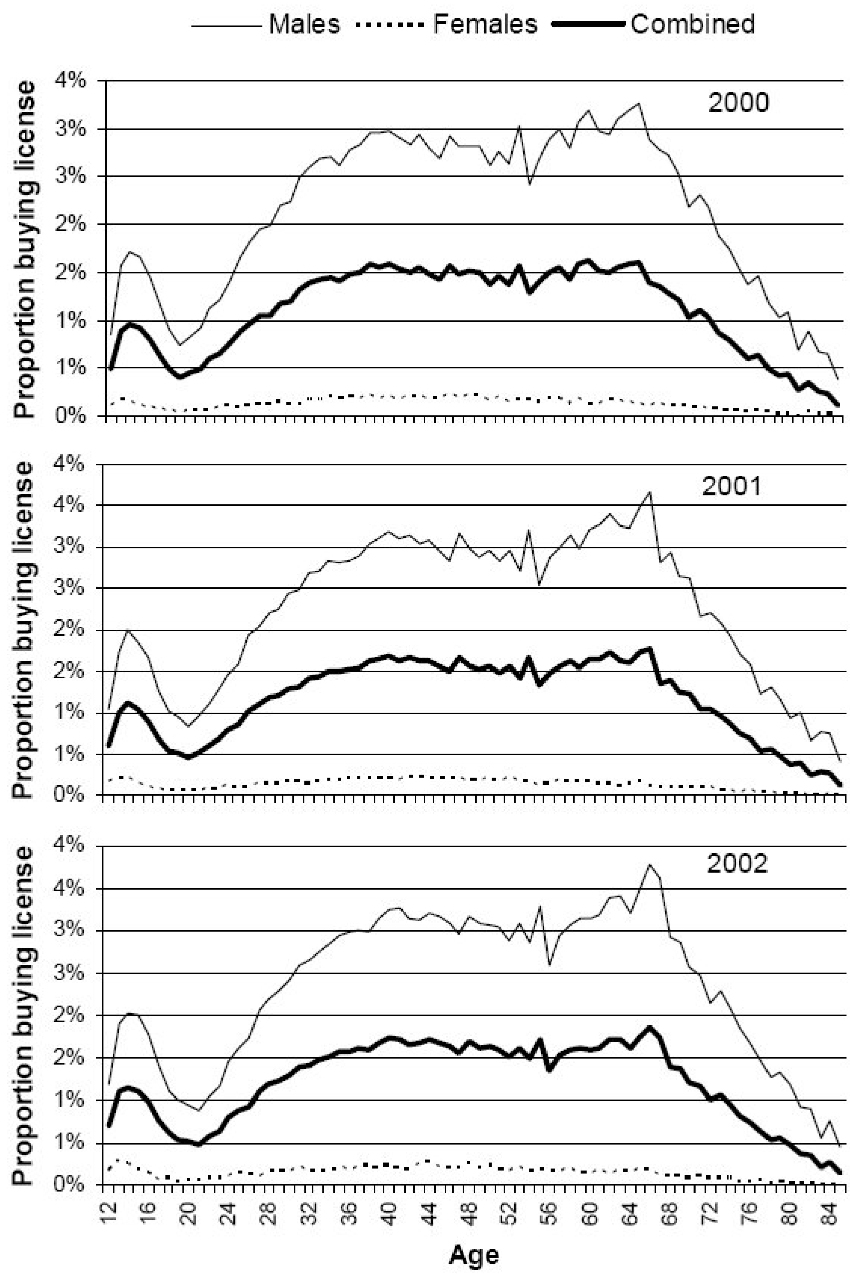


Figure 5. Proportion of Michigan residents that purchased Michigan turkey hunting licenses by age, 2000-2002.

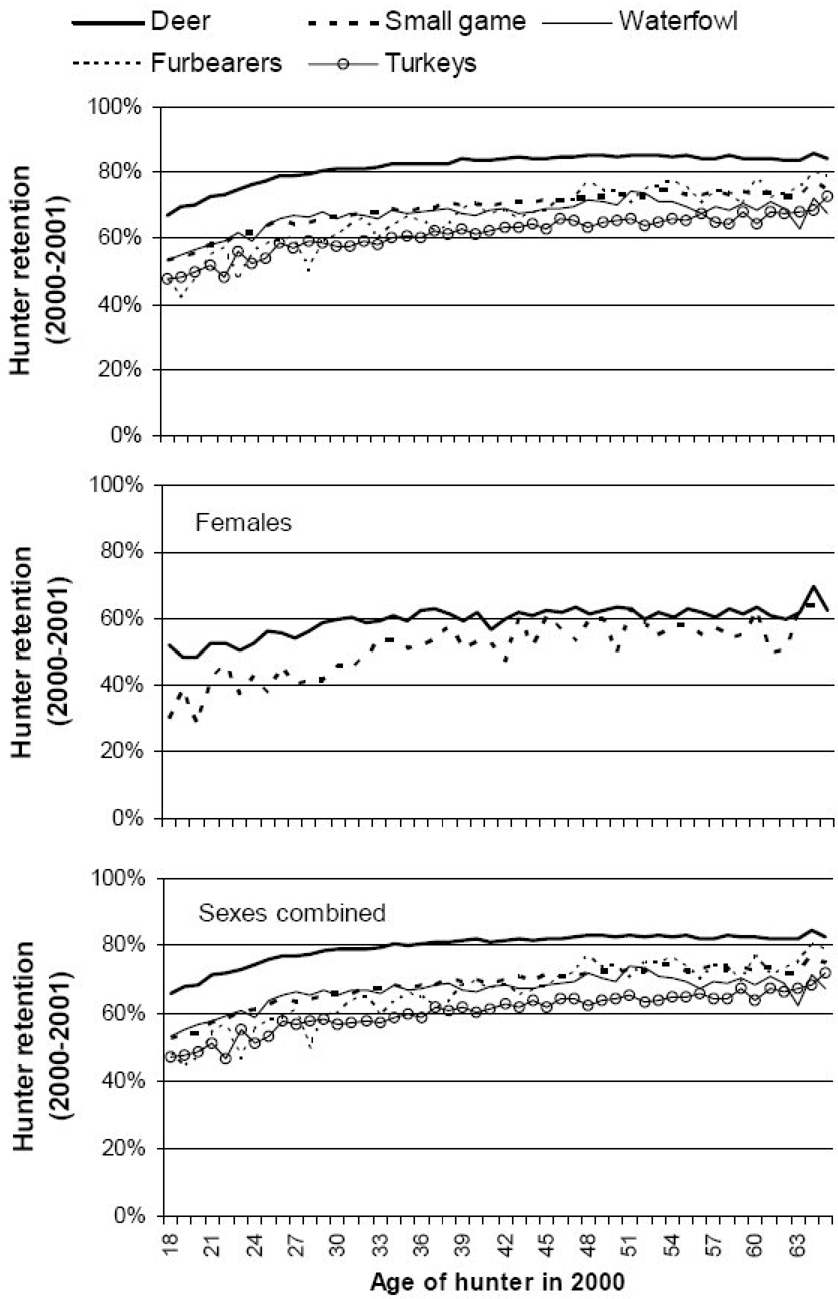


Figure 6. Proportion of hunters that purchased hunting licenses during both 2000 and 2001 in Michigan by age. Hunter retention was not plotted for females hunting waterfowl, furbearers, and turkeys because too few females purchased these license types to produce a smooth plot.

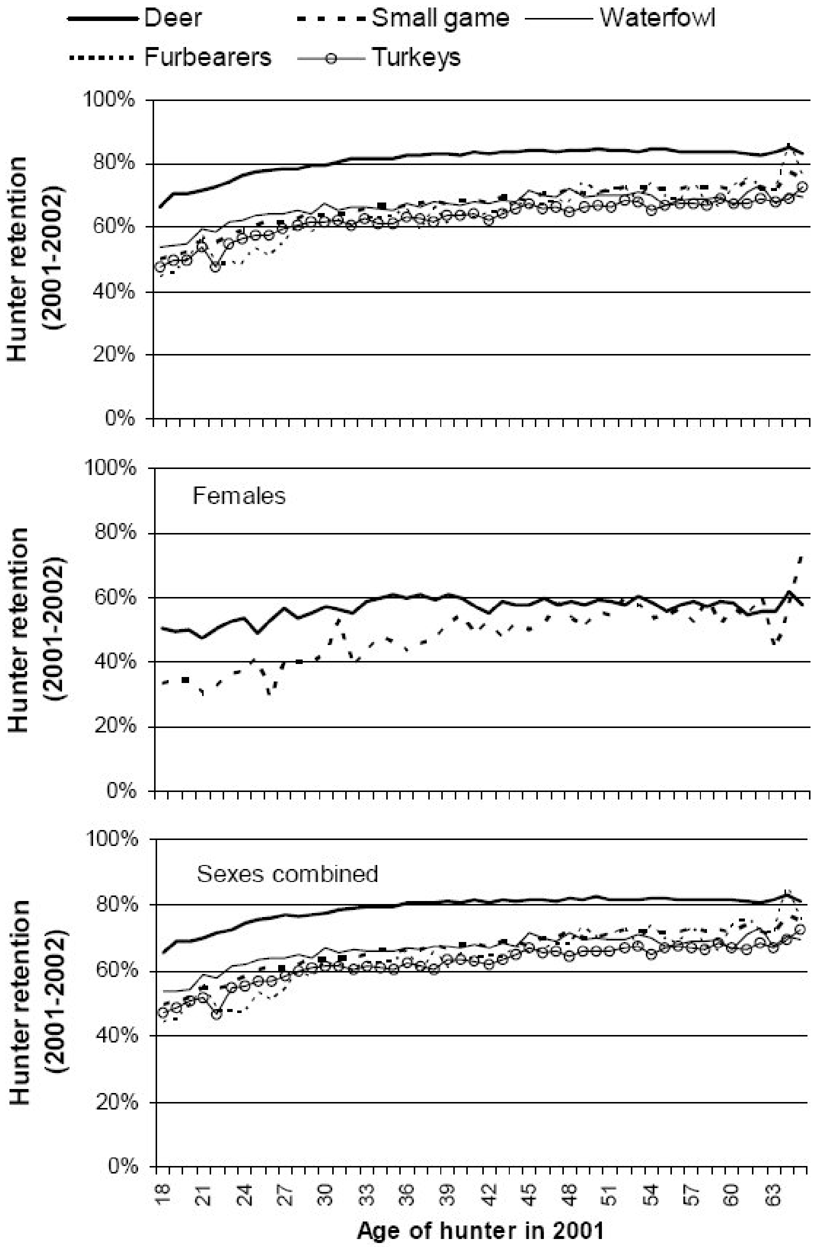


Figure 7. Proportion of hunters that purchased hunting licenses during both 2001 and 2002 in Michigan by age. Hunter retention was not plotted for females hunting waterfowl, furbearers, and turkeys because too few females purchased these license types to produce a smooth plot.

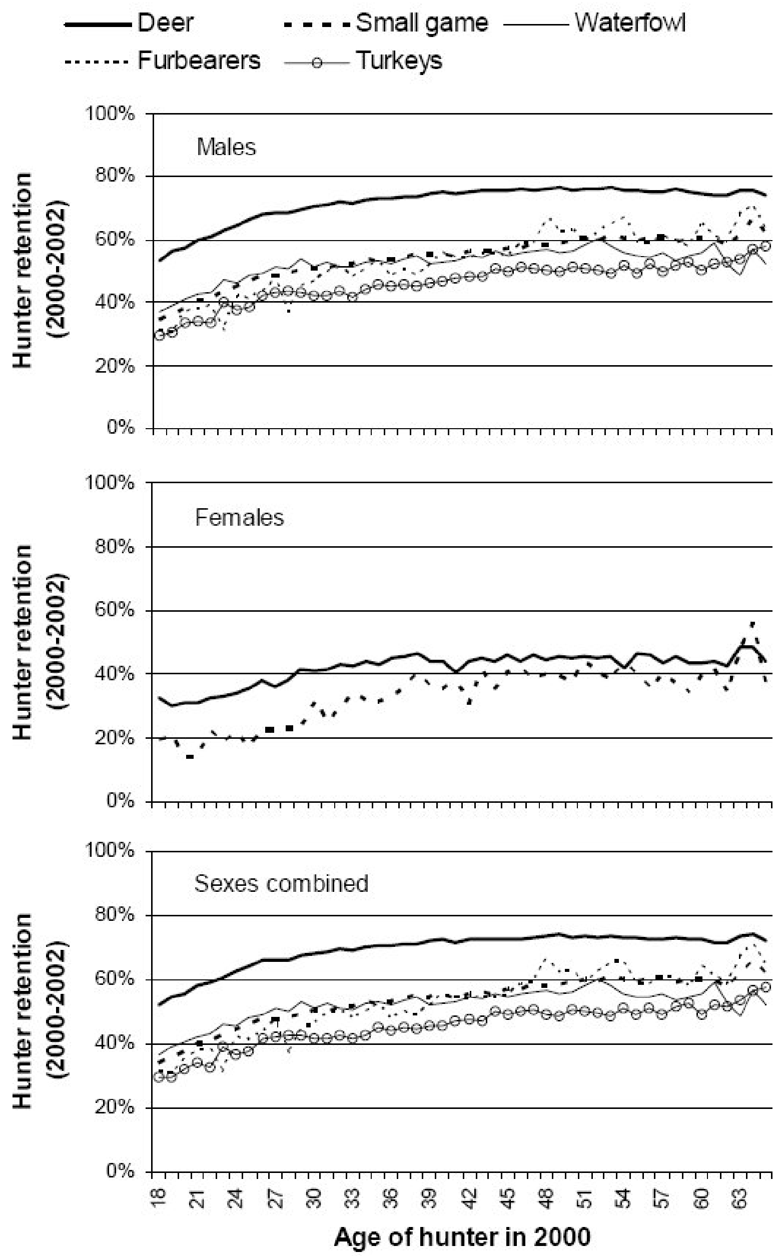


Figure 8. Proportion of hunters that purchased hunting licenses during three consecutive years (2000-2002) in Michigan by age. Hunter retention was not plotted for females hunting waterfowl, furbearers, and turkeys because too few females purchased these license types to produce a smooth plot.

