COOPERATIVE FOREST WILDLIFE RESEARCH - ILLINOIS DEER INVESTIGATIONS

FINAL REPORT

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Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Division of Wildlife Resources
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FINAL REPORT

STATE OF ILLINOIS

W-87-R -23

Project Period: 1 July 1998 through 31 December 2001

Project: Cooperative Forest Wildlife Research - Illinois Deer Investigations

Prepared by Alan Woolf
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NEED: The widespread distribution and abundance of white-tailed deer in Illinois has created new management challenges and problems. There is a recognized need for management to become more proactive and less reactive. Increasingly, more segments of the public are scrutinizing the ability of managers to achieve deer management goals. As deer population levels approach stability in many areas, more hunters criticize perceived population fluctuations. In addition, the increased harvest pressure which has been necessary to control herd growth has precipitated complaints of a declining age structure within the herd. The challenges associated with stabilizing a population without overharvesting, in the face of increasing numbers of deer hunters, are certainly greater now than they have ever been. This necessitates the use of more sophisticated methodologies for monitoring and evaluating population performance and predicting the effects of alternative management options. Further, the problem is compounded by ex-urban development and privatization which may affect available habitat, ability to harvest deer, and deer-human negative interactions.

OBJECTIVES:

1. To examine pregnancy rates, numbers of lactating does (particularly yearlings) at check stations, and factors affecting the harvest of fawns in representative Illinois counties and their implications for deer management.

2. To upgrade the existing Illinois Deer Harvest Analysis and Modeling Program (IDHAMP) to make it compatible with newer (and future) computer operating systems.

3. To assess the impact of "Quality Deer Management" strategies upon population size, sex ratios, and age structure of Illinois deer.

4. To quantify the extent of human development and privatization in rural areas of Illinois and predict impact on management options and deer-human interactions.

EXECUTIVE SUMMARY

In the Executive Summary for the Segment 22 Annual Performance Report (Woolf and Roseberry 2000), we noted that the amended grant agreement was not approved by U.S. Fish and Wildlife Service staff until 4 October 1999 and activities planned for Segment 22 were curtailed and/or suspended pending approval to preclude incurring unauthorized expenses. This delay prevented the anticipated progress and completion of tasks scheduled for Segment 22, which in turn prevented timely completion of the project during Segment 23. We asked for and received a no-cost time extension of 6 months (through December 2001) to allow for thorough analyses of data and presentation of results upon completion of other tasks.

Study 1 (which addressed Objective 1) was completed in Segment 21 and a Completion Report provided. Study 3 was discontinued in the amended Grant Proposal. The following Executive Summary highlights activities and findings for each job in remaining Studies 2, 4, and 5.

Study 2. Population Modeling of the Illinois Deer Herd: Updating the Illinois Deer Harvest Analysis and Modeling Program (IDHAMP)

Job 2.1. Determination of appropriate format.—The objective is to determine the appropriate format/programming language that (1) will allow IDHAMP to operate in the newer operating systems, and (2) will remain compatible with evolving systems. This job was completed and reported in Segment 21.

Job 2.2. Translation of IDHAMP into the updated format.—The objective is to convert IDHAMP into a Windows/Windows NT-based program. Limited progress has been made, but no payments have been authorized to, or requested by the contractor during Segment 23. All available harvest data sets have been compiled and converted into the new format.

Job 2.3. Analyze and Report.—The objective is to prepare products from Jobs 2.1 and 2.2, with appropriate documentation, and provide to Illinois Department of Natural Resources

(IDNR) personnel. Work on this job has been limited to meetings with IDNR staff to review project status, and the preparation of data products. Illinois Department of Natural Resources personnel have been provided with archived copies of all completed data sets in the new format on CD-R disk.

Study 4. Deer Management - White-tailed Deer Harvest Strategies

Job 4.1. Literature Review and Agency Survey.—The objective is to review alternative harvest strategies, including Quality Deer Management (QDM), that have been implemented in other states, and document their strengths, weaknesses, and public acceptance. A self-administered, mail out questionnaire was sent to deer biologists in 32 states east of the Rocky Mountains and 29 (91%) responded. Sixteen (55%) states implement some form of QDM by use of antler restrictions to regulate yearling deer harvest.

Job 4.2. Harvest Strategies and Probable Impacts.—The objective is to test alternative harvest strategies by modeling and simulation to predict their probable impacts on herd density and composition; harvest levels and composition; and hunter opportunity, success, and satisfaction. A deterministic simulation model was created to predict the impacts of QDM strategies on Illinois deer herds, harvests, and hunter satisfaction. Simulation results suggested that QDM would not be an appropriate statewide management option because of the minor changes it would produce. Existing low yearling harvests (~50% of the total antlered harvest) and effective use of antlerless harvests to maintain the state deer population at "cultural carrying capacity" combine to create a statewide situation in Illinois that satisfies both population and harvest goals advocated by QDM proponents.

Job 4.3. Analyze and Report.—The objective is to analyze results and prepare reports for Jobs 4.1-4.3 in a timely manner. Data for this job were summarized in a thesis appended as a job completion report.

Study 5. Impacts of Ex-Urban Development and Privatization on Deer Herd Management

Job 5.1. Human Development and Privatization.—The objective is to quantify the extent of human development and privatization in rural areas of Illinois. Rural development maps were obtained or created for all 98 Illinois counties that have shotgun deer seasons. We identified 472,408 rural structures and buffered each with a 274 m zone representing the area within which hunting is prohibited without the occupant's permission. The potential exclusion zone represented 31.3% (range 20 - 48%) of Illinois rural land area.

Job 5.2. Identifying Areas of Potential Conflict.—The objective is to identify sites of potential human/deer conflict and areas where ex-urban development and/or privatization may have greatest impact on deer populations. Landscape analysis revealed that harvest efficiency was reduced when the number of ex-urban structures increased. Human development influenced county land composition. Although the distribution of ex-urban development was uneven throughout the state, the area of potential conflict was large and virtually statewide. Results indicated that human development affected both harvest efficiency and hunter distribution; findings that portend emerging problems both in deer harvest management, and the more general issue of human-wildlife interactions.

Job 5.3. Effects on Hunter Distribution and Behavior.—The objective is to assess the effect of ex-urban development on hunter distribution in a select area of Illinois and develop models that can predict the impacts of rural development on hunter behavior statewide. Hunter distribution was mapped by helicopter survey of 14 sample blocks (21%) of Jackson County. We observed 191 hunters; 18% were in the restriction zones which represented 36.8% of available county area and 33% of forest cover. Mean distance of hunters to nearest structure (582 m) was greater than random locations revealing that hunter distribution was influenced by structures and their restriction zones. Hunters at 5 southern Illinois and 11 central Illinois county check stations were asked to identify sections where they harvested their deer. These analyses revealed a similar pattern and validated aerial survey findings.

Job 5.4. Analysis and Report.—The objective is to summarize information and propose management strategies to IDNR describing potential impacts of ex-urban development on herd density and hunter opportunity, success, and satisfaction. Findings are reported in a thesis appended to this project final report.

STUDY 2. POPULATION MODELING OF THE ILLINOIS DEER HERD: UPDATING THE ILLINOIS DEER HARVEST ANALYSIS AND MODELING PROGRAM (IDHAMP)

JOB 2.1: DETERMINATION OF APPROPRIATE FORMAT

Objective: To determine the appropriate format/programming language that (1) will allow IDHAMP to operate in the newer operating systems, and (2) will remain compatible with evolving systems.

This job is COMPLETE and was reported in Segment 21

JOB 2.2: TRANSLATION OF IDHAMP INTO THE UPDATED FORMAT

Objective: To convert IDHAMP into a Windows/Windows NT-based program.

The delayed initiation of Segment 22 had a marked effect on this job, as it occurred at a time when the contractor was able to work intensively on the project. The contractor, chosen by SIUC staff for his experience and expertise in computer modeling of deer harvest and population information, is employed on a full time basis with the fish and wildlife agency of the State of Texas. As such, he must balance the work for this project against the competing priorities of his job, making it difficult to make up lost time. Limited progress has been made, but no payments were authorized to, or requested by, the contractor during Segment 23. Substantial progress was made in compiling and editing harvest data sets, and all were converted to the new format for incorporation into the new program. All data, after editing, were archived on CD-R disks, with copies retained by SIU, IDNR, and the contractor.

JOB 2.3: ANALYZE AND REPORT

Objective: To prepare products from Jobs 2.1 and 2.2, with appropriate documentation, and provide to IDNR personnel.

Agency staff have been kept apprised of contractor delays. Illinois Department of Natural Resources staff have received copies of all converted data sets on CD-R disks. No usable products are yet available from Study 2, but no charges have been accrued by Study 2 since

Segment 22. Illinois Department of Natural Resources staff will continue to work with the contractor to construct the updated IDHAMP program, and a continuing Study will remain (with no associated budget) in subsequent segments of the continuing white-tailed deer research project (W87R). At such time as usable modeling/data analyses tools are developed by the contractor, we will consider amending the project if it is determined that funds are necessary to produce a final product.

STUDY 4. DEER MANAGEMENT - WHITE-TAILED DEER HARVEST STRATEGIES

JOB 4.1: LITERATURE REVIEW AND AGENCY SURVEY

Objective: To review alternative harvest strategies, including QDM, that have been implemented in other states, and document their strengths, weaknesses, and public acceptance.

INTRODUCTION

The purpose of this job is to investigate harvest strategies that are implemented in other states, with an emphasis on QDM strategies. Harvest strategies include methods of regulating harvests (permit systems), population goals, and any harvest restrictions related to QDM that are intended to protect yearling males from harvest. The social, biological, and ecological strengths and weaknesses will be determined for each of the harvest strategies examined.

METHODS

A self-administered, mail-out questionnaire developed to obtain harvest strategy information was sent to the state deer biologists for all states east of the Rocky Mountains with the exceptions of Delaware, Illinois, New Hampshire, Rhode Island, and Washington D.C., (n = 32). The questionnaire addressed issues of hunter satisfaction and public acceptance related to harvest strategies along with information about population level goals, methods used to achieve goals, and harvest restrictions related to QDM.

RESULTS

A final response rate of 91% (29 of 32) was achieved for the questionnaire. Results show varying population level goals from state to state for agricultural regions with a combination of either-sex permits/seasons, antlerless permits, and doe days (antlerless seasons) used to accomplish goals. Sixteen of 29 states (55%) implement QDM through the use of antler restrictions to regulate yearling male harvest. Antler restrictions included a non-spike rule, 3-point rule (3 points on 1 side), 4-point rule (4 points on 1 side), 4 points total, 6 points total, and minimum antler main beam spread and main beam length.

JOB 4.2: HARVEST STRATEGIES AND PROBABLE IMPACTS

Objective: To test alternative harvest strategies by modeling and simulation to predict their probable impacts on herd density and composition; harvest levels and composition; and hunter opportunity, success, and satisfaction.

A thesis by Clarke (2001) in lieu of a final report for this job is attached. Following is the abstract of Clarke's (2001) thesis:

There are a variety of approaches for managing white-tailed deer (*Odocoileus virginianus*). Quality Deer Management (QDM) is a strategy that attempts to balance sex ratios and age structures for populations with disproportionately higher numbers of females than males and relatively few adult males (≥2 years old); a result of hunter selection toward males and high yearling male harvests. The 2 primary approaches for QDM are to (1) increase the proportion of females in the harvest, and (2) restrict harvest of yearling males to allow them to reach adult age classes. Hunter interest for QDM in Illinois has created the need to investigate the effects of strategies that protect yearlings from harvest. My objectives were to determine what QDM strategies are currently practiced in other states and determine the impacts of those strategies on the herd and harvest, as well as hunter satisfaction. Quality Deer Management strategies were determined primarily through the use of a self-administered questionnaire sent to deer biologists for states east of the Rocky Mountains ($n = 32$). I used a deterministic simulation model to predict the impacts of QDM strategies on herds and harvests, and made inferences as to their effects on hunter satisfaction. I based the harvest model on Illinois' current permit system and predicted harvests using current sex- and age-specific permit success rates. Strategies modeled included a 3-point rule (minimum of 3 points on 1 side), a 4-point rule, and a 13-inch main beam inside spread restriction. All strategies were modeled with both a low buck harvest scenario (representing current statewide population and harvest conditions in Illinois) and a high buck harvest scenario (representing a hypothetical population with a 90% yearling male harvest). Both scenarios were modeled with adult male permit success increased 50 and 100% to demonstrate possible effects of changes in hunter selectivity toward adult males associated with

implementation of QDM. Antler restrictions produced 12–54% more adult males, 8-54% higher adult male harvests, and 5-38% lower antlered harvests than a non-QDM strategy when modeled with current Illinois conditions. Restrictions produced 216–777% more adult males, 142-537% higher adult male harvests, and 13-57% lower antlered harvests when modeled with hypothetical conditions. Minimum levels of compliance necessary to ensure antler restrictions reduced yearling male harvests were higher for restrictions that protected the greatest numbers of yearlings. Regarding changes in hunter selectivity, QDM produced fewer adult males than a non-QDM strategy when adult male permit success was increased 50% with the 4-point rule, and when increased 100% with both the 4-point rule and the spread restriction under current Illinois conditions. However, antler restrictions led to greater numbers of adult males in the population and harvest for simulations with the hypothetical population regardless of increased success for adult males. Therefore, results indicated that QDM would be most effective in areas with high initial male harvest rates and relatively few adult males in the population.

JOB 4.3: ANALYZE AND REPORT

Objective: To analyze results and prepare reports for Jobs 3.1 and 3.2 in a timely manner.

Work toward meeting the objective of this job was accomplished with preparation of this final performance report and the appended thesis.

STUDY 5. IMPACTS OF EX-URBAN DEVELOPMENT AND PRIVATIZATION ON DEER HERD MANAGEMENT

JOB 5.1: HUMAN DEVELOPMENT AND PRIVATIZATION

Objective: Quantify the extent of human development and privatization in rural areas of Illinois.

JOB 5.2: IDENTIFYING AREAS OF POTENTIAL CONFLICT

Objective: Identify sites of potential human/deer conflict and areas where ex-urban development and/or privatization may have greatest impact on deer populations.

JOB 5.3: EFFECTS ON HUNTER DISTRIBUTION AND BEHAVIOR

Objective: Assess the effect of ex-urban development on hunter distribution in a select area of Illinois and develop models that can predict the impacts of rural development on hunter behavior statewide.

Jobs 5.1, 5.2, and 5.3 the objectives included were collectively studied and reported by Harden (2002) in a thesis that is appended to this final report. Following is the abstract from Harden's (2002) thesis:

Harvest efficiency for white-tailed deer is primarily dependent upon the density and distribution of hunters. Therefore, factors affecting hunter distribution will likely influence harvest efficiency. Previous research has suggested that presence of human habitations may influence the distribution of hunters. To test this assumption, I compiled rural structure maps for 98 of 102 Illinois counties. Based on the Illinois law which prohibits hunting within 274 m of any structure without the occupant's permission, all lands within this distance to rural structures were considered a potential hunter restriction zone. Land cover and deer habitat composition were determined at the individual structure locations, within the above restriction zone, and within each county. These data were then compared to variations in harvest efficiency using stepwise regression models. The influence of this zone on individual hunter distribution was evaluated through hunter surveys at both check stations and from the air. The distribution of hunters in relation to landscape and human development variables was assessed using logistic

regression. Over 4 million hectares (30%) of the rural Illinois landscape falls within the potential hunter restriction zone. The composition of the restriction zone differed from the remainder of counties for all landscape and habitat types assessed. Variables associated with the convergence of human development and deer habitat explained a major proportion of the variation in harvest efficiency. As rural development increased and protected more deer habitat, harvest efficiency decreased. Thus, when human development occupies deer habitat it restricts traditional deer management with hunting. The presence of human developments reduced the use of surrounding areas by hunters thus lowering hunting pressure in the hypothesized "restriction zone". Thus, increases in human development will make it more difficult for successful deer management with traditional methods. By using the models developed here, managers can identify areas of conflict where non-traditional deer management would be most effective.

JOB 5.4 ANALYSIS AND REPORT

Objective: Summarize information and propose management strategies to IDNR describing potential impacts of ex-urban development on herd density and hunter opportunity, success, and satisfaction.

This job has been accomplished with this final performance report and the appended thesis.

LITERATURE CITED

Harden, C. D. 2002. Impacts of human development on deer herd management in the ex-urban landscape. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

Woolf, A., and J. L. Roseberry. 2000. Cooperative Forest Wildlife Research - Illinois Deer Investigations. Illinois Department of Natural Resources, Annual Report, Federal Aid Project W-87-R-22, Springfield, Illinois, USA.

EFFECTS AND FEASIBILITY OF QUALITY DEER MANAGEMENT IN ILLINOIS

by

Kevin G. Clarke

B.S., State University of New York College of Environmental Science and Forestry, 1999

A Thesis
Submitted in Partial Fulfillment of the Requirements for the
Master of Science Degree

Department of Zoology
in the Graduate School
Southern Illinois University
Carbondale
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AN ABSTRACT OF THE THESIS OF

Kevin G. Clarke, for the Master of Science degree in Zoology, presented on October 30 2001, at Southern Illinois University at Carbondale.

Title: Examination of the Effects and Feasibility of Quality Deer Management in Illinois.

Major Professor: Alan Woolf

There are a variety of approaches for managing white-tailed deer (*Odocoileus virginianus*). Quality Deer Management (QDM) is a strategy that attempts to balance sex ratios and age structures for populations with disproportionately higher numbers of females males and relatively few adult males (≥2 years old); a result of hunter selection toward males and high yearling male harvests. The 2 primary approaches for QDM are to (1) increase the proportion of females in the harvest, and (2) restrict harvest of yearling males to allow them to reach adult age classes. Hunter interest for QDM in Illinois has created the need to investigate the effects of strategies that protect yearlings from harvest. My objectives were to determine what QDM strategies are currently practiced in other states and determine the impacts of those strategies on the herd and harvest, as well as hunter satisfaction. Quality Deer Management strategies were determined primarily through the use of a self-administered questionnaire sent to deer biologist for states east of the Rocky Mountains ($n = 32$). I used a deterministic simulation model to predict the impacts of QDM strategies on herds and harvests, and made inferences as to their effects on hunter satisfaction. I based the harvest model on Illinois' current permit system and predicted harvests using current sex- and age-specific permit success rates. Strategies modeled included a 3-point rule (minimum of 3 points on 1 side), a 4-point rule, and a

13-inch main beam inside spread restriction. All strategies were modeled with both a low buck harvest scenario (representing current statewide population and harvest conditions in Illinois) and a high buck harvest scenario (representing a hypothetical population with a 90% yearling male harvest). Both scenarios were modeled with adult male permit success increased 50 and 100% to demonstrate possible effects of changes in hunter selectivity toward adult males associated with implementation of QDM. Antler restrictions produced 12–54% more adult males, 8-54% higher adult male harvests, and 5-38% lower antlered harvests than a non-QDM strategy when modeled with current Illinois conditions. Restrictions produced 216–777% more adult males, 142-537% higher adult male harvests, and 13-57% lower antlered harvests when modeled with hypothetical conditions. Minimum levels of compliance necessary to ensure antler restrictions reduced yearling male harvests were higher for restrictions that protected the greatest numbers of yearlings. Regarding changes in hunter selectivity, QDM produced fewer adult males than a non-QDM strategy when adult male permit success was increased 50% with the 4-point rule, and when increased 100% with both the 4-point rule and the spread restriction under current Illinois conditions. However, antler restrictions led to greater numbers of adult males in the population and harvest for simulations with the hypothetical population regardless of increased success for adult males. Therefore, results indicated that QDM would be most effective in areas with high initial male harvest rates and relatively few adult males in the population.

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This thesis is dedicated to my stepfather of 24 years, Marcelino F. Sierra, who died in March 1998 after a hard fought battle with cancer. Marcel, as we called him, was the Director of Microbiology at the State University of New York Health Science Center at Brooklyn and King's County Medical Center, Brooklyn, New York. He was instrumental in my development as a biologist and introduced me to the world of science by providing me with an opportunity to work as a microbiologist in his laboratories. He supported all of my decisions growing up, even my decision to leave college in 1991 to pursue a career as a professional musician. Marcel's encouragement further led to my decision to return to college in 1997 and pursue a career in wildlife biology. I also would like to acknowledge my grandfather, Joseph Knapik, and my father, David Clarke, who played integral roles in the development of my passion for the outdoors and wildlife by introducing me to the activities of fishing, skiing, and hunting. Further, I would like to thank the Graduate School, Department of Zoology, and the Cooperative Wildlife Research Laboratory at Southern Illinois University at Carbondale (CWRL SIUC), as well as the Illinois Department of Natural Resources, for the funding and support that made it possible for me to complete my Masters research. Most especially I would like to thank my committee members, Alan Woolf, John Roseberry, and Paul Shelton, for the support and direction they provided me during my time at SIUC. I also would like to thank all of the students at CWRL SIUC, especially, Clay Nielsen and Marrett Grund who provided invaluable insight to my work. Finally, I would like to acknowledge my brother, Michael Clarke, as my partner on the slopes whose friendship ensured my sanity,

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INTRODUCTION

There are a variety of approaches for managing white-tailed deer (*Odocoileus virginianus*) populations. Population and harvest goals can vary from managing based on a cultural carrying capacity (CCC; Macnab 1985, Strickland et al. 1996) to managing for maximum sustained yield (MSY; McCullough 1979). Further, population goals can be achieved through a number of strategies based on the manipulation of antlerless and antlered harvests (e.g., either-sex vs. antlerless permits or seasons). For example, during the mid-1900s many states implemented buck-only harvests (Fleming 1983, Gladfelter 1984, Matschke et al. 1984) that relied on antler restrictions (e.g., ≥3 in for legal harvest) to protect females from harvest. This strategy allowed deer populations in the United States to recover after being decimated from market hunting and habitat loss (Gladfelter 1984). Restricting the female harvest allowed wildlife agencies to achieve management goals to increase numbers of deer and future harvests.

With little knowledge of sustained yield theory or the concept of biological carrying capacity (K), many hunters believe that more deer means more deer to harvest. This attitude has translated to a reluctance by hunters to harvest antlerless deer (i.e., hunter selectivity toward males), resulting in overabundant deer herds in some states (Woolf and Roseberry 1998). In addition, hunters selecting males over females can result in populations with skewed sex ratios and male age-structures (McCullough 1990, Nixon et al. 1991). Yearling males are highly vulnerable to harvest due to their general naivety, combined with fall dispersal patterns and rutting activity (Roseberry and Klimstra 1974, Nixon et al. 1991, Hölzenbein and Marchinton 1992). Their increased vulnerability can in turn lead to total buck harvest rates as high as 70–80% (Matschke et al. 1984, Diefenbach et al. 1997), resulting in populations with relatively few older age-class males (Matschke et al. 1984) and disproportionately higher numbers of females (McCullough 1990).

Quality Deer Management (QDM) is a program that attempts to address issues related to overabundance, as well as skewed sex and age structures. The goals of QDM are to promote and maintain healthy deer populations (i.e., reproductively fit), balanced sex ratios, and "natural" male age structures (Kroll and Jacobson 1995). The 2 primary approaches for achieving these goals are to (1) reduce and maintain deer populations well below K and (2) reduce the harvest of yearling males to allow a greater number of them to reach adult age classes (Hamilton et al. 1995*a*, Kroll and Jacobson 1995). Although the first objective can be accomplished through intensive antlerless harvests, reducing yearling harvests requires enforcement of new regulations by state agencies, accept in cases with voluntary programs at a local level (e.g., hunt clubs, private landowners).

There are always uncertainties involved with the implementation of new management strategies. Those related to QDM include (1) impacts of regulations on both herd and harvest numbers and composition; (2) realized levels of compliance to regulations; (3) changes in hunter selectivity, especially toward adult males; and (4) impacts on hunter satisfaction. Harvest simulation models allow managers to address uncertainties and make predictions about management strategies prior to their implementation (Starfield and Bleloch 1986). Models are abstractions of reality that describe processes within a natural system, and thus allow us to test the effects of changes to those processes (Starfield and Bleloch 1986). Xie et al. (1999) used one such model to predict the effects of varying male and female harvest rates, related to QDM, for white-tailed deer in Michigan. Bender and Roloff (1996) also used a harvest simulation model to evaluate harvest alternatives for white-tailed deer in Indiana. In addition to information about harvest strategies provided by models, it is equally important to consider the ecological and social ramifications that models do not address. The Illinois Department of Natural Resources (IDNR) has indicated that some hunters have expressed an interest in the implementation of QDM in Illinois. It is important to understand how a new management policy might affect deer populations and harvests, as well as hunters and the public, so that appropriate decisions can be made. Therefore, my objectives were to (1) determine the strengths and weaknesses (socially and ecologically), and public acceptance of QDM and other management strategies that are implemented in other states; (2) predict the impacts of QDM strategies on herd density and composition and harvest levels and composition in Illinois; and (3) estimate the effect of QDM strategies on hunter satisfaction in Illinois based on predictions of herd and harvest demographics, hunter opportunity, and hunter success.

