ILLINOIS NATURAL HISTORY SURVEY

CENTER FOR WILDLIFE ECOLOGY

BIOLOGY, ECOLOGY, AND MANAGEMENT OF DEER IN THE CHICAGO METROPOLITAN AREA

Project Number W-87-R

Final Report

by

James H. Witham and Jon M. Jones
Illinois Natural History Survey

1 February 1992

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ILLINOIS DEPARTMENT OF CONSERVATION
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TABLE OF CONTENTS

INTRODUCTION

The white-tailed deer (Odocoileus virginianus) is the most extensively managed ungulate in North American and has been the subject of continuous research for >50 years (Halls 1984). Management goals to restore whitetail abundance and distribution have been realized on most historic North American deer range. Modern deer population management attempts, in part, to regulate long term deer densities at levels compatible with range conditions or land uses by offsetting annual recruitment with recreational hunting mortality. This system of deer management is most effective in rural settings where human densities are low, average property size is large, and hunting is a tradition. However, large numbers of deer also inhabit many suburban and suburban-rural fringe areas where their close proximity to people inevitably results in various conflicts. Metro environments contrast with rural areas in that human densities are high, property ownership is finely subdivided, and most residents do not participate in hunting (Kellert 1980). An increasing number of natural resource agencies are now faced with deciding how to address deer-human conflicts in metro areas.

Deer at moderate to high densities are not compatible with all land uses in metro environments which have been modified for, and dominated by, people. Unquestionably, urbanites value the presence of deer (Connelly et al. 1987, Decker and Gavin 1987), in part, because deer are large bodied, easily observed, nonthreatening, herbivores that are a "natural antithesis" to typical city life. Such appreciation, however, is conditional and depends on the willingness of people to tolerate, or to effectively mitigate, the adverse consequences (e.g., accidents, floral damage, ecological damage) that inevitably recur when deer and people occupy common land.

The principal goal of deer management in metropolitan areas is to limit damage caused by deer within a range that is acceptable to residents and/or compatible with local land use, yet maintain deer populations high enough to retain the positive values associated with the presence of deer. Finding and achieving this balance is difficult because metropolitan residents possess diverse and conflicting interests, values, perceptions, and knowledge of wildlife (Kellert 1980). Because of inherently strong social interest, metropolitan deer issues are often intense, highly politicized, and covered extensively by media. Under conditions such as these, achieving consensus on how to address deer-human conflicts may be far more difficult than physically implementing any management program that is selected.

Deer in the CMA received limited, informal study prior to 1983. We found no published data on deer in the CMA and only several informal intradepartmental summaries. For example, Cook County naturalists examined several hundred deer killed by vehicles from 1968 to 1977, but published no reports (Schwarz, Cook Co. For. Pres. Dist., pers. commun., 1983); the IDOC and U.S. Fish and Wildlife Service kept minimal records of deer removed from Chicago-O'Hare International Airport during 1982-1983 (Loomis, IDOC, pers. commun., 1984); and, the locations of deer-vehicle accidents on sections of 2 tollways were evaluated by the Illinois State Police (Burns, Ill. St. Police, unpub. rep., 1984). Other deer studies conducted in more rural areas of central and southern Illinois (e.g., Nixon et al. 1991, Roseberry and Woolf 1991) are important contributions for our understanding of deer management and ecology in Illinois, but do not address deer management needs that are specific to metropolitan northeast Illinois. Because data necessary for metro deer management were inadequate, the IDOC contracted the

Illinois Natural History Survey (INHS) to study whitetail ecology and management in the CMA from 1983 to 1989.

Research goals of the INHS Urban Deer Study were to collect baseline data that would be useful for deer management and to perform short-term, experimental, reductions of deer populations on selected sites that would set precedence for long-term deer management in metropolitan areas of Illinois.

Various substudies were initiated as part of the INHS Urban Deer Study since its inception in 1983. This job completion report includes some extended abstracts that are supported by appended manuscripts. Other substudies are summarized entirely within the text. All work reported in the methods and results sections are segregated by their respective contract Job numbers (i.e., Job No. 104-1 to 104-4) which are listed as objectives on page 4.

Acknowledgments

The authors thank the many people and organizations that contributed to various segments of this program. Specifically, we thank personnel of the Illinois Natural History Survey: Dr. Glen Sanderson, James Seets, Kathy Lee, Janet Rachlow, Dr. William Edwards, Dr. Richard Warner, Elizabeth Cook, Elizabeth Anderson, Larry Gross, Monica Lusk, Carla Heister, and Jose Cisneros; the Illinois Department of Conservation: Dr. John Tranquilli, Jeffrey Ver Steeg, and Forrest Loomis; the Cook County Forest Preserve District: Raymond Schwarz, Chris Anchor, and Arthur Janura; the Lake County Forest Preserve District: Dan Brouillard; the Chicago Zoological Society-Brookfield Zoo: Dr. Bruce Watkins; the Illinois Department of Transportation: EMS helicopter pilots and Gene Milliron; and Chicago-O'Hare International Airport Department of Aviation Safety: Russell Gebhardt.

State: Illinois **Project Number:** W-87-R

Project Type: Research

Project Title: Cooperative Forest Wildlife Research

Sub-Project VII-D: Biology, Ecology, and Management of Deer in the Chicago Metropolitan Area

Study No. 104-1: Life History and Ecology of an Urban Deer Herd

Study Objectives: To investigate and quantify pertinent aspects of life history, ecology, health, abundance, dynamics, and distribution of deer in metropolitan areas of northeastern Illinois relative and necessary to their successful management.

Study No. 104-2: Deer Range Evaluation for Metropolitan Northeastern Illinois

Study Objectives: To measure, map, and otherwise quantify and qualify the present and potential deer range of northeastern Illinois including assessments of present impacts of deer on vegetation.

Study No. 104-3: Management Strategies and Implementation of Experimental Control of Urban Deer

Study Objectives: To design, implement, and evaluate possible alternative strategies for management of deer in urban areas with special respect to northeastern Illinois. Pilot management programs to be undertaken as cooperative programs with the Illinois Department of Conservation and local public agencies sustaining significant deer problems.

Study No. 104-4: Data Base Management, Analysis, and Reporting on Urban Deer Research

Study Objectives: To compile, organize, computerize, and manage for ready access, security, and preservation all data resulting from this study relating to deer, deer range, and other aspects of natural resource information generated by this project. Data to be integrated into data base management system. To generate file and manuscript reports, scientific and professional manuscripts for publication, and news releases for local and statewide distribution.

STUDY AREAS

Chicago Metropolitan Area (CMA)

The 5900 km^2 study area included Cook, DuPage, Kane, and Lake counties in northeastern Illinois (Fig. 1). These counties were selected for study because of their metropolitan characteristics and because they are the only counties in Illinois that are closed to firearm hunting for deer. McHenry and Will counties, which are normally considered as part of the CMA, were excluded from the study area because deer were legally hunted with firearms during regulated hunting seasons. All Illinois counties were open to archery hunting for deer during the 3-month autumn season. On county-owned preserves in the CMA where there were large concentrations of deer, county ordinances prohibited hunting of any type. Thus, our study area was selected, in part, because social and political influences limited hunting as a means for regulating deer abundance and abating deer-related property damage.

Climate in northeastern Illinois is predominately temperate continental with warm, humid summers and cold winters. Local weather changes rapidly and is influenced by the proximity of a site to Lake Michigan which ameliorates temperature extremes, modifies wind patterns, and produces lake-effect precipitation. Average daily maximum temperature during July is 28.5 C. Lowest average daily minimum temperatures occur during December (-6.5 C), January (-10.2 C), and February (-7.7 C). Mean annual precipitation and snowfall are 89.7 cm and 101.1 cm, respectively (Natl. Oceanic and Atmospheric Admin., 1987).