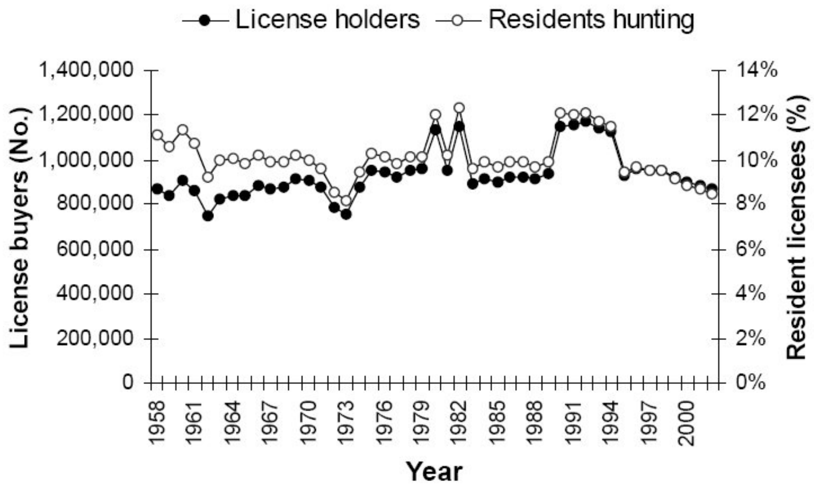


Figure 9. Number of people (both residents and nonresidents) that purchased a Michigan hunting license and proportion of Michigan residents that purchased a hunting license during 1958-2002. A person was counted only once regardless of the number of licenses purchased. It was assumed that 2% of the hunters purchasing a license were nonresidents when calculating participation by Michigan residents.

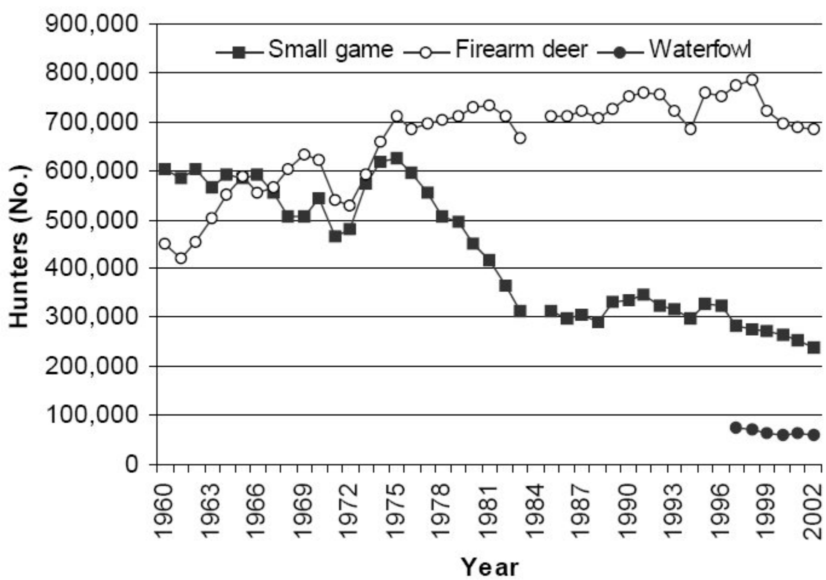


Figure 10. Number of active hunters (i.e. people that went afield) that hunted deer during the regular firearm season (November 15-31), small game, and waterfowl, 1960-2002. Estimates were not available for years when values were not plotted.

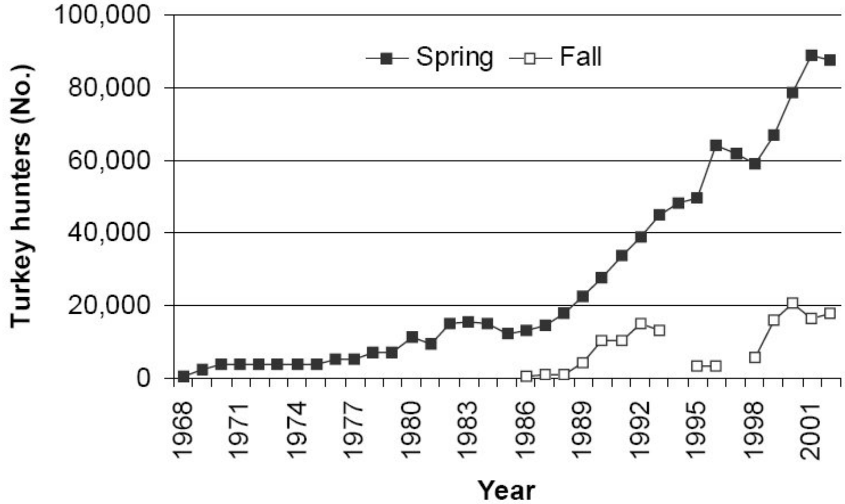


Figure 11. Number of active turkey hunters (i.e. people that went afield) participating in the spring and fall seasons, 1968-2002. No hunting occurred in years when values were not plotted.

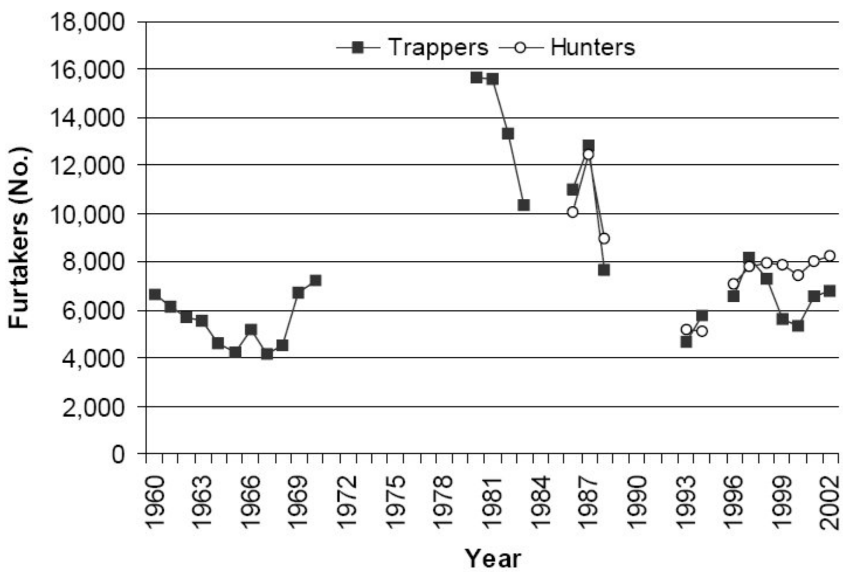


Figure 12. Number of active furtakers (i.e. people that went afield) that trapped or hunted furbearers during 1960-2002. Estimates were not available for years when values were not plotted.

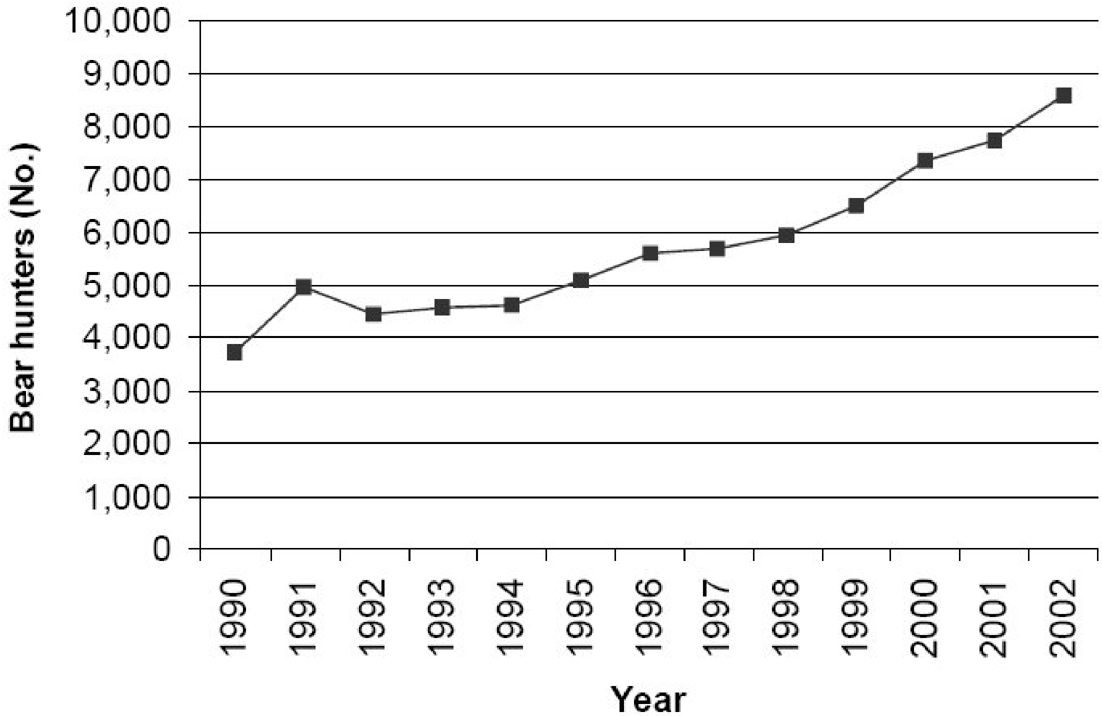


Figure 13. Number of active bear hunters (i.e. people that went afield) during 1990-2002.

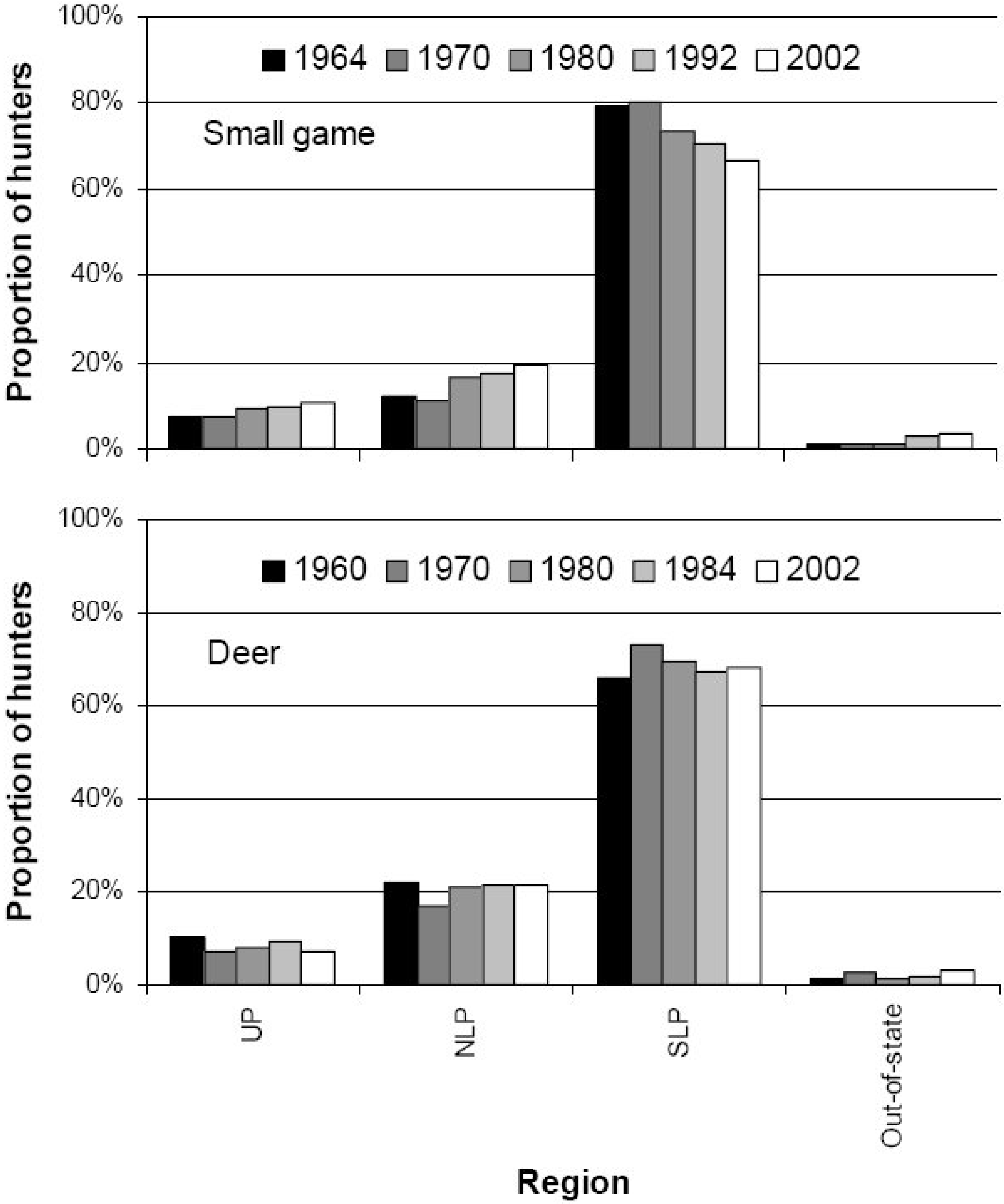


Figure 14. The residency of people that purchased small game and deer hunting licenses in Michigan, 1960-2002 (Ryel 1965b, Langenau et al. 1985, unpubl. Data). Data were not available for the same years for small game and deer hunters.