METHODS

MANAGEMENT STRATEGIES

I reviewed proceedings of the 22nd Annual Meeting of the Southeast Deer Study Group (Fayetteville, Arkansas 1999), agency websites, and scientific literature to obtain information regarding management strategies for white-tailed deer implemented in other states. I obtained additional, and more detailed information from a self-administered mail-out questionnaire (Appendix A) sent to deer biologists in all states east of the Rocky Mountains with the exceptions of Rhode Island, New Hampshire, Delaware, and Illinois ($n = 32$). The questionnaire was in a multiple choice format with extra spaces provided for biologists to elaborate when answer choices were deemed insufficient.

HARVEST SIMULATION MODEL

Model Structure

The harvest simulation model that I used to examine QDM strategies was created using the ecological modeling program Stella II (High Performance Systems, Hanover, New Hampshire, USA). Model input was based on Illinois' current harvest system of either-sex and antlerless permits. The model was composed of 2 interacting components: a population structure and a permit harvest structure. Males and females were modeled separately within the population component of the model. Populations for both sexes were composed of fawn (<1 year old), yearling (1–2 years old), and adult (>2 years old) age classes. Model calculations began with the fall pre-hunt population (N_t). Total harvest losses were subtracted from pre-hunt populations to determine post-hunt populations, from which winter mortalities were subtracted, yielding pre-birth populations. Births were generated in spring based on pre-birth female populations. Summer mortalities were subtracted from post-birth populations to determine the following years' pre-hunt populations (N_{t+1}), with survivors advancing to the next available age-class. Surviving adults were added back into the adult population.

I modeled QDM antler restrictions using a yearling male availability rate input variable that represented the proportions of yearlings in the population available for legal harvest. Since it is unlikely that imposing QDM regulations would result in 100% compliance, I incorporated a compliance rate input variable that modified yearling harvests with antler restrictions. Other input variables included sex- and age-specific initial population sizes, either-sex and antlerless permit numbers, and K.

Population Parameters

The harvest model incorporated sex and age-specific summer and non-hunting winter mortality rates, and age-specific reproductive rates. I modeled rates specific to 5 Illinois regions (Appendix B, Figure 1a) based on 8 deer management units for Illinois (Figure 1b; IDNR, unpublished data). I created the 5 regions modeled by combining deer management units with identical parameter values. Harvest mortalities were additive because non-hunting mortalities were not modified based on harvest levels. I obtained all parameter values and density dependence equations from the Illinois Deer Harvest

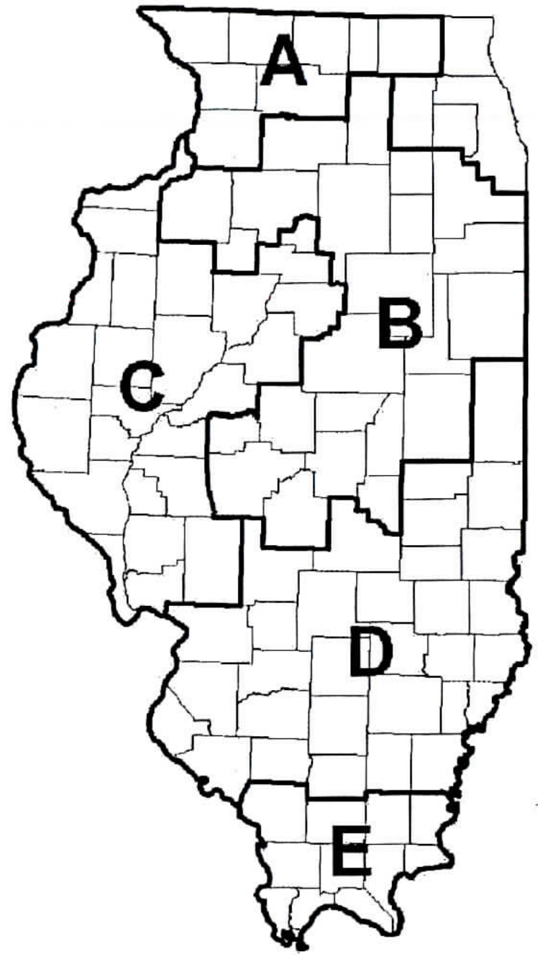

Figure 1a. Map of Illinois with newly designated regions for modeling Quality Deer Management strategies.

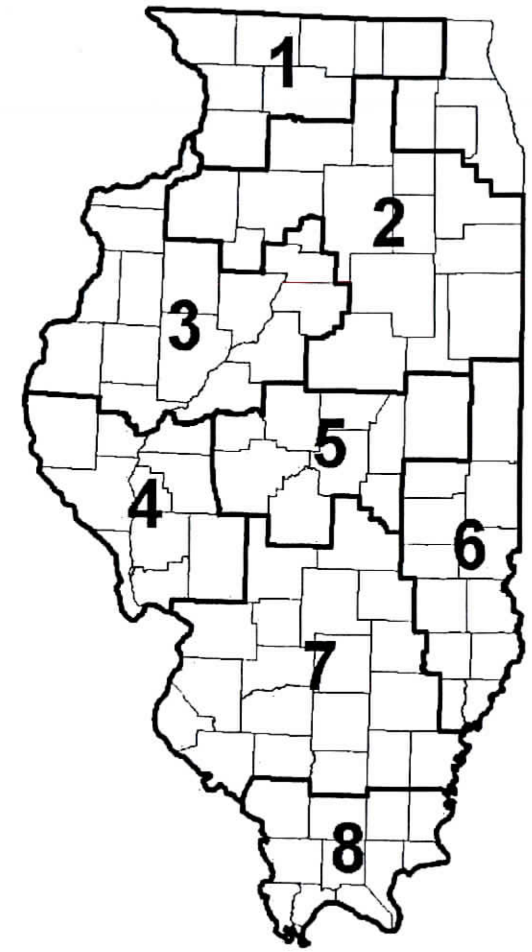

Figure 1b. Map of Illinois with original deer management units.

Analysis and Modeling Program (IDHAMP, Roseberry 1998). Summer and winter mortality rates were calculated as:

$$y = a + bx^e,$$

where a = base level mortality rates, b and e = regression coefficients (Appendix C), and x = the proportion of K for the pre-hunt population. Productivity rates declined at a slope of -1.50 when the total pre-hunt population reached 57% K for fawns, and 71% K for adults. Assumed fetal sex-ratios (% male offspring) were 60.6% for fawns, 55.8% for yearlings, and 51.5% for adults.

Permit Harvest

Sex- and age-specific harvests for each permit type were calculated as:

$$H = P_x \times S_p,$$

where H = number of deer harvested, P_x = number of permits of a particular type issued, and S_p = sex- and age-specific success rate for that permit type. I calculated current sex- and age-specific permit shotgun success rates from 1995–98 Illinois permit numbers and sex- and age-specific harvests (Table 1). Only 1995–98 data were used because trends in data suggested that hunter selectivity by permit type changed over the period of 1991–94 due to the addition of antlerless permits in 1991. Because deer harvested during archery season in Illinois were not aged, I calculated current sex- and age-specific archery permit success rates (Table 2) by multiplying total male and total female archery success rates by the age-specific proportions for shotgun permits.

Table 1. Mean 4-year shotgun permit success rates and ratios of deer to permits (d:p ratio) based on 1995–98 statewide Illinois harvest data.

	Either-sex					Antlerless				
	% success	Range	Modeled	d:p ratio	Range	% success	Range	Modeled	d:p ratio	Range
Fawn male	4.0	3.7– 4.4	0.0– 9.0	0.8	0.7–0.8	9.4	8.3–10.2	0.0–14.4	1.79	1.7–1.9
Yearling male	9.7	9.0–10.4	0.0–14.7	0.5	0.5–0.5	1.7	0.7– 2.4	--	--	--
Adult male	9.9	8.8–10.7	0.0–14.9	0.5	0.5–0.5	0.5	0.3– 0.6	--	--	--
Fawn female	2.8	2.6– 3.1	0.0– 7.8	0.7	0.7–0.7	7.8	7.4– 8.4	0.0–13.8	1.60	1.5–1.7
Yearling female	3.3	3.0– 3.8	0.0– 8.3	0.4	0.4–0.4	9.1	8.3–10.0	0.0–14.1	1.00	1.0–1.0
Adult female	4.1	3.9– 4.6	0.0– 9.1	0.9	0.9–0.9	11.1	10.8–11.6	0.0–16.1	2.16	2.1–2.2

Table 2. Calculated sex- and age-specific archery permit success rates and mean 4-year ratios of deer to permits (d:p ratio) based on 1995–98 statewide Illinois harvest data.

	Either-sex				Antlerless			
	% success	Modeled	d:p ratio	Range	% success	Modeled	d:p ratio	Range
Fawn male	2.0	0.0–5.0	1.2	1.2–1.3	4.3	0.0–7.3	1.3	1.2–1.4
Yearling male	4.9	0.0–7.9	0.8	0.7–0.8	0.0	--	--	--
Adult male	5.0	0.0–8.0	0.8	0.8–0.9	0.0	--	--	--
Fawn female	0.7	0.0–1.0	1.1	1.1–1.1	3.4	0.0–6.4	1.2	1.1–1.2
Yearling female	0.9	0.0–1.2	0.7	0.7–0.7	4.0	0.0–7.0	0.7	0.7–0.8
Adult female	1.1	0.0–1.4	1.5	1.5–1.5	4.9	0.0–7.9	1.6	1.5–1.6

I modeled a positive correlation between permit success rates and pre-hunt deer:permit ratios to allow harvests to vary with changes in populations sizes. This was best represented by the relationship between antlerless archery permit success for all deer and changes in deer:permit ratios ($r^2 = 0.96$, $P < 0.01$) from 1991–98. I also calculated current shotgun and archery deer:permit ratios from 1995–98 Illinois population estimates and permit numbers from IDHAMP (Tables 1 and 2). As with permit success rates, there was little variation in deer:permit ratios during this period. I modeled shotgun permit success rates (Table 1) over a range of deer:permit ratios from 0.0–3.0 for and 0.0–4.0 for either-sex permits and antlerless permits, respectively. I modeled archery permit success rates (Table 2) over a range of deer:permit ratios from 0.0–3.0 for all deer with all permits.

The yearling male availability rate was applied when QDM antler restrictions were modeled (i.e. availability <100%). In these cases, yearling male harvests were calculated as:

$$H_{ym} = N_{ym} \text{ x } A,$$

where H_{ym} = the maximum legal yearling harvest under a particular antler restriction, N_{ym} = the pre-hunt yearling male population, and A = the yearling male availability rate. Harvests calculated using this equation were applied only when H_{ym} was less than the yearling male harvest calculated using the original permit harvest equation. Yearling male harvests under QDM restrictions were further modified to account for non-compliance using the equation:

$$H_{ym} = H_{qdm} + [P_{es} \text{ x } S_{ym} \text{ x } (1 - c)],$$

where H_{ym} = total yearling male harvest, H_{qdm} = maximum yearling male harvest under QDM restrictions with 100% compliance, P_{es} = number of either sex permits issued, S_{ym} = success rate for yearling males with either-sex permits, and c = compliance rate of hunters to QDM regulations.

Crippling losses were calculated by multiplying harvests by crippling rates obtained from IDHAMP. Gun crippling rates used were 0.20 for antlered and 0.25 for antlerless animals. Archery crippling rates were 0.35 for antlered and 0.50 for antlerless animals. Crippling losses were then added to harvests to determine total harvest losses. Sex- and age-specific harvest rates were calculated by dividing total harvest losses by pre-hunt population sizes.

Yearling Antler Characteristics

Availability rates for modeling antler restrictions were based on yearling male antler characteristics in Illinois. I collected antler data from a sample of yearling males at deer check stations in Franklin, Jackson, Johnson, and Pulaski counties during the 2 Illinois 1999 firearm deer seasons (19–21 Nov and 2–5 Dec). Data collected included antler spread and total number of points. Antler spreads represented the maximum inside spread of the main beams and were measured to the nearest 0.64 cm with an aluminum measuring tape. Total antler points were determined by counting all unbroken projections ≥2.54 cm in length. I also obtained antler points data from IDNR for all yearling males harvested statewide during the 1999 Illinois firearm seasons (P. Shelton, IDNR, unpublished data). Antler points and main beam spread data were summarized using descriptive statistics in commercial spreadsheet software.

HARVEST STRATEGY SIMULATIONS

I used a hypothetical deer population at a relative density of 55% K to model harvest strategy simulations based on an estimate of K = 170 deer/258 ha woods. This population density represented the status of the current statewide Illinois population suggested by IDHAMP. I controlled harvest scenarios by manipulating permit success rates and/or numbers of either-sex and antlerless permits issued. All simulations ran for 3 years. Finally, I modeled harvest strategies using parameters for each of the 5 regions described previously for Illinois.

I modeled QDM strategies with a low buck harvest scenario (LBHS) and a high buck harvest scenario (HBHS) to demonstrate the effect of antler restrictions under different initial population and harvest conditions. The LBHS represented current conditions in Illinois with the population sex- and age-structures based on those predicted by IDHAMP for Illinois in 1998. Starting permit numbers were based on current statewide deer:permit ratios. I used preliminary model runs to adjust starting sex- and age-structures for each region modeled. I then adjusted either-sex permit numbers to ensure that statewide harvest rates for yearling and adult males were modeled. Finally, I adjusted antlerless permit numbers to maintain relatively stable antlerless populations over the 3-year period modeled. In addition to the 3-year-runs, QDM strategies were modeled for 10 years with LBHS simulations to allow adult male populations to peak , thereby depicting the maximum benefit from antler restrictions.

The high buck harvest scenario represented a hypothetical population with a higher antlered harvest rate and relatively few adult males, which I accomplished by increasing yearling male permit success. For these simulations I based starting either-sex permit numbers on the current statewide ratio of total deer to either-sex permits, rather than antlered deer to either-sex permits. This reduced the ratio of antlered males to either-sex permits for the starting population and consequently increased the initial adult male harvest rate modeled. Again, I chose antlerless permit numbers that allowed antlerless populations to remain relatively stable over the 3 years modeled.

I modeled all antler restrictions using several different strategies regarding the manipulation of either-sex and antlerless permits. First, I held all permit types constant throughout the simulations. Therefore, changes in adult male harvests associated were simply the result of changes in adult male permit success rates. I then modeled QDM restrictions by adjusting either-sex permits so that ratios of adult males to either-sex permit remained constant (i.e., constant adult male harvest rate). This demonstrated possible changes in adult male harvests resulting from QDM provided either-sex permits could be manipulated so as to maintain a constant adult male harvest rate. Finally, simulations were run with all permit types adjusted to maintain constant ratios of total deer to permits for each permit type. This reflected a management strategy similar to what was used in Illinois from 1991–98.

I modeled variations in hunter compliance to QDM regulations (i.e., antler restrictions) for simulations with all permits held constant. This allowed me to demonstrate the effect of non-compliance on the yearling male harvest rate. For these simulations, I reduced the compliance rate from 100% in 10% increments until the yearling male harvest under antler restrictions was not different from that without antler restrictions.

Changes in hunter selectivity associated with the implementation of QDM restrictions may be reflected in increased harvest rates for adult males (Bender and Roloff 1996). Thus, I modeled all QDM strategies with adult male permit success rates increased 50% and then 100% for both the LBHS and HBHS. Simulations with adult male success adjusted were performed only with all permits constant and either-sex permits adjusted.

Output provided by the model were harvest and population related. Harvest output included sex- and age-specific harvest numbers and rates, and numbers of permits issued. Population output included sex- and age-specific population sizes. Model outputs were interpreted by comparing QDM runs to non-QDM runs. Results of interest to QDM included number of adult males in both the populations and harvests, antlered harvests (≥ 1.5 years old), sex- and age-specific harvest rates, percent yearlings in antlered harvests, total harvests, percent antlerless deer in the total harvests, and total population sizes. It should be noted that I reported all population and harvest results from the final year of the 3-year-simulations.

RESULTS

MANAGEMENT STRATEGIES

Seven of the 21 states for which I obtained information from literature and the internet initiated cooperative programs between state agencies and private landowners to promote and assist improved management of statewide deer herds. Programs included Deer Management Assistance Programs and Managed Lands Programs which focused on promoting herd health and minimizing impacts on habitat. Damage Control Assistance Programs and Urban Deer Management Programs also were initiated in several states to reduce the effects of nuisance and overabundant deer in urban areas and reflect herd management based on CCC. Cooperative programs were dependent upon the use of antlerless harvests to regulate population levels. Further, all states implemented antlerless harvests to achieve statewide population goals either through antlerless seasons/doe days and permits, or either-sex seasons and permits. Does comprised 38% (range = 16–67) of recent annual harvests (n = 17). Information pertaining to goals relative to K (relative densities) was limited.

A final response rate of 91% (29 of 32) was achieved for the harvest strategy questionnaire. Five states provided information on relative densities (% K) of deer herds for forested areas, of which 3 managed herds at 80-100% K, 1 at 65–79% K, and 1 at <50% K. Relative density goals for agricultural areas were 80–100% K (n = 2) and <50% K (n = 2). In addition, 2 states reported that herds in urban regions were managed at <50% K. All 29 states indicated herd levels were manipulated through antlerless harvests. Methods for regulating antlerless harvests included either-sex permits only (n = 2), antlerless permits only (n = 3), doe days (n = 2), or a combination of these (n = 22). Sixteen of 29 states (55%) implemented antler restrictions to protect yearling males from harvest. Of those states, 6 implemented restrictions statewide, 1 on the county level, and 14 on special-use areas. Antler restrictions included a non-spike rule (n = 2), a minimum of 3 points on 1 side (3-point rule, n = 4), a minimum of 4 points on 1 side (4-point rule, n = 6), a minimum of 4 points total (n = 1), a minimum of 6 points total (n = 2), and a minimum antler main beam spread restriction (n = 4). Culling of yearlings with inferior antlers also was practiced in 2 states. Twenty-three of the 29 respondents (79%) reported that surveys were used to determine hunter satisfaction and 11 (38%) used surveys to determine public satisfaction.

YEARLING ANTLER CHARACTERISTICS

I summarized antler spread data from the 1999 Illinois firearm seasons for 363 yearlings from 6 counties (4 checkstations). Mean antler spread was 21.8 cm (SD = 4.8) with a range of 8.2–35.6 cm. Although antler spread data were collected from only 6 counties, I assumed these data were representative of the statewide population. Antler points data from the 1999 Illinois firearm seasons were summarized for 18,236 yearlings statewide. Mean number of total points was 5.7 (SD = 2.9) with a range of 1–17 total points. I assumed there was relative symmetry between numbers of points on both antlers when I determined proportions of yearlings protected by antler restrictions. Therefore, the 3-point rule protected yearlings with <5 points total (40.4%) and the 4-point rule those with <7 points total (72.7%), which translated to availability rates of 59.6 and 27.3%, respectively (Figure 2). The 13-in spread restriction protected 98.8% of all yearlings (i.e., 1.2% availability rate).

HARVEST STRATEGY SIMULATIONS

I ran 395 simulations for the harvest strategies modeled. Yearling and adult male harvest rates were approximately 37 and 30% (34% total antlered harvest), respectively, for non-QDM simulations modeled with current statewide conditions (LBHS). Simulations for the hypothetical conditions (HBHS) employed yearling and adult male harvest rates of approximately 90 and 50% (80% total antlered harvest), respectively. As a result, adult males comprised 4% of the total population, and yearling males 80% of the antlered harvest for HBHS simulations prior to the application of antler restrictions. In contrast, adult males comprised 15% of the total population, and yearling males only 50% of the antlered harvest for LBHS simulations. The proportion of adult males with LBHS simulations increased to 17% after 3 years without QDM because of the low adult male harvest rate representing current statewide conditions.

There was no change in the yearling harvest rate associated with the 2-point (non-spike) rule and 3-point rule for the LBHS. As a result, there was no effect on adult male populations or harvests. Only the 2-point rule had no effect when antler restrictions were modeled with the HBHS. The 3-point rule, 4-point rule, and 13-inch minimum spread restrictions translated to yearling male harvest rates of approximately 60, 27 and 1%,

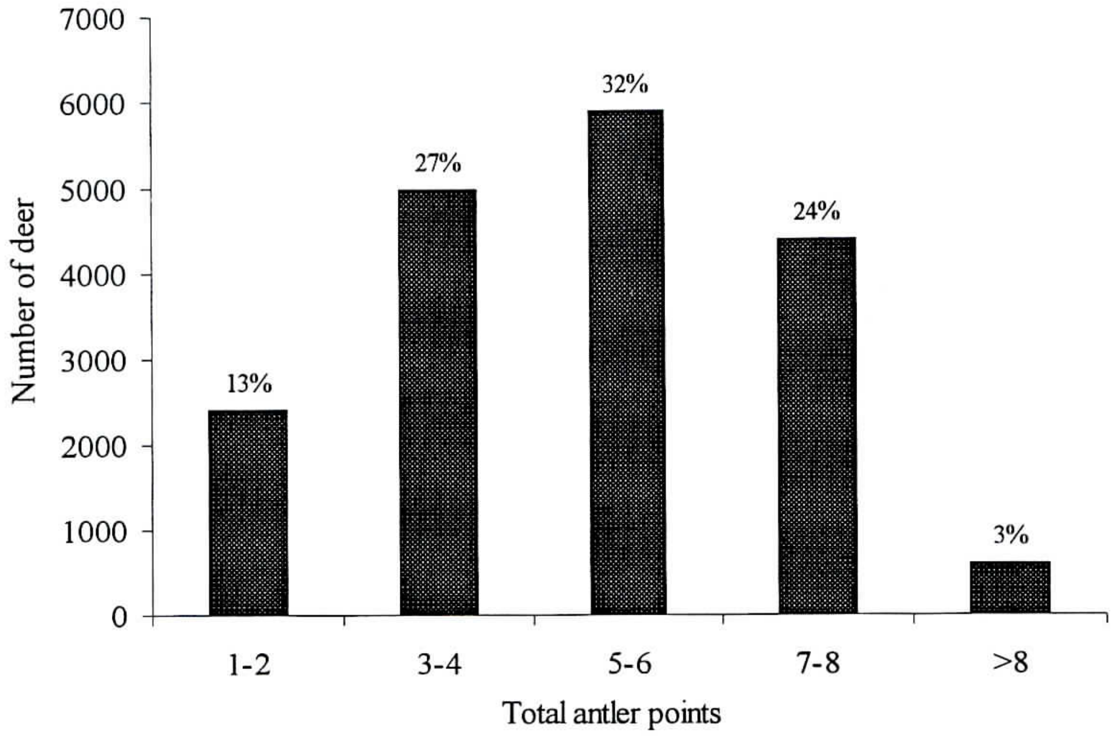

Figure 2. Antler points data for yearling males (n = 18,236) harvested during the 1999 Illinois firearms seasons in Illinois. Data are distributed into antler classes used for modeling yearling availability rates to Quality Deer Management antler restrictions.

respectively. Yearling harvest rates increased, however, as compliance to QDM restrictions was reduced from 100%, thus reducing the effect of antler restrictions on adult male populations (Figures 3 and 4). Minimum compliance levels (i.e., the compliance rate for which an antler restriction no longer resulted in a yearling male harvest rate different from the original rate without QDM) were lowest for antler restrictions that protected the greatest proportion of yearlings from harvest.

Three-year simulations of QDM strategies produced populations with 12–54% more adult males than a non-QDM strategy when modeled with the LBHS, and 216–777% more adult males when modeled with the HBHS (Table 3). In both cases, changes in populations were greater when simulations were run with permits held constant. Adult male populations leveled off after approximately 5 years for simulations with permits constant when the 13-inch spread restriction was modeled with current statewide conditions (LBHS), and produced 68% more adult males than a non-QDM strategy (versus 54% after 3 years). Total deer populations also increased with QDM as a result of changes in adult male populations (Table 4). As with adult male populations, increases were greater for HBHS simulations than LBHS simulations. Proportions of adult males in populations increased from 4 to 10% with the 3-point rule for HBHS simulations with permits held constant. Proportions of adult males increased from 15 to 20% and from 4 to 17% with the 4-point rule for LBHS and HBHS simulations, respectively, and to 25 and 22% with the 13-inch spread restriction for LBHS and HBHS simulations, respectively.