Average daily temperature by month, annual precipitation, and annual snowfall from 1983 to 1988 were compared with 30-year normals determined from

1958 to 1987. Winter temperature varied substantially among years, for example: colder than normal temperatures during winter 1983-84 were temporally interrupted by an exceptionally warm February, colder than normal winter temperatures during 1984-85 and 1987-88 were limited to January and February, and temperatures during each month during winters 1982-83 and 1986-87 exceeded normals. For the 30-year period in which normals were calculated, both the highest (1987) and lowest (1985) average annual temperatures occurred during our study. Total annual precipitation alternated above and below normal values during the study. Total precipitation during 1983 was 39% higher than normal and was the wettest year during the previous 30 years. Snowfall exceeded normal during 2 of 6 years with the greatest amount occurring the first winter of the study (1983-84). Snowfall during 3 winters (i.e., 1982-83, 1985-86, 1986-87) was > 25.0 cm below normal.

Total population size for the CMA was 6,855,400 people in 1988. Most people (5,284,300) live in Cook County which includes the City of Chicago (2,977,520 people). Residents in DuPage (760,800), Kane (315,000), and Lake (495,300) counties comprised 23% of the CMA population (1 July 1988 estimate, Northeast Ill. Planning Comm. 1989). Human densities by county ranged from 232 people/km^2 (Kane) to 2,132 people/km^2 (Cook).

Land cover in the CMA was estimated by E.A. Cook (Illinois Natural History Survey, Champaign) based on Landsat Thematic Mapper data collected 27 June 1988. Counties in the CMA were a gradient of urbanization. Percent cover in urban or residential-use by county ranged from 29% (Kane) to 76% (Cook) and collectively was 57% for the CMA. Percent cropland by county was a reverse gradient of urbanization ranging from Cook County (5%) to more rural Kane County (51%). Trees were present on 25% of the CMA as undeveloped forests, savannas, or residential areas with canopy closure >30%. Percent forest cover was highest in urbanized Cook (30%) and DuPage (31%) counties. Undeveloped forest cover, important as thermal and concealment cover for midwest whitetails during winter (Gladfelter 1984), was comparable in Lake (8%) and Cook (8%), but lower in DuPage (5%) and Kane (4%) counties. More rural counties sustained highest net reductions (8 to 9% from 1985-1988) in deer habitat which resulted primarily from conversion of agriculture to urban uses.

The physiography of northeastern Illinois is well documented (Leighton et al. 1948, Willman 1971, Mapes 1979, and others). The CMA is part of the Great Lake and Till Plains sections of the Central Lowland physiographic province. Illinoian and Wisconsinan glaciation during the Pleistocene created the gently rolling to near level topography of northern Illinois. Soils are derived primarily from deposits of glacial till, outwash sands, and lake-bed sediments, and were described to the association level by Fehrenbacher et al. 1984. Based on physiographic and biotic community similarities, Schwegman (1973) included the study area in the Northeastern Morainal Division of Ilinois, except for southwest Kane County, which is in the Grand Prairie Division.

Swink and Wilhelm (1979) described species, associations, and distribution of native vascular plants in the Chicago region. Schmid (1975) discussed the complex processes (e.g., socioeconomic, climatic) that interacted to produce present-day urban vegetation in Chicago. Spatial and temporal trends in forest resources by counties in Illinois were analyzed by Iverson et al. 1989. Illinois flora were described by Jones (1963) and Mohlenbrock (1975) and are listed on a permanent computer data base (i.e., Illinois Plant Information Network; Iverson and Ketzner 1988).

From the early 1800's to present, people have progressively altered Illinois landscape, initially with conversion of prairie to agriculture, logging, and grazing, and more recently with sustained urbanization. Potential major natural vegetative communities in northeastern Illinois were bluestem (Andropogon spp.) prairie, oak (Quercus spp.)/hickory (Carya spp.), maple (Acer spp.)/basswood (Tilia americana) and oak savannah (Kuchler 1964); however, the intensive land use that typifies this area has left only remnants of these communities. Less than 0.0007 of natural communities that existed in presettlement Illinois remain in a condition of high natural quality (White 1978). The response of people and governments to these state-wide perturbations has been to purchase properties for open space on the periphery of urban centers and to protect remnant natural areas that are representative of presettlement natural communities. Open space properties that are owned by county governments are named "forest preserves" (Wendling et al. 1981). The Cook County Forest Preserve District was officially established in 1914 and charged to:

> "...acquire...and hold lands...containing one or more natural forests or lands connecting such forests or parts thereof, for the purpose of protecting and preserving the flora, fauna, and scenic beauties within such district, and to restore, restock, protect, and preserve the natural forests and said lands together with their flora and fauna, as nearly as may be, in their natural state and condition, for the purpose of the education, pleasure, and recreation of the public" (Forest Preserve District of Cook County, 1918).

Following Cook County, forest preserve districts were established in DuPage, Lake, and Kane counties. By 1988, approximately 7% of the CMA was owned and managed by county forest preserve districts.

Some natural areas are protected as part of the Illinois Nature

Preserves System and are managed for long term ecosystem preservation (Ill. Admin. Code, Title 17, Chapt. V, Part 4000, Management of Nature Preserves). "Nature preserves" are owned by a variety of public and private interests who have legally dedicated, in perpetuity, the protection of their properties against disturbances (Witter 1987). Thus, a county-owned "forest preserve" can also be dedicated as a State Nature Preserve. Two of the INHS study areas, the Ned Brown Preserve and Ryerson Conservation Area, were county forest preserves with parts of their holdings dedicated as State Nature Preserves (i.e., Busse Forest Nature Preserve and Ryerson Nature Preserve, respectively). Busse Forest is further recognized by the U.S. National Park Service as a Registered Federal Natural Landmark which identifies the site as an area of national ecological significance.

Ned Brown Preserve and Busse Forest Nature Preserve

The 1,536 ha Ned Brown Preserve, owned and managed by the Cook County Forest Preserve District, is located in northwest Cook County near Elk Grove Village. Land use adjacent to the Ned Brown Preserve includes several large indoor shopping malls, 2 tollways, 2 state highways, residential developments, and corporate buildings. More than 20 high rise buildings are <1 km from the preserve. Airspace is within the Chicago-O'Hare International Airport Terminal Control Area with jet traffic frequently passing over the preserve on final approach at 800 m AGL. The Ned Brown Preserve was developed for recreational use with paved bike trails, picnic groves, a model airplane flying field, and a 241-ha reservoir with recreation facilities. More than 1.5 million visitors used the preserve during 1985 (Dwyer et al. 1985). The Ned Brown Preserve is 66% woodland dominated by oak (Quercus spp.), sugar maple (Acer saccharum), and basswood (Tilia americana), 10% in old field successional stages, wetlands, and mowed grass; 15% in open water, and 9% in roads and other developments. Quantitative evaluations of vegetation at Ned Brown were a major part of this study are reported elsewhere (pages 20 & 54).

Within the Ned Brown Preserve is the 177-ha Busse Forest Nature Preserve. The site is a dedicated Illinois Nature Preserve and Registered Federal Natural Landmark. The latter is recognition from the U.S. National Park Service as an ecological site of national significance. The preserve is comprised of 5 natural communities: a high quality dry mesic upland forest, mesic upland forest, mesic hardwood, northern flatwoods, and shrub swamp/marsh.