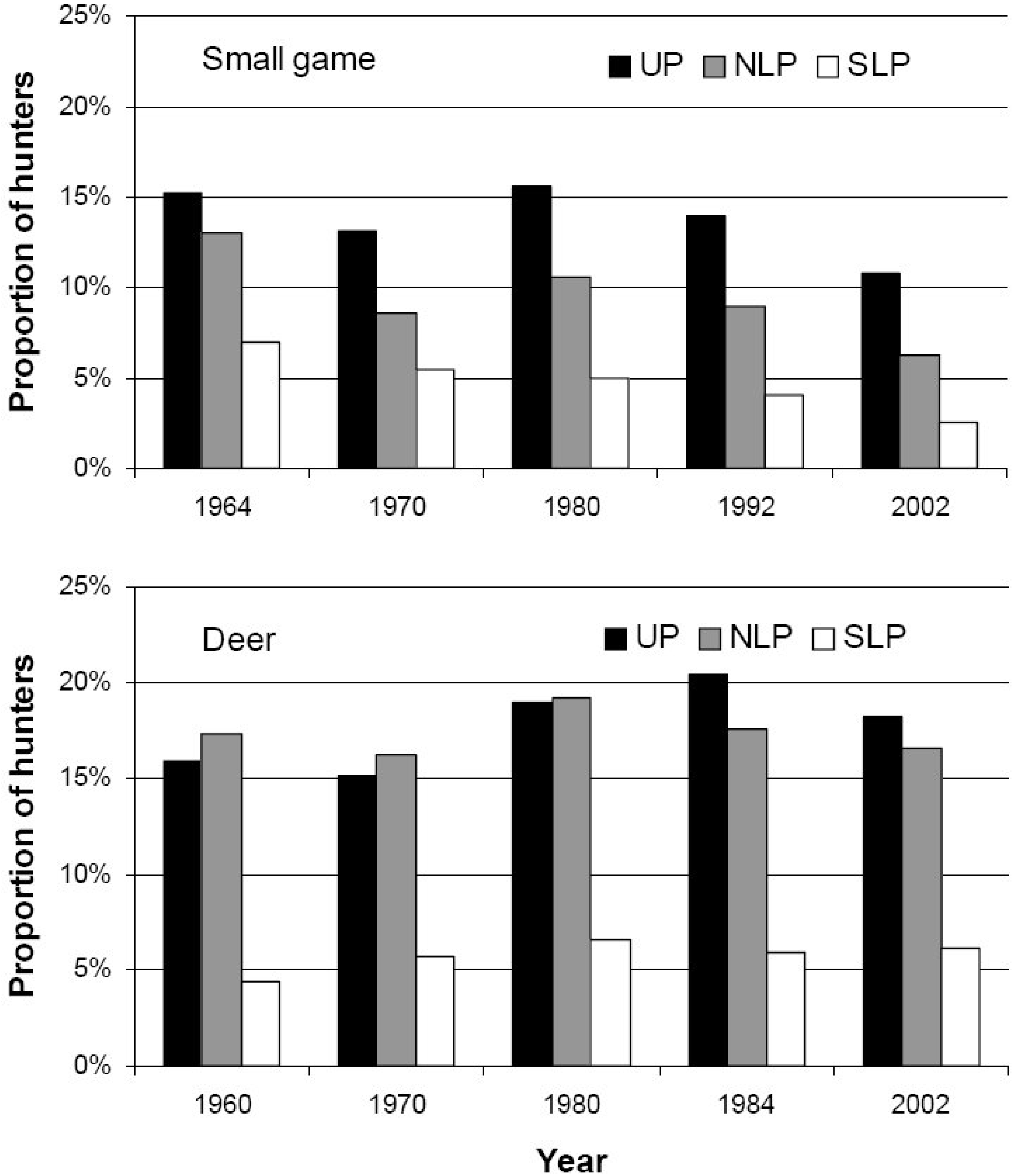


Figure 15. Proportion of Michigan residents that purchased a small game and deer hunting license in Michigan by area of residence, 1960-2002 ((Ryel 1965b, Langenau et al. 1985, unpubl. Data). Data were not available for the same years for small game and deer hunters.

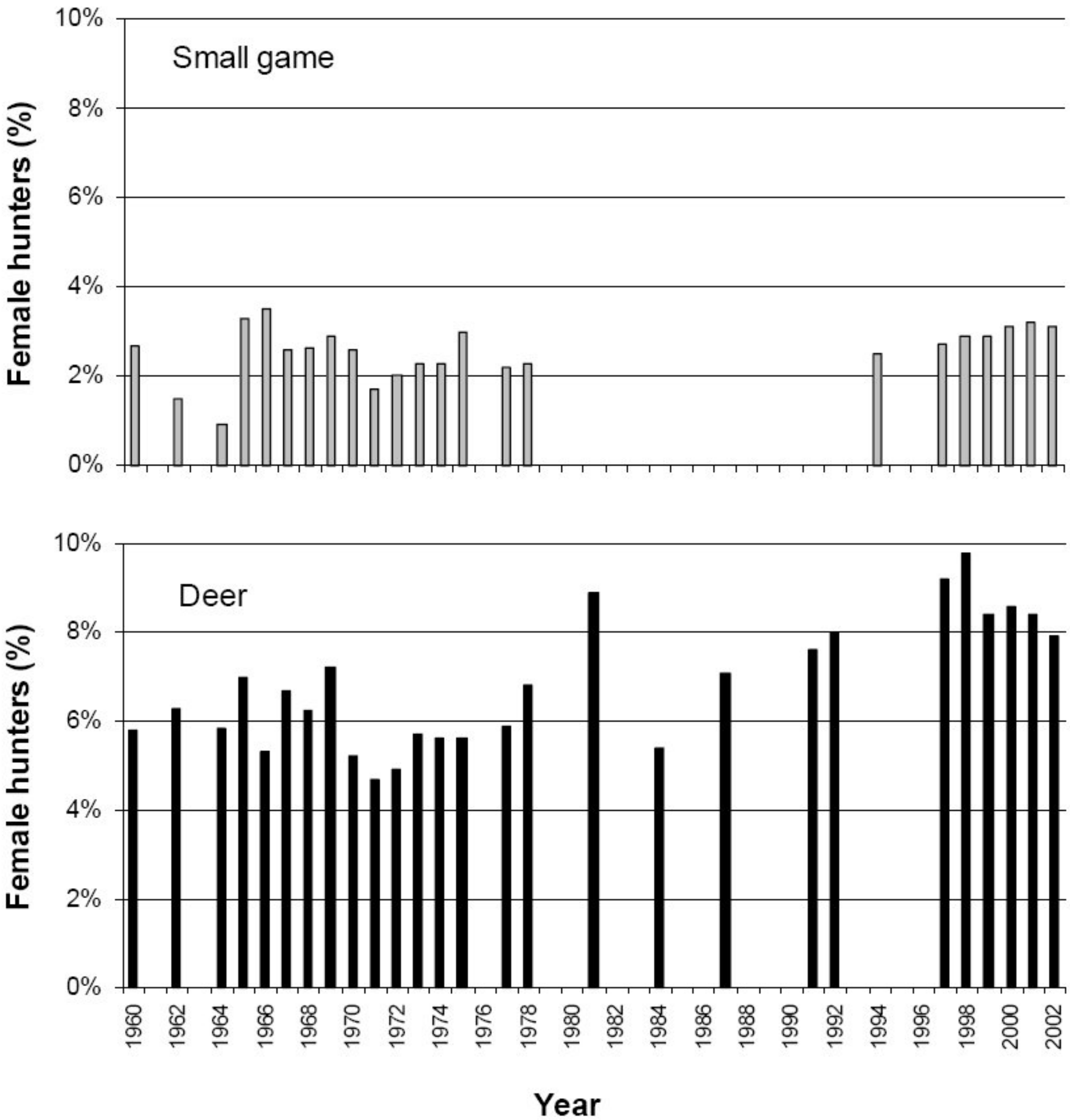


Figure 16. Proportion of female small game and deer license buyers in Michigan, 1960-2002 (Jamsen 19687, Ryel et al. 1970, Langenau et al. 1985, Winterstein 1992, Minnis and Peyton 1994, unpubl. Data).

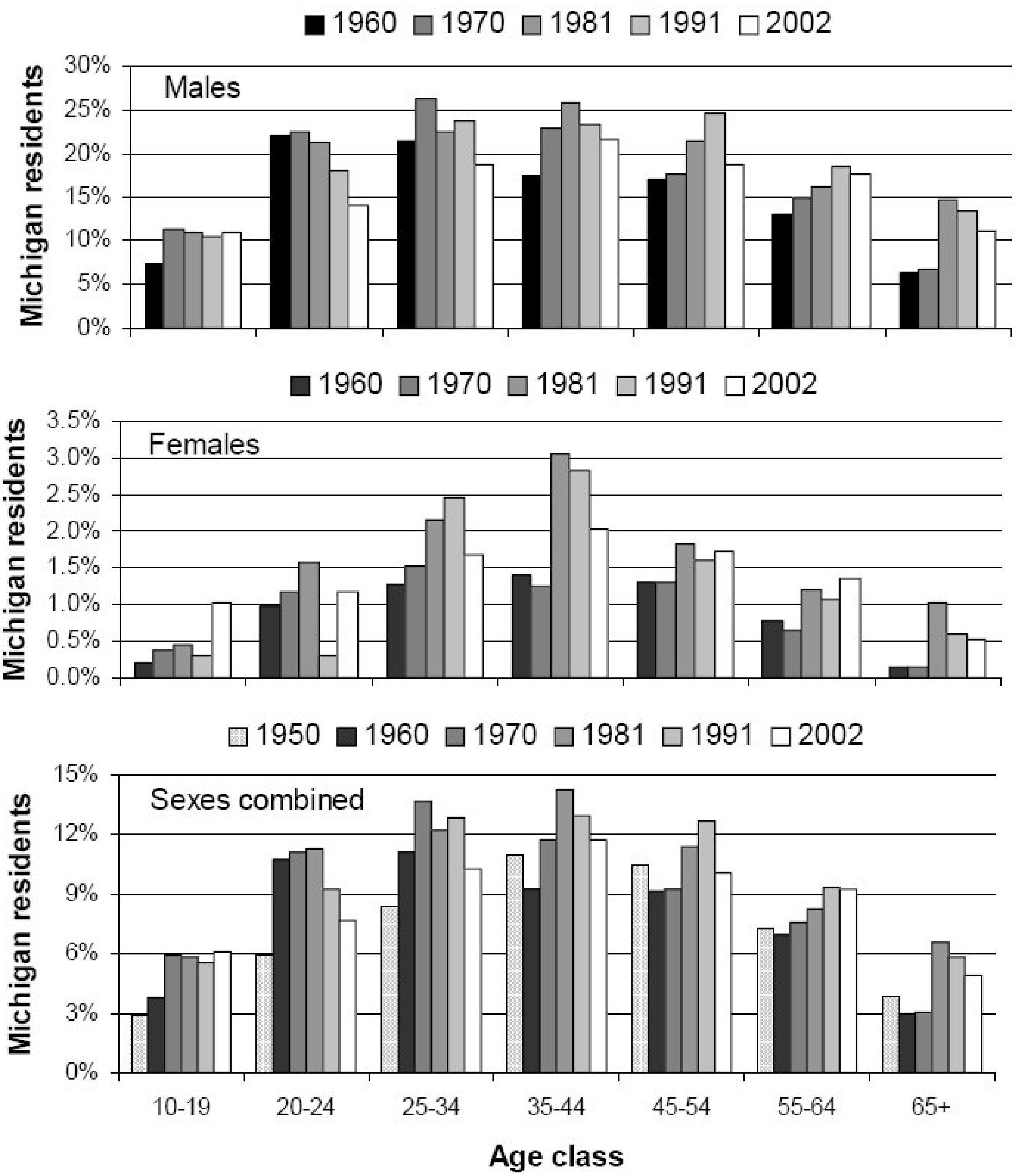


Figure 17. Proportion of Michigan residents that hunted deer by sexes and age, 1950-2002 (Ryel et al. 1970, Winterstein 1992, unpubl. data). Data were available in 1950 for the sexes combined but not for the sexes separately.

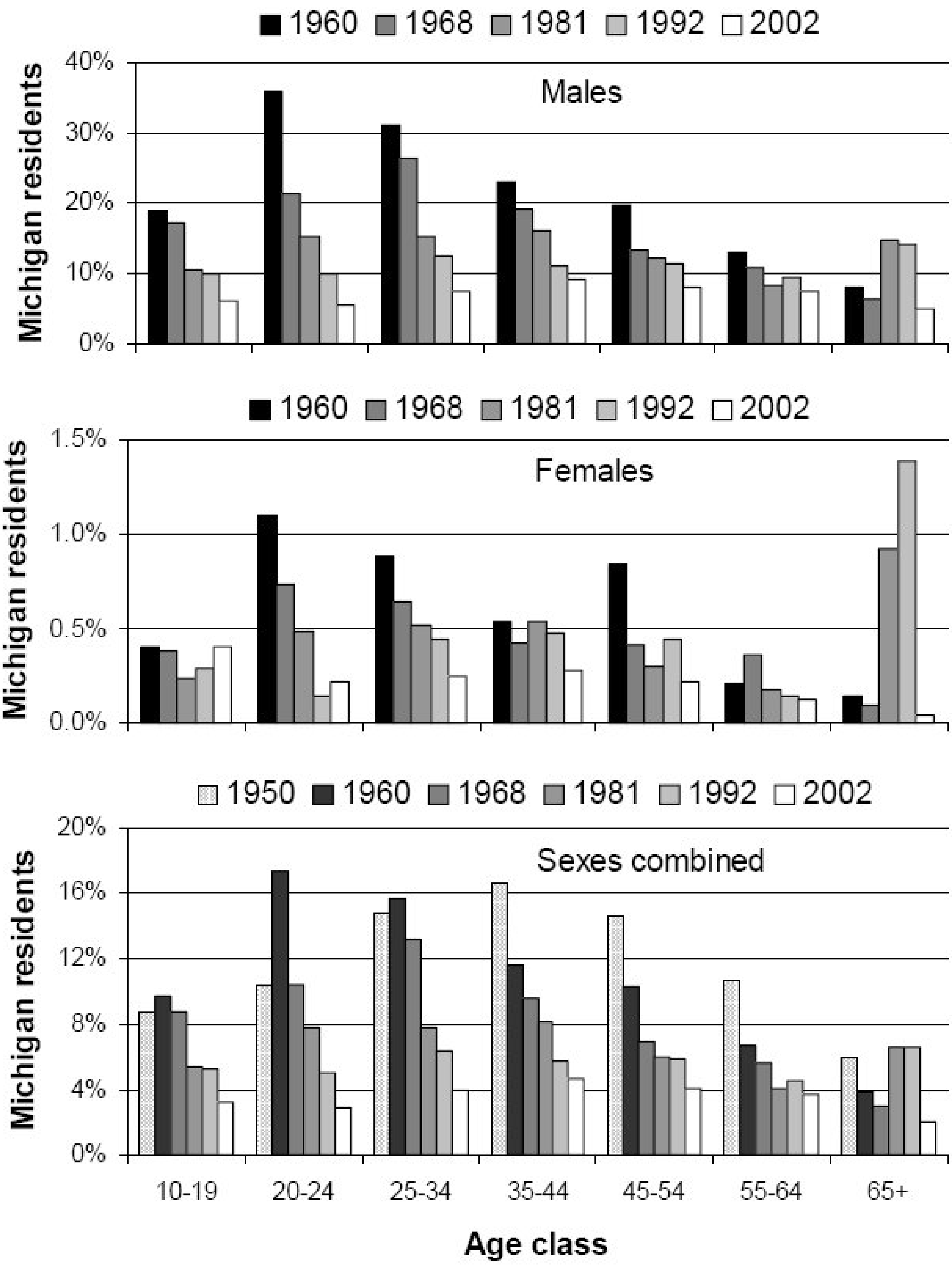


Figure 18. Proportion of Michigan residents that hunted small game by sexes and age, 1950-2002 (Ryel et al. 1970, unpubl. data). Data were available in 1950 for the sexes combined but not for the sexes separately.