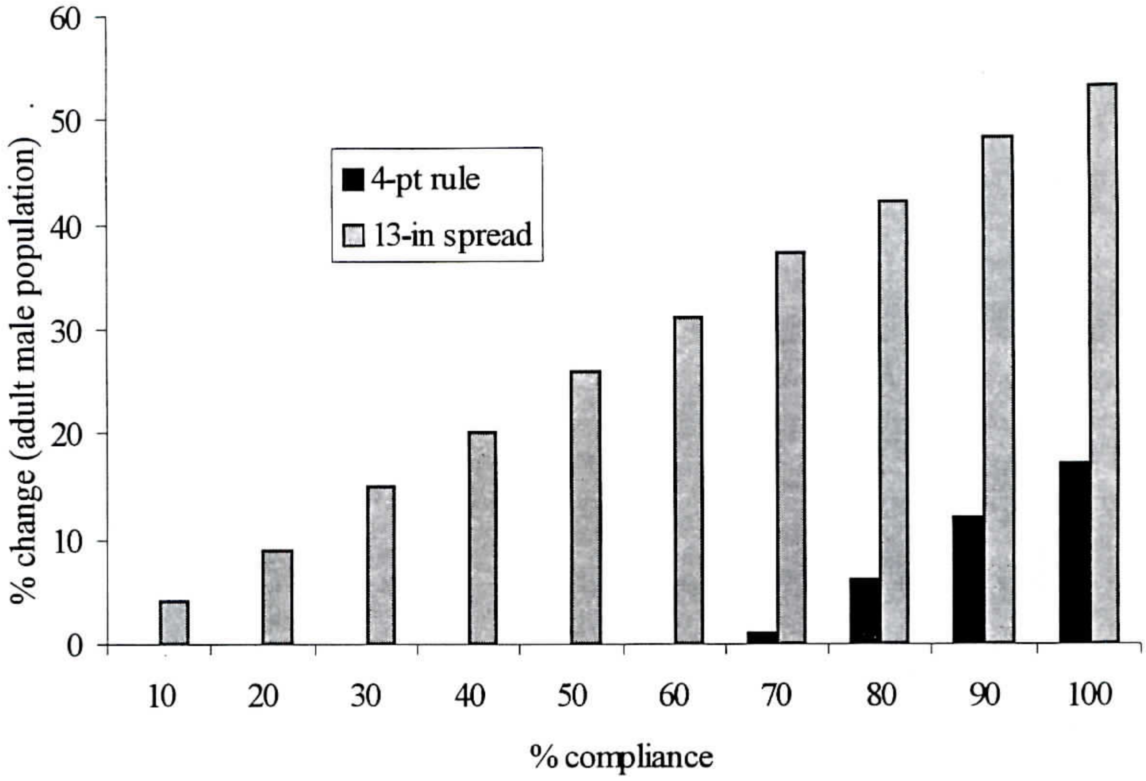

Figure 3. Simulation results depicting the relationship between compliance to Quality Deer Management antler restrictions and changes in adult male populations resulting from antler restrictions with the low buck harvest scenario.

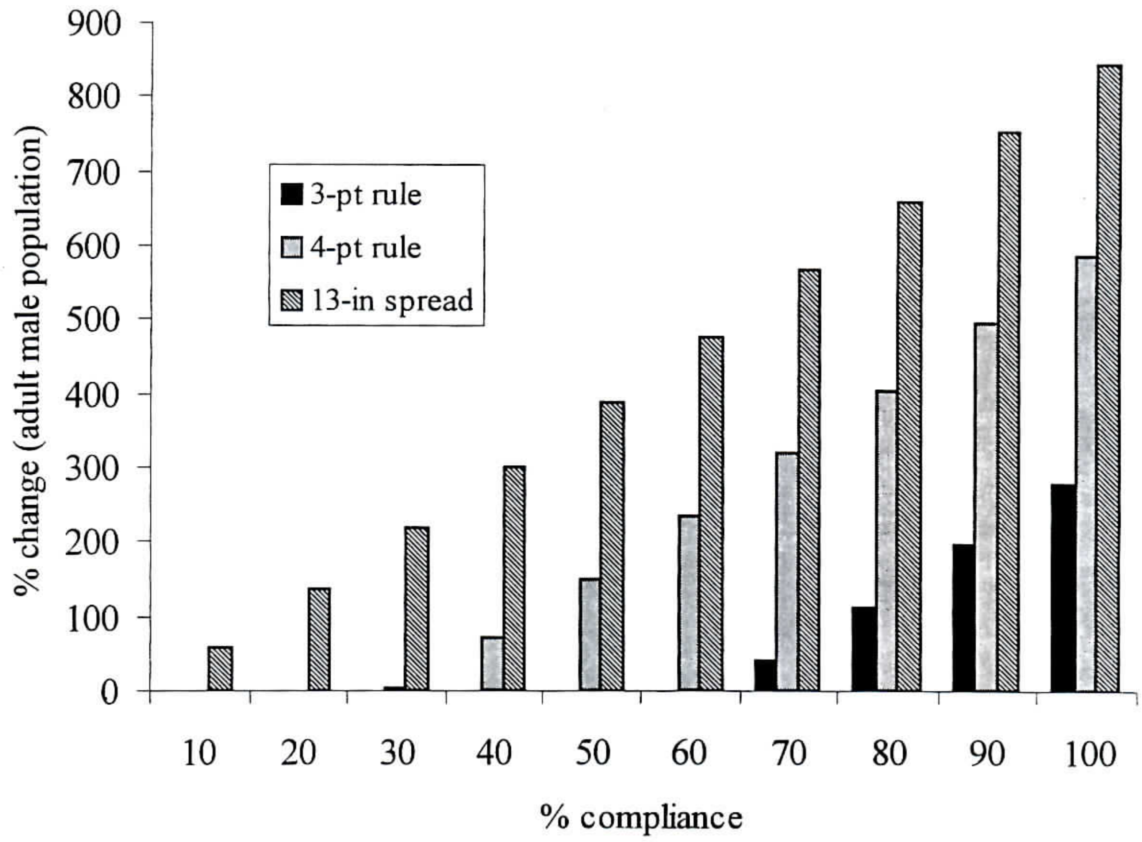

Figure 4. Simulation results depicting the relationship between compliance to Quality Deer Management antler restrictions and changes in adult male populations resulting from antler restrictions with the high buck harvest scenario.

Table 3. Simulation results of harvest strategies for the low buck harvest scenario (LBHS) and high buck harvest scenario (HBHS), expressed as means of 5 Illinois regions modeled. Results represent percent changes from a non-Quality Deer Management strategy.

	Adult male populations		Adult male harvests		Antlered harvests	
Harvest strategy	Permits constant	ES adjusted[a]	Permits constant	ES adjusted	Permits constant	ES adjusted
LBHS						
4-point rule	+16.7	+12.4	+7.8	+22.0	-11.9	-5.3
13-in spread	+53.8	+42.8	+22.0	+54.4	-37.7	-21.6
HBHS						
3-point rule	+265.9	+231.6	+154.6	+208.9	-16.6	-14.0
4-point rule	+565.3	+449.0	+244.1	+405.1	-39.2	-24.4
13-in spread	+816.7	+626.0	+298.8	+564.6	-58.5	-32.5

[a] Either-sex permits adjusted to maintain a constant ratio of permits to adult males throughout the simulation.

Table 4. Simulation results showing changes in total deer populations resulting from Quality Deer Management strategies, expressed as means of 5 Illinois regions modeled.

	% change in total deer populations	
Harvest strategy	Permits constant	All permits adjusted[a]
Low buck harvest scenario		
4-point rule	+2.9	+2.5
13-in spread	+8.1	+7.0
High buck harvest scenario		
3-point rule	+7.0	+5.9
4-point rule	+13.9	+11.6
13-in spread	+19.5	+16.4

[a] All permits adjusted (i.e., either-sex and antlerless, shotgun and archery) to maintain constant ratios of each permit type to the total deer population throughout the simulation.

Antler restrictions produced the highest adult male densities for regions with the highest male recruitment. Because the 3 regions with the highest recruitment (regions B, C, and A in east-central, western, and northern Illinois, respectively) had equal annual male fawn survival, differences in final densities were the result of differences in female natality rates (i.e., those with the higher natality rates having higher recruitment). The 2 regions with the lowest recruitment (regions D and E in south-central and southern Illinois, respectively) were the result of low natality as well as the lowest male fawn survival rates for the state.

Adult male harvests were 8–54% higher, and total antlered harvests 5–38% lower, with QDM than without for the LBHS (Table 3). For the HBHS, QDM produced adult male harvests 142–537% higher than the non-QDM strategy, while total antlered harvests were 13–57% lower (Table 3). Changes in adult male and total antlered harvests were greater when strategies were modeled with either-sex permits adjusted. Adult male harvest rates declined slightly as populations increased over the 3-year-period when strategies were modeled with permits held constant. Percent male yearlings in antlered harvests declined with the application of QDM in all cases, while percent females in total harvests increased (Table 5). Simulations with all permits adjusted (i.e., either-sex and antlerless shotgun and archery permits) in response to changes in total populations resulting from QDM strategies produced changes in adult male populations similar to simulations with permits held constant (Table 6). However, changes in total populations were less for simulations with all permits adjusted rather than held constant.

Table 5. Simulation results of harvest strategies with all permits held constant for both the low buck harvest scenario and high buck harvest scenario, expressed as means of 5 Illinois regions modeled.

Harvest strategy	% yearlings in antlered harvest	% antlerless deer in total harvest
Low buck harvest scenario		
No QDM	49.6	62.2
4-point rule	38.6	65.0
13-in spread	2.4	72.2
High buck harvest scenario		
No QDM	89.0	56.0
3-point rule	68.4	60.1
4-point rule	41.8	67.1
13-in spread	2.6	74.5

Table 6. Simulation results for Quality Deer Management strategies with the low buck harvest scenario (LBHS) and high buck harvest scenario (HBHS), expressed as mean values for 5 Illinois regions modeled. Results represent percent changes from a non-Quality Deer Management strategy.

	Adult male populations		Adult male harvests		Total antlered harvests	
Harvest strategy	Permits constant	All adjusted[a]	Permits constant	All adjusted	Permits constant	All adjusted
LBHS						
4-point rule	+16.7	+17.3	+7.8	+9.5	-11.9	-11.7
13-in spread	+53.8	+52.8	+22.0	+26.4	-37.7	-35.6
HBHS						
3-point rule	+265.9	+261.2	+154.6	+158.2	-16.6	-16.5
4-point rule	+565.3	+551.7	+244.1	+254.4	-39.2	-38.3
13-in spread	+816.7	+794.8	+298.8	+319.0	-58.8	-56.0

[a] All permits (i.e., either-sex and antlerless, shotgun and archery permits) adjusted to maintain a constant ratios of each permit type to the total deer population throughout the simulation.

Quality Deer Management strategies with the LBHS produced fewer adult males in the final populations than a non-QDM strategy when adult male permit success was increased 50% with the 4-point rule, and when increased 100% with both the 4-point rule and the spread restriction (Table 7). In addition, total antlered harvests were higher with QDM than without. A 13-inch spread restriction produced 17–26% more adult males and 4–18% lower antlered harvests compared to non-QDM simulations when success was increased 50%.

Adult male harvests rates increased to 45 and 60% (initially 30%) when adult male permit success was increased 50 and 100%, respectively. All QDM strategies with adult male permit success increased for HBHS simulations produced higher adult male populations and harvests, and lower total antlered harvests, than the non-QDM strategy (Table 8). However, adult male harvests were higher, and adult male populations lower, than QDM strategies modeled without adult success adjusted. Adult male harvest rates increased to 76 and 97% (initially 50%) when adult male permit success was increased 50 and 100%, respectively. Again, adult male harvest rates declined slightly when populations increased for simulations with all permits held constant. Likewise, harvest rates increased slightly when adult male populations declined.

Table 7. Simulation results of Quality Deer Management strategies applied to statewide conditions (low buck harvest scenario) and adult male permit success increased 50 and 100%, expressed as means of 5 Illinois regions modeled. Results reported as percent changes from non-Quality Deer Management simulations.

	Adult male populations		Adult male harvests		Total antlered harvests	
	Permits constant	ES adjusted[a]	Permits constant	ES adjusted	Permits constant	ES adjusted
Success increased 50%						
4-point rule	-8.1	-9.8	+41.1	+45.2	+4.8	+6.7
13-in spread	+26.0	+16.5	+62.1	+90.0	-17.7	-3.8
Success increased 100%						
4-point rule	-33.0	-28.4	+65.9	+58.3	+17.2	+13.7
13-in spread	-1.4	-6.2	+97.0	+106.8	-0.7	+4.9

[a] Either-sex permits adjusted to maintain a constant ratio of permits to adult males throughout the simulation.

Table 8. Simulation results of Quality Deer Management strategies applied to populations with a 80% initial antlered male harvest (high buck harvest scenario) and adult male permit success increased 50 and 100%, expressed as means of all 5 regions modeled. Results reported as percent changes from non-Quality Deer Management simulations.

	Adult male populations		Adult male harvests		Total antlered harvests	
	Permits constant	ES adjusted[a]	Permits constant	ES adjusted	Permits constant	ES adjusted
Success increased 50%						
3-point rule	+185.4	+154.4	+226.9	+252.6	-9.1	-9.1
4-point rule	+447.4	+324.8	+364.0	+482.1	-26.9	-16.3
13-in spread	+678.3	+463.4	+453.9	+668.9	-42.6	-20.7
Success increased 100%						
3-point rule	+121.3	+99.9	+262.9	+268.8	-5.4	-7.0
4-point rule	+345.5	+234.9	+454.2	+511.3	-17.6	-13.3
13-in spread	+555.7	+343.7	+573.1	+706.9	-30.4	-16.8

[a] Either-sex permits adjusted to maintain a constant ratio of permits to adult males throughout the simulation.

DISCUSSION

MANAGEMENT STRATEGIES

In Midwest agricultural states such as Illinois, the abundance of food resources from crops makes it possible for deer populations to reach extremely high densities. Therefore, deer populations must be managed based on CCC, typically well below K, to reduce human-deer conflicts while providing sufficient numbers to satisfy hunters. The harvest strategy questionnaire identified 2 states for which herds in agricultural areas are maintained at relative densities <50% K. This is the case in Illinois as well, where model estimates show the vulnerable deer population (based on areas open and closed to hunting) to be relatively stable at approximately 55–60% K (IDNR, unpublished data).

Managing herd levels based on CCC also is important in urban-suburban settings where high densities result in increased deer-vehicle collisions (Butfiloski et al. 1997), zoonoses (Conover 1997), and damage to ornamental plantings (Butfiloski et al. 1997, McCullough et al. 1997). Conover et al. (1995) estimated that annual damage due to deer-vehicle collisions was approximately $1 billion in the United States, while damage to crops was approximately $100 million annually (Conover 1997). In addition, there were 16,461 reported cases of Lyme disease as of 1996 (Centers for Disease Control and Prevention 1997). For the 2 states in which biologists provided information for urban areas, both indicated that populations in these areas were managed for density goals of <50% K. The risk involved with managing herds at <50% K is that, based on sustained yield theory, continued overharvest can lead to extirpation (McCullough 1979). This may be socially unacceptable as residents in some urban settings enjoy the esthetic benefits provided by the opportunities to view wildlife, including deer. However, it is highly unlikely that there could be enough hunting pressure to extirpate any deer population in the United States.

Maintaining deer populations at high relative densities (≥65% K) can have both ecological and biological ramifications in addition to the negative social impacts previously discussed. Questionnaire results indicated that deer populations are managed at 65–79% K in forested regions of 1 state, ≥80% K in forested regions in 3 states, and ≥80% K in agricultural regions in 2 states. Since productivity declines as deer populations approach K, maintaining herds at these levels produces the lowest sustainable harvests (McCullough 1979). Further, managing for densities close to K could lead to a decline in physical condition if herds exceed K. Socially, this may be unacceptable as people are often aggrieved by the sight or notion of starving deer. High relative deer densities do provide the greatest opportunities to hunters and wildlife enthusiasts for viewing deer in terms of numbers and visible deer sign (e.g. rubs and scrapes), but produce the lowest sustainable yields and the fewest opportunities to harvest trophies due to low numbers of adult males and poor antler quality (McCullough 1979). High deer densities also have been found to negatively affect abundance and richness of herbaceous and woody vegetative species in forested areas (Behrend et al. 1970, Tilghman 1989). Further, DeCalesta (1994) observed that increasing deer densities in Pennsylvania were correlated with declines in diversity and abundance of songbirds in forested areas, likely associated with effects of browsing. DeCalesta and Stout (1997) suggested that deer densities be maintained at <20% K for sustaining species diversity and abundance of flora and fauna, and 20–39% K for sustaining timber resources. Survey results showed that only 1 state attempted to manage its deer in forested areas at <50% K.

In some states the difficulty of achieving population level goals is exacerbated by the fact that much of the land available for deer hunting is private property. For example, 90% of the annual harvest in Mississippi occurs on private lands (Guynn et al. 1983). In these cases cooperative management programs between agencies and private landowners, such as Deer Management Assistance Programs and Managed Lands Programs, are imperative to attain statewide management goals. These programs provide incentives to landowners, such as additional antlerless permits, to secure their cooperation. In any case, obtaining population level goals is best achieved through harvest strategies that incorporate doe/antlerless harvests. All states reviewed and surveyed implemented antlerless harvests, with percent does in recent harvests ranging from 16–67%.

Although antlerless harvests are likely the most effective tool for achieving population goals, establishing goals for percent does/antlerless deer in total harvests as a strategy can be misleading. This type of strategy requires that doe harvests be held at some proportion of the buck harvest, with buck quotas thereby regulating the proportion of does in the total kill (Hayne and Gwynn 1977). Downing (1981) argued that most state agencies do not collect sufficient population and harvest data for this strategy to work. Data required include (1) estimates of female recruitment, (2) estimates of female non-hunting mortality rates, and (3) numbers of males harvested (Downing 1981). Insufficient data collection precludes managing for population stability, as herds with high recruitment will be under harvested, and herds with poor recruitment will be over harvested (Downing 1981). Further, Downing (1981) suggested that proportions of does in total harvests do not reflect trends in populations as this statistic could be affected by changes in buck harvests (e.g., changes in hunter selectivity due to QDM regulations). Therefore, harvest goals should be based on a variety of population indices that allow managers to track changes in total populations and adjust harvests accordingly.

MODEL ASSUMPTIONS

Modeling Harvests

Because I modeled harvests based on permit success rather than harvest rates I had to make an assumption about changes in success related to changes in sex and age-specific population sizes. Therefore, I assumed that permit success was positively correlated with deer:permit ratios. Success did not increase proportionately with populations, however, which caused adult male harvest rates to decline as their populations increased for simulations with all permits held constant. Although deer harvests are typically modeled using constant harvest rates (McCullough et al. 1990, Bender and Roloff 1996, Downing 1996, Xie et al. 1999), I believe that modeling permit success is justified since permit success in Illinois varied little from 1991–98, even with changes in deer populations (IDNR, unpublished data). This may be especially true for the harvest of adult male harvest rates when their populations increase. Van Etten et al. (1965) found that adult males were the least vulnerable cohort to harvest during controlled hunts in an enclosure. Therefore, large increases in their populations, as might be seen when QDM is applied to a population with very few adult males initially, could result in a decline in their overall harvest rate. Modeling a constant ratio of either-sex permits to adult males served to demonstrate the potential increase in adult male harvests if their harvest rates were kept constant.

Archery Permit Success

Sex- and age-specific archery permit success rates were not available because deer harvested with archery permits are not aged in Illinois. For this reason I assumed that the age structures for the male and female harvests with either-sex and antlerless archery permits were the same as harvests with either-sex and antlerless shotgun permits. It is possible that archery hunters are more selective when harvesting bucks with either-sex permits than shotgun hunters because archery season currently (approximately 3.5 mo) is considerably longer than the firearms season (7 days). Therefore, a higher proportion of adult males may be harvested with either-sex archery permits than with shotgun permits. This would mean that the current statewide adult male harvest rate modeled was too low, and thus, the current yearling male harvest rate modeled too high. In contrast, low success of archery hunters, combined with the difficulty involved with harvesting adult males, could actually lead to a lower proportion of adult males harvested with either-sex archery permits than with shotgun permits. As a result, the current statewide adult male harvest rate modeled would be too low, and the yearling male harvest rate too high. Regardless of which scenario may be true, total archery harvests from 1995–98 were

<30% of the total combined archery and shotgun harvests, and therefore the error in harvest rate estimates attributed to my assumption about sex- and age-specific archery permit success rates was minimal.

Yearling Availability Rates and Harvests

I modeled availability rates for QDM antler restrictions based on antler characteristics of yearlings in the Illinois harvest. The availability rates reflected the proportion of yearlings in the living population that would be available to harvest under a particular restriction. Therefore, I assumed that proportions of yearlings in antler classes used to determine availability rates were the same for the living and harvested populations. For example, if 27% of all yearlings in the harvest had ≤5 points total, then it was assumed that 27% of all yearlings in the living population had ≤5 points total. I contend that many hunters select bucks to harvest based on numbers of antler points. Therefore, a hunter with a choice of several yearlings to shoot would select an 8-point over a 6-point, or a 6-point over a 4-point. If this were true, yearlings in the harvest would be biased toward those with greater numbers of points, thus skewing the proportions of yearlings in the antler classes representing the availability rates.

When calculating yearling male harvests under antler restrictions I assumed that assumed that reduction in yearling male harvests resulting from QDM antler restrictions did not result in increased harvests of antlerless deer with either-sex permits because of the opportunities provided hunters for harvesting antlerless deer with antlerless permits. I further assumed that all yearlings not protected by the restrictions would be harvested as long as it did not result in a harvest rate higher than the initial (non-QDM) harvest rate. Therefore, if the initial yearling harvest rate was 90% and the availability rate was determined to be 50%, then the new (QDM) harvest rate would be 50%. An alternative method of modeling yearling male harvests could have been to assume that if the initial yearling harvest rate was 90% and the availability rate 50%, then only 50% of the non-QDM harvest would be taken once the restriction was implemented (i.e., a 45% QDM harvest rate). Differences in results for QDM simulations resulting from these 2 methods of modeling yearling harvests would likely be inconsequential however.

HARVEST SIMULATIONS

The success of QDM strategies hinges upon compliance by hunters to harvest regulations. If compliance rates fall below some critical level (i.e., minimum compliance), antler restrictions would have no effect. Although it is not known what level of compliance will be achieved with the implementation of antler restrictions, it would likely not be 100%. Non-compliance can be both voluntary and involuntary. Involuntary non-compliance would be due to hunters simply making mistakes in the field when attempting to judge whether a buck is legal for harvest. Voluntary non-compliance to QDM would come from hunters that do not support the implementation of QDM. Such might be the case for hunters who view QDM strictly as trophy management, but are not trophy hunters themselves. In fact, results of a survey of hunters conducted by Decker et al. (1980) identified the desire to harvest a trophy deer as only the seventh most important aspect of the hunt. Implementation of QDM in a situation where it is not favored could lead to high levels of voluntary non-compliance and preclude any chances for success. Therefore, it would be important to determine acceptance to QDM strategies prior to implementation. In Georgia, where QDM restrictions were implemented countywide, a 67% majority support was required by surveyed hunters and landowners to even consider implementation (Grahl and McDonald 1998). When compliance was modeled, I found that restrictions that protected the greatest proportions of yearlings provided the greatest "room for error" (error being non-compliance). It would make sense then to choose an antler restriction that protects as many yearlings as possible without reducing opportunities for hunters to harvest adults. Of the restrictions I modeled for Illinois, a 13-inch inside spread restriction would seem most appropriate as it would protect nearly 100% of all yearlings, versus approximately 40 and 73% with a 3-point and 4-point rule, respectively.

Because of the current low buck harvest rate in Illinois (approximately 33%), antler restrictions modeled under these conditions (LBHS) produced relatively small changes in the adult male population. The spread restriction with 100% compliance produced adult male populations 42–54% higher (depending whether modeled with either-sex permits adjusted or with all permits held constant) than the non-QDM strategy, while the 4-point rule resulted in populations 12–17% higher. Therefore, a spread restriction applied to a population with 5 adult males/km^2 woods might produce 2 additional adult males/km^2 woods several years down the road, while the 4-point rule would produce <1 additional adult male. The issues associated with involuntary non-compliance to a spread restriction, combined with any voluntary non-compliance, would make it impossible to achieve these results. Further, even if these results were achieved, it is possible that they could go virtually unnoticed by hunters because of the wariness of adult male deer that hunters might never see.

Changes in adult male populations were much greater when antler restrictions were modeled with an initial antlered male harvest rate of 80% (HBHS), versus 34% (LBHS). Likewise, the potential changes in adult male harvests also were much greater. Although such dramatic increases in adult male populations (as much as 817% with the 13-inch spread restriction) may seem improbable, they are simply the result of the initial (non-QDM) conditions modeled. Simulations with the hypothetical (HBHS) and current statewide conditions (LBHS) were run with identical starting population sizes and proportions of yearling males in the total population. However, the initial yearling harvest rate of 90% for HBHS simulations resulted in starting populations with considerably fewer adult males (4% versus 15%). Such a high yearling harvest rate prohibits males from reaching adult age classes. As a result, the same antler restrictions modeled with HBHS produced considerably greater changes in adult male populations, primarily due to the large addition of animals into the 2-year-old age-class. Thus, these changes did not result in greater proportions of adult males in final populations than with LBHS simulations.

Such dramatic increases in numbers of adult males resulting from antler restrictions that protect yearlings can cause total deer populations to increase as well. For example, application of the 13-inch spread restriction with HBHS simulations caused total populations to increase approximately 20%, versus only 8% for LBHS simulations.

Therefore, antlerless harvests would need to be increased to protect against undesirable changes in the total deer population. Simulations with all permits adjusted to maintain constant ratios of each permit type to the total deer population reflected this type of management. This strategy provided the best protection against total population increases than simulations with only either-sex permits adjusted or all permits held constant as a result of increased numbers of antlerless permits. Further, the strategy of increasing all permit types with respect to changes in adult male populations produced results similar to simulations with all permits were held constant.