Chicago-O'Hare International Airport

The 3,116 (7,700 ac) Chicago-O'Hare International Airport (O'Hare) is owned and operated by the City of Chicago Department of Aviation. It is a major commercial aviation facility that serves over 50 airlines and averages 110 arrivals/departures each hour. The airport facility is dominated by a complex system of highways, parking lots, terminals, support buildings, and runways (typescript O'Hare Factsheet 7/90). About 650 ha of undeveloped property lies near runways and on the airport periphery. This undeveloped property is comprised of early second growth (i.e., shrubs and saplings) woodlots, a mixture of early successional fields, swamp/marsh, 3 tree nurseries maintained for the Chicago Park District, and mowed grassland near runways.

Aerial photographs of O'Hare and adjacent properties were reviewed for 1949, 1963, 1975, and 1985. The sequence of photographs showed successional changes in vegetation that increased quality and quantity of deer habitat on undeveloped airport property. The agricultural-influenced landscape of 1949 had by 1985 evolved into a more structurally diverse mixture of plant communities which has favored establishment and increase of deer. Conversely, during the same period, most private property immediately north, west, and south of O'Hare was developed for residential, commercial, and industrial uses. East of the airport, separated by a 1.3 to 2.0 km strip of commercial development, are county forest preserves which sustain deer herds at >15 deer/km^2 (Witham and Jones, this study).

Ryerson Conservation Area and Ryerson Nature Preserve

Ryerson Conservation Area (Ryerson) is a 223-ha preserve within the Lake County Forest Preserve District (LCFPD) which included 27 preserves totaling 5,368 ha (range 7-562 ha) in 1990. Ryerson is located 50 km north of Chicago in southeastern Lake County near the village of Deerfield.

Historic land use at Ryerson was reviewed by Nuzzo (1988). Permanent settlement occurred in 1834 with an active sawmill operating from 1835-1870 near the southern property boundary. Timber lots (2-8 ha each) were purchased by nearby farmers in the 1850's and used for cattle grazing and timber production. In the 1890's, an amusement park was built on the southern part of the preserve, but was discontinued before 1915. The timber lots were sold in the 1920's to Chicago residents who used these sites as vacation retreats. Edward L. Ryerson purchased land in this area from 1927 to 1939. From 1966 to 1972, acting to protect the continuity and natural qualities of their properties, Ryerson and other landholders donated their estates to the Lake County Forest Preserve District. These donated properties comprise the

Ryerson Conservation Area; 2 high quality natural areas (61 and 52 contiguous ha) within the RCA were dedicated as the Edward L. Ryerson Nature Preserve (RNP) on 27 April 1972 and 21 May 1979, respectively.

Nuzzo (1988) described the climate, physiography, geology, soils, hydrology, biota, and significant natural features of RCA. The RNP is comprised of 9 natural communities: dry-mesic upland forest (white oak-swamp white oak-sugar maple), mesic upland forest (sugar maple-basswood-red oak), mesic floodplain forest (sugar maple-basswood-red oak), wet-mesic floodplain forest (silver maple-bur oak-swamp white oak), wet floodplain forest (silver maple-cottonwood-boxelder), northern flatwoods (swamp white oak), sedge meadow (sedges-bullrushes), fen, and low-gradient river.

METHODS

Study No. 104-1: Life History and Ecology of an Urban Deer Herd

Population parameters

Deer abundance

Deer counts: Cook, DuPage, and Lake counties.-- Deer were counted in Cook, DuPage, and/or Lake counties from a Cessna 172 fixed-wing aircraft during 1984-1985 and from a Bell Long-Ranger helicopter during 1985-1988. The helicopter was favored because of greater maneuverability and improved safety while flying at low altitudes (90-150 m AGL) and reduced speeds (50-60 knots) over developed areas and near major airports. Areas with vegetative cover that was relatively homogeneous were surveyed systematically by flying parallel transects determined by aircraft instrumentation and visual ground references. Transect widths were not measured, but we estimate that they varied from 100 m in mature forests to 300 m for agricultural fields without standing crops. We divided smaller preserves, and areas with heterogeneous vegetative cover types, into subunits with boundaries that were defined by natural features (e.g., changes in vegetation, rivers, lakes) and roads that were visible from the air; we searched these subunits systematically and then totaled all nonduplicate deer counted within each preserve. Individual preserves were surveyed $\leq$ 1 time annually and from 1 to 5 times during the study. Surveys were conducted during winter when snow depth exceeded 10 cm. Two observers in verbal contact counted deer from 1 side of the aircraft.

Our aerial counts reflect the maximum number of independent observations of deer that we made on each site at the time of the census only. We deleted observations where duplicate sightings may have occurred. These included deer that were disturbed by the aircraft and traveled into areas yet to be surveyed. Most deer observed during surveys remained stationary or moved <50 m toward cover or other deer. Because many factors preclude counting all deer on a site, we refer to data based on our counts as "minimum" numbers or "minimum" densities.

We divided the number of deer counted by forest preserve area to determine deer densities. Areal measurements of sizes of individual preserves DuPage and Lake counties were provided by their forest preserve districts. Sizes of preserves in Cook County were determined with a dot grid overlaid on forest preserve maps. Contiguous preserves were divided into subunits defined by administrative boundaries, bisecting roads, or other features that were readily visible from the air.

For the purpose of publication, we redefined preserves by contiguity of property irrespective of administrative divisions (e.g., preserves on the Des Plaines River in Cook and Lake counties were considered as 1 large preserve) and then estimated minimum deer densities for these areas. The objective was to determine the minimum number of deer on selected metropolitan forest preserves during winter. The abstract is listed in Results (page 41) and the publication (Witham and Jones 1990) is Appendix A.

Deer count: Kane County.--Deer in Kane County were counted by 2 observers in a fixed-wing aircraft during January 1987. Unlike censuses in Cook, DuPage, and Lake counties where deer were counted only on forest preserve properties, the 2-day count in Kane County included all county land west of the Fox River. Complete coverage was possible for this area because the landscape is dominated by open agricultural fields and had relatively less woodland than other counties within the study area. The objective of this survey was to estimate winter distribution of deer, only.

Reproductive performance and fetal sex ratio

We compared fecundity among fawn, yearling, and adult does that were collected from Ned Brown, Des Plaines, Palos, Northwest Cook, and Non-Cook areas, during 1983-1985. Fetuses were counted and sexed during postmortem examinations during January-May. Does were separated into fawn, yearling, and adult age classes, based on wear and replacement of dentition. We examined the reproductive tracts of does collected at the Ned Brown Preserve annually until 1989.

Survival rates

Deer were live captured and released at the Ned Brown Preserve during 2 winters. All deer received an aluminum tag in each ear. Does were fitted with black plastic neck collars that were marked with numbers or letters made from colored reflector material. Bucks were uniquely marked in both ears with color-coded, plastic cattle-tags and streamers. Thus, each deer could be individually recognized at a distance during subsequent field work which included spotlight counts, live capture, and sharpshooting. Some deer were never observed after release; however, most (94/103, 91%) deer were reobserved or their fates were determined through tag returns. The small size of Ned Brown Preserve (1,536 ha), extensive use by recreationists, intensive fieldwork by INHS, and cooperation from local police departments and county personnel who reported deer mortalities to INHS, increased our ability to determine the status of marked deer.

Although the 103 deer that were live captured in this study segment were not radio collared, the high percentage of marked deer that we reobserved at Ned Brown enabled us to use Program MICROMORT (Heisey 1985) to estimate survival rates. Survival rates of fawns, yearlings, and adults, were calculated by 6-month intervals. Only marked deer that were known to be alive at the beginning of a time period were used in the analyses. Because some deer may have died and were not reported to INHS, our estimates represent maximum survival rates.