Table 1. Hunting licenses that were available to hunt game animals in Michigan, 2000-2002.

Species	Hunting license types	Species that can be taken
Bear	Resident, Senior, Nonresident, and Lifetime bear hunting licenses	Black bear
Deer	Resident, Senior, Junior, and Nonresident Combination; Resident, Senior, and Nonresident Firearm; Resident, Senior, Junior, and Nonresident Archery; Early, Harsens, Shiawassee, Resident, Junior, and Nonresident Antlerless; and Military hunting licenses	White-tailed deer
Elk	Elk Hunting License	Elk
Furbearers[a]	Resident, Senior, Junior, and Nonresident fur harvester licenses; Resident, Junior, and Nonresident trapping only; and Military Fur Harvester licenses	Badger, beaver, bobcat, coyote, fisher, fox, mink, muskrat, opossum, otter, raccoon, skunk, or weasels
Small game[a,b,c]	Resident, Senior, Junior, Nonresident, 3-day Nonresident, and Military small game hunting licenses	Coyote, American crow, snowshoe hare, ring-necked pheasant, cottontail rabbit, ruffed grouse, squirrels, skunk, waterfowl, or American woodcock
Turkey	Resident, Senior, and Nonresident spring turkey hunting licenses; and Resident, Senior, and Nonresident fall turkey hunting licenses	Wild turkey
Waterfowl[d]	Waterfowl Hunting and Military Waterfowl licenses	Ducks or geese

[a] Landowners (or their designee) could take raccoons and coyotes throughout the year on their property without a license if these animals were causing damage.

[b] Landowners and their families that hunted on property where they live could hunt small game without a hunting license.

[c] Only residents could hunt coyotes with a small game license. Nonresidents were required to purchase a Fur Harvesters License to hunt coyotes.

[d] Waterfowl hunters were normally required to purchase both a small game license and a waterfowl hunting license. Hunters 12-15 years of age could legally hunt waterfowl without a waterfowl hunting license; however, they were required to purchase a small game license.

Table 2. Number of people that purchased a Michigan hunting license during 2000-2002.[a]

Hunting license type	Year 2000	Year 2001	Year 2002
Bear[b]	7,900	8,262	9,107
Deer	810,864	800,872	788,180
Elk[b]	365	247	142
Fur harvester	17,346	18,871	19,386
Small game	354,858	347,314	327,279
Turkey[b]	96,484	103,386	107,316
Spring turkey	84,355	95,595	98,286
Fall turkey	25,507	19,348	21,952
Waterfowl	66,110	65,961	64,582
All types[c]	895,853	884,859	868,915

[a]Within each license type, a person is counted only once regardless of the number of licenses purchased.
[b]A restricted number of licenses were available, and these licenses were distributed using a random drawing.
[c]Total for all types does not equal sum of all license types because people can purchase multiple license types.

Table 3. Residency of people (%) that purchased Michigan hunting licenses in 2000.

Area[a]	Bear	Deer	Elk	Fur harvester	Small game	Turkey	Spring turkey	Fall turkey	Waterfowl	All types
	License type									
DNR Administrative Units										
West Upper Peninsula	21.1	6.0	1.9	9.4	9.1	4.5	3.8	8.7	4.4	6.2
East Upper Peninsula	5.6	1.9	1.4	4.4	2.7	0.9	0.8	1.3	2.2	1.9
NE Lower Peninsula	10.4	7.0	15.1	10.2	7.1	9.2	8.4	12.9	5.6	6.9
NW Lower Peninsula	8.1	8.8	9.9	9.2	7.3	8.7	8.9	7.2	5.3	8.4
Saginaw Bay	11.6	11.9	14.2	14.1	10.9	13.8	13.8	15.2	11.1	11.6
SW Lower Peninsula	11.6	18.6	15.3	16.1	17.3	21.9	22.7	18.7	20.9	18.4
SC Lower Peninsula	11.0	16.4	14.8	16.2	14.4	17.1	18.1	11.5	15.0	16.0
SE Lower Peninsula	19.7	26.3	27.1	20.2	27.6	23.0	22.4	24.0	30.7	26.6
Ecoregions										
Upper Peninsula	26.5	7.8	3.4	13.6	11.7	5.3	4.5	9.8	6.5	8.0
Northern Lower Peninsula	25.0	21.8	31.6	25.5	19.6	24.1	23.2	28.8	15.9	21.1
Southern Lower Peninsula	47.6	67.4	65.0	60.6	65.2	69.6	71.2	60.9	72.8	66.9
Out of state	0.9	3.1	0.0	0.3	3.6	1.0	1.1	0.5	4.8	4.0

[a]See Figure 1 for area boundaries.

Table 4. Residency of people (%) that purchased Michigan hunting licenses in 2001.

Area[a]	Bear	Deer	Elk	Fur harvester	Small game	Turkey	Spring turkey	Fall turkey	Waterfowl	All types
	License type									
DNR Administrative Units										
West Upper Peninsula	22.5	5.9	0.8	9.6	8.5	4.3	3.8	9.3	4.2	6.0
East Upper Peninsula	4.9	1.8	1.2	4.3	2.6	0.9	0.8	1.4	2.0	1.8
NE Lower Peninsula	11.0	7.0	15.4	10.1	6.9	7.3	7.1	7.9	5.4	6.8
NW Lower Peninsula	6.7	8.9	9.8	9.3	7.3	9.0	9.1	7.3	5.3	8.5
Saginaw Bay	11.3	11.9	12.6	13.9	11.0	13.2	13.4	11.5	11.1	11.6
SW Lower Peninsula	11.4	18.8	16.7	16.3	17.6	24.1	23.7	32.8	21.1	18.6
SC Lower Peninsula	10.2	16.4	12.2	16.3	14.6	18.3	19.0	12.3	15.2	16.0
SE Lower Peninsula	20.3	26.3	31.3	19.6	28.1	21.8	22.0	17.0	31.1	26.8
Ecoregions										
Upper Peninsula	27.3	7.6	2.0	13.7	11.0	5.1	4.5	10.3	6.1	7.7
Northern Lower Peninsula	24.1	21.9	30.4	25.7	19.5	22.1	21.8	22.2	15.6	21.2
Southern Lower Peninsula	47.0	67.5	67.6	60.1	66.2	71.8	72.5	67.0	73.8	67.3
Out of state	1.6	3.0	0.0	0.5	3.4	1.1	1.1	0.4	4.5	3.9

[a]See Figure 1 for area boundaries.

Table 5. Residency of people (%) that purchased Michigan hunting licenses in 2002.

Area[a]	Bear	Deer	Elk	Fur harvester	Small game	Turkey	Spring turkey	Fall turkey	Waterfowl	All types
	License type									
DNR Administrative Units										
West Upper Peninsula	21.1	5.7	1.4	9.8	8.1	4.1	3.6	8.3	4.1	5.8
East Upper Peninsula	4.6	1.7	0.0	4.3	2.5	0.8	0.7	1.1	2.0	1.8
NE Lower Peninsula	12.5	6.7	16.9	10.6	6.7	6.1	6.2	3.8	5.5	6.6
NW Lower Peninsula	7.9	8.7	9.9	9.2	7.4	8.0	8.1	6.3	5.4	8.4
Saginaw Bay	12.1	11.9	13.4	14.1	11.2	13.0	13.2	9.7	11.4	11.6
SW Lower Peninsula	10.6	18.9	14.8	16.7	18.0	25.2	24.6	35.0	21.2	18.7
SC Lower Peninsula	10.5	16.7	17.6	15.6	15.0	19.5	19.9	18.7	15.2	16.3
SE Lower Peninsula	19.5	26.5	26.1	19.4	27.8	22.1	22.4	16.7	30.6	26.8
Ecoregions										
Upper Peninsula	25.6	7.3	1.4	13.9	10.4	4.8	4.2	9.0	6.0	7.4
Northern Lower Peninsula	27.3	21.5	33.8	25.9	19.5	19.4	19.5	16.3	16.0	20.8
Southern Lower Peninsula	45.9	68.1	64.8	59.9	66.8	74.6	75.1	74.2	73.5	67.8
Out of state	1.2	3.1	0.0	0.3	3.3	1.1	1.1	0.5	4.5	3.9

[a]See Figure 1 for area boundaries.

Table 6. Sex of people (%) that purchased Michigan hunting licenses, 2000-2002.

Hunting license	2000 Male	2000 Female	2001 Male	2001 Female	2002 Male	2002 Female
Bear	91.7	8.3	91.9	8.1	92.3	7.7
Deer	91.4	8.6	91.6	8.4	92.1	7.9
Elk	90.1	9.9	96.4	3.6	90.8	9.2
Fur harvester	97.9	2.1	97.8	2.2	97.8	2.2
Small game	96.9	3.1	96.8	3.2	96.9	3.1
Turkey	94.0	6.0	94.0	6.0	93.8	6.2
Spring turkey	94.2	5.8	94.0	6.0	93.8	6.2
Fall turkey	94.3	5.7	94.6	5.4	94.5	5.5
Waterfowl	98.0	2.0	98.0	2.0	97.9	2.1
All types	91.5	8.5	91.7	8.3	92.0	8.0

Table 7. Mean age of people buying a Michigan hunting license during 2000-2002.[a]

	Year								
	2000			2001			2002		
License type	Males	Females	Combined	Males	Females	Combined	Males	Females	Combined
Bear[b]	43	41	43	44	42	44	44	44	44
Deer	40	40	40	41	40	41	41	40	41
Elk[b]	46	42	46	46	37	45	47	38	46
Fur harvester	42	39	42	42	38	42	43	40	43
Small game	40	34	39	40	34	40	40	33	40
Turkey[b]	44	42	43	44	41	43	44	41	44
Spring turkey[b]	43	42	43	44	41	43	44	41	44
Fall turkey[b]	46	43	46	47	43	47	46	44	46
Waterfowl[c]	40	37	40	40	36	40	40	36	40
Any species	40	40	40	40	40	40	41	39	40

[a]Age on October 1.
[b]A restricted number of licenses were available and were distributed using a random drawing.
[c]Hunters 12-15 years of age could legally hunt waterfowl without a waterfowl hunting license; however, they were required to purchase a small game license.

Table 8. Percentage of Michigan residents purchasing a Michigan hunting license, by age and sex, during 2000-2002.

	Year								
	2000			2001			2002		
Age[a]	Males	Females	Combined	Males	Females	Combined	Males	Females	Combined
≥12	19.1	1.7	10.2	18.9	1.7	10.1	18.5	1.6	9.8
≥16	19.4	1.7	10.3	19.2	1.7	10.2	18.8	1.6	9.9
12-17	16.6	1.5	9.3	16.5	1.6	9.2	16.3	1.7	9.2
12-18	16.4	1.5	9.1	16.2	1.5	9.1	16.0	1.6	9.0
12-19	16.2	1.4	9.0	16.0	1.5	8.9	15.8	1.6	8.9
18-24	16.2	1.3	8.8	15.7	1.3	8.6	15.0	1.2	8.2
25-34	21.5	2.1	11.8	20.9	2.0	11.5	20.0	1.8	11.0
35-44	23.5	2.4	12.9	23.4	2.4	12.8	23.1	2.2	12.6
45-54	20.2	2.1	11.0	20.4	2.0	11.1	20.2	1.9	10.9
55-64	19.7	1.7	10.4	19.3	1.6	10.2	19.2	1.5	10.1
65-74	15.8	1.0	7.7	16.2	1.0	7.9	16.0	0.9	7.8
75-84	8.3	0.4	3.5	8.3	0.4	3.5	8.3	0.3	3.5
≥85	3.2	0.1	1.0	3.1	0.1	1.0	2.9	0.1	0.9

[a]Age on July 1. July 1 was used because the U.S. Census Bureau reports Michigan demographic estimates as of July 1.

Table 9. Number of people that purchased a hunting license to hunt only a single species in Michigan, 2000-2002.[a]

Species group	Year 2000	Year 2001	Year 2002
Bear[b]			
Number (N)	536	550	545
%[c]	6.8	6.7	6.0
Deer			
N	499,307	492,295	492,078
%	61.6	61.5	62.4
Elk[b]			
N	25	12	7
%	6.8	4.9	4.9
Fur harvester			
N	709	809	795
%	4.1	4.3	4.1
Small game			
N	59,922	58,213	53,637
%	16.9	16.8	16.4
Turkey[b]			
N	6,729	7,487	9,234
%	7.0	7.2	8.6
Spring turkey			
N	6,280	7,241	8,772
%	7.4	7.6	8.9
Fall turkey			
N	758	459	757
%	3.0	2.4	3.4
Waterfowl[d]			
N	351	283	261
%	0.5	0.4	0.4
Any single type[e]			
N	567,270	559,436	556,262
%	63.3	63.2	64.0

[a]Within each species group, a person is counted only once regardless of the number of licenses purchased.
[b]A restricted number of licenses were available, and these licenses were distributed using a random drawing.
[c]Within each species group, the percentage of license buyers that only purchased a license to hunt this species.
[d]Waterfowl hunters normally were required to purchase both small game and waterfowl hunting licenses.
[e]Fall and spring turkey licensees treated as hunters pursuing separate species.

Table 10. Number of people buying licenses to hunt multiple species in Michigan during 2000.