For all simulations, QDM strategies resulted in the highest adult male densities for regions with the highest recruitment. Although this knowledge of the effect of recruitment is useful, the benefits of a strategy like QDM are derived more from the relative changes in adult male densities within an area and not necessarily the absolute densities of adult males that are achieved. For instance, regions with the highest adult male densities following QDM also were those regions with the highest adult male densities prior to QDM, simply because of differences in recruitment. The changes (percent increases) resulting from QDM were very similar for all regions, and differences did not appear related to differences in recruitment. Further, since there were no differences in yearling or adult male annual mortality rates between regions, no conclusions could be drawn about their effect versus the effect of recruitment.

Although the spread restriction modeled produced both the greatest changes in populations and harvests, it also would likely lead to the highest levels of non-compliance because of the higher levels of involuntary non-compliance associated with this type of restriction. While hunters can easily count numbers of points, it is impossible to measure the antler spread before taking a shot. Spread restrictions are typically chosen by determining the outside antler main beam spread that corresponds with the distance between the tips of a bucks ears when they are facing forward (typically a 15-in outside spread [Hamilton et al. 1995*b*] or 13-in inside spread). Determining whether a buck has legal antlers in this manner relies strictly on the judgement of hunters, with errors in judgement resulting in involuntary non-compliant kills. The question is raised then whether the hunter should be penalized for non-compliant kills. If hunters were penalized, those that used their best judgement but accidentally shot a buck with a 12.5 versus 13-inch inside spread would suffer the same consequences as those who simply chose not to comply. Likewise, if hunters were not penalized, only the true "trophy" hunters would comply with restrictions and QDM strategies would have little to no success. Therefore, it would make most sense to employ an antler restriction based on number of points rather than a spread restriction.

In addition to the negative effects of non-compliance and modeling errors, changes in hunter selectivity could further serve to negate possible increases in adult male populations if QDM were applied statewide under current conditions (LBHS simulations). Bender and Roloff (1996) suggested that implementation of QDM restrictions would lead to a change in hunter selectivity toward adult males and result in an increase in their harvest rate. This scenario was represented by QDM simulations with adult male permit success increased. The 13-inch spread restriction produced only 17–26% more adult males than no QDM when adult male permit success was increased

50%. Further, there was essentially no change when success was increased 100%, even when modeled with the unlikely scenario of 100% compliance. Additionally, when success was increased 50 and 100% with the 4-point rule, QDM actually produced fewer adult males than no QDM because of their increased harvest rate.

Although it is not known with certainty what changes might occur with the implementation of QDM, I believe the following is a possible scenario. Greater opportunities to harvest an adult male associated with QDM could cause hunters to spend more time and effort in an attempt to do so, rather than simply taking the first buck they see (often a yearling). Thus, the potential changes in adult male populations resulting from QDM strategies with current Illinois harvest conditions would be relatively small and do not warrant a change in current management policy on such a large scale.

Increasing adult male permit success rates for HBHS simulations (90% non-QDM yearling harvest rate) did not preclude increases in adult male populations, although changes resulting from antler restrictions were smaller than when success was not adjusted. Even the 3-point rule produced 100–121% more adult males when success was doubled (i.e., increased 100%). This demonstrates the effectiveness of QDM applied to populations with very high yearling male harvests despite possible increases in adult male harvest rates. Further, I feel it is unlikely that permit success would increase so much as to result in a harvest rate >90% for adult males as was seen when success was increased 100% with HBHS simulations. Hayne and Gwynn (1977) claimed that it would be almost impossible to harvest 70–80% of the adult males because of their wariness.

Roseberry and Klimstra (1974) found that adult males were the least vulnerable to harvest of all the sex and age-classes and as a result, adult male harvests are inherently limited.

However, as Bender and Roloff (1996) further suggested, increased adult male harvest rates associated with QDM may preclude increases in numbers of trophy males (≥3.5 years old). Since the large increases in adult males with HBHS simulations were primarily due to the addition of 2.5-year-olds, increased harvest pressure on 2.5-year-old males could be sufficient to prevent many of these animals from living past 2.5 years.

Although adult male harvest rates may increase as a result of changes in hunter selectivity, Illinois' permit system protects against further increases that might result from increased use of QDM areas by hunters. Shotgun permits are county-specific in Illinois. In addition, special hunt areas in Illinois require permits specific to those areas, as is the case with the Crab Orchard National Wildlife Refuge and other specially regulated areas. The same strategy should thus be applied to areas established as QDM-only.

HUNTER SATISFACTION

Quality Deer Management strategies would likely lead to the highest levels of hunter satisfaction among what Decker and Connelly (1989) described as achievement-oriented hunters (i.e., those concerned with the challenge of the hunt and successful bagging of game). They found achievement-oriented hunters to be younger aged hunters (30–44 years old) with fewer years of hunting experience (1–10 years). Their presence in the hunting population, therefore, is dependent upon hunter recruitment. Appreciative-oriented hunters (i.e., those that enjoy the esthetic benefits of nature) as described by

Decker and Connelly (1989) also might benefit from QDM strategies because of the increased presence of buck sign, such as rubs and scrapes, as well as opportunities to see larger, older males, even if a shot did not present itself.

Minor changes in both adult male populations and harvests resulting from QDM strategies modeled with statewide conditions (LBHS) likely preclude increased hunter satisfaction resulting from implementation of QDM statewide in Illinois. Quality Deer Management simulations with a 13-inch spread restriction (i.e., restriction that produced the greatest change in populations and harvests) resulted in 22% more adult males in the harvest when modeled all permits held constant and 100% compliance, and 54% more adult males when modeled with a constant adult male harvest rate and 100% compliance. However, it is unlikely that compliance to restrictions would be 100%, especially for a spread restriction because of the likelihood of involuntary non-compliance. Further, it is improbable that managers could detect changes in adult male populations so as to properly adjust either-sex permits to maintain a constant adult male harvest rate. Even if these maximum benefits were achieved, they might not be sufficient to satisfy hunters expecting greater changes in harvests associated with QDM. For example, if normal (non-QDM) harvests are typically 2 adult males/km^2 (a realistic scenario), a spread restriction might increase that harvest to 3 adult males/km^2. Further, declines in total antlered harvests associated with QDM restrictions could contribute to a decline in hunter satisfaction among all orientations of hunters; a situation exacerbated by hunters penalized for involuntary non-compliance to restrictions.

However, QDM could result in increased hunter satisfaction if implemented for populations with high yearling harvests and very few adult males, as with HBHS simulations. Under these conditions even the 3-point restriction produced 232–266% more adult males and 155–209% higher adult male harvests, while total antlered harvests declined only 17%. This provides greater opportunities for both viewing and harvesting adult males, as well as the associated increase in visible buck sign in the field. In addition, since herds in Illinois are currently managed for CCC, it may not be necessary to reduce deer populations in order to achieve the quality goals of QDM. Therefore, hunters would not see fewer deer as a result of its implementation.

Implementing QDM in appropriate areas where it is preferred by hunters (e.g., smaller areas where mainly those supporting QDM would hunt) would further ensure high hunter satisfaction. This would allow restrictions that protect greater numbers of yearlings. Quality Deer Management proponents would likely not be disappointed with declines in antlered harvests because of the absence of yearlings in the harvest.

MANAGEMENT IMPLICATIONS

In conclusion, I believe that QDM is a feasible management alternative for Illinois only if it is implemented under limited, appropriate conditions. First and foremost, simulation results suggest that QDM would not be appropriate statewide because of the minor changes that it would produce. This is directly attributed to the low current statewide harvest rate for yearling males. As a result, IDHAMP output suggests that adult males comprise a slightly larger portion of the total statewide deer population than yearling males as of 1998 (IDNR, unpublished data). In addition, yearling males comprise only approximately 50% of the total antlered harvest in Illinois (IDNR, unpublished data). Bender and Roloff (1996) suggested that QDM need only be applied in situations where yearlings account for ≥65% of the antlered harvest. Low yearling harvests, plus the use of antlerless harvests to maintain populations at CCC, creates a situation statewide in Illinois that satisfy both the population and harvest goals of QDM.

However, there may be local areas in Illinois where yearling male harvest rates are considerably higher than what occurs statewide, and that harbor populations with few adult males. Results of simulations for the hypothetical population with a 90% initial (non-QDM) yearling male harvest rate, and a starting population comprised of only 4% adult males, indicated that large increases in both adult male populations and harvests could be achieved with QDM antler restrictions. Areas in Illinois that meet these conditions would benefit most from a QDM-type strategy, provided a management goal was to increase the number of adult males in the population and harvests. There are inherent problems with small scale implementation of QDM, however. One such problem is the dispersal of yearling males out of protected areas and into non-protected areas where they would be harvested. Therefore, an area considered for implementation must be large enough to provide protection to dispersing yearlings. Also, too small an area might support too few deer for QDM to have any noticeable affect because restrictions would protect very few individuals.

The importance of compliance to the success of QDM warrants limiting implementation to areas where it is preferred by hunters so as to minimize levels of voluntary non-compliance. This also ensures higher levels of hunter satisfaction since hunters that prefer QDM would tolerate lower antlered harvests provided increased opportunities to see and harvest adult males. Additionally, restrictions based on antler points only would be most appropriate as it would help limit levels of involuntary non-compliance and further improve chances of success for QDM. Finally, it is important to understand that along with compliance, the initial conditions for areas where QDM would be implemented strongly dictate the ability of such a strategy to produce any change from the status quo with respect to herd and harvest numbers and composition.

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Appendix A. Questionnaire administered to state deer biologists for obtaining information about white-tailed deer harvest strategies.

Name ______________________ State ______________________

Title ______________________

Please check the appropriate boxes for answers that apply. Check more than one if applicable.

1. Are management decisions based on an estimate of Biological Carrying Capacity (K)? □ yes □ no

   If yes, check the appropriate level (%K) that populations are managed for in;

a)	forested regions	□ 80-100	□ 65-79	□ 50-64	□ <50	□ NA
b)	agricultural regions	□ 80-100	□ 65-79	□ 50-64	□ <50	□ NA
c)	urban regions	□ 80-100	□ 65-79	□ 50-64	□ <50	□ NA

   If no, what target densities (deer/mi^2 or deer/mi^2 of woods [circle one]) are deer managed for in;

a)	forested regions	□ 0-19 □ other ______________	□ 20-39	□ 40+
b)	agricultural regions	□ 0-19 □ other ______________	□ 20-39	□ 40+
c)	urban regions	□ 0-19 □ other ______________	□ 20-39	□ 40+

2. Do you implement harvest of antlerless deer statewide (where hunting is permitted)? □ yes □ no

3. Where harvest of females is permitted, how is the harvest regulated?
   □ either-sex permits/hunting
   □ antlerless permits
   □ doe days
   □ other (specify)

____

____

4. Do you implement "Quality Deer Management" (QDM) strategies, or any harvest strategies that restricts the harvest of yearling males? ☐ yes ☐ no

If yes,

a) Check the appropriate levels and strategies that are implemented.

☐ statewide
- ☐ non-spike rule
- ☐ 2-pt rule (minimum no. of pts. on one side)
- ☐ 3-pt rule
- ☐ 4-pt rule
- ☐ culling (specify) ______________________
- ☐ other ______________________

☐ countywide
- ☐ non-spike rule
- ☐ 2-pt rule (minimum no. of pts. on one side)
- ☐ 3-pt rule
- ☐ 4-pt rule
- ☐ culling (specify) ______________________
- ☐ other ______________________

☐ special use areas
- ☐ non-spike rule
- ☐ 2-pt rule (no. of pts. on 1 side)
- ☐ 3-pt rule
- ☐ 4-pt rule
- ☐ culling (specify) ______________________
- ☐ other ______________________

b) What was the decision to implement QDM based on?

____

____

____

5. Have you conducted any surveys to determine hunter/public satisfaction with management strategies? ☐ yes ☐ no

If yes,

a) Are the majority (>50%) of hunters satisfied? ☐ yes ☐ no

Comments ______________________________

b) Is the public satisfied? ☐ yes ☐ no

Comments ______________________________

Appendix B. Reproductive and mortality rates obtained from the Illinois Deer Harvest Analysis and Modeling Program used for modeling Quality Deer Management strategies in Illinois, 2000.

				Summer mortality						Winter mortality					
	Natality			Male			Female			Male			Female		
Region	Fawn	Year	Adult	Fawn	Year	Adult	Fawn	Year	Adult	Fawn	Year	Adult	Fawn	Year	Adult
A	0.62	1.46	1.80	0.11	0.02	0.02	0.09	0.05	0.05	0.06	0.07	0.10	0.06	0.07	0.07
B	0.86	1.82	2.10	0.11	0.02	0.02	0.09	0.10	0.03	0.06	0.14	0.10	0.06	0.07	0.07
C	0.75	1.55	1.80	0.11	0.02	0.02	0.09	0.05	0.01	0.06	0.14	0.10	0.06	0.07	0.07
D	0.60	1.55	1.80	0.16	0.02	0.02	0.13	0.05	0.02	0.06	0.14	0.10	0.06	0.07	0.07
E	0.40	1.50	1.75	0.23	0.02	0.02	0.19	0.05	0.02	0.06	0.14	0.10	0.06	0.07	0.07

Appendix C. Regression coefficients obtained from the Illinois Deer Harvest Analysis and Modeling Program used for modeling density dependent summer and winter mortality in Illinois, 2000.

	Summer mortality		Winter mortality	
	b	*e*	*b*	*e*
Male fawns	0.229	3.440	0.376	4.450
Male yearlings	0.061	4.828	0.305	4.828
Male adults	0.061	4.828	0.305	4.828
Female fawns	0.229	3.440	0.376	4.450
Female yearlings	0.139	3.787	0.122	4.828
Female adults	0.061	4.828	0.122	4.828

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Examination of the Effects and Feasibility of Quality Deer Management in Illinois

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IMPACTS OF HUMAN DEVELOPMENT ON DEER HERD MANAGEMENT IN THE EX-URBAN LANDSCAPE

by

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B.S. University of Tennessee at Martin

A Thesis
Submitted in Partial Fulfillment of the Requirements for
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AN ABSTRACT OF THE THESIS OF

CHARLES HARDEN, for the Master of Science degree in ZOOLOGY, presented on January 7, 2002, at Southern Illinois University at Carbondale.

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MAJOR PROFESSOR: Dr. Matthew C. Nicholson

Harvest efficiency for white-tailed deer is primarily dependent upon the density and distribution of hunters. Therefore, factors affecting hunter distribution will likely influence harvest efficiency. Previous research has suggested that presence of human habitations may influence the distribution of hunters. To test this assumption, I compiled rural structure maps for 98 of 102 Illinois counties. Based on the Illinois law which prohibits hunting within 274 m of any structure without the occupant's permission, all lands within this distance to rural structures were considered a potential hunter restriction zone. Land cover and deer habitat composition were determined at the individual structure locations, within the above restriction zone, and within each county. These data were then compared to variations in harvest efficiency using stepwise regression models. The influence of this zone on individual hunter distribution was evaluated through hunter surveys at both check stations and from the air. The distribution of hunters in relation to landscape and human development variables was assessed using logistic regression. Over 4 million hectares (30%) of the rural Illinois landscape falls within the potential hunter restriction zone. The composition of the restriction zone differed from the remainder of counties for all landscape and habitat types assessed. Variables associated with the convergence of human development and deer habitat explained a major proportion of the variation in harvest efficiency. As rural

development increased and protected more deer habitat, harvest efficiency decreased. Thus, when human development occupies deer habitat it restricts traditional deer management with hunting. The presence of human developments reduced the use of surrounding areas by hunters thus lowering hunting pressure in the hypothesized "restriction zone". Thus, increases in human development will make it more difficult for successful deer management with traditional methods. By using the models developed here, managers can identify areas of conflict where non-traditional deer management would be most effective.

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INTRODUCTION

The increase of white-tailed deer (*Odocoileus virginianus*) populations throughout the United States has brought on numerous conflicts with humans which have been estimated to cost $1.35 billion annually (Conover 1997). Consequently, substantial research has been conducted assessing the extent of these problems and attempting to develop ways to manage them. Indeed, the control of human/deer conflicts is an important aspect of nearly all deer management programs (Brush and Ehrenfield 1991). Hunter harvest is recognized as the most effective management tool to reduce such conflicts and control deer populations (Moore and Folk 1978, Brush and Ehrenfield 1991). Because of this, all factors that affect efficient hunter harvest should be quantified and if possible addressed. According to Hansen et al. (1986), the primary factor affecting harvest in Illinois is the density and distribution of hunters throughout the landscape.

Foster et al. (1997) documented that landscape pattern and human population influence deer vulnerability to harvest. The authors found that deer in Illinois counties with high non-metropolitan human population densities were less susceptible to hunter harvest than deer in less densely populated counties. Human population density probably does not directly affect deer susceptibility, rather it is likely a rough measure of the human influence on the landscape and potentially on hunter distribution. Rural development changes deer habitat and can certainly impact landscape structure and composition. However, its affect on hunter distribution is less clear. The impacts of development obviously vary based on the number and arrangement of structures across the landscape and can only be addressed by a detailed mapping approach.

Previous research has documented that deer utilize refuges in order to avoid hunting pressure and harvest (Kammermeyer and Marchinton 1975, Nixon et al. 1991). However, the degree of utilization of refuges by individual deer varied between studies. Kammermeyer and Marchinton (1975) found that their refuge population doubled while Nixon et al. (1991) found only 20% of their marked deer returned to the refuge at the onset of hunting season. Kammermeyer and Marchinton (1975) concluded that if deer can move freely between contiguous refuge and hunted areas, inadequate harvest and overpopulation may result. These studies, however, were conducted only on localized areas and individual herds. It is unknown if this phenomenon influences deer management at regional and statewide levels. In addition, it is unclear whether areas beyond those specifically set aside to protect wildlife can act as effective refuges for deer.

Foster et al. (1997) found that the major factor influencing vulnerability of deer to harvest was the proportion of a county with forested cover. The smaller and more highly fragmented the forested land area in a county, the higher the vulnerability of deer to harvest. It seems reasonable, therefore, that the quality of habitats contained within potential refuges for deer impacts their use as refuges. Therefore, assessments of the effect of human development on deer harvest must not ignore landscape composition, especially the composition of habitats surrounding rural developments.

In Illinois, it is illegal to hunt deer with a firearm within 274 m (300 yards) of an occupied structure without the permission of the landowner or tenant (Illinois Department of Natural Resources 1999). This rule obviously affects hunter distribution and likely assists in the creation of non-hunted or lightly hunted areas which could serve as "virtual refuges" for deer. If so, this supports the hypothesis that rural development affects hunter harvest efficiency by directly affecting the distribution of hunters.

The goal of my study was to test the hypothesis that increased rural development results in decreased hunter harvest efficiency by reducing hunting pressure in areas surrounding development. In addition, I examined the relationship of landscape characteristics associated with rural development and the potential hunter exclusion zone with harvest efficiency. If my hypothesis is true, then special efforts may be required by agencies to specifically target and harvest deer utilizing these areas.

METHODS

STUDY AREA

Land cover in Illinois is dominated by agriculture with approximately 60% of the state in some type of row crop (e.g. corn and soybeans). Only 11% of Illinois is forested though county levels range from 60% in the unglaciated Shawnee Hills region in extreme southern Illinois to <5% in the intensively-farmed east-central portion of the state (Foster 1997). There is very little urban influence over the landscape, <4% of the state urbanized. The state deer herd was estimated by the Illinois Deer Harvest and Modeling Program (IDHAMP) to be approximately 880,000 animals before the 2000 hunting season (IDHAMP: Roseberry 1995). More than 270,000 shotgun deer permits were issued annually from 1996-1999 with the harvest at approximately 134,000 animals each year (IDHAMP: Roseberry 1995).

My study included all counties in Illinois open to firearms hunting (98 of 102). The remaining counties comprise the Chicago metropolitan area (Cook, Dupage, Kane and Lake) and are closed to shotgun hunting. Counties were chosen as my sample unit because the Illinois Department of Natural Resources (IDNR) uses them as the basis for population modeling efforts and as the management unit for the shotgun permit system in the state. Furthermore, because this study was focused on the influence of rural human development on deer harvest, all lands within municipal boundaries were excluded from analysis (4% of state land area).

MAPPING EX-URBAN DEVELOPMENT

A spatial database consisting of the locations of all rural structures in the 98 counties included in the study was assembled from a variety of sources. These sources included digital data from individual county governments ($n = 4$), hard copy "rural road atlas" maps provided by counties ($n = 7$), and maps created by manually digitizing points for structures indicated on 1:24,000 scale United States Geological Survey (USGS) topographic maps ($n = 87$). Data provided by the counties were considered the most accurate and up to date because they were based on phone services to individual structures. In addition, these data are updated regularly by counties because they are used to direct emergency services (i.e. data provided were updated in 2000). Digital USGS topographic maps which were used to develop the majority of the rural structure database were last updated in 1990.

COMBINING DEVELOPMENT WITH HABITAT

As noted earlier, IDNR regulations prohibit hunting within 274 m of any inhabited structure without the permission of the occupant (IDNR 1999). Therefore, a contiguous buffer of 274 m was established around all rural structures for each county using a geographic information system (ArcView 3.2, Environmental Systems Research Institute, Redlands, California). This buffer was produced using the Xtools extension to ArcView and represented the hypothesized defacto refuge area available to deer in that county. For each county, the number and density of structures as well as the area and proportion of each county falling within 274 m of a structure were calculated and used in further analysis. Also calculated were land area in county, and proportion of county within municipal bounds.

In addition to quantifying areas surrounding rural structures, these areas also were characterized using the Illinois deer habitat database developed by Roseberry and Woolf (1998) which categorized the suitability of lands for white-tailed deer based on proximity to food and cover. Lands within the database were classified into 5 distinct categories. Non-habitat consisted of urban areas, water bodies, roads, grassland and agriculture >500 m from forest edge, and forest cover >1,000 m from forest patch edges. Cover denoted forest areas ≤500 m from forest edge. Forage indicated grassland and agriculture within 200 m of forest edge. Forests from 500 to 1,000 m inside edges of forest patches were classified as marginal cover. Marginal forage denoted areas between 200 and 500 m from forest edge.

The above deer habitat model was combined with rural structure data and the potential hunter exclusion zone to characterize the potential refuge area available to deer in each county. The habitat in which each rural structure occurred was determined via overlay analysis. In addition, the composition of each county and the portion of each county within 274 m of rural structures were estimated by intersecting the habitat model with county and potential hunter exclusion zone maps, respectively.

Structure, restriction zone, and county areas also were characterized using land cover information available within the Illinois Geographic Information System Database (IDNR 1996). This database contained a land cover classification based on Landsat TM satellite imagery identified at a ground resolution of 28.5 x 28.5 m. Because Foster et al. (1997) found that certain land cover characteristics (particularly forest) were related to harvest efficiency, a subset of the land cover data base (forest, agriculture, grassland) was utilized. Similar to that described for the habitat model above, the type of habitat present at each structure as well as the composition of each county and potential hunter exclusion zone area were determined.

COMPARISON OF DIFFERENT MAPPING METHODS

To assess the accuracy of using the digitized USGS maps in lieu of more current information, I manually digitized the structures in a portion of each county to construct a digital structure map. I then compared the total number of structures and proportion of the overall area within the 274 m buffer using each of the 2 mapping methods (Table 1).

In all cases, more structures were present in the digital data provided by counties. This is likely due to population growth over the 10 year period between development of the 2 data sources. In Williamson County, county provided data had substantially more structures than the USGS data indicated, but this also can be attributed to increased development. The proportion of each sample area within 274 m of rural structures calculated using USGS data was always within 5% of the county derived estimate except for Williamson County where the USGS estimate was 10% less. Again, this is likely explained by higher levels of rural development in this county during the 1990's.

Table 1. The number of rural structures and proportion of selected areas within 274 m of rural structures as estimated by county-provided digital data and USGS topographic maps.

	Number of structures		Proportion of sample area	
	county-digital	USGS	county-digital	USGS
Jackson	3,990	3,846	0.39	0.38
Johnson	1,913	1,494	0.36	0.32
Saline	2,930	2,847	0.36	0.37
Williamson	5,865	2,645	0.51	0.41

Although some differences existed in the methods for deriving rural structure data, in all cases, the best data available was incorporated. Furthermore, trends in the size of the area potentially impacted by rural development were consistent between the methods. Therefore, the more accurate and more recent county-provided data were used whenever possible in analysis.

HARVEST EFFICIENCY

Harvest efficiency (C_V) within each county was defined as the proportion of the deer population harvested per unit of hunting effort (Roseberry and Woolf 1991) and calculated using the formula $C_V = (K / P_v) / E$. The number of deer harvested (K), estimates of county level deer populations vulnerable to hunting (P_v), and number of shotgun permits issued (E) were provided by IDNR, as stored in and retrieved from the Illinois Deer Harvest and Modeling Program (IDHAMP; Roseberry 1995). Shotgun deer permits in Illinois are issued on a per county basis and allow hunting in that county only. Additionally, there is mandatory registration of all hunter harvested deer in Illinois which provides an accurate estimate of total deer harvest.