Age composition and longevity of deer removed from the Ned Brown Preserve

Deer that were removed by sharpshooters from the Ned Brown Preserve from 1984 to 1988, were aged by dental wear and replacement (i.e., fawns and yearlings; Severinghaus 1949) or cementum annuli counts (i.e., adults; Matson's, Milltown, Mont.). Only adult deer that received "A" or "B" confidence ratings (i.e., Matson's subjective assessment based on clarity of cementum annuli) were included. By backdating, we reconstructed the composite age structure of these deer on 1 June 1984.

Deer health

Health/condition evaluations

Relative condition of deer on forest preserves.--We contrasted selected skeletal and body measurements, "fat indices" and reproductive performance of deer at 5 contiguous areas in the CMA (Fig 2). Our objective was to assess whether the health of deer differed among preserves that were in close proximity; detection of area differences would suggest that deer management in the CMA be scaled for individual preserves. Areas were selected because of their diverse characteristics relative to development. Four areas were forest preserves in Cook County and their associated buffer areas. The fifth area (Non-Cook) included DuPage, Kane and Lake counties, collectively. Two of the areas in Cook County, the Ned Brown Preserve (Ned Brown) and the Des Plaines River preserves (Des Plaines) had extensive residential and commercial development on their peripheries (see page 61). A third site, the Palos-Sag Valley Preserves (Palos), was partially developed with some adjacent cropland. The remaining area, including northwest Cook County preserves (Northwest), was a suburban-rural interface dominated by cropland and estates. The relative status of areas from most developed to least developed was:

Ned Brown = Des Plaines > Palos > Non-Cook $\geq$ Northwest

From December 1983 to October 1985, 88 agencies, organizations, and individuals reported the locations of deer carcasses to INHS. INHS personnel responded promptly to these reports and removed carcasses, or parts of carcasses, regardless of condition. The majority of deer collected were killed or injured by vehicles. In cases where the cause of death was inconclusive, internal trauma revealed during postmortem examinations suggested that many of these deer were also injured by vehicles. Additional data were collected from deer that were shot or live-trapped and euthanized by INHS personnel.

Numerous indices have been used by workers to assess relative skeletal growth, fat deposition and utilization, and productivity (Watkins et al. 1991). Our selection of 9 indices was influenced by the typical condition of deer carcasses available (i.e., carcasses with varying trauma). We censored affected measurements when normal carcass conformation was distorted (e.g., bloat, subcutaneous hemorrhaging, skeletal fractures) or incomplete. Whole body weight (whole weight) was determined on a "machete counterweight scale" in 0.45 kg (1.0 lb) increments. Chest girth (girth), right hind foot (hindfoot), and total body length (total length) were measured in mm with a flexible steel tape using methods of Feldhamer et al. (1985). The right femur (femur) was incised from the muscle, placed on a flat measurement board, and measured from the proximal condyle head to the most distal part of the femur. A left hind foot or left femur measurement was substituted when the right counterpart was unusable. A skeletal ratio was developed from femur/hindfoot after Klein (1964). We removed the left kidney and adherent fat to determine a kidney fat index (KFI) using methods of Riney (1955). Body fat deposition at 6 locations and musculature were scored using a visual evaluation technique reported by Kistner et al. (1980). Each deer was aged by tooth wear and replacement (Severinghaus 1949) and categorized as a fawn (< 1 year), yearling, or adult (≥ 2 years).

To isolate the effects of location, we compared physical measurements and condition evaluations among deer of similar sex, age class, and season using a 1-way ANOVA. We assumed that observations were independent, that errors were normally distributed, and that error variances were equal. These assumptions are plausible because there were no repeated measurements on individual deer, diagnostics on the subsample of residuals from the 1-way ANOVA tests indicated that the assumption of normality was reasonable, and data were categorized by factors that were the main contributors (i.e., sex, age, season, location) to variations. Data were pooled from both years of collection and Tukey's test was used to identify differences ($P \leq 0.05$).

Body composition/condition evaluation of fawns.-- This is 1 of 3 publications resulting from cooperative studies with the Chicago Zoological Society. The principal cooperator was Dr. Bruce Watkins, Animal Nutritionist, Brookfield Zoo, Brookfield, IL. The objective was to determine how various health indices (i.e., condition) were related to body size, body composition, and metabolic status of white-tailed deer fawns collected in the CMA. The abstract is listed in Results (page 49) and the publication (Watkins et al. 1991) is Appendix B.

Body composition change of fawns during winter.-- This is the second of 3 publications resulting from cooperative studies with the Chicago Zoological Society. The principal cooperator was Dr. Bruce Watkins, Animal Nutritionist, Brookfield Zoo, Brookfield, IL. The objectives were to: 1) to investigate changes in body composition and chemical component distribution as fawns underwent net catabolism during winter, and 2) to calculate the composition and energy content of lost weight based on changes in body composition with decreasing weight. The abstract is listed in Results (page 50) and the publication (Watkins et al. 1992) is Appendix C.

Estimating fawn body composition with deuterium oxide.-- This is the last of 3 publications resulting from cooperative studies with the Chicago Zoological Society. The principal cooperator was Dr. Bruce Watkins, Animal Nutritionist, Brookfield Zoo, Brookfield, IL. The objective was to evaluate the efficacy of D_2O dilution for predicting body composition of white-tailed deer fawns under field conditions. The abstract is listed in Results (page 50) and the publication (Watkins et al. 1990) is Appendix D.

Parasites of urban deer

Helminthic and protozoan parasites of urban deer.--Fecal samples were routinely collected during postmortem evaluations of deer from December 1983 to October 1985. We contracted J.G. Cisneros, a microbiologist whose M.S. thesis involved examination of deer parasites using fecal flotation methods (Samuel and Trainer 1969) to examine 270 fecal samples, from deer > 1 year, for helminthic and protozoan parasites. The abstract is listed in Results (page 51) and the unpublished report (Cisneros, J.G. 1987. Helminthic and protozoan parasites of white-tailed deer in urban areas of northeastern Illinois. Unpub. Rep. Sub. to Ill. Natural History Survey-Wildl. Sec., Champaign. 15pp) is Appendix E.

Histopathology.--Lung, liver, and kidney tissue samples were collected during postmortem evaluations conducted in 1984 and 1985, and submitted for histopathologic analyses to Dr. John Sundberg, Veterinary Diagnostic Laboratory, Univ. of Illinois, Champaign. Tissues were fixed in neutral buffered 10% formalin, embedded in paraffin, sectioned at 6 um, stained with hemotoxylin and eosin, and examined for evidence of microscopic pathology.

California encephalitis: Jamestown Canyon virus.--We provided blood sera from deer live captured in Cook County to Dr. Paul R. Grimstad, Dep. Biology, Univ. Notre Dame, Indiana. Dr. Grimstad evaluated the incidence of infection of California encephalitis (Jamestown Canyon virus) among 3 deer age classes (i.e., fawn, yearling & adult).

Lyme disease.-- We did not evaluate Lyme disease in this study. Callister et al. (1991) surveyed forested areas near Milwaukee, Wisconsin, and Chicago, for rodents and ticks infected with *Borrelia burgdorferi*, the causative agent of Lyme disease. Two voles captured in 1988 near Chicago tested positive for *B. burgdorferi*, however, no *Ixodes* spp. ticks were captured. The authors hypothesized that *B. burgdorferi* is rare in northeastern Illinois because of the absence of specific tick vectors.