Primary species	People buying license to hunt primary species	People that also purchased a license to hunt a secondary species: Bear	Deer	Elk	Fur harvester	Small game	Turkey	Spring turkey	Fall turkey	Waterfowl
Bear[a]										
Number (N)	7,900		7,153	14	922	5,324	2,491	2,180	794	1,256
%	100		90.5	0.2	11.7	67.4	31.5	27.6	10.1	15.9
Deer										
N	810,864	7,153		334	15,578	278,296	87,002	75,649	24,121	51,880
%	100	0.9		<0.1	1.9	34.3	10.7	9.3	3.0	6.4
Elk[a]										
N	365	14	334		21	228	156	131	67	50
%	100	3.8	91.5		5.8	62.5	42.7	35.9	18.4	13.7
Fur harvester										
N	17,346	922	15,578	21		14,872	5,377	4,815	1,726	4,755
%	100	5.3	89.8	0.1		85.7	31.0	27.8	10.0	27.4
Small game										
N	354,858	5,324	278,296	228	14,872		59,779	52,103	17,682	65,187
%	100	1.5	78.4	0.1	4.2		16.8	14.7	5.0	18.4
Turkey[a]										
N	96,484	2,491	87,002	156	5,377	59,779		84,355	25,507	17,461
%	100	2.6	90.2	0.2	5.6	62.0		87.4	26.4	18.1
Spring turkey[a]										
N	84,355	2,180	75,649	131	4,815	52,103	84,355		13,378	15,640
%	100	2.6	89.7	0.2	5.7	61.8	100		15.9	18.5
Fall turkey[a]										
N	25,507	794	24,121	67	1,726	17,682	25,507	13,378		5,083
%	100	3.1	94.6	0.3	6.8	69.3	100	52.4		19.9
Waterfowl[b]										
N	66,110	1,256	51,880	50	4,755	65,187	17,461	15,640	5,083	
%	100	1.9	78.5	0.1	7.2	98.6	26.4	23.7	7.7	

[a]A restricted number of licenses were available and were distributed using a random drawing.
[b]Waterfowl hunters normally are required to purchase both small game and waterfowl hunting licenses.

Table 11. Number of people buying licenses to hunt multiple species in Michigan during 2001.

Primary species	People buying license to hunt primary species	People that also purchased a license to hunt a secondary species								
		Bear	Deer	Elk	Fur harvester	Small game	Turkey	Spring turkey	Fall turkey	Waterfowl
Bear[a]										
Number (N)	8,262		7,492	7	1,197	5,526	2,872	2,680	655	1,310
%	100		90.7	0.1	14.5	66.9	34.8	32.4	7.9	15.9
Deer										
N	800,872	7,492		229	16,922	272,555	92,902	85,588	18,434	52,106
%	100	0.9		<0.1	2.1	34.0	11.6	10.7	2.3	6.5
Elk[a]										
N	247	7	229		21	159	113	105	26	41
%	100	2.8	92.7		8.5	64.4	45.7	42.5	10.5	16.6
Fur harvester										
N	18,871	1,197	16,922	21		15,973	6,272	5,864	1,516	5,249
%	100	6.3	89.7	0.1		84.6	33.2	31.1	8.0	27.8
Small game										
N	347,314	5,526	272,555	159	15,973		63,390	58,423	13,534	65,138
%	100	1.6	78.5	<0.1	4.6		18.3	16.8	3.9	18.8
Turkey[a]										
N	103,386	2,872	92,902	113	6,272	63,390		95,595	19,348	18,780
%	100	2.8	89.9	0.1	6.1	61.3		92.5	18.7	18.2
Spring turkey[a]										
N	95,595	2,680	85,588	105	5,864	58,423	71,196		11,557	17,588
%	100	2.8	89.5	0.1	6.1	61.1	100		12.1	18.4
Fall turkey[a]										
N	19,348	655	18,434	26	1,516	13,534	19,348	11,557		4,106
%	100	3.4	95.3	0.1	7.8	70.0	100	59.7		21.2
Waterfowl[b]										
N	65,961	1,310	52,106	41	5,249	65,138	18,780	17,588	4,106	
%	100	2.0	79.0	0.1	8.0	98.8	28.5	26.7	6.2	

[a]A restricted number of licenses were available and were distributed using a random drawing.
[b]Waterfowl hunters normally are required to purchase both small game and waterfowl hunting licenses.

Table 12. Number of people buying licenses to hunt multiple species in Michigan during 2002.

Primary species	People buying license to hunt primary species	People that also purchased a license to hunt a secondary species: Bear	Deer	Elk	Fur harvester	Small game	Turkey	Spring turkey	Fall turkey	Waterfowl
Bear[a]										
Number (N)	9,107		8,315	3	1,275	5,894	3,196	2,987	683	1,399
%	100		91.3	<0.1	14.0	64.7	35.1	32.8	7.5	15.4
Deer										
N	788,180	8,315		129	17,514	257,491	94,973	86,730	20,618	51,141
%	100	1.1		<0.1	2.2	32.7	12.0	11.0	2.6	6.5
Elk[a]										
N	142	3	129		11	83	65	63	14	31
%	100	2.1	90.8		7.7	58.5	45.8	44.4	9.9	21.8
Fur harvester										
N	19,386	1,275	17,514	11		16,287	6,575	6,139	1,660	5,336
%	100	6.6	90.3	0.1		84.0	33.9	31.7	8.6	27.5
Small game										
N	327,279	5,894	257,491	83	16,287		63,416	57,922	14,759	63,813
%	100	1.8	78.7	<0.1	5.0		19.4	17.7	4.5	19.5
Turkey[a]										
N	107,316	3,196	94,973	65	6,575	63,416		98,286	21,952	19,166
%	100	3.0	88.5	0.1	6.1	59.1		91.6	20.5	17.9
Spring turkey[a]										
N	98,286	2,987	86,730	63	6,139	57,922	98,286		12,922	17,880
%	100	3.0	88.2	0.1	6.2	58.9	100		13.1	18.2
Fall turkey[a]										
N	21,952	683	20,618	14	1,660	14,759	21,952	12,922		4,430
%	100	3.1	93.9	0.1	7.6	67.2	100	58.9		20.2
Waterfowl[b]										
N	64,582	1,399	51,141	31	5,336	63,813	19,166	17,880	4,430	
%	100	2.2	79.2	<0.1	8.3	98.8	29.7	27.7	6.9	

[a]A restricted number of licenses were available and were distributed using a random drawing.
[b]Waterfowl hunters normally are required to purchase both small game and waterfowl hunting licenses.

Table 13. Percentage of hunters purchasing a hunting license during two consecutive years.[a]

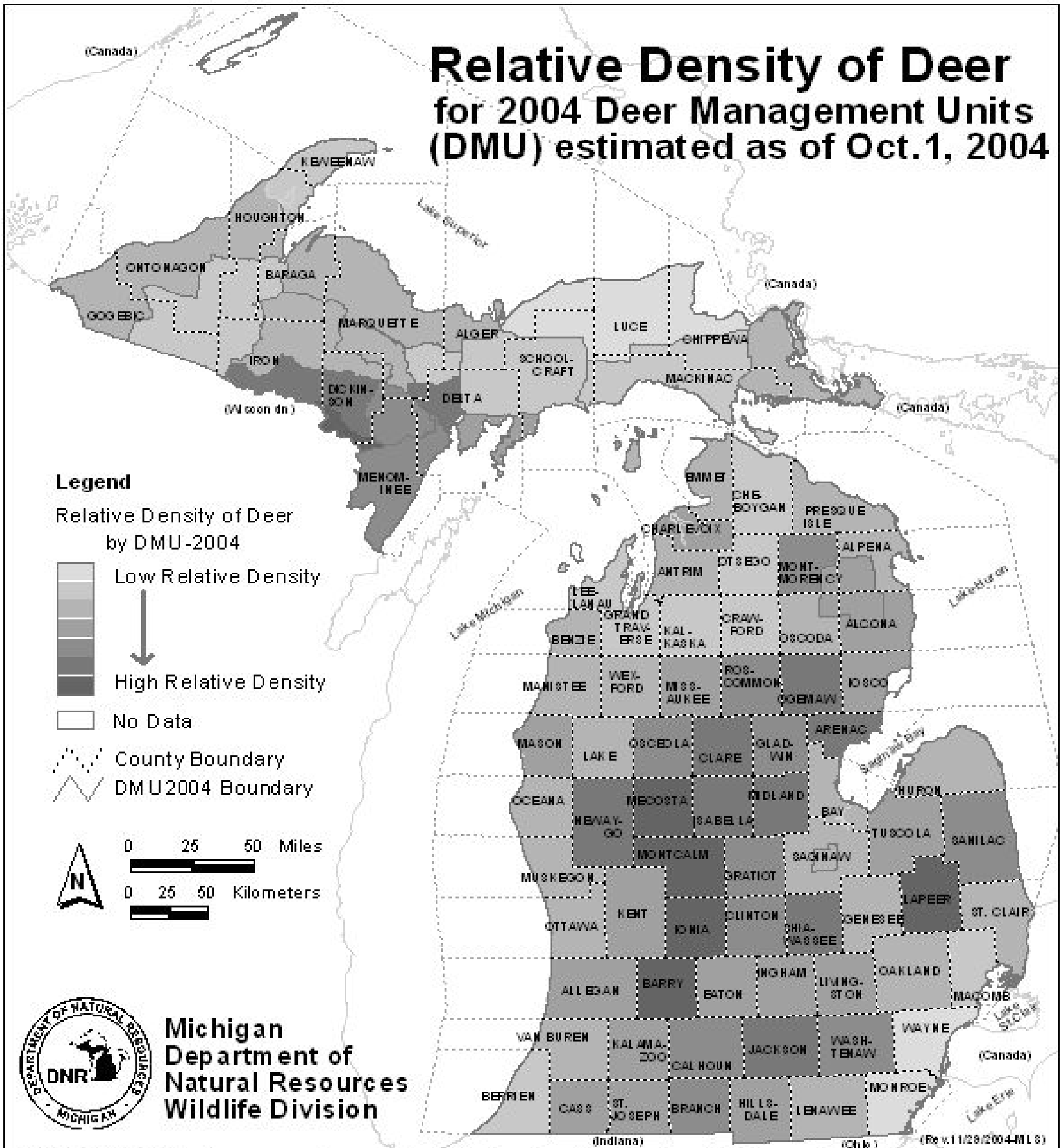
License type	Period 2000-2001 Male	Female	Combined	Period 2001-2002 Male	Female	Combined
Bear[b]	5.1	3.2	4.9	6.4	3.4	6.1
Deer	81.8	59.7	79.9	81.2	57.1	79.2
Elk[b]	0.0	0.0	0.0	0.0	0.0	0.0
Fur harvester	67.3	52.3	67.0	65.3	50.8	65.0
Small game	69.3	50.7	68.8	67.5	47.2	67.0
Turkey[b]	62.7	49.6	61.9	64.4	52.4	63.7
Spring turkey	63.9	50.7	63.1	64.1	51.8	63.4
Fall turkey	31.4	23.7	30.9	40.3	32.3	39.9
Waterfowl	67.2	50.7	66.9	66.7	51.4	66.4
All types	81.5	60.0	79.7	80.7	57.5	78.7

[a]Includes only people that were at least 18 years old on October 1 of the first year of the interval.
[b]A restricted number of licenses were available and were distributed using a random drawing.

Table 14. Proportion of people that purchased a hunting license in 2000 that also purchased licenses during 2000-2002.

License type	One year (2000 only) Males	Females	Combined	Two years (2000 and either 2001 or 2002) Males	Females	Combined	Three Years (2000-2002) Males	Females	Combined
Bear[a]	82.2	85.8	82.5	16.0	13.9	15.8	1.8	0.3	1.7
Deer	13.1	33.4	14.9	15.3	24.3	16.0	71.6	42.4	69.1
Elk[a]	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Fur harvester	26.1	41.5	26.4	19.9	19.0	19.9	54.0	39.5	53.7
Small game	23.3	43.0	23.9	22.4	24.5	22.4	54.3	32.5	53.7
Turkey[a]	27.5	42.1	28.4	24.9	24.1	24.8	47.6	33.7	46.8
Spring turkey[a]	26.3	40.5	27.1	25.0	24.3	25.0	48.7	35.1	48.0
Fall turkey[a]	59.3	69.4	59.9	24.5	20.2	24.3	16.1	10.4	15.8
Waterfowl	26.1	42.6	26.5	21.4	24.9	21.5	52.4	32.4	52.0
Any species	13.6	33.2	15.3	15.0	23.9	15.8	71.3	42.9	68.9

[a]A restricted number of licenses were available and were distributed using a random drawing.



PLEASE NOTE: This is a comparative map of relative deer densities based on 2003 seasonal data collections at the DMU level. The actual numeric values calculated may not accurately reflect the deer density throughout the year or across the entire DMU, but these data can be used to illustrate a comparative trend in deer populations. Local habitat conditions and other local factors (urbanization, agricultural activity, hunting pressure, etc.) affect local population levels and deer movement behavior. These conditions may cause higher or lower local deer densities within a DMU. Due to DMU level calculations, large differences in densities may appear between adjacent DMUs, when actual change is gradual. This representation is not meant to replace local knowledge or scouting of prospective hunting locations. The DNR promotes becoming familiar with your local habitat dynamics and with local game-species behavior patterns. Scout your local area to ensure safety and enjoyment of your outdoor experience. Division reports provide details about deer management, harvest estimates, hunting participation, and hunter success estimates.

For more information, see the DNR on the internet at "http://www.michigan.gov/dnr".

Source: Michigan DNR
www.michigan.gov/dnr/1,1607,7-153-10363_10856_10905---,00.html

White-tailed deer and landscape effects on forest structure and species composition [DRAFT]

Joseph P. LeBouton, Michael Walters, Jianguo Liu, Frank Lupi, Edward J. Laurent and Laila Racevskis

MICHIGAN STATE UNIVERSITY EXTENSION

Managing forests for multiple uses including sustained timber yield is an ecologically complex task. In northern hardwood forests over much of the eastern United States including Michigan, white-tailed deer have a huge impact on sustained yield because of browse impacts on forest regeneration.

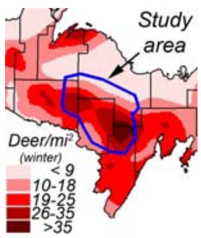


Figure 1. The study area encompasses a gradient in average winter deer density observed between 1981 and 2000. Data from MDNR spring fecal pellet counts.

Many studies have shown that when deer are excluded from forests, tree seedlings establish, grow, and become part of the forest canopy more quickly than in similar forests with deer. In exclosures (fenced areas designed to exclude deer), tree species such as eastern hemlock (*Tsuga canadensis*) and northern white cedar (*Thuja occidentalis*) survive, while they are stunted or killed by deer browse outside exclosures. Most exclosure studies contrast areas of high deer density with areas of zero deer (the exclosures), but they cannot answer the question of *how many* deer are "too many" for a number of purposes, including maintaining plant species diversity and high forest regeneration rates in managed forests. Similarly, exclosure studies are expensive, and thus limited to few exclosures and small areas. These studies are able to address detailed questions about how deer affect particular forest stands, but are less effective in explaining how highly mobile deer herds affect forest regeneration across a larger land area of hundreds of square miles.