For each county, a mean efficiency for a 5-year period (1990-1994) was determined. This time period was chosen to match the time periods of the land cover data (completed 1990), and USGS topographic maps (updated 1990). Mean efficiency was used in analysis to remove variation in individual years that may have arisen due to factors other than habitat quality such as weather.

HUNTER SURVEYS

To assess the effects of development on hunter distribution, both aerial and deer check station surveys were conducted to determine the locations of hunters relative to rural structures. A block sampling technique following section lines from the Public Land Survey System was utilized in both surveys. Prior to the firearms season, optimum size of survey blocks and appropriate altitude for aerial surveys were determined with 2 test flights. During one of the test flights, both 9-section (3 x 3 mi or 23.31 km^2) and 16-section (4 x 4 mi or 41.44 km^2) blocks were flown to determine which size would be more suitable for surveys. The 9-section block was chosen because it afforded the maximum sampling area that could be searched efficiently. To assess the visibility of hunters via aerial survey, a test flight was performed over a local shooting preserve. Even though small game hunters at the preserve were only required to wear an orange cap they were still observable at altitudes >300 m.

Using the Animal Movement Extension (version 2.0) to ArcView (Hooge and Eichenlaub 1997), 20 random points were placed throughout Jackson County, Illinois. The sections (2.59 km^2) in which each point fell were then identified, and these sections were made the southwest corners of 9-section survey blocks. Blocks containing municipal areas, overlapping blocks, or blocks crossing the county boundary were excluded. Fourteen of the 15 remaining sample blocks (Figure 1), were surveyed which totaled 33,232 ha (126 square miles), or 21% of Jackson County. Surveys were flown by

Figure 1. Jackson County, Illinois, aerial survey sampling blocks (9 mi^2 or 2,331 ha) used for the 2000 hunter surveys.

helicopter at 150-300 m above ground level. Survey methods consisted of an initial flight of the perimeter of the survey area. When forest areas were encountered, the perimeter flight was abandoned and parallel transects were flown over the forest block until all forest areas were thoroughly searched. As hunters were observed, their locations were noted as accurately as possible on 1:24,000 scale USGS topographic maps. If trucks or All Terrain Vehicles (ATV's) were observed parked on the edge of forest areas, search effort was intensified and usually, the corresponding hunter was easily observed. Aerial surveys were performed on 17 and 18 November 2000 which was the opening weekend of shotgun season in Illinois.

A check station survey of hunter locations also was performed. As hunters registered harvested deer at selected county check stations, as required by Illinois law, each hunter was asked to identify the location where their deer were taken. These data were collected from Jackson, Johnson, Union, Washington, and Williamson counties (Figure 2). Illinois Department of Transportation (IDOT) county road maps at a scale of 1:126,720 (1 in = 2 mi) were shown to each hunter who then identified the section (259 ha, 1 mi^2) in which the animal was harvested. Additional hunter location point data were provided by R. Cortinas and U. Kitron (University of Illinois, unpublished data) and were collected from 11 county check stations, but provided locations in 19 counties (Bureau, Cass, Fulton, Grundy, Kankakee, Knox, Lasalle, Lee, Livingston, Marshall, Mason, Menard, Ogle, Peoria, Putnam, Schuyler, Stark, Will, and Woodford; Figure 3). For these counties, hunters were similarly interviewed at check stations regarding their hunting location. However, 1:50,000 scale topographic maps

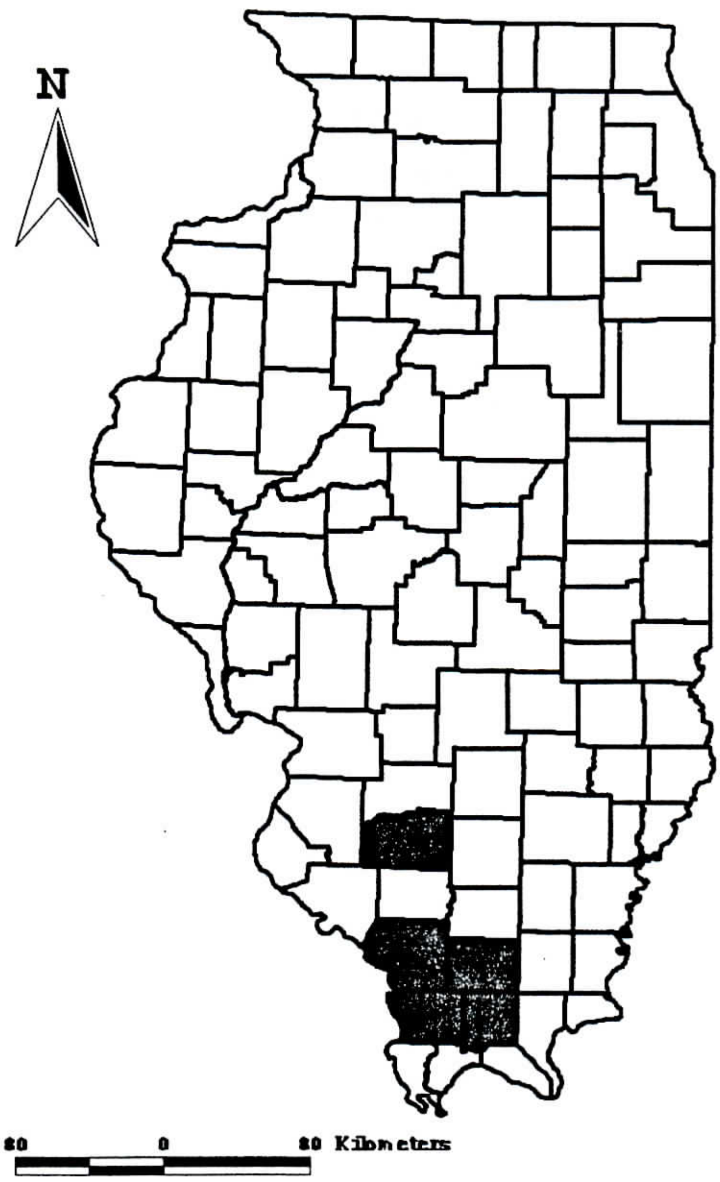

Figure 2. Counties sampled in the hunter survey conducted at deer check stations in southern Illinois, 2000.

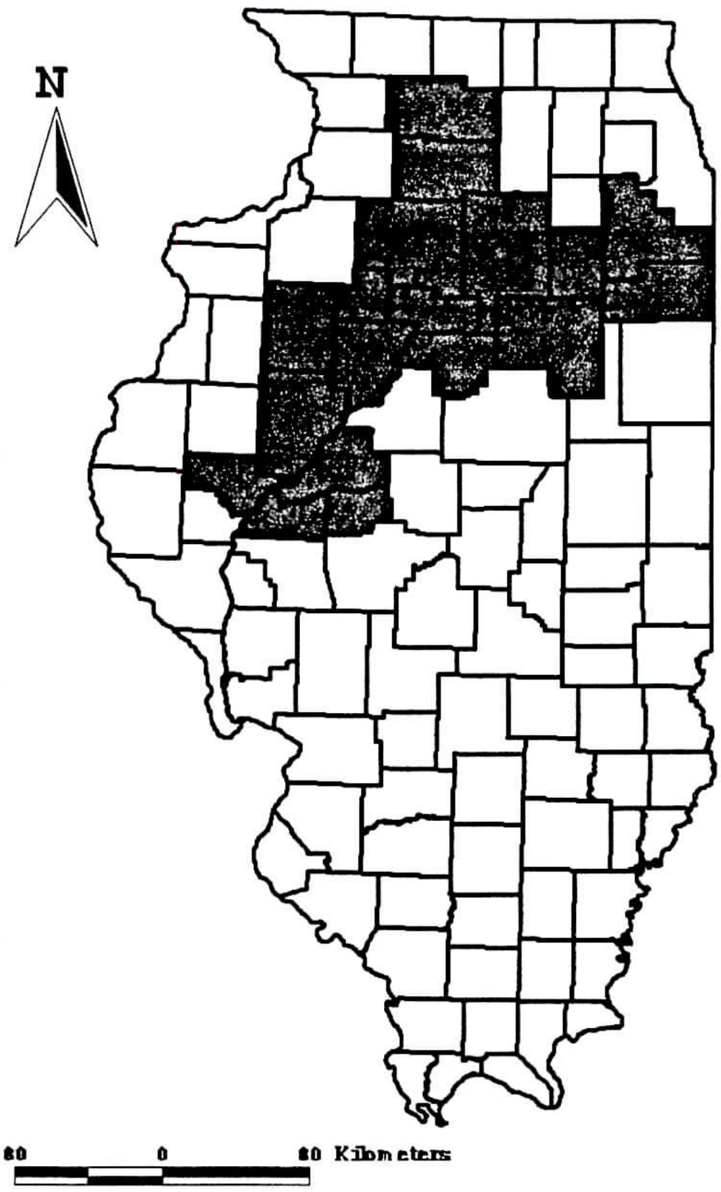

Figure 3. Counties sampled in the hunter survey conducted at deer check stations in Central Illinois, 2000. These data were provided by R. Cortinas and U. Kitron.

were presented to the hunter and that report was recorded as a point location.

STATISTICAL ANALYSIS

Both univariate and multivariate statistics were used in this study. All statistical analyses were run in the programs STATISTIX (Analytical Software 1996) or S-PLUS 6 (Insightful Corporation, Seattle, Washington). Significance was determined at $\propto = 0.05$. All variables were tested for normality and transformed as necessary to meet assumptions. Independent variables in multivariate analysis also were tested for collinearity using Pearson product moment correlations ($r > 0.70$).

The composition of areas within 274 m of rural structures (restriction zone) and the entire county were tested for differences with paired *t*-tests. To determine whether hunters were distributed further than random from rural structures; the distances from all hunter locations to rural structures were compared to an equal number of random locations using a Kolmogorov-Smirnov test. Ground survey hunter densities from Jackson County were compared to the aerially observed hunter densities with Pearson product moment correlation.

The influence of development on harvest efficiency was tested with stepwise multiple regression using true stepping. For all regression models, the single variable of a correlated group of independent variables was offered to the model based on its correlation to harvest efficiency or biological reasoning. A $P < 0.15$ was used for both entry into and retention in the model. Five separate stepwise regression models (county, structure, potential hunter exclusion zone, interaction, and combined) were run to examine the effects of certain categories of variables on harvest efficiency. The county model examined the effect of each county's composition on harvest efficiency. The influence of rural development based on structure locations in particular habitats was tested with structure variables. Potential hunter exclusion zone variables then focused on the influence of the restriction zone and the habitats it occupied. The interaction model evaluated discrepancies between potential hunter exclusion zone and county proportional composition. Finally, the combined model included the best predictor variables from the structure, potential hunter exclusion zone, and interaction models. County composition variables were excluded from the combined model due to their high correlations with human development and restriction zone variables.

Stepwise logistic regression was utilized to test the ability of landscape and human development variables to predict the presence or absence of hunters based on data from aerial and check station surveys. Jackson County aerial survey data provided sections with both known presence ($n = 67$) and absence ($n = 59$) of hunters. Combined check station data (known hunter sections) were compared with random sections (assumed absent of hunters) which did not overlap hunter reported sections. In all analyses, a $P < 0.15$ was used for entry and retention in the model. LeCessie-VanHouwelingen-Copas-Hosmer (C-H-C-H) goodness-of-fit test (Hosmer et al. 1997) was utilized to indicate which model (based on aerial data or check station data) best fit the data.

RESULTS

RURAL DEVELOPMENT

A total of 472,408 rural structures was identified in the 98 Illinois counties included in this study. The mean number of rural structures observed per county was 4,816 $\pm$ 236 ($\bar{x} \pm$ SE) and ranged from 801-16,480. The potential hunter restriction zone within a county averaged 43,997 $\pm$ 1,824 ha overall and ranged from 10,720 to 92,895 ha. Overall, 4,311,710 ha of the rural Illinois landscape fell within the defined restriction zone ($\leq$274 m of rural structures, the area that potentially represents a virtual refuge to deer). Within counties, this zone comprised a mean of 31.3% and ranged from 20.3% to 48.2%.

COMPOSITION OF HUNTER RESTRICTION ZONE

The composition of the restriction zone differed significantly from that of the county for all habitat types assessed based on pair-wise t-tests (Figure 4). Overall, the restriction zone contained a lower proportion of the 3 habitat types identified from the Illinois Landcover database (i.e. agriculture, $t = -4.69$, $P \leq 0.001$; forest, $t = -5.05$, $P \leq 0.001$; and grassland, $t = -19.50$, $P \leq 0.001$) than the county with the greatest difference observed in the proportion of grassland present. Despite this, a greater proportion of deer forage was observed within the restriction zone than the county ($t = 11.62$, $P \leq 0.001$). However, a lower proportion of deer cover was observed near rural structures than in the county at large ($t = -5.45$, $P \leq 0.001$).

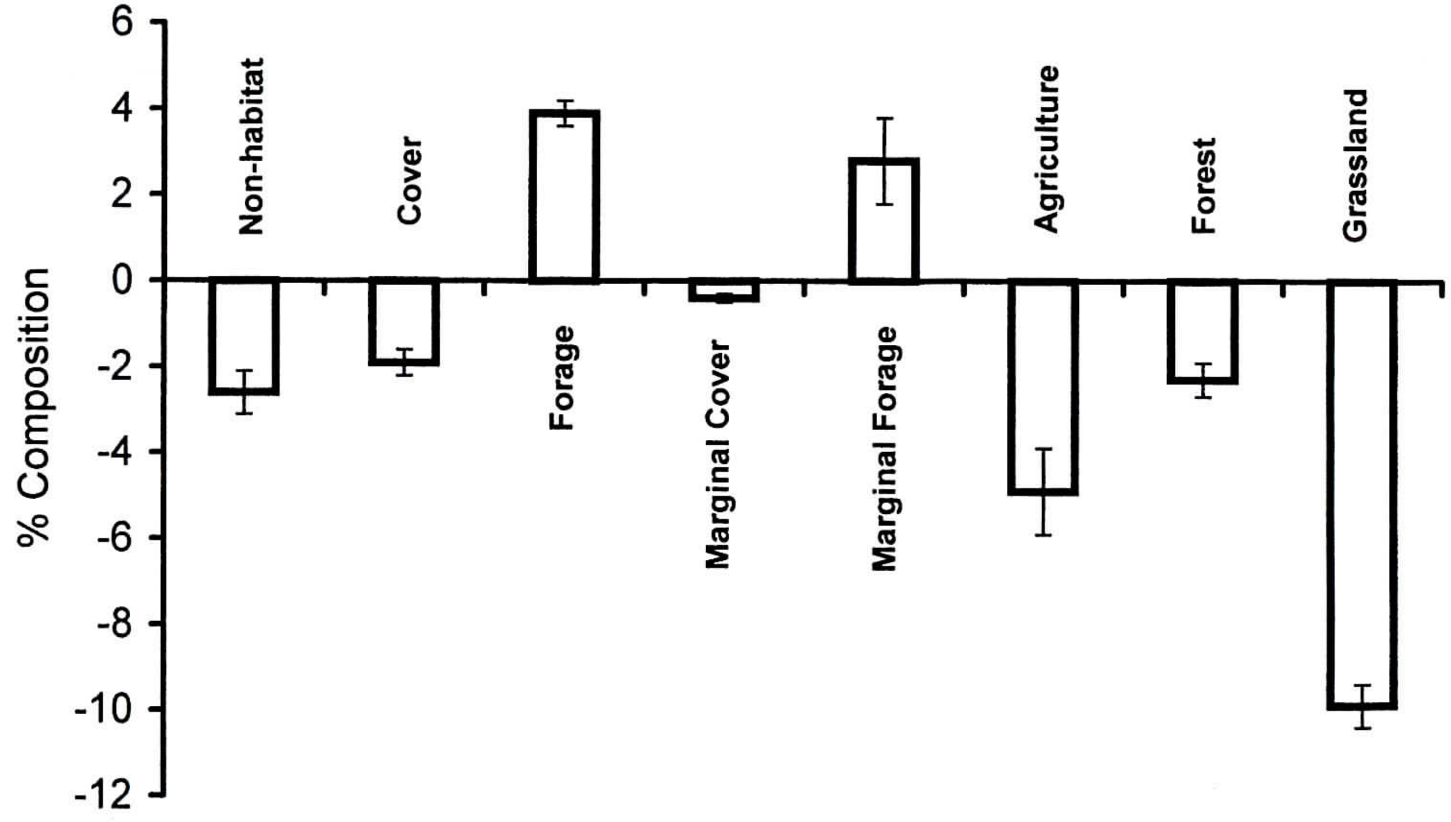

Figure 4. Mean difference in composition (% restriction zone - % county) between areas surrounding rural developments and the total county landscape for 98 study counties of Illinois. (Error bars reflect standard error.)

INFLUENCE ON HARVEST EFFICIENCY

County Model

To test the influence of habitat composition on harvest efficiency in each county, 11 variables describing the habitats available within counties were assessed. This set of variables was reduced to 5 after testing for collinearity (Table 2; a complete list of data can be found in Appendix A) and was entered into stepwise multiple regression. The resulting model explained a large proportion of variation in mean harvest efficiency (R^2 = 0.79, P = 0.018). All 5 variables entered into analysis remained in the model (Table 3) with proportion of a county classified as cover explaining the greatest proportion (Partial R^2) of the variation in harvest efficiency, and higher efficiency occurring when a lower proportion of deer cover was available in a county. County land area explained the second greatest proportion of harvest efficiency with higher efficiencies occurring in smaller counties. Proportion of county in grassland, marginal cover, and marginal forage each contributed a small but significant portion to the county model.

Structure Model

I also examined the influence of the location and number of rural structures in a county on harvest efficiency. Twelve variables associated with rural structures were identified of which 8 were analyzed by multiple regression after assessment for collinearity (Table 4). Six variables were retained in the structure model which explained a large proportion of variation in harvest efficiency (R^2 = 0.70, P = 0.026). Proportion of structures in non-habitat and number of rural structures within the county together accounted for the majority of variation in harvest efficiency (Table 5).

Table 2. Variables describing the habitat composition of counties used to assess variation in mean harvest efficiency in Illinois, 1990-1994.

Variable	Mean	*SE*	Min	Max
County land area (ha) [a]	142,852	5,836	44,592	307,180
Proportion of county in deer cover [a]	0.134	0.010	0.003	0.505
Proportion of county in forest	0.149	0.011	0.004	0.619
Proportion of county in marginal cover [a]	0.570	0.001	0.000	0.088
Proportion of county in municipal boundary	0.037	0.004	0.007	0.209
Proportion of county in agriculture	0.588	0.017	0.100	0.851
Proportion of county in forage	0.211	0.010	0.012	0.405
Proportion of county in grassland [a]	0.186	0.007	0.075	0.494
Proportion of county in cover and forage	0.345	0.019	0.015	0.820
Proportion of county in marginal forage [a]	0.174	0.011	0.024	0.309
Proportion of county in non-habitat	0.450	0.023	0.058	0.946

[a] Variables entered into stepwise model.

Table 3. Stepwise multiple regression model for prediction of county harvest efficiency based on county-level landscape variables in Illinois, 1990-1994. Deer cover and forage variables are based on a habitat model developed by Roseberry and Woolf (1998).

Variable	Coefficient	*SE*	Student's *t*	Partial R^2	Model R^2	*P*
Constant	-0.003	0.116	-0.03			
Log proportion of county in deer cover	-0.525	0.055	-9.52	0.463	0.463	<0.001
County land area	-2.95E-06	2.68E-06	-11.01	0.275	0.738	<0.001
Proportion of county in grassland	-0.871	0.200	-4.35	0.041	0.779	<0.001
Log proportion of county in marginal deer cover	-7.678	3.069	-2.50	0.008	0.783	0.014
Proportion of county in marginal deer forage	-0.490	0.294	-1.66	0.006	0.793	0.099

Table 4. Variables describing the distribution and abundance of rural structures used to assess variation in mean harvest efficiency in Illinois, 1990-1994.

Variable	Mean	*SE*	Min	Max
Number of structures in county [a]	4,820	326	801	16840
Proportion of structures in agriculture [a]	0.205	0.010	0.028	0.684
Proportion of structures in forage	0.295	0.012	0.014	0.622
Proportion of structures in grassland [a]	0.577	0.013	0.106	0.867
Proportion of structures in cover and forage	0.395	0.016	0.016	0.837
Proportion of structures in cover [a]	0.099	0.006	0.001	0.366
Proportion of structures in forest	0.120	0.007	0.009	0.404
Structures per hectare within zone	0.104	0.004	0.042	0.289
Structures per hectare within county [a]	0.033	0.002	0.012	0.139
Proportion of structures in marginal cover [a]	0.117	0.000	0.000	0.014
Proportion of structures in marginal forage [a]	0.186	0.007	0.013	0.388
Proportion of structures in non-habitat [a]	0.417	0.020	0.075	0.970

[a] Variables entered into stepwise model.

Table 5. Stepwise regression model for prediction of county harvest efficiency based on distribution and abundance of rural structures in Illinois, 1990-1994.

Variable	Coefficient	*SE*	Student's *t*	Partial R^2	Model R^2	*P*
Constant	2.484	0.360	6.89			<0.001
Proportion of structures in non-habitat	0.884	0.121	7.27	0.414	0.414	<0.001
Log number of rural structures	-0.638	0.070	-9.09	0.206	0.620	<0.001
Log proportion of structures in marginal cover	-75.554	17.59	-4.29	0.020	0.640	<0.001
Proportion of structures in agriculture	-1.323	0.309	-4.28	0.016	0.656	<0.001
Proportion of structures in grassland	-0.984	0.256	-3.85	0.034	0.700	<0.001
Log proportion of structures in deer cover	-0.151	0.092	-1.64	0.008	0.708	0.104

Proportion of structures in marginal cover, agriculture, grassland, and cover also contributed to the model. High harvest efficiency was observed when there were few rural structures in a county and those structures were in areas that were not considered deer habitat.

Restriction Zone Model

The influence of the potential no hunting zone and the habitat it included on harvest efficiency was assessed using 10 variables associated with the restriction zone (Table 6). Only 4 of the original suite of variables were analyzed by stepwise regression because of collinearity. The final regression model retained only 2 variables and explained less than half of the variation in harvest efficiency ($R^2 = 0.44$, $P = 0.047$). As the proportion of the county within the potential no hunting zone and the proportion of the zone that was forested increased, harvest efficiency decreased (Table 7).

Restriction Zone-County Interaction Model

I also assessed how well harvest efficiency was explained by variables that described the composition of the restriction zone in relation to the county. Included in the model were 8 variables which described the proportion of the county-wide area present within the restriction zone for each cover and habitat class. Testing for collinearity reduced the 8 variables to 6 (Table 8). Four variables were retained in the model which explained almost 40% of the variation in mean harvest efficiency ($R^2 = 0.384$, $P = 0.053$), although the final model was slightly above the level of significance. As the proportion of the county's agriculture within the restriction zone increased, harvest efficiency decreased. Also, as the proportion of county marginal forage and

Table 6. Variables associated with the size and habitat composition of the restriction zone used to assess variations in mean harvest efficiency in Illinois, 1990-1994. This zone is legally defined in Illinois as areas within 274 m of rural structures and represents the restricted area in which deer cannot be hunted without landowner permission.

Variable	Mean	*SE*	Min	Max
Proportion of county within zone [a]	0.310	0.005	0.203	0.482
Proportion of zone cover	0.114	0.008	0.003	0.407
Proportion of zone forest [a]	0.126	0.008	0.005	0.424
Proportion of zone marginal cover [a]	0.000	0.000	0.000	0.011
Proportion of zone agriculture [a]	0.538	0.015	0.047	0.772
Proportion of zone forage	0.251	0.011	0.014	0.479
Proportion of zone grassland	0.087	0.003	0.035	0.207
Proportion of zone cover and forage	0.365	0.018	0.017	0.850
Proportion of zone marginal forage	0.202	0.007	0.024	0.374
Proportion of zone non-habitat	0.424	0.022	0.047	0.958

[a] Variables entered into stepwise model.

Table 7. Stepwise regression model for prediction of county harvest efficiency based on variables associated with the size and habitat composition of the restriction zone in Illinois counties, 1990-1994.

Variable	Coefficient	*SE*	Student's *t*	Partial R^2	Model R^2	*P*
Constant	-0.499	0.147	-3.38			0.001
Log proportion of buffer forested	-0.570	0.070	-8.13	0.421	0.421	0.006
Proportion of county within buffer	-0.725	0.382	-1.90	0.021	0.442	<0.001

Table 8. Variables describing the relationship between the restriction zone and the remainder of county which were used to assess variation in mean harvest efficiency in Illinois, 1990-1994.