Study No. 104-2: Deer Range Evaluation

Effects of deer on forest vegetation

Historical perspective and objectives

We selected Busse Woods Nature Preserve and the Ned Brown Preserve as a local study site to evaluate the effects of deer on forest vegetation (Fig. 3). Concerns about the effects that white-tailed deer were having upon the understory vegetation structure, abundance, and diversity at Busse Woods Nature Preserve, Cook County Forest Preserve District became prevalent in 1983. Personal observations by laypersons, as well as biologists and botanists, noted a marked decline in flowering spring ephemerals, the formation of obvious browse lines, and an abundance of deer.

Baseline data on vegetation within Busse Forest prior to understory degradation by deer are extremely limited and consist of personal observations, qualitative assessments conducted by volunteer land stewards for the Nature Conservancy, and quantitative assessments of cover types, canopy trees, shrubs/saplings, grade or quality of the nature preserve as a natural area, and qualitative evaluation of the presence of species listed as endangered or threatened as determined during the Illinois Natural Areas Inventory (NAI) (White 1978). Observations by volunteer land stewards focused on the occurrence of herbaceous understory species in 1977-79 and 1985 (L. Baker, volunteer land steward, pers. commun.); however, consistency among survey techniques and plant identification capabilities of the volunteer stewards were not documented. No quantitative information exists on the herbaceous understory plant abundance and composition in the nature preserve prior to noticeable browse lines, the decline of understory plants, and increased openness within the woodlot. The duration and intensity of deer browsing pressure prior to 1983 is unknown, although qualitative assessments indicate that browselines were not present in the late 1970's (i.e., 1976-1978). Additionally, historical land use of the woodlot prior to purchase by the Cook County Forest Preserve District and dedication as a State nature preserve and a Registered Federal Natural Landmark is poorly documented.

Quantitative pre-degradation information on the understory shrubs and saplings in the nature preserve were collected during the 1976 Natural Areas Inventory. Additional sapling inventory work was conducted in Busse Woods North, a woodlot essentially contiguous with Busse Nature Preserve, as part of a doctoral research project during 1974-77 (Guth 1980). Comparisons between the latter studies and the INHS study are inherently limited by differences in objectives, sampling techniques, and cover types/areas sampled.

The primary objectives of this portion of the INHS Urban Deer Study were to quantitatively characterize the current state of the understory vegetation in the native woodlots within the Ned Brown Preserve and to evaluate regeneration in the absence of deer and during the reduction of deer numbers. More specifically, objectives included the evaluation of: 1) the regeneration (i.e., increases in percent cover, density, and number of species) of all understory plants < 1m in the absence of deer browsing by comparing a deer-proof exclosure to an adjacent control plot in a similarly browsed woodlot (i.e., Busse Woods North) adjacent to the nature preserve, 2) the percent cover, density, and species composition of all understory plants < 1m in Busse Nature Preserve, 3) the density, species composition, and potential impacts of deer upon the shrubs and saplings > 1m and < 2.5 cm diameter at breast height (DBH), 4) the species composition and stem densities of saplings in the 2.5 - 10.2 cm DBH size class, 5) changes in the understory vegetation (i.e., 2-4, above) as deer numbers on the nature preserve were reduced, and 6) all parameters, listed in 2-5, in all 4 mature second growth woodlots in the Ned Brown Preserve. In order to quantify the potential reduction in plant species diversity, vigor, and density caused by high deer numbers in the nature preserve and in the absence of comparable site-specific vegetation data prior to understory degradation in the nature preserve, concurrent plant measurements in nearby and less intensely browsed woodlots were necessary for comparative purposes; emphasis was placed on the nearest, most similar woodlot with low to moderate deer density (i.e., Busse Woods South). Soil types, canopy tree composition, and percent canopy closure were evaluated due to the possibility that any one, or all, of these variables could cause the observed differences in the understory vegetation of the nature preserve and Busse Woods South (Busse South).

Plant measurements

Busse exclosure and control plot.-- A 22m X 52m exclosure was constructed in Busse Woods North during the fall of 1983 to evaluate the type and expediency of understory plant regeneration in a heavily browsed woodlot. Although the exclosure was not constructed in the nature preserve, Busse Woods North is essentially continuous with the latter and had sustained similar browsing pressure; therefore, we used the exclosure analyses to predict regeneration potential within the nature preserve.

The exclosure was constructed of standard livestock/field fencing to a height of 2.4 m. Twelve 20-m permanent sampling transects were established across the width of the exclosure and 4 m apart along the length of the exclosure. This allowed a 1-m buffer zone from the exclosure fence to the area being sampled to minimize potential microenvironmental influences upon plants due to the differential heating, heat retention, and leaf litter accumulation associated with the fencing. Sampling was conducted annually from 1984 to 1989 and was limited to all understory plants $\leq$ 1m. Measurements included percent cover via the line intercept method (Canfield 1941, Mueller-Dumbois and Ellenburg 1974), stem densities via 4-1m^2 quadrats randomly located along each permanent transect, and number of species encountered along the line intercepts and in the quadrats. An unfenced control plot of similar size was established $\leq$9m from the exclosure and sampled identically for comparative purposes. Sampling was conducted in both plots during August 1984 and thereafter during April and May (1985-1989) when spring ephemerals were fully developed and woody understory plants had leafed out.

Statistical comparison of mean stem densities and percent cover between the exclosure and control plot were limited to nonparametric procedures due to the non-normal distribution of the original data and subsequent data transformations. The 1989 vegetation data were not available during statistical analyses. Rank test selected for the comparisons were Friedman's and Bonferroni's (Proc MRANK; Statistical Analysis System; Sarle 1983) and Kruskal-Wallis one-way analysis of variance (NPAR TESTS; SPSS/PC+; Norusis 1988).

Busse Nature Preserve: plants < 1m.-- Five permanent compass lines were established on an east-west bearing across the entire nature preserve at a constant random (north-south) distance from one another, thereby insuring representative sampling of the nature preserve. Although these compass lines traversed several community/cover types and boundaries, this stratified random sampling scheme allowed us to characterize the entire woodlot understory. To evaluate percent cover, 5 - 20m permanent line intercepts were established along each compass line (n=25); initial location along the compass line and orientation were randomly determined. Along each 20m intercept line, two-1m^2 quadrats were randomly placed during each sampling session (n=50) to determine stem densities. Mean percent cover was determined for each understory species ≤ 1m by measuring any portion of a plant that overlapped the 20m intercept line; total intercepts (mm) were summed by species, divided by the sum of all line lengths, and expressed as a percentage. Average stem densities were evaluated by counting all stems within the 1-m^2 quadrats, summing by species, and dividing by the total number of quadrats. The sparse nature of the understory vegetation in this highly browsed woodlot and the clumped distribution of some plants were probably major contributing factors that resulted in data that were not normally distributed. Therefore, statistical comparison of vegetation parameters over time were via the nonparametric

Kruskal-Wallis one-way analysis of variance (NPAR TESTS; SPSS/PC+, Inc.; Norusis 1988).

In the absence of baseline data on understory species composition, cover, and stem densities for Busse Nature Preserve, a woodlot within 0.5 km of BNP (i.e., Busse Woods South) was sampled similarly for comparative purposes. Although Busse Woods South (BWS) was considerably smaller than BNP (34 ha versus 130 ha, respectively), its proximity to BNP and minimal evidence of browsing made it a convenient "control plot". Sampling intensity was less in Busse South due to the smaller size of this woodlot; the number of line intercepts and quadrats used during sampling in 1986 and 1987 were 15 and 30, respectively.