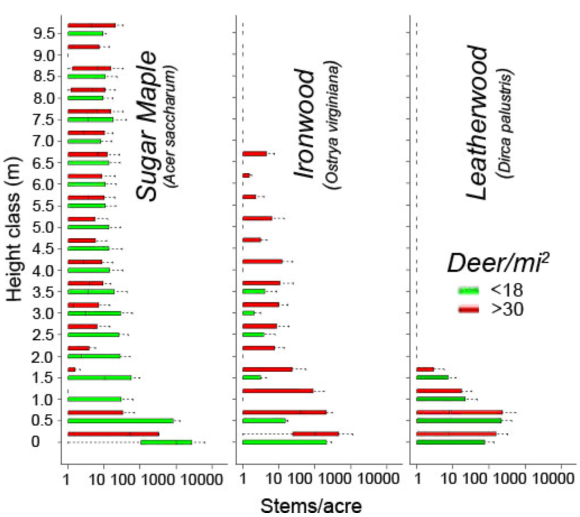


Figure 2. Stem density by height class in low vs. high deer density plots for three common understory species.

For northern hardwood stands, our study addressed the questions: 1) How does the distribution of height classes and density of tree seedlings change as deer densities change, and 2) How does the surrounding landscape affect how deer browse?

We measured vegetation structure and composition, including all vascular plants, in 453 vegetation plots across a study area in the central Upper Peninsula of Michigan (Figure 1). Northern hardwood stands accounted for 234 plots. The study area has a strong gradient in deer density, from <9 deer/mi^2 in the north to >35 deer/mi^2 in the south. We related our vegetation information to deer density information.

Our preliminary analyses indicate lower sugar maple sapling density and higher ironwood sapling density in areas that experienced high winter deer populations between 1981 and 2000 (Figure 2). Height classes that are within the reach of deer in the winter (0.25m to 1.5m tall) were the most heavily affected, with ironwood replacing sugar maple as the dominant understory sapling in high deer density plots. We also found a legacy effect of past high deer densities: In areas that have had high deer density for the past 20 years, there is a lower density

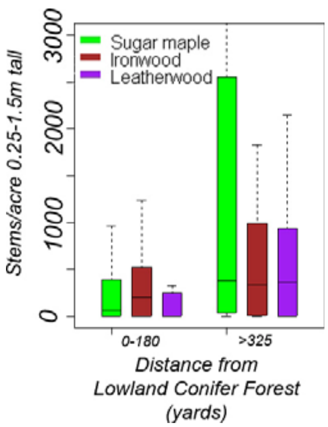


Figure 3. Stem density of 3 species in plots grouped by distance from lowland conifer forest.

of larger height classes that are above the immediate effects of deer (>2m tall). Thus, forest structure and composition may be affected for decades by deer browse effects on young seedlings and saplings. Not all understory shrubs and trees showed as strong a response to deer density as did sugar maple and ironwood. Leatherwood, for example, showed little change in stem density in any height class (Figure 2).

The landscape surrounding northern hardwood stands also impacted stem density, presumably by providing winter habitat for deer. In particular, the distance from a northern hardwood stand to the nearest lowland conifer stand affects sapling density. As the distance from lowland conifer stands increases, the sugar maple sapling class increases nearly tenfold in density, and ironwood and leatherwood also increase (Figure 3). This may be because northern hardwood food sources nearest thermal cover habitat are exploited more heavily by deer than food sources far from thermal cover.

Finally, for the herb layer we are finding evidence of a shift in plant community composition and a decrease in plant diversity with increasing deer density. For example, median percent ground cover of sedges and grasses, which may compete with young tree seedlings for resources, approximately doubles in high deer density areas over low deer density areas (Figure 4). Median percent cover of other herbaceous species that are more palatable to deer decreased slightly over the same increase in deer density.

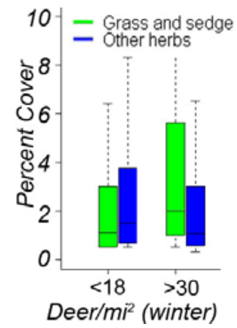


Figure 4. Herb layer cover in low- vs. high-deer-density stands.

Management Considerations

It will surprise no one that deer reduce northern hardwood regeneration rates and remove seedlings and saplings of economically valuable species. But the exact density of deer that forests can maintain without compromising plant diversity and adequate forest regeneration of desirable species is unknown. Despite the preliminary stage of our data analysis, we can offer some suggestions for forest managers. When considering a plan for harvest and regeneration:

Forest managers should be aware of local winter-time deer densities. In addition to regional estimates based on DNR pellet count analyses (e.g., Hill 2001), managers can use vegetation and location to help guide them. In areas that have been actively managed by selection methods, clues that deer densities may be high in a particular stand include some combination of low densities of trees 0.25 to 1.5 m tall, and high densities of ironwood, spruce and other less palatable species 0.25 to 1.5 m tall, *relative to* sugar maple, ash and other more palatable species. Seedling densities <0.25m can be high or low, but often most of the taller individuals will show evidence of browse. High sedge and grass ground cover under canopy or in a recent clear-cut is also an indicator of high deer density over the last 10-20 years. Finally, close proximity (<200 m) to either upland or lowland conifer forests, and especially cedar swamps, may also indicate relatively high wintertime deer densities.

In areas of high deer densities and if merchantable tree characteristics are appropriate, alternatives to single tree and small group selection systems could be considered. Larger openings, including large group selection and patch cuts often result in high densities of regeneration that "saturate" the forage demand of local deer populations. Due to greater resource availability in larger openings, regeneration grows quickly through the height range susceptible to deer (~0.25-1.5 m tall) and thus has a greater likelihood of escaping deer browsing. However, in the highest winter deer density areas even very aggressive canopy removal may not be sufficient to allow advance regeneration to escape deer browse.

Deer and sedge impact tree regeneration in working forests: Possible restoration treatments [DRAFT]

Jesse A. Randall and Michael B. Walters

Land use and deer management practices in Michigan have caused unprecedented high deer densities. Intense deer browsing has strong negative impacts on forest herbs, tree recruitment, and forest vertical structure. There are some species, however, that are avoided as browse. One of these, Pennsylvania sedge (*Carex pennsylvanica*), has increased dramatically. Even if deer are completely removed it is believed that established sedge maintains dominance by out-competing reestablishing tree seedlings and herbs. Thus, tree seedling regeneration and forest herbs can be negatively impacted by deer directly via browse, and indirectly via competition from high sedge densities. However, the relative effects of deer vs. sedge on tree regeneration and herbs are unknown. It is possible that if sedge effects are strong, reducing sedge densities with management interventions such as herbicides could increase tree, shrub, and herb establishment even in the presence of deer browse pressure. In a series of experiments we examined the effects of deer and sedge removal on vegetation, and evaluated the effectiveness of practical sedge removal treatments on tree regeneration.

Effects of sedge and deer removal: trees

Our preliminary analyses indicate that at high deer densities (>31 deer/mi^2 outside our deer exclosures) maple seedlings greater than 25 cm tall were very rare (Figure 1a), leaving virtually no potential for future sapling-sized trees. At high deer densities with sedge *removed*, seedling densities were higher than without sedge removed, but still there was no recruitment to larger size classes (Figure 1a). In contrast, four years after deer removal (using exclosures), sugar maples grew into larger size classes both with and without sedge removal, but recruitment into taller height classes was much greater with sedge removed (Figure 1b). Thus, both deer and high sedge densities negatively impact height growth and survival of tree seedlings. Removing sedge alone may not be adequate to get sufficient tree recruitment in areas with very high deer density. Removing *all* vegetation with a broad spectrum herbicide applied in summer killed nearly all advance regeneration, resulting in low densities of young seedlings. No recruit sized individuals existed 4 years after spraying (Fig 1a).

Effects of sedge and deer removal: herbaceous vegetation

In addition to killing advance tree regeneration, using broad-spectrum herbicides in summer to control sedge also kills non-target species, such as forest herbs. Surprisingly, in exclosures four years after complete vegetation removal with non-selective herbicide we found a 20% increase in the number of herb species present (i.e., species richness). However, this increase was largely due to an increase in “weedy” species such as mullein, mustard, and Linaria spp., rather than native forest herbs. Removing sedge alone should be an improvement over broad-spectrum herbicide in maintaining forest herbs, but we found that sedge removal and high deer densities decreased herb species richness. The remaining vegetation may be more nutritional and/or more visible to deer. This result must be interpreted carefully since the small size of each treatment area (10x10m) may have contributed to herbaceous species declines by creating a small “oasis” of high quality browse that contrasted sharply with the sedge-dominated landscape surrounding it. If sedge were removed over a much larger area, herbs and tree regeneration may be able to overcome browse pressure by saturating deer with high quality food.

Timing broad-spectrum herbicide application to control sedge and minimize unwanted impacts

Over larger (1/2 acre) study plots than used in our first experiment and without exclosures (deer ~ 30/mi^2), we compared the effects of summer (July 15th) vs. fall (Nov 1st) spraying of a broad-spectrum herbicide on sedge and other vegetation. We found that both summer and fall applications decreased sedge biomass two years after application (figure 1c), but the early fall application had little impact on non-target species. In fact, fall application increased the plant species richness compared to areas not sprayed (in contrast to our results from 10 x 10 m plots, above), whereas summer application reduced species richness (Fig.1d). Fall and summer treatment areas had 14 and 9 species, respectively, which were absent in non-sprayed areas. Of these, 43% and 78% respectively were weedy species. Thus, fall spraying resulted in increased species richness and decreased invasion of weeds compared to summer spraying.

Management Recommendations

Our results suggest that summer application of broad-spectrum herbicide has too many negative impacts on potential tree recruits and herbaceous vegetation to be useful for controlling sedge in most situations. Also, selective sedge removal may not increase tree seedling recruitment and plant diversity in small treatment areas with very high deer densities. However, in areas with lower deer densities, and/or possibly if applied over large areas, selective sedge removal may enhance the growth rates and survival of tree seedlings and maintain/increase non-target plant diversity. In summary, for northern hardwood stands that have been or will soon be partially (e.g. selection) harvested within two years:

1) Apply broad-spectrum herbicide just after leaf off in autumn. At this time sedge and some grasses are the predominant photosynthetically active (and thus herbicide sensitive) plants. In special cases, summer treatment may be desirable if the understory has high densities of undesirable advanced regeneration such as ironwood.

2) Apply herbicide to relatively large areas (i.e., several acres). This may be especially effective in areas where deer densities are moderated by factors such as distance to winter thermal cover and increased snow depth (for further details see LeBouton et al.). The increased browse quantity and quality resulting from spraying are more likely to saturate and thus overcome local deer browse pressure if these effects occur over a larger area.

3) Consider reducing basal area to lower levels (50-60ft^2/acre) than those typically used for partial cutting to open the canopy for aerial spraying and to promote rapid growth of seedlings into and through the zone of deer foraging.

4) Factors other than deer and sedge may be limiting tree seedling recruitment. These factors include a) seed limitations that could result from insufficient densities of large seed producing trees, and b) stand structure. For example, self-thinning closed canopy forests transmit little light to the forest floor resulting in low seedling densities.

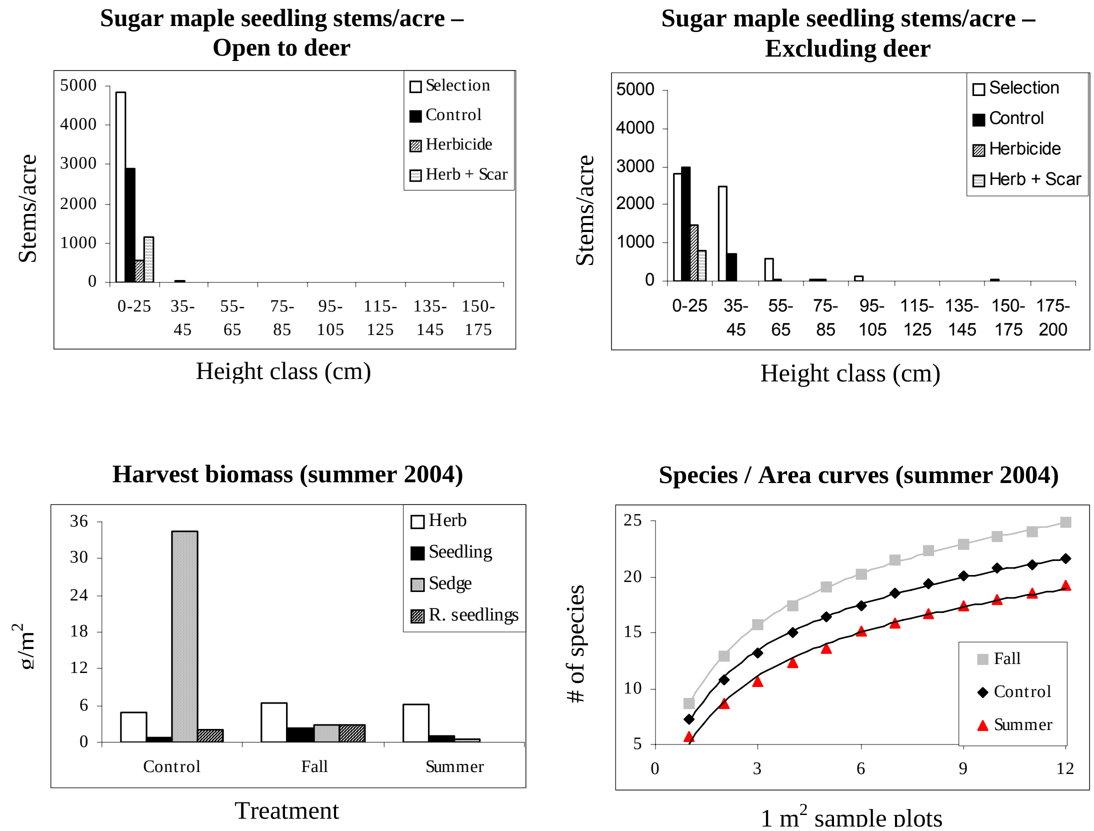


Figure 1. ***A)*** *Sugar maple seedling stems/acre by height class and treatment 4 years following treatment in areas open to deer,* ***B)*** *Sugar maple seedling stems/acre by height class and treatment 4 years following treatment in areas excluding deer,* ***C)*** *2004 harvest biomass by treatment and plant functional group,* ***D)*** *2004 summer species / area curves by treatment. Data are from field experiments in Faithorn and Meyer Townships, Menominee County, MI. (Randall and Walters unpublished data).*

INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS

INTERNATIONALER VERBAND FORSTLICHER FORSCHUNGSANSTALTEN

UNION INTERNATIONALE DES INSTITUTS DES RECHERCHES FORESTIERES

XVII IUFRO World Congress

JAPAN 1981

IUFRO

PROCEEDINGS—REFEREATE—EXPOSES

DIVISION 1

MANAGEMENT OF ALLEGHENY HARDWOODS FOR TIMBER AND WILDLIFE

David A. Marquis
Principal Research Silviculturist
USDA Forest Service
Northeastern Forest Experiment Station
Warren, Pennsylvania, USA

INTRODUCTION

Allegheny hardwood forests occur primarily on the plateaus of Pennsylvania and New York in the northeastern United States, at elevations between 150 and 600 m. The annual precipitation in these areas averages 100 cm.