Definition	Mean	*SE*	Min	Max
Proportion of county's marginal deer cover in zone [a]	0.073	0.014	0.000	0.872
Proportion of county's agriculture in zone [a]	0.288	0.006	0.032	0.501
Proportion of county's deer cover in zone	0.297	0.011	0.070	0.636
Proportion of county's deer forage in zone	0.382	0.009	0.215	0.605
Proportion of county's forest in zone [a]	0.304	0.011	0.075	0.642
Proportion of county's grassland in zone [a]	0.474	0.008	0.150	0.681
Proportion of county's marginal deer forage in zone [a]	0.382	0.007	0.045	0.647
Proportion of county's non-habitat in zone [a]	0.291	0.006	0.166	0.442

[a] Variables entered into stepwise model.

marginal cover increased within the restriction zone, harvest efficiency decreased. Finally, as the proportion of a county's forest within the restriction zone increased, harvest efficiency increased (Table 9).

Combined Model

In a final assessment of how harvest efficiency was affected by rural development in Illinois, I combined all variables used in the above modeling efforts, except for the county model. All independent variables entered into the rural structure model, the restriction zone model, and the model describing the interaction between the restriction zone and the remainder of the county (*n* = 16) were tested again for collinearity and further reduced to 14 before entering into the final stepwise model (Table 10). A 9 variable model explained a majority of variation in mean harvest efficiency ($R^2 = 0.84$, $P = 0.014$). The primary contributors to the model were proportion of the restriction zone in forest, number of rural structures in the county, and proportion of county's forest within the restriction zone (Table 11). Smaller, and positively associated contributions were made by proportion of restriction zone in agriculture, and proportion of the county's grassland within the restriction zone. Similarly small but negatively associated variables were proportion of rural structures in agriculture, proportion of rural structures in grassland, proportion of county's marginal cover within the restriction zone, and proportion of structures in marginal cover.

Table 9. Stepwise regression model for prediction of county harvest efficiency based on variables describing the interaction between the restriction zone and the remainder of a county in Illinois, 1990-1994.

Variable	Coefficient	*SE*	Student's *t*	Partial R^2	Model R^2	*P*
Constant	0.449	0.138	3.24			0.001
Proportion of county's agriculture in zone	-0.848	0.457	-1.86	0.210	0.210	0.066
Proportion of county's forest in zone	1.391	0.273	5.10	0.067	0.277	<0.001
Proportion of county's marginal forage in zone	-1.947	0.537	-3.62	0.076	0.353	0.005
Log proportion of county's marginal cover in zone	-1.131	0.508	-2.23	0.033	0.386	0.028

Table 10. Combined variables from structure, restriction zone, and interactive models used to assess variation in mean harvest efficiency in Illinois, 1990-1994. Correlation of variables with harvest efficiency based on pearson product moment correlation is also presented.

Variable	*r*	*P*	Original model
Proportion of county's marginal deer cover within zone [a]	-0.109	0.284	interactive
Proportion of county's agriculture within zone [a]	-0.458	<0.001	interactive
Proportion of county's marginal deer forage within zone [a]	-0.311	0.001	interactive
Proportion of county's grassland within zone [a]	0.031	0.761	interactive
Proportion of county's forest within zone [a]	0.228	0.023	interactive
Proportion of county's non-habitat within zone [a]	-0.213	0.035	interactive
Proportion of zone forested [a]	-0.649	<0.001	exclusion zone
Proportion of zone marginal cover	-0.306	0.002	exclusion zone
Proportion of zone in agriculture [a]	0.486	<0.001	exclusion zone
Proportion of structures in agriculture [a]	0.051	0.615	structure
Proportion of structures in grassland [a]	0.090	0.375	structure
Number of structures in county [a]	-0.312	0.001	structure
Proportion of structures in marginal cover [a]	-0.344	<0.001	structure
Proportion of structures in marginal forage [a]	-0.324	0.001	structure
Proportion of structures in deer cover [a]	-0.465	<0.001	structure
Proportion of structures in non-habitat	0.643	<0.001	structure

[a] Variables entered into stepwise model.

Table 11. Stepwise regression model for prediction of county harvest efficiency in Illinois based on structure, restriction zone, and restriction zone-county interaction variables, 1990-1994

Variable	Coefficient	*SE*	Student's *t*	Partial R^2	Model R^2	*P*
Constant	2.307	0.270	8.54			<0.001
Log proportion of restriction zone forested	-0.443	0.058	-7.51	0.421	0.421	<0.001
Log number of rural structures	-0.882	0.061	-14.28	0.122	0.543	<0.001
Proportion of county's forest in restriction zone	1.258	0.195	6.44	0.199	0.742	<0.001
Proportion of restriction zone in agriculture	0.516	0.116	4.42	0.042	0.784	<0.001
Proportion of structures in agriculture	-0.984	0.197	-4.99	0.014	0.798	<0.001
Proportion of structures in grassland	-0.682	0.166	-4.11	0.019	0.817	<0.001
Proportion of county's grassland in restriction zone	0.485	0.207	2.34	0.011	0.828	0.021
Log proportion of county's marginal cover in zone	-0.543	0.288	-1.89	0.009	0.837	0.062
Log proportion of structures in marginal cover	-25.084	14.39	-1.74	0.006	0.843	0.084

AERIAL SURVEY OF HUNTERS

One hundred and ninety-one hunters were observed during the helicopter survey on 17-18 November, 2000. Only 18% ($n = 35$) of hunters observed were within the restriction zone which represented 36.8% of the available survey area and 33.0% of available surveyed forest; significantly less than expected by chance ($\chi^2 = 17.77$, $df = 1$, $P < 0.001$). Mean distance from these hunters to the nearest structure (582 $\pm$ 28 m) was further ($D = 0.21$, $P < 0.001$) than random (495 $\pm$ 26 m). Mean number of hunters per section was 1.65 $\pm$ 0.20.

HUNTER CHECK STATION SURVEYS

Hunter surveys conducted in Central Illinois resulted in 920 point locations reported by successful hunters. Sixteen percent ($n = 156$) of hunters were within the restriction zone which, similar to aerial survey results, was fewer than expected ($\chi^2 = 32.43$, $df = 1$, $P < 0.001$) since the restriction zone in these counties represented 28% of the available county area and 26% of available county forest. In addition, mean distance from these hunters to the nearest structure (497 m, SE = 8.14) was further ($D = 0.04$, $P < 0.001$) than random (461 m, SE = 11.90). Point data were summarized by sections to facilitate combination with Southern Illinois check station data. In the Southern Illinois check station survey, 901 hunters identified 549 sections in which they harvested deer. Mean number of hunters in these sections was 1.6 (SE = 0.05) compared to 1.31 (SE = 0.02) in the Central Illinois data.

COMPARISON OF AERIAL SURVEY TO CHECK STATION DATA IN JACKSON COUNTY

Comparison of aerial survey data to check station data validated its use as an index for actual hunter distibution. Within individual sections, the number of hunters observed using both methods was significantly correlated but at a low level (n = 126, r = 0.21, P = 0.015). Comparisons within a 2 by 2 section area were better correlated but not significantly (n = 14, r = 0.50, P = 0.062). When the evaluation area was expanded to a 3 by 3 section window, the density of hunters observed showed the highest degree of correlation (n = 14, r = 0.73, P = 0.002).

AERIAL SURVEY LOGISTIC MODEL

I used hunter distribution data collected from the aerial survey to predict the presence of hunters based on characteristics associated with the sections in which they were observed. Hunter densities within sections ranged from 0 - 12 for the 126 sections surveyed. No hunters were observed within 59 of the sections while the other 67 sections contained $\geq$1 hunters. The number of rural structures within the section, the proportion of the section within the restriction zone, the proportion of the section forested, and the proportion of the section's total forest within the restriction zone were calculated for each of the sections surveyed. Using these data, sections in which no hunters were observed were compared to those with hunters (Table 12). Only the proportion of section forested differed significantly between hunter presence or absence. A stepwise logistic regression model was then utilized to assess the influence of these variables on

Table 12. Variables used to predict hunter presence as observed in Jackson County Illinois during the 2000 aerial hunter survey. Mean values for hunter presence or absence and t-tests for differences are also presented.

	Hunters Present		Hunters Absent				
Variable	Mean	*SE*	Mean	*SE*	*t*	*df*	*P*
Number of Rural Structures	10.13	1.62	18.71	5.33	1.43	124	0.154
Proportion of section within restriction zone	0.34	0.02	0.38	0.02	1.05	124	0.296
Proportion of section forested	0.50	0.03	0.30	0.03	-4.13	124	<0.001
Proportion of total forest within section	0.29	0.02	0.31	0.03	0.65	124	0.518

hunter presence or absence. The model correctly differentiated sections with hunters from those without according to the proportion of the section forested (Log(£) = 15.96, *df* = 1, $n = 126$, $P < 0.001$; Table 13). Correct classification rate was 70.4% (Kruskal's Gamma = 0.41, Brier = 0.219). C-H-C-H goodness-of-fit indicated the model fit the data well ($z = -0.026$, $P = 0.97$).

COMBINED CHECK STATION SURVEYS LOGISTIC MODEL

To see if successful hunters distributed themselves in a non-random manner, 1,250 sections containing 1,810 hunter reported harvest locations were examined. Since the original check station survey data only contained locations of successful hunters, I used an equal number of sections from which no hunter locations were reported to represent non-hunted areas. Rural structures, proportion of sections within the restriction zone, forest proportion, proportion of a section's total forest within the restriction zone, and proportion of section within municipal boundary were determined for each of the survey blocks with the goal of predicting hunter or random sections. Univariate comparisons of successful hunter versus random sections revealed that the number of structures and proportion of section forested were the only 2 variable which differed (Table 14).

Table 13. Stepwise logistic regression model used to predict hunter presence based on Jackson County, Illinois 2000 aerial survey data.

Variable	Coefficient	*SE*	Wald χ^2	*P*
Intercept	-0.973	0.3429	-2.84	0.004
Proportion of section forested	2.730	0.728	3.75	<0.001

Table 14. Variables used to predict the presence of successful hunters using check station hunter survey data in Illinois, 2000. Mean values for successful hunters and random sections and t-tests for differences are also presented.

	Successful Hunters		Random Sections				
Variable	Mean	*SE*	Mean	*SE*	*t*	*df*	*P*
Rural Structures	13.05	0.74	10.86	0.57	-2.33	2352	0.018
Proportion of section within restriction zone	0.31	0.005	0.31	0.005	0.34	2499	0.733
Proportion of section forested	0.30	0.006	0.21	0.006	-9.02	2514	<0.001
Proportion of total forest in restriction zone	0.29	0.007	0.29	0.008	-0.53	2457	0.601
Proportion of section within municipal bounds	0.03	0.003	0.004	0.004	1.60	2342	0.106

Stepwise logistic regression also successfully differentiated sections with hunters from random sections assumed to be without hunters (Log(£) = 98.04, $df = 3$, $n = 2{,}512$, $P < 0.001$; Table 15). Correct classification rate was 62.6% (Kruskal's Gamma = 0.254, Brier = 0.24). However, the C-H-C-H goodness-of-fit test indicated the model failed to fit the data ($z = -3.79$, $P < 0.001$). Variables retained by the model were the log of proportion of a section forested, proportion of a section's forest within the restriction zone, and the proportion of a section within the restriction zone.

Table 15. Stepwise logistic regression model used to predict successful hunter presence based on combined Southern and Central Illinois hunter location data collected at county check stations, 2000.

Variable	Coefficient	*SE*	Wald χ^2	*P*
Intercept	-0.446	0.089	-5.01	<0.001
Log proportion of section forested	5.050	0.525	9.61	<0.001
Proportion of section's forest within restriction zone	0.363	0.187	1.94	0.052
Proportion of section within restriction zone	-0.427	0.267	-1.60	0.110

DISCUSSION

MAPPING METHODS

Although the Illinois Commerce Commission (www.icc.state.il.us/) web page records indicated that approximately 73% of Illinois was served by computerized emergency response systems, only 11 counties provided rural development data for this project. This discrepancy was due to erroneous reporting of complete county systems, or inability or unwillingness of counties to provide data. When complete, the computerized emergency response system could serve as an excellent source of information in ecological and epidemiological studies where the precise location of human developments is necessary. Unfortunately, it is unclear when this system will be complete for Illinois, and when it is complete, based on my experience, the database may not be completely accessible.

Structures present on the USGS topographic maps served as an excellent alternative to emergency response data. However, these data did have some limitations. The format (digital raster graphic) required the structures to be located individually and digitized on screen which was very time consuming. Additionally, the last update of the maps was in 1990 which could reduce the desired accuracy. Regardless of potential error, the best data available were utilized. In instances where errors did occur, estimates of human development and any conclusions based on these data were conservative. However, while potentially less accurate, USGS maps temporally matched both landcover data, the deer habitat model, and harvest efficiency calculations which were all produced in the early 1990's.

This study may be the first attempt to utilize digital mapping of rural structure locations in wildlife habitat analysis on a statewide scale. Vogel's (1989) study of deer density and distribution in response to housing was based on structures mapped from the ground obviously limiting the size of the area included in his study. Odell and Knight (2001) incorporated distance to individual structures as a wildlife response, but did not incorporate this concept into GIS on a large scale. With urban sprawl continuing to expand and human pressure on the rural environment increasing large scale studies using these data and examining these types of issues are essential.

COMPOSITION OF RESTRICTION ZONE AND COUNTY

For all land cover types and deer habitat classes, the composition of the restriction zone, i.e. areas within 274 m of rural developments, was significantly different from that of the county. These compositional differences indicate that rural structures are not randomly distributed across the landscape. A higher percentage of deer foraging habitats were present within the restriction zone. According to Roseberry and Woolf (1998), these habitats describe grassland areas within 500 m of forest edge. Given that human habitations tend to be dominated by manicured lawns and ornamental trees, it is reasonable to assume that when human development is in areas with moderate amounts of forested habitat, there will be an increase in foraging habitat for deer. Alternatively, these data suggest that humans tend to build rural structures near forest edge. In either scenario, deer may benefit from moderate levels of human development because these factor in determining harvest efficiency (cover consisted of forest <500 m from forest edge). As cover area increased, harvest efficiency decreased. Smaller areas of cover are easier for hunters to thoroughly search and thus were highly correlated with increased harvest efficiency. The proportion of a county in grassland also was negatively correlated with harvest efficiency. Grassland included areas of old field or Conservation Reserve Program (CRP) lands that may provide a sanctuary and thus may be overlooked by hunters. Gould and Jenkins (1993) concluded that CRP enhanced habitat options for white-tailed deer in a landscape dominated by agriculture. Furthermore, they found that deer use of CRP fields was greater than habitat availability during bedded (i.e. resting) periods in the fall. Therefore, grassland may provide protection from harvest for deer depending upon the type of grassland present (fallow, pasture, old field, shrub).

Human Development and Hunter Restriction Zone

The primary purpose of this study was to examine the influence of rural human development and the associated hunter restriction zone on harvest efficiency. As predicted, harvest efficiency was affected by rural development and the characteristics of the 274 m hunter restriction zone around rural development. The 9 variable model explained 84% of the variation in harvest efficiency.

Three of those 9 variables accounted for 74% of harvest efficiency variation. Proportion of the restriction zone forested was negatively correlated with harvest efficiency and explained the greatest portion of the variation in harvest efficiency. It is likely that increased forest within this area corresponded to a decrease in harvest efficiency because it represented deer habitat protected from hunting by the presence of the rural structures and the surrounding restriction zone. The number of rural structures within the county also explained a large proportion of variation in harvest efficiency in Illinois. The negative association with rural structures suggested that increased numbers of rural structures act as a hindrance to hunter distribution and access to deer in the county thereby reducing harvest efficiency. Proportion of the county's total forest within the restriction zone accounted for the third largest portion of harvest efficiency. The positive relationship with harvest efficiency indicated that as the proportion of total forest within the restriction zone increased, huntable forest outside the restriction zone decreased, likely making it easier for hunters to evenly distribute themselves and harvest deer. It is evident that human development in or around deer habitat directly impedes hunter harvest efficiency. Moreover, as rural development increases, this clear conflict between humans and deer management objectives will also increase.

HUNTER DISTRIBUTION

Aerial Survey

One of the main purposes of the aerial survey was to test the assumption that structures and the hunter restriction zone actually influenced hunter distribution. Restriction zones were not absolutely devoid of hunters, but there were fewer hunters in these areas and they were further from structures than expected. So it appears that structures did influence hunter distribution. Recent research into hunter distribution has primarily described hunter reaction to road closures in western wilderness areas (Lyon and Burcham 1998, Gratson and Whitman 2000). Determining hunter distribution assisted in understanding how managing access influences hunter density, success, and ultimately the mortality of the hunted species (Gratson and Whitman 2000). Both this study and Gratson and Whitman (2000) found that reduced access equates with reduced hunter densities which in turn leads to reduced mortality.

Aerial Survey Versus Check Station Data

Hunter distribution data from the aerial survey was correlated with check station data at 2 of the 3 scales I examined. Although significant, the 1 mi^2 level exhibited a low correlation between survey methods ($r = 0.21$). However, at the largest scale (3 by 3 section) the correlation was much higher ($r = 0.73$). The fact that best correlations existed at the largest scale was likely due to an issue of scale. In this type of analysis, higher correlations were expected at the larger spatial scales. Further, the aerial survey sampled all hunters, whereas the check station data only sampled successful hunters. Successful hunters then had an option to register their deer at 1 of 2 check stations in Jackson County or any of the surrounding county's check stations. An additional complicating factor was our sampling on the first and third days of the season at the check station compared to the first and second day for the aerial survey. If the check station sampling was more thorough (over all 3 days of the first season), then the correlations may have been present at the finer scales.

Even though interview and mail survey data were the most common methods of determining hunter location and distribution (Lyon and Burcham 1998, Albert el al. 2001), I am not aware of studies that have tested the accuracy and reliability of these methods of data collection. Using aerial survey to validate hunter reported locations represents a method to confirm the reliability of check station data from successful hunters to represent the distribution of all hunters across the landscape. Based on my findings, hunter interviews can be a valid method of determining variations in hunter densities across landscapes. However interview data is only an index of actual hunter distribution particularly when samples are small.

Check Station Surveys

One mile square sections containing successful hunters differed from random sections in the number of rural structures they contained and the proportion of the section forested. Sections containing successful hunters contained a higher proportion of forest than random. Oddly, more rural structures were present within successful hunter sections than random ones. This contradicted the results from the harvest efficiency analysis which suggested that increased number of structures reduced hunter densities. However, these were successful hunters and may indicate these hunters have an advantage of hunting in areas of low hunting pressure, but high deer densities. One potential problem with this analysis is the use of random sections to represent non-hunted areas. In fact, these areas may simply represent areas where hunters were unsuccessful.

Predicting Hunter Distribution

Based on multiple logistic regression, hunter presence from aerial surveys was reliably predicted by the proportion of sections forested. Hunter locations determined from successful hunters at check stations were also predicted by proportion of section forested, proportion of total forest within restriction zone, and proportion of section within restriction zone. However, the goodness-of-fit test indicated the check station model did not fit the data well. Therefore, based on my 2 sampling efforts, predictions of hunter density should only be attempted with the aerial survey logistic model. However, the aerial survey model predicted hunter presence or absence based on forest as the single variable. This is an obvious relationship which was not useful in explaining any influences by human development, and the restriction zone on hunter distribution.

Perhaps looking for areas devoid of hunters is the wrong approach. The aerial survey point data determined that the restriction zone reduced hunter densities but did not exclude all hunters. A linear regression analysis identifying areas of differing hunter densities may be more appropriate and incorporate human development variables. The use of a logistic model was necessitated by the lack of variation (i.e. 107 of 126 sections surveyed had ≤ 3 hunters) in hunter density in the data available. A larger data set may have been able to overcome this limitation.

MANAGEMENT IMPLICATIONS

Accurate maps of rural structures in my study provided a detailed assessment of determining the cumulative influence of human development on harvest susceptibility of deer at large scales. Rural structures may modify deer habitat, or may simply occupy good deer habitat and prevent hunter access (Brown et al 2000). This impact likely varies depending upon the number and arrangement of rural structures (Vogel 1989) and could only be addressed by a detailed mapping approach which my study included.

Based on my study and others it seems that rural human development affects hunter access, distribution, and ultimately deer vulnerability rates (Gratson and Whitman 2000). Human development changes the landscape as demonstrated by the different habitat types present around rural structures. Hunter distribution is also influence by human development through reduced. In turn, the harvest efficiency is reduced by insufficient hunter density and distribution. Clearly, if left unaddressed, the impacts of continued rural development will influence the future of hunting as a deer management tool.

Current deer management efforts are primarily focused on keeping populations at cultural carrying capacity (Minnis and Payton 1995). The preferred method of state agencies to accomplish this goal is hunter harvest (Brush and Ehrenfield 1991). Managers should be mindful that hunter numbers in the United States are stable or decreasing, and that their ability to access hunting areas often influenced their decision to pursue or abandon the sport (Adams et al. 2000). The issue of ex-urban development will become more important in the future and require further study. I established how hunter access was reduced by human development. It is unknown whether deer densities and movement patterns adjust in an opposite manner and increase near human development (Kammermeyer and Marchinton 1975). It could be that just the protection of certain portions of deer habitat provided source populations for other areas as shown by Nixon et al. (1991). My results indicate this phenomenon can have an affect on very large scales regardless of individual deer response. A large scale (i.e. county or state) telemetry study of deer movements in regard to this phenomena may shed further light on this.

Regardless of whether deer recognize the restriction zone as a refuge or not, harvest efficiency was reduced when human development increased and the proportion of the restriction zone forested increased. While my model evaluated harvest efficiency at a large scale, it may be possible to refine the results to identify specific areas of predicted reduced harvest efficiency. It may be wise to attempt to predict areas of lower harvest efficiency and presumably increased human deer conflict on those small scales such as a section ($1mi^2$). Identification of these "hot spots" would be the first step toward establishing management plans emphasizing alternative harvest strategies such as archery and culling, which could address these problems on local scales.