Busse Nature Preserve: shrubs and saplings > 1m.-- Fifty square quadrats (5m X 5m) were randomly placed in the nature preserve to determine stem densities of shrubs and saplings > 1m in 2 size classes; < 2.5cm and 2.5 - 10.2 cm DBH during 1985. The same number of quadrats was used in 1986 and 1987 but were located at permanently marked points on the permanent compass lines established in BNP for other understory measurements (discussed above). During all years, the number, species, and diameter at breast height of each stem located within the $25m^2$ quadrats was recorded. Estimated number of stems per hectare were calculated via extrapolation from the number of stems recorded per unit area sampled. Statistical comparisons between years were made using the Kruskal-Wallis one-way analyses of variance (NPAR TESTS; SPSS/PC+, Inc.; Norusis 1988).

Other measurements for comparative purposes.-- Soil types were mapped and quantified for 4 mature second growth woodlots in the Ned Brown Preserve; these analyses were based on the National Cooperative Soil Survey of Cook

County (Mapes 1976). Additionally, percent canopy closure $\geq$ 1.5m above the ground was determined by the point intercept-canopy camera technique (Hays et al. 1981). Sample points were established as center points of 5 X 5 m sample plots used to quantify density of shrubs and samplings (described above). Dominance, density, and frequency of canopy trees > 10.2 cm DBH were quantified in 1985 via the point-centered quarter plotless technique (Cottam and Curtis 1956, Mueller-Dombois and Ellenburg, 1974). Comparisons between woodlots are limited to the nature preserve and Busse South and are empirical; the latter analyses were conducted to identify similarities between woodlots and to evaluate potential influences any dissimilarities may have on differences between woodlot understories.

Deer habitat evaluations

Landsat satellite imagery evaluation

Landsat Thematic Mapper satellite imagery data (1985 and 1988) and geographic information system technologies were used to inventory land cover in Cook, DuPage, Kane, and Lake counties under a separate contract (E.A. Cook, Illinois Natural History Survey, Champaign). Land cover classes defined in this study were: forest with >70% canopy closure, forest with 30-69% canopy closure, savanna with canopy closure <30%, forest residential, nonmaintained grass, cropland, alfalfa/sod, maintained grass, residential without trees, urban disturbed, urban features, urban water, and water. We then reevaluated these cover types based on their hypothetical and relative value as deer habitat (i.e., primary, secondary, tertiary, nonhabitat and water) in the CMA. Our objectives were to estimate percent and total deer habitat in the CMA during 1988 and to evaluate net changes in deer habitat from 1985 to 1988. A manuscript was drafted that describes this evaluation; the abstract is listed in Results (page 61) and the entire manuscript (Witham et al., no date, unpub. man.) is Appendix F.

Changes in land use: Insularity of the Ned Brown Preserve

We evaluated changes in land use near the Ned Brown Preserve, Cook County, to assess the influence of suburban development on preserve insularity. The study site (225km^2) extended distally 5 km in each direction from the boundaries of the Ned Brown Preserve. Black and white aerial photographs of the study area were purchased (Chicago Aerial Survey, Des Plaines) for years 1949, 1964, 1970, and 1985. Individual prints were superimposed into composite pictures for each respective year. A lighted image enlarger was used to classify features within 1-ha cell units based on Universal Transverse Mercator (UTM) coordinates. Each cell was classified for development, vegetation, water, and roads. Development classifications included: 1) no development, 2) low density housing of 1-2 units, 3) medium density housing of 3-4 units, 4) high density housing of >4 units, 5) building/pavement, 6) construction, and 7) unknown. Road types were: 1) no roads, 2) secondary roads, 3) main roads 2 or 4 lane roads >5 km in length, 4) major highways >5 lanes, 5) secondary/main road combination, 6) secondary/major combination, and 7) main/major combination. Vegetation was categorized as: 1) no vegetation, 2) agriculture field, 3) grass, 4) mixed vegetation, 5) closed canopy forest, and 6) unknown. Water resources were divided by: 1) no water, 2) stream, 3) shoreline, 4) open water, 5) marsh shoreline, and 6) marsh. Geographic Information System (pMAP, Spatial Information Systems, Inc., Omaha) software was used for data analyses. The pMAP program was used because it was compatible with our field office personal computer, but was limited by cell dimension restrictions.

Deer-vehicle accidents

Accident costs

The average cost of deer-vehicle accidents cannot be determined directly by reviewing police accident forms. Gross estimates of damage (i.e., > or < $250.00) listed on accident forms are of no quantitative value. We found no public agency or insurance company that separated deer-vehicle accident records for cost evaluation. To obtain these data, we selected and contacted a sample of individuals who had hit deer with their vehicles and requested their cooperation in answering questions on repairs and personal injury. Cook County Sheriff's Police (CCSP) accident reports were selected for this evaluation because: 1) they were presorted by the Cook County Highway Department and were readily available, 2) the annual number of accidents investigated by CCSP was much higher than other police departments, and 3) accidents locations were broadly distributed because CCSP has county-wide jurisdiction.

Six accident costs reported by Hansen (1983) were used in our questionnaire: 1) repair, 2) towing, 3) substitute vehicle, 4) medical for injuries incurred, 5) lost wages, and 6) other costs. From 1984 to 1988, questionnaires were mailed annually to individuals involved in deer-vehicle accidents that were investigated by CCSP. A followup questionnaire was sent to non-respondents; some non-respondents were contacted by telephone.

Questionnaires from 1984 were used to test (t-test, alpha=0.05) the hypothesis that the average cost of accidents investigated by CCSP were not different from those of other municipal police departments in Cook County. A failure to reject this hypothesis suggests that CCSP records are probably representative of other police departments county-wide. Municipal police department records used in this evaluation were from: Barrington, Barrington Hills, Bartlett, Des Plaines, Elk Grove, Glenview, Hoffman Estates, Mt. Prospect, Northbrook, Northfield, Rolling Meadows, South Barrington, and Wheeling.

Distribution of accidents and regional trends

We determined the distribution of deer-vehicle accidents by county on state-numbered highways using IDOT records for 1975, 1981 and 1987. The IDOT provided computer printouts that listed individual deer-vehicle accidents with accompanying codes for milepost locations on highways within the 4-county study area. Unfortunately, IDOT highway milepost codes were not easily deciphered and were independent of actual milepost markers that are visible on road systems. This complexity resulted from the construction of many new roads after the original numbering scheme was developed. INHS staff consulted extensively with IDOT personnel to interpret inconsistencies in the coding system. Accident locations were plotted using pMAP software and the Universal Transverse Mercator grid as a coordinate base. We selected $1km^2$ as the unit cell size because of pMAP spatial limitations (i.e., maximum 100 X 100 cells). universal transverse mercator (UTM) system was used as a coordinate grid base.

We compared trends in the frequency of deer-vehicle accidents by county with regression models. Again, IDOT accident records were used as a data source; IDOT records reflect the minimum number of deer-vehicle accidents reported for state-numbered highways, only.

Study No. 104.3: Management Strategies and Experimental Control

Experimental deer herd reductions

Deer reduction at Ned Brown Preserve

Herd reduction at Ned Brown was a precedent setting opportunity that expanded opportunities for deer management in the CMA by demonstrating that local deer abundance could be effectively and safely reduced using lethal removal techniques. Work at Ned Brown contributed to concepts now used as guidelines for deer management on dedicated state nature preserves and protocol for donating venison to charities for human consumption.

Background information.-- The deer herd at Ned Brown Preserve was selected for more intensive study during the first year of the research program. Characteristics that made Ned Brown desirable included: 1) good initial cooperation from the landowner (i.e., Cook County Forest Preserve District), 2) presence of a high density deer herd, 3) intensive site use by publics, 4) a relatively high degree of site insularity because of extensive peripheral development which limited deer emigration, 5) presence of a dedicated state nature preserve (i.e., Busse Forest) with recognized ecological values within Ned Brown (i.e., Busse Forest), and 6) visible degradation of understory vegetation, and 7) proximity to the INHS field office in northwest Cook County.