These forests originated after commercial clearcutting during the rail-road-logging era, between 1890 and 1930. They are second-growth, replacing the original beech-hemlock-maple forests that were there when the area was first settled in the 1800's. Black cherry, sugar maple, red maple, and white ash are the primary components of the Allegheny hardwood type; birch, beech, hemlock, and yellow-poplar are common associates (Marquis 1975).

The Allegheny forest region is one of the few large blocks of contiguous forest land in the northeastern United States, but it is surrounded on all sides by the eastern megalopolis. Nearly one-third of the entire United States population lives within a day's drive of the region. As a result, there is a large and nearby market for forest products, and great demands are placed on the forest land for outdoor recreation as well.

Allegheny hardwood forests provide an important share of the Nation's ash and maple timber—ash for baseball bats and tool handles; maple for furniture, flooring, and specialty products. But the prime timber species is black cherry, an outstanding furniture wood that grows in commercial quantities primarily on the Allegheny Plateau. Deer hunting is another major use of Allegheny forests. Pennsylvania ranks first in the Nation in the sale of hunting licenses; well over a million are sold each year, and deer harvests exceed 200,000 animals annually (Holt 1980).

Although both timber and deer are major resources in Allegheny forests, their management has not been well coordinated in the past. Deer populations are regulated through hunting, which is under control of the State game agencies. Populations in Pennsylvania have been maintained at a very high level since the 1920's, when complete protection of does from hunting combined with abundant browse from extensive clearcutting to produce an irruption in the population (Leopold 1943, Bennett 1957). The high population has permitted large deer harvests and good hunter success, providing excellent outdoor recreation opportunities for a large number of people and supporting an extensive recreation industry built around hunting.

But the high deer populations in Pennsylvania have had detrimental affects on other resources. As the second-growth forests began to reach maturity and were harvested, regeneration failures due to deer browsing became common. Over half of the harvest cuttings made during the 1960's and early 1970’s failed to produce satisfactory natural regeneration. Estimates of the impact on future timber production suggest that deer browsing will reduce timber income by an average of $32 per hectare per year over the entire Allegheny Plateau, an overall loss of about 50 percent of total timber value (Marquis 1981).

Excessive browsing has also affected other resources. Food and cover for other species of wildlife such as rabbits, hares, and grouse have been drastically reduced, and the deer themselves show typical symptoms of undernourishment such as small size and poor antler development (Latham 1977).

The long-term solution to this problem will require coordination of management efforts between the agencies that regulate the dear population and the agencies or individuals who own and manage the land. Deer populations will have to be reduced for the habitat to recover and seedlings to become established, at least initially. Later, it may be possible to increase populations again as silvicultural practices are instituted to raise the carrying capacity of the habitat.

In the interim, much research effort has been directed toward the development of silvicultural techniques to secure adequate seedling regeneration in spite of the high deer population. These techniques have permitted continuation of timber harvesting without a complete loss of forest vegetation, and are now being integrated into a more intensive, coordinated scheme to maximize both timber and deer under multiple-use management.

The extremely high deer populations in Allegheny hardwoods, and the silvicultural practices developed to accommodate timber management to these conditions, provide excellent insight into techniques that may be used elsewhere to sustain high levels of output from both timber and deer resources.

TREE REGENERATION WITH HIGH DEER POPULATIONS

Direct protection

When it first became apparent that excessive deer browsing was resulting in complete failure of tree regeneration on many clearcut areas, fencing to exclude deer from the site was considered. Although a 2.5-m-high fence of standard woven mesh wire is effective, its cost, $400 to $600 per hectare, is prohibitive for general use (Marquis 1978a).

A search for other forms of direct protection included tests of plastic and nylon fence materials and various designs of electric fencing. Cost savings achieved through easier erection of plastic fence materials were more than offset by high prices for the plastic and increased maintenance caused by falling limbs and similar damage. Electric fences appear more promising (Brenneman 1981), especially a new 5-wire design that utilizes high-tensile-strength wire that is not easily broken by falling limbs, a high-voltage, low-amperage energizer that is not shirted out by vegetation, and a solar-cell-powered battery charger that minimizes maintenance. Even so, costs of this fence average $175 to $225 per hectare.

Any fence that completely excludes deer from regeneration areas also eliminates their access to a major food source. If all regeneration cuts ware fenced, the amount of deer food produced might be reduced by 20 or 25 percent as shown below:

	Area within deer range	Food production	Total deer food produced on 500 ha	
			With regeneration areas unfenced	With regeneration areas fenced
	ha	kg/ha/yr	kg/yr	
Regeneration stands	50	450	22,500	0
Unthinned stands	300	100	30,000	30,000
Thinned stands	150	225	33,750	33,750
Total	500		86,250	63,750

The figures above are based on the assumptions that a) the area of management appropriate for such calculations is the home range of a deer, approximately 500 hectares (a radius of about 1.25 km); b) this area is under even-age management on a 100-year rotation and contains 10 percent regeneration, 60 percent unthinned poletimber, and 30 percent thinned sawtimber. Deer food production factors are based on average amounts of seedling regeneration and herbaceous ground cover in Allegheny hardwood stands plus equations relating seedling size or herbaceous coverage to dry weight of browsable twigs and foliage last than 1.5 m above ground. Similar assumptions will be used throughout this discussion in calculations of deer food production.

In addition to fencing, forms of direct protection that would permit seedling establishment without completely excluding deer from the area were also investigated. Chemical repellents of various types all proved ineffective where alternate foods were scarce. Individual seedling protectors of wire or plastic mesh were more effective, but required periodic maintenance and were more expensive than any of the other techniques tested if used in adequate numbers to provide full stocking over the entire area (Marquis 1977).

Fertilization

As an alternative to direct protection, we investigated fertilization to encourage seedlings to grow rapidly above the reach of deer. Nitrogen and phosphorus from ammonium nitrate and triple superphosphate, applied at element rates of 168 and 49 Kg per hectare, stimulated rapid height growth of species such as back cherry. Average height increases of more than 1 meter were obtained during the 2 years after fertilizers were applied, and some individual stems grew nearly 2.5 m in l year. Fertilization reduces the time seedlings are subject to browsing to a few years rather than the ~6 to 8 years typically required (Auchmoody 1978), greatly improving regeneration success where there are adequate numbers of seedlings.

Aerial fertilization is now a standard practice on the Allegheny National Forest, where it is used during the second or third year after harvest cutting to provide added insurance against regeneration failure where success is not certain. Current costs of about $250 per hectare have thus far prevented its use on other ownerships.

Fertilization has a significant short-term affect on deer food production. Total dry weight and crude protein content of woody and herbaceous food produced during the first few years after cutting are substantially increased. But accelerated growth hastens stand development and reduces the length of time that vegetation remains in the zone that deer can reach. The net effect is no significant change in food production over the first ~8 to 10 years, but a redistribution of the tine that food is available after cutting (Parrow et al. 1976). Thus, total deer food production is not affected by fertilization, but regeneration cuts met be scheduled at shorter intervals to insure a constant progression of new openings within the home range of deer.

<u>Selection of regeneration areas</u>

Direct protection and fertilization are sometimes the only way to insure perpetuation of forest trees on sites that are difficult to regenerate. But costs of $200 to $600 per hectare at the time of stand establishment are considered prohibitive in U.S. practice. Techniques that do not require large investments were needed to assure regeneration over the majority of Allegheny hardwood areas.

Early experiences with regeneration clearcuts on the Allegheny Plateau showed that nearly half the stands had failed to regenerate satisfactorily after cutting. The other half, however, regenerated satisfactorily in spite of deer browsing. Studies of the stand and site conditions before cutting revealed that nearly all stands that regenerated satisfactorily had an abundance of advance seedlings in the understory (Grisez and Peace 1973). Although very small (generally less than 15 cm tall) due to browsing and dense overstories, these advance seedlings provide the basis for a new stand after overstory removal. Where advance seedlings were absent, the few new seedlings that became established after cutting were consumed by deer.

Thus, the strategy for successful regeneration in the presence of a large deer herd emerged: provide such a dense regrowth of seedlings that deer cannot eat all of them before some grow out of reach.

Vary large numbers of advance seedlings are necessary to insure that this dense regrowth occurs immediately after overstory removal. A guide for the amounts of advance regeneration required has been developed. It requires a survey of advance reproduction before cutting; 70 percent of the 1.8-m-radius plots examined must contain at least 25 black cherry or 100 desirable seedlings total. This guide insures both adequate numbers and suitable distribution of advance seedlings over the area.

No Allegheny hardwood stands with less than 40,000 seedlings per hectare have qualified for harvest cutting under this guide, and stands that do qualify average more than 100,000 advance seedlings per hectare. Obviously, very large numbers of these small advance seedlings are required to provide regrowth dense enough to overwhelm the deer.

The high number of advance seedlings required is the result of the current high deer population: If deer populations are managed at lower levels in the future, fewer advance seedlings will be required.

Currently, we are conducting dear enclosure studies to define the relationship between deer population level and the numbers of advance seedlings that will produce successful regeneration after harvest cutting. Deer populations of 0, 10, 20, 40, and 80 deer per 260 hectares are being maintained in fenced enclosures of either 13 or 26 hectares where there are uncut, thinned, and clearcut stands in proportions typical of a managed even-aged forest. Data from this study will not only provide information on amounts of advance regeneration required at various deer levels, but will provide guidance on deer population levels appropriate to achieve a balance between timber and wildlife resources.

Site and amount of regeneration openings

Since the strategy for securing successful regeneration is to overwhelm the deer with more seedlings than they can consume, other factors that affect the availability of deer food need to be evaluated. The size of regeneration openings was initially thought to be of importance; the larger the opening, the more seedlings to overwhelm deer. Also, deer in other geographic areas have been found to use small openings (less than 2 hectares) more heavily than larger ones (McCaffery and Creed 1969), presumably because of the proximity of protective cover. But we have not found size of the individual opening to be important--in a study of 34 clearcuts that ranged from 2 to 50 ha, there was no significant relationship between regeneration success and opening size.

A more important factor is the total area in regeneration openings within the home range of deer. The larger the proportion of the total forest area in regeneration openings, the greater the deer food production, and the lower the browsing impact on seedling regeneration. Thus, four openings of 10 hectares produce about the same amount of deer food and have about the same impact on browsing pressure as one opening of 40 hectares.

The variation in total deer food production on a 500-ha area that might result from differences in both area in regeneration openings and regeneration potential of the openings is shown in Table 1.

Note that increasing the area in regeneration openings from 10 to 50 hectares increases total food production by only 5 percent when the regeneration potential is low. The reason is that food production in clearcuts that do not contain an abundance of seedlings is not much different from food production in other stands, so changing the proportion of openings has only a small effect. Production lost from the smaller area in openings is partially, offset by production from the larger area in thinned and uncut stands.

Thinned stands, because they have moderately high food production and considerably more area than regeneration openings, make an important contribution to total food production, especially when regeneration potential is low. For example, with 10 hectares in openings rather than 50, total food production will range from 70,250 kg if the 40 hectares not clearcut are left uncut to 75,250 kg if the 40 hectares not clearcut are all thinned. This compares to 76,250 if all 40 hectares were clearcut.

Table 1.—Total production of deer food on a 500-ha area as affected by proportion of regeneration openings and regeneration potential

Stand Class	Food production	2% of area in regeneration openings		10% of area in regeneration openings	
		Area	Food Production	Area	Food Production
	kg/ha/yr	ha	kg/yr	ha	kg/yr
	LOW REGENERATION POTENTIAL: 25,000 SEEDLINGS PER ha				
Regeneration	250	10	2,500	50	12,500
Uncut	100	320	32,000	300	30,000
Thinned	225	170	38,250	150	33,750
Total		500	72,750	500	76,250
	AVERAGE REGENERATION POTENTIAL: 75,000 SEEDLINGS PER ha				
Regeneration	450	10	4,500	50	22,500
Uncut	100	320	32,000	300	30,000
Thinned	225	170	38,250	150	33,750
Total		500	74,750	500	86,250
	HIGH REGENERATION POTENTIAL: 300,000 SEEDLINGS PER ha				
Regeneration	1,350	10	13,500	50	67,500
Uncut	100	320	32,000	300	30,000
Thinned	225	170	38,250	150	33,750
Total		500	83,750	500	131,250

Note also in Table 1 that the effect of area in clearcuts is quite different when the regeneration potential is high. In this case, increasing the area in regeneration openings from 10 to 50 hectares produces well over 50 percent increase in total deer food production from the 500-hectare deer.

The food production in openings that contain an abundance of vegetation is so much greater than in other stands that area in openings become a major factor affecting total food production.

To reduce browsing damage to seedlings, it is therefore important to a) insure that areas to be regenerated contain as many advance seedlings as possible, and b) schedule as much area as possible in cleat-cuts and thinnings. Both measures will increase the total food supply and reduce the damage. However, where regeneration potential is low, it is not possible to overwhelm the deer simply by scheduling more area in cuttings; raising the regeneration potential of areas to be harvested is more important.

Shelterwood cutting

Many stands do not naturally have large numbers of advance seedlings. In fact, only about 25 percent of the Allegheny hardwood stands that are ready to be harvested have enough advance seedlings to qualify for clear-cutting under the guidelines previously described. For stands with insufficient advance seedlings, other silvicultural techniques were needed to greatly increase the regeneration potential. Shelterwood cutting is widely used to improve the amount or size of advance regeneration, but little was known about the residual densities, numbers of cuttings, or intervals between cuttings that would produce best results.