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Appendix A. Ex-urban development data for 98 of 102 Illinois counties. Data summarized by county for both area and proportions of the Illinois Deer Habitat Model and selected classess from the Illinois Land Cover Database.

		jackson	ıontgomery	carroll	alexander	gallatin	massac	pope	hardin	randolph
County	area (hectares)	156092	183860	120317	65604	84937	62580	96911	46698	154208
	area in buffer (hectares)	52634	60700	39538	15094	19895	23131	22119	16012	48171
	proportion of county in buffer	0.34	0.33	0.33	0.23	0.23	0.37	0.23	0.34	0.31
	rural homes (number)	8352	4166	3347	2237	1542	2772	1706	1344	4191
	home per hectare (in buffer)	0.16	0.07	0.08	0.15	0.08	0.12	0.08	0.08	0.09
	home per hectare (in county)	0.05	0.02	0.03	0.03	0.02	0.04	0.02	0.03	0.03
	municipal area	6965	5033	1954	3682	1682	1665	700	857	6281
	% municipal area	0.045	0.027	0.016	0.056	0.020	0.027	0.007	0.018	0.041
Deer Habitat										
Non-habitat	home points (number)	1057	1821	1538	432	638	296	128	103	1095
	percentage of total points	0.13	0.44	0.46	0.19	0.41	0.11	0.08	0.08	0.26
	within 300 yards (hectares)	6467	32668	21457	2703	9028	2779	1053	882	10644
	within county (hectares)	24704	109775	67184	15304	33035	8254	6314	2751	33222
	buffer area / county area	0.26	0.30	0.32	0.18	0.27	0.34	0.17	0.32	0.32
	within buffer / tot. buffer	0.12	0.54	0.54	0.18	0.45	0.12	0.05	0.06	0.22
	within county / tot. county	0.16	0.60	0.56	0.23	0.39	0.13	0.07	0.06	0.22
Cover	home points (number)	3060	288	231	570	136	261	359	289	375
	percentage of total points	0.37	0.07	0.07	0.25	0.09	0.09	0.21	0.22	0.09
	within 300 yards (hectares)	17632	5530	3524	4847	2340	4177	8203	6526	6813
	within county (hectares)	52793	15921	12670	19992	15401	13846	48956	23472	31661
	buffer area / county area	0.33	0.35	0.28	0.24	0.07	0.30	0.17	0.28	0.22
	within buffer / tot. buffer	0.33	0.09	0.09	0.32	0.12	0.18	0.37	0.41	0.14
	within county / tot. county	0.34	0.09	0.11	0.30	0.18	0.22	0.51	0.50	0.21

Appendix A. Continued

		jackson	ıontgomery	carroll	alexander	gallatin	massac	pope	hardin	randolph
homes per hectare of cover w/in 300 yards		0.174	0.052	0.066	0.118	0.058	0.062	0.044	0.044	0.055
buffer cover - county cover		0.00	0.00	-0.02	0.02	-0.06	-0.04	-0.13	-0.10	-0.06
Forage	home points (number)	3358	1335	885	926	441	1387	1014	836	1639
	percentage of total points	0.40	0.32	0.26	0.41	0.29	0.50	0.59	0.62	0.39
	within 300 yards (hectares)	19239	11922	8083	4925	4119	9319	10116	7089	17245
	within county (hectares)	42611	27848	22201	22847	17160	23223	26314	14846	50508
	buffer area / county area	0.45	0.43	0.36	0.22	0.27	0.40	0.38	0.48	0.34
	within buffer / tot. buffer	0.37	0.20	0.20	0.33	0.21	0.40	0.46	0.44	0.36
	within county / tot. county	0.27	0.15	0.18	0.35	0.20	0.37	0.27	0.32	0.33
Marginal Cover	home points (number)	49	0	1	10	3	0	9	12	1
	percentage of total points	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	within 300 yards (hectares)	494	0	29	160	42	16	138	136	17
	within county (hectares)	7284	13	518	5167	1409	244	8615	1887	752
	buffer area / county area	0.07	0.00	0.06	0.03	0.03	0.07	0.02	0.07	0.02
	within buffer / tot. buffer	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00
	within county / tot. county	0.05	0.00	0.00	0.08	0.02	0.00	0.09	0.04	0.00
Marginal Forage	home points (number)	822	722	692	299	324	828	194	104	1081
	percentage of total points	0.10	0.17	0.21	0.13	0.21	0.30	0.11	0.08	0.26
	within 300 yards (hectares)	8764	10580	6643	2451	4365	6844	2321	1313	13446
	within county (hectares)	22007	25353	16384	8712	16249	15404	6014	2844	31888
	buffer area / county area	0.40	0.42	0.41	0.28	0.27	0.44	0.39	0.46	0.42
	within buffer / tot. buffer	0.17	0.17	0.17	0.16	0.22	0.30	0.10	0.08	0.28
	within county / tot. county	0.14	0.14	0.14	0.13	0.19	0.25	0.06	0.06	0.21

Appendix A. Continued

Landcover Subset		jackson	ıontgomery	carroll	alexander	gallatin	massac	pope	hardin	randolph
Forest	home points (number)	3376	345	300	654	151	312	348	314	482
	percentage of total points	0.40	0.08	0.09	0.29	0.10	0.11	0.20	0.23	0.12
	within 300 yards (hectares)	19036	5981	4019	5307	2529	4512	8581	6798	7307
	within county (hectares)	65846	17061	14516	27449	17868	15164	60014	26065	33860
	buffer area/county area	0.29	0.35	0.28	0.19	0.14	0.30	0.14	0.26	0.22
	within buffer / tot. buffer	0.36	0.10	0.10	0.35	0.13	0.20	0.39	0.42	0.15
	within county / tot. county	0.42	0.09	0.12	0.42	0.21	0.24	0.62	0.56	0.22
buffer forest - county forest		-0.06	0.01	-0.02	-0.07	-0.08	-0.05	-0.23	-0.13	-0.07
Agriculture	home points (number)	896	1411	684	545	826	456	264	123	926
	percentage of total points	0.11	0.34	0.20	0.24	0.54	0.16	0.15	0.09	0.22
	within 300 yards (hectares)	15915	39483	19410	6126	13860	7076	3619	1819	21214
	within county (hectares)	49567	129857	62208	22731	50974	23200	11866	4699	63623
	buffer area / county area	0.32	0.30	0.31	0.27	0.27	0.31	0.30	0.39	0.33
	within buffer / tot. buffer	0.30	0.65	0.49	0.41	0.70	0.31	0.16	0.11	0.44
	within county / tot. county	0.32	0.71	0.52	0.35	0.60	0.37	0.12	0.10	0.41
Grassland	home points (number)	3653	2305	2236	869	520	1922	1026	819	2411
	percentage of total points	0.44	0.55	0.67	0.39	0.34	0.69	0.60	0.61	0.58
	within 300 yards (hectares)	16080	14413	14613	2677	2973	10689	9190	6761	17116
	within county (hectares)	27761	29499	34074	4960	6716	20166	21450	13308	40403
	buffer area / county area	0.58	0.49	0.43	0.54	0.44	0.53	0.43	0.51	0.42
	within buffer / tot. buffer	0.10	0.08	0.12	0.04	0.04	0.17	0.09	0.14	0.11
	within county / tot. county	0.18	0.16	0.28	0.08	0.08	0.32	0.22	0.28	0.26

Appendix A. Continued

		monroe	st. clair	clinton	white	edwards	hamilton	jefferson	wayne	jo daviess	stephenson
County	area	103133	174685	130394	129896	57627	112847	151189	185224	160293	146225
	buffer	35639	64376	42034	33521	17916	31093	53752	49512	46412	55884
	% county in buffer	0.35	0.37	0.32	0.26	0.31	0.28	0.36	0.27	0.29	0.38
	structures	3289	10294	3588	2427	1184	2092	5021	3277	3480	4858
	homes/ha. In buffer	0.09	0.16	0.09	0.07	0.07	0.07	0.09	0.07	0.07	0.09
	homes/ha. In county	0.03	0.06	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.03
	municipal area	3030	33070	2624	1794	1389	1443	5184	2151	2722	4246
	% municipal area	0.029	0.189	0.020	0.014	0.024	0.013	0.034	0.012	0.017	0.029
Non Habitat	structures	1093	4580	2061	741	286	493	962	887	1001	2832
	% total structures	0.33	0.44	0.57	0.31	0.24	0.24	0.19	0.27	0.29	0.58
	ha. In 300yds.	7125	23138	24318	10171	3802	7016	9328	13601	12907	33817
	ha. In county	22260	57722	72553	42135	11204	28232	29205	51469	41472	87038
	buffer/county	0.32	0.40	0.34	0.24	0.34	0.25	0.32	0.26	0.31	0.39
	in buffer/total buffer	0.20	0.36	0.58	0.30	0.21	0.23	0.17	0.27	0.28	0.61
	in county/total county	0.22	0.33	0.56	0.32	0.19	0.25	0.19	0.28	0.26	0.60
Cover	structures	690	1806	215	155	28	74	327	115	207	212
	% total structures	0.21	0.18	0.06	0.06	0.02	0.04	0.07	0.04	0.06	0.04
	ha. In 300yds.	7290	9177	3012	3114	1315	2944	7174	3271	5601	1970
	ha. In county	23582	22077	14635	15649	7112	15943	26695	21984	29633	6275
	buffer/county	0.31	0.42	0.21	0.20	0.18	0.18	0.27	0.15	0.19	0.31
	in buffer/total buffer	0.20	0.14	0.07	0.09	0.07	0.09	0.13	0.07	0.12	0.04
	in county/total county	0.23	0.13	0.11	0.12	0.12	0.14	0.18	0.12	0.18	0.04

Appendix A. Continued

		monroe	st. clair	clinton	white	edwards	hamilton	jefferson	wayne	jo daviess	stephenson
homes/ha cover in buffer		0.095	0.197	0.071	0.050	0.021	0.025	0.046	0.035	0.037	0.108
buffer cover - county cover		-0.02	0.02	-0.04	-0.03	-0.05	-0.05	-0.04	-0.05	-0.06	-0.01
Forage	structures	1036	2497	560	796	410	754	2392	1025	1360	766
	% total structures	0.31	0.24	0.16	0.33	0.35	0.36	0.48	0.31	0.39	0.16
	ha. In 300yds.	12978	17181	5969	9958	6096	10281	21510	14252	15836	7787
	ha. In county	32129	34696	18759	35682	19934	35415	53222	53112	53894	20558
	buffer/county	0.40	0.50	0.32	0.28	0.31	0.29	0.40	0.27	0.29	0.38
	in buffer/total buffer	0.36	0.27	0.14	0.30	0.34	0.33	0.40	0.29	0.34	0.14
	in county/total coun	0.31	0.20	0.14	0.27	0.35	0.31	0.35	0.29	0.34	0.14
Marg Cover	structures	6	50	21	0	0	0	0	0	19	0
	% total structures	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
	ha. In 300yds.	56	133	150	0	0	0	0	0	48	0
	ha. In county	777	1081	826	77	184	15	129	337	742	0
	buffer/county	0.07	0.12	0.18	0.00	0.00	0.00	0.00	0.00	0.06	#DIV/0!
	in buffer/total buffer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	in county/total coun	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marg Forage	structures	464	1361	731	735	460	771	1340	1250	893	1048
	% total structures	0.14	0.13	0.20	0.30	0.39	0.37	0.27	0.38	0.26	0.22
	ha. In 300yds.	8188	14745	8582	10251	6703	10849	15727	18385	11866	12213
	ha. In county	21431	31135	20998	34562	17809	31803	36370	56174	32184	28259
	buffer/county	0.38	0.47	0.41	0.30	0.38	0.34	0.43	0.33	0.37	0.43
	in buffer/total buffer	0.23	0.23	0.20	0.31	0.37	0.35	0.29	0.37	0.26	0.22
	in county/total coun	0.21	0.18	0.16	0.27	0.31	0.28	0.24	0.30	0.20	0.19

Appendix A. Continued

		monroe	st. clair	clinton	white	edwards	hamilton	jefferson	wayne	jo daviess	stephenson
Forest	structures	747	2078	272	162	43	99	386	149	308	400
	% total structures	0.23	0.20	0.08	0.07	0.04	0.05	0.08	0.05	0.09	0.08
	ha. In 300yds.	7677	9918	3414	3446	1582	3277	7809	3800	6349	2621
	ha. In county	25226	24400	16088	16665	8029	16822	28477	23911	33359	7672
	buffer/county	0.30	0.41	0.21	0.21	0.20	0.19	0.27	0.16	0.19	0.34
	in buffer/total buffer	0.22	0.15	0.08	0.10	0.09	0.11	0.15	0.08	0.14	0.05
	in county/total coun	0.24	0.14	0.12	0.13	0.14	0.15	0.19	0.13	0.21	0.05
buff forsest - cnty forest		-0.03	0.01	-0.04	-0.03	-0.05	-0.04	-0.04	-0.05	-0.07	-0.01
Agriculture	structures	798	1623	912	896	351	613	820	789	123	206
	% total structures	0.24	0.16	0.25	0.37	0.30	0.29	0.16	0.24	0.04	0.04
	ha. In 300yds.	19335	35646	25488	21248	10670	16406	20850	28156	12873	25761
	ha. In county	55043	85980	76232	90974	35677	64844	59361	114841	42974	74645
	buffer/county	0.35	0.41	0.33	0.23	0.30	0.25	0.35	0.25	0.30	0.35
	in buffer/total buffer	0.54	0.55	0.61	0.63	0.60	0.53	0.39	0.57	0.28	0.46
	in county/total coun	0.53	0.49	0.58	0.70	0.62	0.57	0.39	0.62	0.27	0.51
Grassland	structures	1007	3498	2142	1220	705	1325	3420	2212	2878	4216
	% total structures	0.31	0.34	0.60	0.50	0.60	0.63	0.68	0.68	0.83	0.87
	ha. In 300yds.	6625	13880	11343	7665	5088	10902	23199	16577	25516	25812
	ha. In county	12719	25542	24132	17117	11424	28285	49488	41141	43861	56190
	buffer/county	0.52	0.54	0.47	0.45	0.45	0.39	0.47	0.40	0.58	0.46
	in buffer/total buffer	0.06	0.08	0.09	0.06	0.09	0.10	0.15	0.09	0.16	0.18
	in county/total coun	0.12	0.15	0.19	0.13	0.20	0.25	0.33	0.22	0.27	0.38

Appendix A. Continued

		winnebago	boone	mchenry	rock island	whiteside	williamson	johnson	saline	lee	lasalle
County	area	134465	73031	158129	117091	180794	115015	90269	100166	188718	297310
	buffer	53406	30956	62720	37879	62257	55445	31837	35427	54613	92895
	% county in buffe	0.40	0.42	0.40	0.32	0.34	0.48	0.35	0.35	0.29	0.31
	structures	13810	5273	11726	5927	9302	16032	4459	5010	5245	10246
	homes/ha. In buff	0.26	0.17	0.19	0.16	0.15	0.29	0.14	0.14	0.10	0.11
	homes/ha. In cou	0.10	0.07	0.07	0.05	0.05	0.14	0.05	0.05	0.03	0.03
	municipal area	23431	1925	29096	16314	4525	8943	2148	3527	2621	11311
	% municipal area	0.174	0.026	0.184	0.139	0.025	0.078	0.024	0.035	0.014	0.038
Non Habitat	structures	6107	2261	4957	2173	5715	2501	598	1232	3385	5760
	% total structures	0.44	0.43	0.42	0.37	0.61	0.16	0.13	0.25	0.65	0.56
	ha. In 300yds.	24186	18094	26154	13627	40117	6075	2241	9322	41096	64515
	ha. In county	54641	45251	65791	42813	118472	14381	6943	25974	146144	218732
	buffer/county	0.44	0.40	0.40	0.32	0.34	0.42	0.32	0.36	0.28	0.29
	in buffer/total buff	0.45	0.58	0.42	0.36	0.64	0.11	0.07	0.26	0.75	0.69
	in county/total cou	0.41	0.62	0.42	0.37	0.66	0.13	0.08	0.26	0.77	0.74
Cover	structures	1840	323	1888	675	521	2008	793	488	372	938
	% total structures	0.13	0.06	0.16	0.11	0.06	0.13	0.18	0.10	0.07	0.09
	ha. In 300yds.	5122	1375	6816	4703	2594	14436	9253	5078	2354	6082
	ha. In county	10226	2718	11433	13319	8096	34470	35184	19582	6387	16707
	buffer/county	0.50	0.51	0.60	0.35	0.32	0.42	0.26	0.26	0.37	0.36
	in buffer/total buff	0.10	0.04	0.11	0.12	0.04	0.26	0.29	0.14	0.04	0.07
	in county/total cou	0.08	0.04	0.07	0.11	0.04	0.30	0.39	0.20	0.03	0.06

Appendix A. Continued

		winnebago	boone	mchenry	rock island	whiteside	williamson	johnson	saline	lee	lasalle
homes/ha cover in buffer		0.359	0.235	0.277	0.144	0.201	0.139	0.086	0.096	0.158	0.154
buffer cover - county cove		0.02	0.01	0.04	0.01	0.00	-0.04	-0.10	-0.05	0.01	0.01
Forage	structures	3434	1313	2676	1978	1431	8258	2449	1941	804	2401
	% total structures	0.25	0.25	0.23	0.33	0.15	0.52	0.55	0.39	0.15	0.23
	ha. In 300yds.	11672	4616	14655	11052	8083	24360	15260	11026	5241	11774
	ha. In county	21874	8871	25344	24559	21070	40202	34858	26636	14787	25785
	buffer/county	0.53	0.52	0.58	0.45	0.38	0.61	0.44	0.41	0.35	0.46
	in buffer/total buff	0.22	0.15	0.23	0.29	0.13	0.44	0.48	0.31	0.10	0.13
	in county/total cou	0.16	0.12	0.16	0.21	0.12	0.35	0.39	0.27	0.08	0.09
Marg Cover	structures	0	0	30	11	0	3	8	0	0	0
	% total structures	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ha. In 300yds.	0	0	48	30	0	31	33	0	0	2
	ha. In county	11	0	55	1081	106	1219	1692	2108	14	56
	buffer/county	0.00	#DIV/0!	0.87	0.03	0.00	0.03	0.02	0.00	0.00	0.04
	in buffer/total buff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	in county/total cou	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.02	0.00	0.00
Marg Forage	structures	2429	1376	2175	1090	1635	3262	610	1349	684	1147
	% total structures	0.18	0.26	0.19	0.18	0.18	0.20	0.14	0.27	0.13	0.11
	ha. In 300yds.	12313	6784	14784	8464	11462	10539	5048	9996	5920	10520
	ha. In county	25738	14268	29764	19453	28526	16290	9439	22360	18763	24756
	buffer/county	0.48	0.48	0.50	0.44	0.40	0.65	0.53	0.45	0.32	0.42
	in buffer/total buff	0.23	0.22	0.24	0.22	0.18	0.19	0.16	0.28	0.11	0.11
	in county/total cou	0.19	0.20	0.19	0.17	0.16	0.14	0.10	0.22	0.10	0.08

Appendix A. Continued

		winnebago	boone	mchenry	rock island	whiteside	williamson	johnson	saline	lee	lasalle
Forest	structures	2500	557	2285	864	822	2141	827	523	570	1027
	% total structures	0.18	0.11	0.19	0.15	0.09	0.13	0.19	0.10	0.11	0.10
	ha. In 300yds.	6068	1736	7963	5286	3261	15172	9649	5375	2772	6473
	ha. In county	11613	3282	13160	15891	9599	36927	38546	23057	7337	17491
	buffer/county	0.52	0.53	0.61	0.33	0.34	0.41	0.25	0.23	0.38	0.37
	in buffer/total buff	0.11	0.06	0.13	0.14	0.05	0.27	0.30	0.15	0.05	0.07
	in county/total cou	0.09	0.04	0.08	0.14	0.05	0.32	0.43	0.23	0.04	0.06
buff forsest - cnty forest		0.03	0.01	0.04	0.00	0.00	-0.05	-0.12	-0.08	0.01	0.01
Agriculture	structures	394	282	663	191	674	2406	459	1053	608	1460
	% total structures	0.03	0.05	0.06	0.03	0.07	0.15	0.10	0.21	0.12	0.14
	ha. In 300yds.	20429	1467	22574	13709	37474	12500	4939	16600	36921	58095
	ha. In county	55414	45530	64644	42799	122085	24941	14533	48965	146081	212350
	buffer/county	0.37	0.03	0.35	0.32	0.31	0.50	0.34	0.34	0.25	0.27
	in buffer/total buff	0.38	0.05	0.36	0.36	0.60	0.23	0.16	0.47	0.68	0.63
	in county/total cou	0.41	0.62	0.41	0.37	0.68	0.22	0.16	0.49	0.77	0.71
Grassland	structures	7834	4313	6398	4051	6628	9811	2660	2991	3851	6680
	% total structures	0.57	0.82	0.55	0.68	0.71	0.61	0.60	0.60	0.73	0.65
	ha. In 300yds.	22239	12177	25148	16152	18689	23901	15640	11135	12875	23802
	ha. In county	37807	19928	41522	32046	36009	35085	31184	19777	27541	45816
	buffer/county	0.59	0.61	0.61	0.50	0.52	0.68	0.50	0.56	0.47	0.52
	in buffer/total buff	0.17	0.17	0.16	0.14	0.10	0.21	0.17	0.11	0.07	0.08
	in county/total cou	0.28	0.27	0.26	0.27	0.20	0.31	0.35	0.20	0.15	0.15

Appendix A. Continued

		putnam	kendall	scott	knox	grundy	will	kankakee	ford	mercer	henderson	lawrence	union
County	area	44592	83443	65398	186524	111459	219759	176304	125898	147230	102737	96797	109345
	buffer	10720	34041	19035	53674	32661	82593	60871	34293	43904	24118	31045	37919
	% county in	0.24	0.41	0.29	0.29	0.29	0.38	0.35	0.27	0.30	0.23	0.32	0.35
	structures	801	5829	1268	4482	3960	16480	10109	4206	3709	1866	2829	4106
	homes/ha. Ir	0.07	0.17	0.07	0.08	0.12	0.20	0.17	0.12	0.08	0.08	0.09	0.11
	homes/ha. Ir	0.02	0.07	0.02	0.02	0.04	0.07	0.06	0.03	0.03	0.02	0.03	0.04
	municipal ar	2126	3405	1552	8083	3704	46111	8089	1857	2866	2574	1356	2476
	% municipal	0.048	0.041	0.024	0.043	0.033	0.210	0.046	0.015	0.019	0.025	0.014	0.023
Non Habitat	structures	280	3573	294	1561	2331	9367	6279	4081	1589	773	728	355
	% total struc	0.35	0.61	0.23	0.35	0.59	0.57	0.62	0.97	0.43	0.41	0.26	0.09
	ha. In 300yd	4395	23254	4695	21035	21264	50275	42462	32853	20477	9438	6152	3066
	ha. In county	20481	60148	20112	73917	76306	115793	129619	119105	67895	41489	20501	13521
	buffer/count	0.21	0.39	0.23	0.28	0.28	0.43	0.33	0.28	0.30	0.23	0.30	0.23
	in buffer/tota	0.41	0.68	0.25	0.39	0.65	0.61	0.70	0.96	0.47	0.39	0.20	0.08
	in county/tot	0.46	0.72	0.31	0.40	0.68	0.53	0.74	0.95	0.46	0.40	0.21	0.12
Cover	structures	130	525	113	516	280	1701	1150	7	331	312	235	1051
	% total struc	0.16	0.09	0.09	0.12	0.07	0.10	0.11	0.00	0.09	0.17	0.08	0.26
	ha. In 300yd	1536	2221	2040	5339	2160	6218	3010	127	2821	2664	3696	12306
	ha. In county	7408	3490	8661	23365	5683	13044	5395	383	11985	13493	15858	38213
	buffer/count	0.21	0.64	0.24	0.23	0.38	0.48	0.56	0.33	0.24	0.20	0.23	0.32
	in buffer/tota	0.14	0.07	0.11	0.10	0.07	0.08	0.05	0.00	0.06	0.11	0.12	0.32
	in county/tot	0.17	0.04	0.13	0.13	0.05	0.06	0.03	0.00	0.08	0.13	0.16	0.35

Appendix A. Continued

		putnam	kendall	scott	knox	grundy	will	kankakee	ford	mercer	henderson	lawrence	union
homes/ha cover in buf		0.085	0.236	0.055	0.097	0.130	0.274	0.382	0.055	0.117	0.117	0.064	0.085
buffer cover - county c		-0.02	0.02	-0.03	-0.03	0.02	0.02	0.02	0.00	-0.02	-0.02	-0.04	-0.02
Forage	structures	264	1053	506	1526	790	3115	1441	61	931	472	1076	2115
	% total struc	0.33	0.18	0.40	0.34	0.20	0.19	0.14	0.01	0.25	0.25	0.38	0.52
	ha. In 300yd	2887	4251	6536	14969	4416	12398	6897	488	9577	6061	11438	16560
	ha. In county	8891	7052	19743	46853	11565	23379	13358	1526	31707	24625	33113	36321
	buffer/count	0.32	0.60	0.33	0.32	0.38	0.53	0.52	0.32	0.30	0.25	0.35	0.46
	in buffer/tota	0.27	0.12	0.34	0.28	0.14	0.15	0.11	0.01	0.22	0.25	0.37	0.44
	in county/tot	0.20	0.08	0.30	0.25	0.10	0.11	0.08	0.01	0.22	0.24	0.34	0.33
Marg Cover	structures	0	0	0	1	1	0	5	0	0	14	0	40
	% total struc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
	ha. In 300yd	1	2	0	0	8	17	19	0	2	93	0	451
	ha. In county	424	5	3	70	52	41	40	0	411	600	52	6415
	buffer/count	0.00	0.40	0.00	0.00	0.15	0.41	0.48	#DIV/0!	0.00	0.16	0.00	0.07
	in buffer/tota	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	in county/tot	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.06
Marg Forage	structures	127	678	355	878	558	2297	1234	57	858	315	790	545
	% total struc	0.16	0.12	0.28	0.20	0.14	0.14	0.12	0.01	0.23	0.17	0.28	0.13
	ha. In 300yd	1899	4311	5761	12328	4811	13491	8302	824	11024	5852	9704	5533
	ha. In county	5619	9384	15327	34905	14176	27987	19875	3031	32364	22526	25916	12142
	buffer/count	0.34	0.46	0.38	0.35	0.34	0.48	0.42	0.27	0.34	0.26	0.37	0.46
	in buffer/tota	0.18	0.13	0.30	0.23	0.15	0.16	0.14	0.02	0.25	0.24	0.31	0.15
	in county/tot	0.13	0.11	0.23	0.19	0.13	0.13	0.11	0.02	0.22	0.22	0.27	0.11

Appendix A. Continued

		putnam	kendall	scott	knox	grundy	will	kankakee	ford	mercer	henderson	lawrence	union
Forest	structures	151	595	138	663	313	2061	1439	39	432	398	274	1143
	% total struc	0.19	0.10	0.11	0.15	0.08	0.13	0.14	0.01	0.12	0.21	0.10	0.28
	ha. In 300yd	1621	2383	2356	6367	2397	7175	3561	205	3331	3246	5121	13297
	ha. In county	7865	3741	9526	26246	6229	14562	6237	548	14107	16245	16872	49477
	buffer/county	0.21	0.64	0.25	0.24	0.38	0.49	0.57	0.37	0.24	0.20	0.30	0.27
	in buffer/tota	0.15	0.07	0.12	0.12	0.07	0.09	0.06	0.01	0.08	0.13	0.16	0.35
	in county/tot	0.18	0.04	0.15	0.14	0.06	0.07	0.04	0.00	0.10	0.16	0.17	0.45
buff forsest - cnty fore		-0.03	0.03	-0.02	-0.02	0.02	0.02	0.02	0.00	-0.02	-0.02	-0.01	-0.10
Agriculture	structures	104	875	454	863	731	1631	991	973	426	335	938	513
	% total struc	0.13	0.15	0.36	0.19	0.18	0.10	0.10	0.23	0.11	0.18	0.33	0.12
	ha. In 300yd	5868	20492	10605	32184	19997	33946	36788	26498	23702	14706	19769	6681
	ha. In county	23468	58943	38093	112583	78624	93255	126023	106640	86565	64855	63508	20877
	buffer/county	0.25	0.35	0.28	0.29	0.25	0.36	0.29	0.25	0.27	0.23	0.31	0.32
	in buffer/tota	0.55	0.60	0.56	0.60	0.61	0.41	0.60	0.77	0.54	0.61	0.64	0.18
	in county/tot	0.53	0.71	0.58	0.60	0.71	0.42	0.71	0.85	0.59	0.63	0.66	0.19
Grassland	structures	512	3837	657	2783	2281	9218	4915	2859	2727	960	1362	2173
	% total struc	0.64	0.66	0.52	0.62	0.58	0.56	0.49	0.68	0.74	0.51	0.48	0.53
	ha. In 300yd	2727	9424	5579	13391	7866	32288	16537	6401	15814	4952	6001	15760
	ha. In county	6779	14773	14343	34594	15936	55852	29672	14032	39146	15000	11981	30155
	buffer/county	0.40	0.64	0.39	0.39	0.49	0.58	0.56	0.46	0.40	0.33	0.50	0.52
	in buffer/tota	0.06	0.11	0.09	0.07	0.07	0.15	0.09	0.05	0.11	0.05	0.06	0.14
	in county/tot	0.15	0.18	0.22	0.19	0.14	0.25	0.17	0.11	0.27	0.15	0.12	0.28