Although Ned Brown was considered a potential site for experimental deer herd reduction (Job 104.3) from the outset, the transition to this project segment was solidified in FY85 by circumstances unforeseen at the beginning of the study. Mr. George Fell (Natural Land Institute, Rockford, Ill.) expressed concern (9 Jul 85 letter to Illinois Nature Preserves Commission) regarding the extreme degradation of flora caused by deer browsing in Busse Forest

Nature Preserve. Additionally, the potential loss of sensitive plants were noted by the Busse Forest land steward (Baker, unpub. notes). This concern was reinforced at the 25 July 1985 Nature Preserves Commission meeting by Fell and INHS personnel. A special Nature Preserves Commission meeting on 25 August 1985 was held at the Ned Brown Preserve which included presentations by INHS on the urban deer research program and deer-plant interactions and discussion by DOC Wildlife Division personnel regarding a substantial decline in Pittman-Robertson funding for FY86 which jeopardized the INHS study. Cook County Forest Preserve District personnel led a 20-minute walking tour of Busse Forest to view the degraded understory. Discussions at this meeting led to a cooperative agreement among agencies which included a commitment from the DOC to extend the INHS research program for 3 years, funding from the Cook County Forest Preserve District ($22,000.00) and Illinois Nature Preserves Commission ($8,000.00) to offset the decline in Pittman-Robertson funds for the project, and a commitment from INHS to initiate experimental deer herd reduction at Ned Brown during winter 1985-86.

A deer reduction plan for Ned Brown Preserve was drafted by INHS and presented at the 26 September 1985 meeting of the INHS Community Liaison Committee. All attending members (INHS, Max McGraw Wildlife Foundation, Illinois Audubon Society, DOC, U.S. Fish and Wildlife Service, Sierra Club, Morton Arboretum, and Cook County Forest Preserve District) supported the plan. Minutes of the meeting were sent to non-attending members (American Humane Association, Brookfield Zoo, DuPage County Forest Preserve District, Fund for Animals, Great Lakes Outdoor Writers, Illinois Nature Preserves Commission, Illinois Wildlife Federation, Kane County Forest Preserve District, and Lake County Forest Preserve District), of the Committee.

Deer management plan and evaluations.-- The deer reduction plan was simple in design (Table 2). A problem statement identified that the large population of white-tailed deer at Ned Brown Preserve had severely degraded the Busse Forest understory, that deer were chronically malnourished, and that deer-vehicle accidents on nearby roads were high. Program objectives were: 1) to reduce deer browsing pressure to levels that enable the regeneration of forest trees and understory plant species, 2) to significantly reduce the number of reported deer-vehicle accidents on state-numbered highways near Ned Brown, and 3) to significantly improve average physical condition of the deer herd. A decision rule of 8 deer/km^2, based on helicopter census during winter, was established as a preliminary target density. Deer would be removed until the target density was achieved and then maintained at, or below, that threshold density. Adjustment of the decision rule density would be based on quantitative evaluations relative to program objectives which included: 1) plant measurements, 2) deer-vehicle accident rates on nearby highways, and 3) average condition (fat depot, physical measurements, and reproductive performance).

Sharpshooting was the primary method used to remove deer at the Ned Brown Preserve. We used sharpshooting because of its proven effectiveness in reducing deer abundance during other removal programs (e.g. Ishmael & Rongstad 1984). Spot light shooting was confined to large woodlots that provided a safe backstop for discharged bullets. Deer were removed during hours when the preserve was closed to the public and entry gates were locked. Some shooting sites were preselected and baited with shelled corn. Sharpshooters were stationed in blinds near bait sites or were within a vehicle that moved in a circuit among bait sites. We used a 1-way ANOVA and Bonferroni's t-test, which controls type I error rate, to test for differences in deer removal rates among herd reduction years 1985-86, 1986-87, and 1987-88. Comparisons were significant at ≤ 0.05.

Methods used to evaluate the responses of plants (page 23) and changes in the condition of Ned Brown deer (page 16) were similar to methods described previously in this report. To evaluate the effect of herd reduction on the frequency of deer-vehicle accidents, we contrasted annual accident rates on highways near the Ned Brown Preserve during 1982-1988, with accident rates from 3 other locations (northwest Cook, Des Plaines, and Palos) in Cook County where deer-vehicle accidents were common. To standardize data, we used only IDOT records from state-numbered highways and calculated accident rates (deer accidents/1 km highway) instead of frequencies to compensate for differences in highway lengths among areas. No corrections were made for traffic volume. A correlation matrix was used to compare accident rates between locations.

Deer Reduction at Chicago-O'Hare International Airport

The second experimental deer reduction program (1 Dec 1987 to 15 Apr 1988) by INHS was at Chicago-O'Hare International Airport (O'Hare). In this program we established a different level of involvement for state biologists, to design and implement a short-term herd reduction program for the purpose of training site personnel who would then direct subsequent herd management and damage abatement activities.

Background information.-- Deer management at O'Hare prior to 1980 was poorly documented. Some illegal shooting of deer occurred from 1960 to the early 1980's. The airport perimeter fence was cut periodically and deer entrails were occasionally found by airport personnel. Local residents and O'Hare employees may have performed illegal "deer control" during this period.

First official reduction of deer numbers was precipitated by a deer-jet collision (American Airlines DC-10) on 31 March 1982. Following this accident, the U.S. Fish and Wildlife Service (FWS), the Illinois Department of Conservation (DOC), and O'Hare personnel coordinated a series of deer drives during April-May 1982 in which a minimum of 14 deer were shot by the DOC and FWS personnel (Garrow, DOC, unpub. notes). The deer drives were discontinued because few deer were being taken, deer had become extremely wary, and because of increased potential for deer being driven onto runways. Airport officials chose not to implement a FWS recommendation to construct a 12-foot high deer-proof fence on the east and northeast perimeters of O'Hare. Options for deer removal were reviewed by the Federal Aviation Administration, DOC, O'Hare, and FWS on 20 January 1983. The DOC recommended using Stephenson box traps to live capture deer. Subsequently, 2 deer were captured and transported to the Des Plaines Conservation area during winter 1983, one which died of capture-related injuries (Gebhardt, O'Hare, pers. commun.). O'Hare personnel continued to live-trap deer from 1984 to 1987. No records were maintained, although no deer were captured during winters of 1985-86 and 1986-87. The O'Hare Aviation Safety Director estimated that 5 deer were live-captured during 1983-1987. Deer drives were conducted in spring 1983 and 1984. Five deer were shot by DOC and FWS employees on 5 May 1983. Drives were unsuccessful on 8-9 May 1984 and no deer were removed.

The INHS Urban Deer Study functioned as the on-site liaison between the DOC and O'Hare from 1984 to 1988. Helicopter counts were conducted during winters of 1984 (n=9 deer), 1985 (n=8 deer), 1986 (n=14 deer), and 1987 (n=43 deer). Deer were frequently sighted near, and on, active runways during early spring, 1987. On 17 March, a jet struck and killed a 36-kg male fawn on runway 14R that caused repair damage > $100,000.00. This accident renewed airport interest in deer management. Authorized by the O'Hare Aviation Safety Department, Chicago Animal Control personnel darted 5 deer by remote chemical injection (CAP-CHUR gun) during May 1987, but none were captured. Subsequently, a corral trap was constructed by Chicago Animal Control in May, but was removed in July after no deer were captured.