A series of experiments was launched to investigate the silvical requirements of the various Allegheny hardwood species. These included detailed studies of sunlight requirements, using shade cloth tents of varying densities, and artificial control of other environmental factors, such as soil moisture and temperature. Similar experiments were conducted in forested areas where cutting to varying residual densities was used to vary sunlight exposure and other environmental factors. Auxiliary treatments, such at trenching, irrigation, supplemental lighting, soil heating cables, and fertilization, were used to separate canopy effects from soil effects. Seedlings grown in pots under various cutting regimes for various lengths of time were transferred to a clearcut to determine the ability of different sizes and ages of seedlings to survive complete overstory removal. And finally, large-scale cutting experiments were employed to test the effects of various shelterwood regimes over a wide range of site and stand conditions.

In brief, we learned that reducing canopy density to about 60 percent of full stocking produced small increases in the amounts of sunlight and soil moisture available for seedling establishment and altered light quality so as to increase seed germination of for-red-sensitive species such as red maple. The improved conditions provided good seed germination and greatly improved initial seedling survival so that the number of advance seedlings gradually increased over a 5- to 10-year period. For example, the number of advance seedlings increased by 121,000 stems per hectare over a 6-year period in one experiment, compared to the uncut control (Marquis 1978b).

Although it maximized the number of advance seedlings, the comparatively high density of the shelterwood overstory (60 percent) permitted only minor increases in seedling growth. Thus, advance seedlings remain small under this regime. But this is a distinct advantage under very high levels of deer population, far the small understory seedlings are browsed only lightly.

Once an adequate number of advance seedlings has become established, the overstory should be completely removed in a single operation. The small advance seedlings survive well if they have started under a 60 percent canopy, and the full sunlight insures that they will grow as rapidly as possible out of the reach of deer (Marquis 1979).

One difficulty experienced with this two-cut shelterwood sequence is that undesirable understory plants, such as beech root suckers, noncommercial striped maple seedlings, and herbaceous ferns and grasses, may be stimulated to the detriment of desired seedlings. High deer populations over many years have aggravated this problem, because heavy browsing on the more palatable tree seedlings has permitted expansion of these undesirable and less palatable plants to fill the void (Marquis and Grisez 1978). Once established, ferns and grasses are capable of interfering with subsequent seedling establishment through an allelopathic mechanism (Horsley 1977). In stands where these plants are present, herbicides must be used to remove the interfering plants before the seed cut of the shelterwood sequence. Although this also removes desired seedlings, it reduces interference and prepares the site for reestablishment of desirable seedlings, which is more rapid that reestablishment of the undesirable ones (Horsley 1978).

<u>Rotation length strategies</u>

A short-term technique to circumvent browsing damage is simply to delay regeneration harvest cuts until some future time when the deer population may be lower. Such a policy might at first appear unwise, since it could disrupt the even flow and total sustained yield of timber products, and could conceivably make regeneration even more difficult on those few areas still harvested, because deer pressure would be concentrated on a smaller area of regeneration opening.

But extended rotations have some advantages not immediately apparent. Allegheny hardwood forests are complicated mixtures of tolerant and intolerant species with widely different growth rates and timber values. They are very complex to manage for even timber alone, not always following patterns expected of even-aged stands of a single or similar species. Although the current practice is to clearcut the entire stand when the intolerants, such as black cherry, mature (80 to 100 years), the slower-growing tolerant sugar maple and beech are seldom mature at that time. Clearcutting tends to sacrifice many tolerant stems that are just reaching their period of maximum value growth.

To evaluate the trade-offs of various rotation-length strategies, we used computer stand-growth simulation to compare financial returns from timber production under a wide variety of cutting strategies. The effect of these strategies on total deer food production was also calculated.

In brief, it was found that stands containing 70 or more percent intolerant species were most profitably managed for timber if clearcut and regenerated as soon as the intolerants mature, as is the current practice. But stands with less than 70 percent intolerant species can sometimes be made to produce higher yields by harvesting only the intolerants when they mature and carrying the tolerant species for an additional 30 years or so until they, too, reach maturity. This requires maintaining a modest percentage of intolerants in the stands to serve as seed sources until the end of the rotation. And this strategy is profitable only where the tolerants are large enough to mature in an additional 30 to 40 years. If they take longer than that, it is possible to earn more by starting over with a new crop of fast-growing high-value intolerants.

Extending the rotation increases the proportion of sawtimber-size stands, and--since these are the stands suitable for commercial thinning—increases the proportion of the area thinned. As a result, total deer food production is maintained at about the same level under the extended rotation as under the more traditional one. The reduction in food production from regeneration stands is offset by an increase in production from the stands thinned, as shown in the tabulation below:

	Area ha	Production factor kg/ha/yr	Total production kg/yr
Single rotation			
Regeneration stands	50	450	22,500
Unthinned stands	300	100	30,000
Thinned stands	150	225	33,750
Total	500		86,250
Extended rotation	35	450	15,750
Regeneration stands	270	100	27,000
Unthinned stands	195	225	43,875
Thinned stands			
Total	500		86,625

MANAGEMENT GUIDES FOR TIMBER AND DEER

The silvicultural practices described briefly here provide ways to insure seedling regeneration in the presence of a large deer herd. Stand and site conditions differ greatly, and the best practice, combination of practices, differs accordingly. To insure proper application of the practices most appropriate to each stand, we have developed a series of management guidelines that bring together all pertinent information in a form that makes it simple for the practicing forester to evaluate stand condition and choose an appropriate prescription for stand treatment. This reduces the many complex decisions to their simplest form, removing much of the subjective judgment that has been required in the past.

There are three steps: stand examination, stand analysis, and prescription. The examination is a traditional wedge-prism cruise of the overstory, supplemented by measurement of specific site and understory factors that influence regeneration or deer food production. These data are summarized and analyzed in ways that reveal major aspects of the stand’s potential for future growth, stage of maturity, need for thinning, ability to regenerate and provide deer food, etc. From this information, plus a series of guidelines in the form of flow charts, a stand prescription can be developed that includes a detailed description of treatments to be applied, and if cutting is involved, amounts to be cut in the various species groups and size classes to achieve the desired residual stand.

The flow charts show a series of decision points concerning stand or site conditions that have an impact on the final prescription. The path taken from each decision point is determined from some quantitative measure of stand or site condition, with critical levels determined from experience and incorporated into descriptive guides. Figure 1 is one of these flow charts.

Because the prescription process has been reduced to objective decisions, the entire process can actually be handled by computer. Data from the stand examination are fed into the computer and summarized, and a recommended prescription is produced.

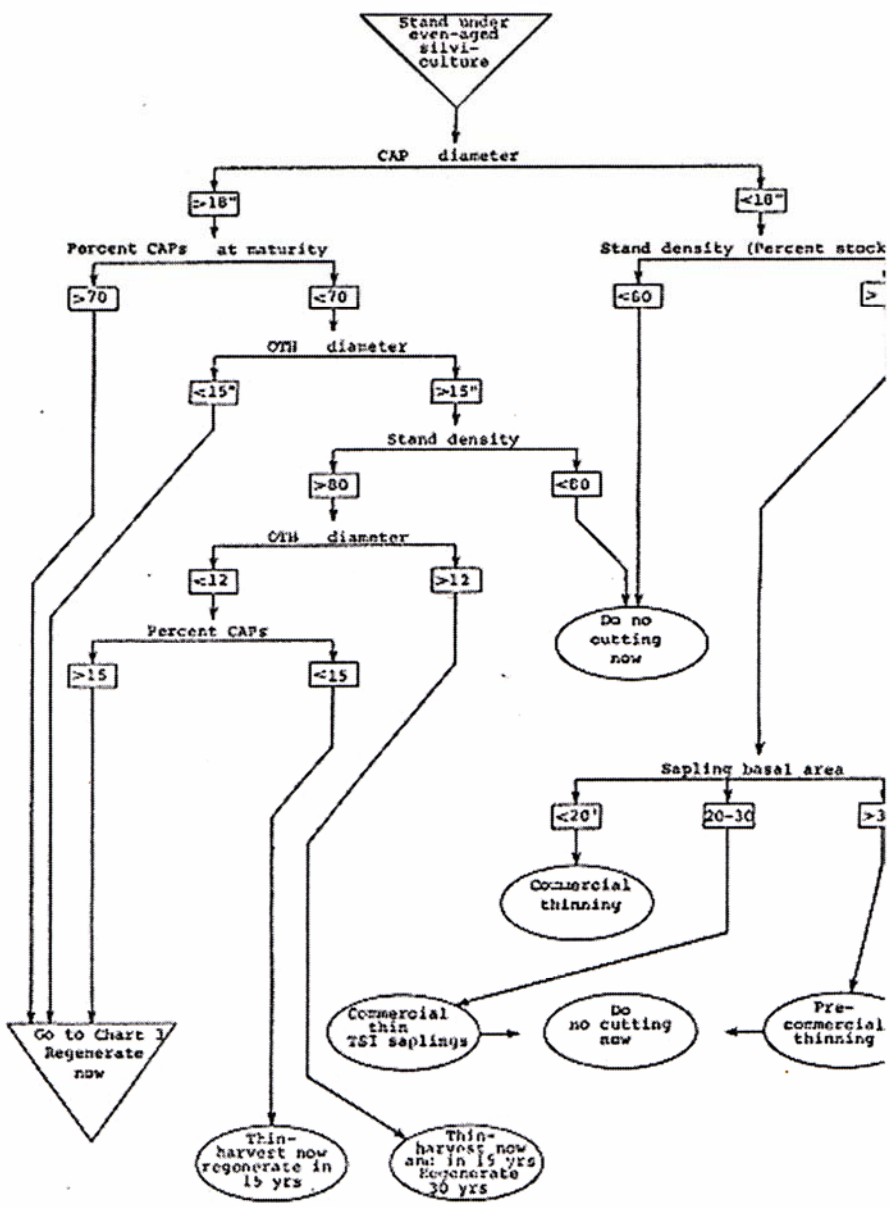
In our experience to date, the computer-generated prescriptions are generally silviculturally sound and practical, and extremely useful to the forester in managing his forest. Of course, no guides of this type can ever be complete for all of the many possible circumstances that might be encountered, so they must be used as a supplement to professional judgment, not as a substitute for it. If used in that way, they can be a powerful tool in the consistent application of practices currently considered optimal.

SUMMARY

The management practices and techniques described here were originally developed to insure adequate seedling regeneration in the presence of a large deer herd. The key is providing so much deer food within the home range of the local herd that the deer cannot consume all of it, and some seedlings will escape to form the next stand. This is accomplished by selecting areas with abundant advance regeneration, by stimulating advance regeneration through shelterwood cutting (using herbicides for site preparation where needed), maximizing the area in high deer-food producing condition (regeneration and thinned areas), and sometimes through special measures such as fertilization and direct protection. Control over the deer population is essential, but once it is achieved, those same techniques will become an integral part of a coordinated management system for Allegheny hardwoods that should allow sustained high yields of both timber and deer.

Keywords: Multiple use, Allegheny hardwoods, Natural regeneration, deer habitat

Figure 1 - Decision chart for intermediate culture of even-aged stands. This chart is one of five that comprise the Allegheny hardwood silviculture guidelines. These charts are used with additional written material providing detailed definitions of each decision point and prescription. CAPs = cherry, ash, poplar. OTH=all other species.



LITERATURE CITED

Auchmoody, L. R. 1978. Response of young black cherry to fertilization. In Agronomy Abstracts, Am. Soc. Agron. Meet., Chicago, Ill. p. 186

Bennett, A. L. 1957. Deer mismanagement-a threat to sustained yield forestry in Pennsylvania. Proc. Soc. Am. For. Annu. Meet. 1937. pp. 101-104.

Brenneman. Ronnie 1981. Here's how electric fencing helps control deer browsing. Pa. For. 71(1):10-11.

Grisez, Ted J. and Peace, Maurice R. 1973. Requirements for advance reproduction to Allegheny hardwoods—an interim guide. USDA For. Serv. Rcs. Note NE-180, 5 pp.

Holt, Coleman. 1980. Impacts of high deer population on forest regeneration and herd condition in the Allegheny hardwood region of Pennsylvania. The Allegheny News, Winter 1980, Allegheny Sec., Soc. Am. For., 3 pp.

Horsley, Stephen B. 1977. Allelopathic inhibition of black cherry II. Inhibition by woodland grass, ferns, and club moss. Can. J. For. Res. 7:515-519.

Horsley, Stephen B. 1978. Herbicide treatment of fern and grass understories with Roundup: A new tool in Allegheny hardwood silviculture. The Allegheny News, Summer 1979, Allegheny Sec., Soc. Am. For. 2 pp.

Latham, Roger. 1977. Deer appetite gives others indigestion. Pittsburgh Press, Sept. 4, 1977, p. D-10.

Leopold, Aldo. 1943. Deer irruptions, Wis. Conserv. Bull. 8(B): 3-11.

Marquis, David A. 1975. The Allegheny hardwood forest of Pennsylvania. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-15, 32 pp.

Marquis, David A. 1977. Devices to protect seedlings from deer browsing. U.S. Dep. Agric. For. Serv. Res. Note NE-243, 7 pp.

Marquis, David A. 1978a. Tree regeneration and deer. Pa. For. Resour. 61, Coop. Ext. Serv., Pa. State Univ. 4 pp.

Marquis, David A. 1978b. The effect of environmental factors on the natural regeneration of cherry-ash-maple forests in the Allegheny Plateau region of the eastern United States. In: Proc. Symp. Fevillus Precleaux, Nancy, France. pp. 90-99.

Marquis, David A. 1979. Shelterwood cutting in Allegheny hardwoods. J. For. 77:140-144.

Marquis, David A. 1981. The effect of deer browsing on timber production in Allegheny hardwood forests of Pennsylvania. U.S. Dep. Agric. For. Serv. Res. Pap. NE-475. 10 p.

Marquis, David A. and Grisez, Ted J. 1978. The effect of deer enclosures on the recovery of failed clearcuts on the Allegheny Plateau. U.S. Dep. Agric. For. Serv. Res. Note NE-270, 5 pp.

McCaffery, Keith R. and Creed, William. 1969. Significance of forest openings to deer in northern Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. 44, 104 pp.

Parrow, L. C., Auchmoody, L. R., Bickelhaupt, D. H. and Leaf, A. L. 1976. Biomass and elemental content estimates in young fertilized and unfertilized black cherry stands. In Agronomy Abstracts, Am. Soc. Agron. Meet., Houston. Tex. 183 pp.