Appendix A. Continued

		adams	bond	mcdonough	bureau	calhoun	champaign	christian	clark	coles	crawford	dekalb	dewitt
County	area	226152	99181	153056	226449	73614	258410	185297	130668	132123	115386	164319	104871
	buffer	66232	31463	42947	59698	21256	70207	45886	50704	44133	43254	52121	23811
	% county i	0.29	0.32	0.28	0.26	0.29	0.27	0.25	0.39	0.33	0.37	0.32	0.23
	structures	5841	2192	2834	3934	2531	7137	3595	5689	5125	4544	5003	1613
	homes/ha.	0.09	0.07	0.07	0.07	0.12	0.10	0.08	0.11	0.12	0.11	0.10	0.07
	homes/ha.	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.04	0.04	0.04	0.03	0.02
	municipal a	5351	1862	4365	6220	1937	11556	4651	1896	4452	1962	5835	1463
	% municip	0.024	0.019	0.029	0.027	0.026	0.045	0.025	0.015	0.034	0.017	0.036	0.014
Non Habitat	structures	1479	721	1447	2416	584	6267	2364	1247	2307	1291	3919	1016
	% total str	0.25	0.33	0.51	0.61	0.23	0.88	0.66	0.22	0.45	0.28	0.78	0.63
	ha. In 300	16281	11345	21978	40134	2979	61385	32766	10332	21377	8538	42966	15573
	ha. In cour	55676	38865	78983	149628	14312	226834	144353	31929	78472	21345	135684	77829
	buffer/cou	0.29	0.29	0.28	0.27	0.21	0.27	0.23	0.32	0.27	0.40	0.32	0.20
	in buffer/to	0.25	0.36	0.51	0.67	0.14	0.87	0.71	0.20	0.48	0.20	0.82	0.65
	in county/t	0.25	0.39	0.52	0.66	0.19	0.88	0.78	0.24	0.59	0.18	0.83	0.74
Cover	structures	564	137	100	277	626	141	130	598	374	346	193	112
	% total str	0.10	0.06	0.04	0.07	0.25	0.02	0.04	0.11	0.07	0.08	0.04	0.07
	ha. In 300	7385	3653	2848	3121	7177	1271	1594	8949	4990	6785	1150	1266
	ha. In cour	35804	14020	15185	14021	28662	2826	5855	27045	11808	22278	2904	5564
	buffer/cou	0.21	0.26	0.19	0.22	0.25	0.45	0.27	0.33	0.42	0.30	0.40	0.23
	in buffer/to	0.11	0.12	0.07	0.05	0.34	0.02	0.03	0.18	0.11	0.16	0.02	0.05
	in county/t	0.16	0.14	0.10	0.06	0.39	0.01	0.03	0.21	0.09	0.19	0.02	0.05

Appendix A. Continued

		adams	bond	mcdonough	bureau	calhoun	champaign	christian	clark	coles	crawford	dekalb	dewitt
homes/ha cover in t		0.076	0.038	0.035	0.089	0.087	0.111	0.082	0.067	0.075	0.051	0.168	0.088
buffer cover - count		-0.05	-0.03	-0.03	-0.01	-0.05	0.01	0.00	-0.03	0.02	-0.04	0.00	0.00
Forage	structures	2175	835	733	723	996	374	555	2622	1638	1867	445	242
	% total stri	0.37	0.38	0.26	0.18	0.39	0.05	0.15	0.46	0.32	0.41	0.09	0.15
	ha. In 300y	22919	9170	9165	8076	8734	3248	4737	19880	10126	16490	3164	3348
	ha. In cour	77583	25063	29608	28050	21162	6908	13291	42993	20390	41392	7823	9938
	buffer/cou	0.30	0.37	0.31	0.29	0.41	0.47	0.36	0.46	0.50	0.40	0.40	0.34
	in buffer/to	0.35	0.29	0.21	0.14	0.41	0.05	0.10	0.39	0.23	0.38	0.06	0.14
	in county/t	0.34	0.25	0.19	0.12	0.29	0.03	0.07	0.33	0.15	0.36	0.05	0.09
Marg Cover	structures	34	0	1	0	30	0	0	0	0	0	0	0
	% total stri	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ha. In 300y	171	0	12	4	69	0	0	0	4	0	0	1
	ha. In cour	1674	0	68	510	1690	0	6	23	16	56	0	4
	buffer/cou	0.10	#DIV/0!	0.18	0.01	0.04	#DIV/0!	0.00	0.00	0.25	0.00	#DIV/0!	0.25
	in buffer/to	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	in county/t	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marg Forage	structures	1589	499	553	518	295	355	546	1222	806	1040	446	243
	% total stri	0.27	0.23	0.20	0.13	0.12	0.05	0.15	0.21	0.16	0.23	0.09	0.15
	ha. In 300y	19473	7293	8942	8360	2296	4302	6167	11469	7634	11406	4838	3621
	ha. In cour	50083	19388	24921	28021	5849	10406	17150	26793	17012	28354	12201	10175
	buffer/cou	0.39	0.38	0.36	0.30	0.39	0.41	0.36	0.43	0.45	0.40	0.40	0.36
	in buffer/to	0.29	0.23	0.21	0.14	0.11	0.06	0.13	0.23	0.17	0.26	0.09	0.15
	in county/t	0.22	0.20	0.16	0.12	0.08	0.04	0.09	0.21	0.13	0.25	0.07	0.10

Appendix A. Continued

		adams	bond	mcdonough	bureau	calhoun	champaign	christian	clark	coles	crawford	dekalb	dewitt
Forest	structures	772	167	175	372	749	277	180	525	473	429	303	142
	% total str	0.13	0.08	0.06	0.09	0.30	0.04	0.05	0.09	0.09	0.09	0.06	0.09
	ha. In 300	8906	3907	3415	3526	7493	1541	1823	9444	5386	7313	1384	946
	ha. In cour	41258	14571	16771	16009	31784	3225	6377	27964	12467	23320	3296	5956
	buffer/cou	0.22	0.27	0.20	0.22	0.24	0.48	0.29	0.34	0.43	0.31	0.42	0.16
	in buffer/to	0.13	0.12	0.08	0.06	0.35	0.02	0.04	0.19	0.12	0.17	0.03	0.04
	in county/t	0.18	0.15	0.11	0.07	0.43	0.01	0.03	0.21	0.09	0.20	0.02	0.06
buff forsest - cnty fc		-0.05	-0.02	-0.03	-0.01	-0.08	0.01	0.01	-0.03	0.03	-0.03	0.01	-0.02
Agriculture	structures	1399	310	666	489	662	719	1076	1539	859	1218	732	1104
	% total str	0.24	0.14	0.24	0.12	0.26	0.10	0.30	0.27	0.17	0.27	0.15	0.68
	ha. In 300	34672	15429	30094	40499	6600	51725	32327	30479	27155	27221	36591	15287
	ha. In cour	120215	56261	108865	161759	18092	213363	153704	81213	95582	74069	129781	78625
	buffer/cou	0.29	0.27	0.28	0.25	0.36	0.24	0.21	0.38	0.28	0.37	0.28	0.19
	in buffer/to	0.52	0.49	0.70	0.68	0.31	0.74	0.70	0.60	0.62	0.63	0.70	0.64
	in county/t	0.53	0.57	0.71	0.71	0.25	0.83	0.83	0.62	0.72	0.64	0.79	0.75
Grassland	structures	3342	1616	1852	2982	766	3539	1841	3160	3230	2366	3459	172
	% total str	0.57	0.74	0.65	0.76	0.30	0.50	0.51	0.56	0.63	0.52	0.69	0.11
	ha. In 300	19966	11101	8534	13994	5536	12790	7903	9293	9504	7292	12504	5952
	ha. In cour	51491	24180	20358	36002	12125	23147	16350	16232	16193	13170	22350	14041
	buffer/cou	0.39	0.46	0.42	0.39	0.46	0.55	0.48	0.57	0.59	0.55	0.56	0.42
	in buffer/to	0.09	0.11	0.06	0.06	0.08	0.05	0.04	0.07	0.07	0.06	0.08	0.06
	in county/t	0.23	0.24	0.13	0.16	0.16	0.09	0.09	0.12	0.12	0.11	0.14	0.13

Appendix A. Continued

		douglas	edgar	brown	franklin	cass	clay	cumberland	effingham	fayette	fulton	greene	hancock
County	area	108027	161423	79708	111770	99470	121504	89750	124315	187906	228872	141853	211343
	buffer	50898	44539	17562	39362	20374	44031	38981	53847	60097	63917	35415	54902
	% county ir	0.47	0.28	0.22	0.35	0.20	0.36	0.43	0.43	0.32	0.28	0.25	0.26
	structures	2169	3430	1013	4404	1427	5266	5541	8398	5653	5855	2223	3849
	homes/ha.	0.04	0.08	0.06	0.11	0.07	0.12	0.14	0.16	0.09	0.09	0.06	0.07
	homes/ha.	0.02	0.02	0.01	0.04	0.01	0.04	0.06	0.07	0.03	0.03	0.02	0.02
	municipal a	1806	2337	732	6166	1662	2099	1234	4026	2511	5455	2833	7661
	% municipa	0.017	0.014	0.009	0.055	0.017	0.017	0.014	0.032	0.013	0.024	0.020	0.036
Non Habitat	structures	1669	1670	160	934	468	1781	1775	3188	2277	1269	736	1623
	% total stru	0.77	0.49	0.16	0.21	0.33	0.34	0.32	0.38	0.40	0.22	0.33	0.42
	ha. In 300y	21365	22796	2550	7020	6980	13830	12168	20721	20634	12354	10198	22620
	ha. In coun	92497	103744	11423	22714	39456	38599	31401	51792	67799	49520	43695	84680
	buffer/coun	0.23	0.22	0.22	0.31	0.18	0.36	0.39	0.40	0.30	0.25	0.23	0.27
	in buffer/tot	0.42	0.51	0.15	0.18	0.34	0.31	0.31	0.38	0.34	0.19	0.29	0.41
	in county/to	0.86	0.64	0.14	0.20	0.40	0.32	0.35	0.42	0.36	0.22	0.31	0.40
Cover	structures	20	180	49	554	184	253	334	772	363	493	149	194
	% total stru	0.01	0.05	0.05	0.13	0.13	0.05	0.06	0.09	0.06	0.08	0.07	0.05
	ha. In 300y	585	3591	2734	5450	2532	4446	5068	6667	8033	9894	4025	4308
	ha. In coun	2036	11691	23377	19492	14929	17730	12396	17192	31105	50162	22556	25081
	buffer/coun	0.29	0.31	0.12	0.28	0.17	0.25	0.41	0.39	0.26	0.20	0.18	0.17
	in buffer/tot	0.01	0.08	0.16	0.14	0.12	0.10	0.13	0.12	0.13	0.15	0.11	0.08
	in county/to	0.02	0.07	0.29	0.17	0.15	0.15	0.14	0.14	0.17	0.22	0.16	0.12

Appendix A. Continued

		douglas	edgar	brown	franklin	cass	clay	cumberland	effingham	fayette	fulton	greene	hancock
homes/ha cover in I		0.034	0.050	0.018	0.102	0.073	0.057	0.066	0.116	0.045	0.050	0.037	0.045
buffer cover - count		-0.01	0.01	-0.14	-0.04	-0.03	-0.04	-0.01	-0.01	-0.03	-0.06	-0.05	-0.04
Forage	structures	229	967	536	1813	510	1658	2286	2786	1837	2560	766	1117
	% total stru	0.11	0.28	0.53	0.41	0.36	0.31	0.41	0.33	0.32	0.44	0.34	0.29
	ha. In 300y	1958	10070	7981	15405	6238	12541	12392	15326	17988	26209	10786	13720
	ha. In coun	4971	24491	32302	36610	23407	33040	24906	29932	50055	81244	40361	51988
	buffer/coun	0.39	0.41	0.25	0.42	0.27	0.38	0.50	0.51	0.36	0.32	0.27	0.26
	in buffer/tot	0.04	0.23	0.45	0.39	0.31	0.28	0.32	0.28	0.30	0.41	0.30	0.25
	in county/to	0.05	0.15	0.41	0.33	0.24	0.27	0.28	0.24	0.27	0.35	0.28	0.25
Marg Cover	structures	0	0	0	0	1	0	0	0	0	0	0	1
	% total stru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ha. In 300y	0	0	4	7	16	0	0	0	0.24	5	0.11	23
	ha. In coun	0	1	242	384	1360	54	0	3	333	186	76	220
	buffer/coun	#DIV/0!	0.00	0.02	0.02	0.01	0.00	#DIV/0!	0.00	0.00	0.03	0.00	0.10
	in buffer/tot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	in county/to	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marg Forage	structures	251	613	268	1103	264	1574	1146	1652	1176	1533	572	914
	% total stru	0.12	0.18	0.26	0.25	0.19	0.30	0.21	0.20	0.21	0.26	0.26	0.24
	ha. In 300y	2976	7979	4291	11479	4606	13211	9351	11129	13438	15452	10404	14229
	ha. In coun	7182	19217	11631	26423	18580	29950	19811	21457	36107	42324	32333	41744
	buffer/coun	0.41	0.42	0.37	0.43	0.25	0.44	0.47	0.52	0.37	0.37	0.32	0.34
	in buffer/tot	0.06	0.18	0.24	0.29	0.23	0.30	0.24	0.21	0.22	0.24	0.29	0.26
	in county/to	0.07	0.12	0.15	0.24	0.19	0.25	0.22	0.17	0.19	0.18	0.23	0.20

Appendix A. Continued

		douglas	edgar	brown	franklin	cass	clay	cumberland	effingham	fayette	fulton	greene	hancock
Forest	structures	43	243	58	627	264	293	754	780	356	706	154	255
	% total stru	0.02	0.07	0.06	0.14	0.19	0.06	0.14	0.09	0.06	0.12	0.07	0.07
	ha. In 300y	688	7414	2995	6039	1435	4821	5453	7082	8489	11234	4270	4999
	ha. In coun	2221	11534	24526	21439	19014	18670	13074	17973	33023	54509	23586	27641
	buffer/coun	0.31	0.64	0.12	0.28	0.08	0.26	0.42	0.39	0.26	0.21	0.18	0.18
	in buffer/tot	0.01	0.17	0.17	0.15	0.07	0.11	0.14	0.13	0.14	0.18	0.12	0.09
	in county/to	0.02	0.07	0.31	0.19	0.19	0.15	0.15	0.14	0.18	0.24	0.17	0.13
buff forsest - cnty fc		-0.01	0.10	-0.14	-0.04	-0.12	-0.04	-0.01	-0.01	-0.03	-0.06	-0.05	-0.04
Agriculture	structures	640	855	263	778	243	1431	1290	1410	1000	1641	1008	1158
	% total stru	0.30	0.25	0.26	0.18	0.17	0.27	0.23	0.17	0.18	0.28	0.45	0.30
	ha. In 300y	18842	5674	8603	16577	11760	26433	24381	30478	29029	33163	22639	36599
	ha. In coun	90061	124316	33115	46736	60149	74760	60442	74762	99044	106987	90077	135839
	buffer/coun	0.21	0.05	0.26	0.35	0.20	0.35	0.40	0.41	0.29	0.31	0.25	0.27
	in buffer/tot	0.37	0.13	0.49	0.42	0.58	0.60	0.63	0.57	0.48	0.52	0.64	0.67
	in county/to	0.83	0.77	0.42	0.42	0.60	0.62	0.67	0.60	0.53	0.47	0.64	0.64
Grassland	structures	1437	2046	681	2462	843	3106	3315	5059	3980	3303	792	2248
	% total stru	0.66	0.60	0.67	0.56	0.59	0.59	0.60	0.60	0.70	0.56	0.36	0.58
	ha. In 300y	5416	9905	5473	14371	4943	11667	7773	14140	20915	16860	7323	11804
	ha. In coun	10105	19599	19166	27709	14683	23292	12619	24114	46344	48768	21248	32919
	buffer/coun	0.54	0.51	0.29	0.52	0.34	0.50	0.62	0.59	0.45	0.35	0.34	0.36
	in buffer/tot	0.05	0.06	0.07	0.13	0.05	0.10	0.09	0.11	0.11	0.07	0.05	0.06
	in county/to	0.09	0.12	0.24	0.25	0.15	0.19	0.14	0.19	0.25	0.21	0.15	0.16

Appendix A. Continued

		henry	iriquois	jasper	jersey	livingston	logan	macon	macoupin	madison	marion	marshall
County	area	213844	289713	128983	97908	270789	160313	151723	224819	191838	149161	103331
	buffer	63957	90186	49561	33049	70355	40484	42053	66800	76131	52649	24118
	% county in	0.30	0.31	0.38	0.34	0.26	0.25	0.28	0.30	0.40	0.35	0.23
	structures	5686	11405	6810	3909	6129	2765	5198	5334	13463	5221	1518
	homes/ha. I	0.09	0.13	0.14	0.12	0.09	0.07	0.12	0.08	0.18	0.10	0.06
	homes/ha. I	0.03	0.04	0.05	0.04	0.02	0.02	0.03	0.02	0.07	0.04	0.01
	municipal ai	5759	4014	1566	2618	3422	2773	15083	6879	37845	5351	1720
	% municipa	0.027	0.014	0.012	0.027	0.013	0.017	0.099	0.031	0.197	0.036	0.017
Non Habitat	structures	3158	9500	2663	1191	5009	2176	3372	1821	5427	1257	854
	% total struc	0.56	0.83	0.39	0.30	0.82	0.79	0.65	0.34	0.40	0.24	0.56
	ha. In 300yc	44324	74296	17481	7824	60785	31957	30683	21663	24432	13090	14748
	ha. In count	154601	241782	48535	25882	240436	128002	114514	84951	61798	42885	65749
	buffer/count	0.29	0.31	0.36	0.30	0.25	0.25	0.27	0.26	0.40	0.31	0.22
	in buffer/tota	0.69	0.82	0.35	0.24	0.86	0.79	0.73	0.32	0.32	0.25	0.61
	in county/tot	0.72	0.83	0.38	0.26	0.89	0.80	0.75	0.38	0.32	0.29	0.64
Cover	structures	428	196	288	921	170	54	451	1105	2500	463	124
	% total struc	0.08	0.02	0.04	0.24	0.03	0.02	0.09	0.21	0.19	0.09	0.08
	ha. In 300yc	2536	1918	4923	8290	1144	857	2667	10856	13559	7070	2022
	ha. In count	7391	5588	15462	25794	2830	3851	5085	37892	26112	25936	10406
	buffer/count	0.34	0.34	0.32	0.32	0.40	0.22	0.52	0.29	0.52	0.27	0.19
	in buffer/tota	0.04	0.02	0.10	0.25	0.02	0.02	0.06	0.16	0.18	0.13	0.08
	in county/tot	0.03	0.02	0.12	0.26	0.01	0.02	0.03	0.17	0.14	0.17	0.10

Appendix A. Continued

		henry	iriquois	jasper	jersey	livingston	logan	macon	macoupin	madison	marion	marshall
homes/ha cover in b		0.169	0.102	0.059	0.111	0.149	0.063	0.169	0.102	0.184	0.065	0.061
buffer cover - county		0.01	0.00	-0.02	-0.01	0.01	0.00	0.03	-0.01	0.04	-0.04	-0.02
Forage	structures	1170	863	2126	1262	480	219	935	1546	3755	2168	338
	% total struc	0.21	0.08	0.31	0.32	0.08	0.08	0.18	0.29	0.28	0.42	0.22
	ha. In 300yc	7432	5778	13881	10542	3444	2864	4619	19933	22645	18165	4108
	ha. In count	19294	15053	32934	26028	8857	10421	8329	54524	41065	43014	14519
	buffer/count	0.39	0.38	0.42	0.41	0.39	0.27	0.55	0.37	0.55	0.42	0.28
	in buffer/tota	0.12	0.06	0.28	0.32	0.05	0.07	0.11	0.30	0.30	0.35	0.17
	in county/tot	0.09	0.05	0.26	0.27	0.03	0.07	0.05	0.24	0.21	0.29	0.14
Marg Cover	structures	0	0	0	55	0	0	0	12	72	0	0
	% total struc	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	ha. In 300yc	0	0	0	308	0	0	3	41	113	0	0
	ha. In count	8	0	33	1677	0	0	30	78	260	0	571
	buffer/count	0.00	#DIV/0!	0.00	0.18	#DIV/0!	#DIV/0!	0.10	0.53	0.43	#DIV/0!	0.00
	in buffer/tota	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	in county/tot	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Marg Forage	structures	930	846	1733	480	470	316	440	850	1709	1333	202
	% total struc	0.16	0.07	0.25	0.12	0.08	0.11	0.08	0.16	0.13	0.26	0.13
	ha. In 300yc	9664	8044	13274	6084	4981	4804	4080	14304	15380	14322	3238
	ha. In count	26831	23274	30451	15913	15267	15264	9660	40503	31195	32016	10370
	buffer/count	0.36	0.35	0.44	0.38	0.33	0.31	0.42	0.35	0.49	0.45	0.31
	in buffer/tota	0.15	0.09	0.27	0.18	0.07	0.12	0.10	0.21	0.20	0.27	0.13
	in county/tot	0.13	0.08	0.24	0.16	0.06	0.10	0.06	0.18	0.16	0.21	0.10

Appendix A. Continued

		henry	iriquois	jasper	jersey	livingston	logan	macon	macoupin	madison	marion	marshall
Forest	structures	560	340	327	1049	295	110	561	1164	2805	523	149
	% total struc	0.10	0.03	0.05	0.27	0.05	0.04	0.11	0.22	0.21	0.10	0.10
	ha. In 300yc	3079	2321	5360	8872	1469	1080	2979	11394	13094	7562	2177
	ha. In count	8666	6308	16435	28749	3452	4361	5485	39195	27856	26934	11585
	buffer/count	0.36	0.37	0.33	0.31	0.43	0.25	0.54	0.29	0.47	0.28	0.19
	in buffer/tot	0.05	0.03	0.11	0.27	0.02	0.03	0.07	0.17	0.17	0.14	0.09
	in county/tot	0.04	0.02	0.13	0.29	0.01	0.03	0.04	0.17	0.15	0.18	0.11
buff forsest - cnty for		0.01	0.00	-0.02	-0.03	0.01	0.00	0.03	0.00	0.03	-0.04	-0.02
Agriculture	structures	788	2287	1951	928	1323	964	565	1814	2103	753	173
	% total struc	0.14	0.20	0.29	0.24	0.22	0.35	0.11	0.34	0.16	0.14	0.11
	ha. In 300yc	38540	67170	34088	15540	52888	30125	26979	40101	41122	23304	14932
	ha. In count	148312	238001	91433	48271	227721	131527	112702	145708	90514	72712	68805
	buffer/count	0.26	0.28	0.37	0.32	0.23	0.23	0.24	0.28	0.45	0.32	0.22
	in buffer/tot	0.60	0.74	0.69	0.47	0.75	0.74	0.64	0.60	0.54	0.44	0.62
	in county/tot	0.69	0.82	0.71	0.49	0.84	0.82	0.74	0.65	0.47	0.49	0.67
Grassland	structures	4481	7272	3974	1214	3855	1338	2563	1568	5094	3615	1113
	% total struc	0.79	0.64	0.58	0.31	0.63	0.48	0.49	0.29	0.38	0.69	0.73
	ha. In 300yc	20441	17235	9137	7021	13386	8025	9447	12026	17246	19929	6024
	ha. In count	45953	34284	16431	14490	30073	17888	15206	26783	30121	40576	16145
	buffer/count	0.44	0.50	0.56	0.48	0.45	0.45	0.62	0.45	0.57	0.49	0.37
	in buffer/tot	0.10	0.06	0.07	0.07	0.05	0.05	0.06	0.05	0.09	0.13	0.06
	in county/tot	0.21	0.12	0.13	0.15	0.11	0.11	0.10	0.12	0.16	0.27	0.16