Deer management plan and evaluations.-- A management plan (Table 3) was written by INHS which: 1) described habitat, herd origin, and deer behavior that contributed to airport deer conflicts, 2) reviewed historic and recent deer control activities at O'Hare, 3) listed deer control alternatives, 4) suggested goals and alternative strategies for herd reduction, carcass disposition, and media contact, and 5) defined state involvement in airport deer control activities.

Deer Reduction at Ryerson Conservation Area

The third and final experimental deer reduction program for INHS was conducted with the Lake County Forest Preserve District at Ryerson Conservation Area during 1988-1989. Ryerson was a pivotal program that set precedence for state involvement in urban deer management in Illinois. All deer management activities at Ryerson were conducted and funded by the landowner. INHS and the newly established DOC Urban Deer Project cooperatively facilitated deer management by providing training opportunities and technical information to Lake County. Additionally, INHS collaborated with Lake County in designing and drafting the deer management plan. Deer management at Ryerson was opposed by a coalition of local citizens and the Humane Society of the United States (HSUS). The protracted controversy associated with Ryerson stimulated state agencies to address critical urban deer management recommendations made by INHS to: 1) establish a permanent DOC Urban Deer Project with a manager stationed in the CMA, 2) define the role of the DOC as a technical advisor and/or facilitator for urban deer issues on CMA property not owned by the state, 3) develop a state position on the translocation of deer, and 4) refine written guidelines for deer management on dedicated state nature preserves.

Background information.-- There is no specific date when impacts caused by deer at Ryerson were first recognized. Awareness of impacts at Ryerson can best be described as an accumulation of subjective observations by site personnel during 1984-1987 who noted a decline in flowering by spring ephemeral herbaceous plants, the appearance of a rudimentary browseline, and more frequent observations of deer. It is likely that a general awareness of potential impacts at Ryerson was also influenced by increased regional attention to deer-plant relationships at the Ned Brown Preserve in Cook County.

Although the Natural Areas Inventory and ecological studies at Ryerson provided valuable records (Bushey 1978, Mierzwa 1987, Nuzzo 1988), none of these evaluations by themselves, or collectively, yielded quantitative baseline data sufficient to corroborate the perceptions of site personnel that deer were increasing in abundance and changing floral composition and structure. Thus, the collection of baseline data on deer and deer herbivory by the LCFPD started after impacts caused by deer were first suspected. The first attempt to count deer on Ryerson was on 14 February 1985 (n=14 deer) during a cooperative aerial count with INHS personnel in a fixed-wing Cessna 172; however, the survey was terminated in flight because of air turbulence. Subsequent aerial deer counts helicopter were made by county and state personnel on 16 March 1987 (N=32 deer), 31 December 1987 (N=52 deer), and February 1989 (n=76 deer). A 0.1 ha deer exclosure was built during autumn 1987. Quantitative measurements of plants within the exclosure and on an adjacent unfenced control plot required many days to complete during spring 1988. The extensive time required to measure plants using methods described in this report (page 23) for the Ned Brown Preserve, prompted Lake County to contract a 3-year (1989-1991) study to investigate more efficient methods for monitoring the effects of deer browsing on key indicator plant species.

The decision by the Forest Preserve District to reduce deer abundance at Ryerson was protracted over 15 months (November 1987 to January 1989). Conservation staff reviewed alternative techniques to reduce deer numbers and openly favored selective removal by sharpshooters. This preference was based on efficiency and because sharpshooters was successfully used by INHS at the Ned Brown Preserve in Cook County. Some local residents strongly opposed any killing of Ryerson deer. Although opinions changed over time and varied among individuals, the suggested alternatives to killing deer were fencing, fertility control, supplemental feeding, and translocation. The negative public reaction during this period progressed sequentially from: 1) verbal and written objection by individuals, 2) petitions and organized mailings, 3) opposition group formation, 4) fund raising, 5) submitting an alternative proposal to control deer numbers by fertility control using local veterinarians, 6) opposition coalition formed with assistance from Humane Society of the United States (HSUS), 7) group protest demonstration, and 8) litigation.

On 26 January 1989, the Concerned Veterinarians and Citizens to Save the Ryerson Deer (CVCSRD), 3 individual members of CVCSRD, and the Humane Society of the United States (HSUS) initiated litigation against the Lake County Forest Preserve District (LCFPD), the LCFPD Board of Commissioners, the Illinois Nature Preserves Commission (INPC), the Illinois Department of Conservation (DOC), and the director or president of each respective defendant organization. The 79-page complaint included a total of 10 counts for alleged violations by 1 or more of the defendants. The plaintiffs requested a temporary restraining order alleging that the defendants failed to comply with various regulations of the Illinois Natural Areas Preservation Act (Ill. Rev. Stat. Chapt. 105), the Illinois Wildlife Code (Ill. Rev. Stat. Chap. 61), and established administrative procedures (Ill. Adm. Code Title 17 Chap. V); a preliminary injunction enjoining the defendants from issuing permits and implementing deer removal; and a declaratory judgment that the Ryerson deer management proposal was procedurally and substantively improper and therefore invalid (No. 89 Chap. 57, 19th Judicial Circuit Court, Lake County, Illinois).

Court proceedings occurred over 3 days (31 January and 2-3 February 1989). The principal issue on the first court day was whether the plaintiffs provided adequate verification of allegations. Verifications were considered insufficient to grant a temporary restraining order; however, the court allowed the plaintiffs to submit amended verifications before the court rendered judgment on 2 February. The court ruled that amended verifications provided by the plaintiffs on 2 February were sufficient to issue a temporary restraining order to maintain status quo on Ryerson (i.e., deer removal procedures could not be started until the issue was decided in court). At the request of the defendants, the court agreed to consider whether a bond should be posted by the plaintiffs. On 3 February, the defendants successfully argued that a failure to promptly implement the deer removal plan could result in deer browsing sufficient to cause irreparable harm to remnant plant species on the preserve. For this reason, the court set bond at $35,000.00; however, the plaintiffs chose not to post bond and an agreement with the defendants was reached. The Final Judgment Order issued by the court reflected the terms of the agreement which modified enactment of the deer removal plan by: 1) delaying shooting by sharpshooters from 1 February to 7 March, 2) mandating that all reasonable efforts would be made to translocate as many deer as possible and that live trapping would continue after 6 March, 3) requiring that costs for translocation, serological tests, veterinarian services, and construction of 2 additional box traps be borne by the plaintiffs, and 4) setting a maximum of 48 hours that live trapped deer could be held post capture prior to translocation (i.e., intent was to define a maximum holding time allowed for completing serological testing prior to translocation). All pending motions for costs and sanctions were withdrawn by the plaintiffs and the suit was dismissed without costs and with prejudice.

Deer management plan and evaluations.-- The forest preserve district proposal was developed as an operational plan for deer management on the RCA and was used as an application for state deer removal (DOC) and special use (Nature Preserve Commission) permits. INHS helped the forest preserve district to design and write sections of the deer management plan. The plan was designed as a 3-year pilot study because many uncertainties existed which could not be assessed without field work. The structure and key elements of the pilot program are outlined in Table 4.

The Ryerson deer management plan was approved by the DOC with the following stipulations:

1. The live-capture, translocation, and release of deer into a free-ranging situation was not permitted.

2. Translocation of deer was permitted only to not-for-profit zoological institutions.
3. Live-trapping and euthanasia was allowed providing the method of euthanasia did not render the carcass unsuitable for human consumption.
4. Selective removal by sharpshooters was permitted.
5. Carcasses must be processed by a state licensed meat processing facility and donated to charitable organizations for human consumption.
6. The DOC supported the use of experimental reproductive inhibitors.
7. All activities on the dedicated nature preserve must be consistent with Illinois Nature Preserve Guidelines for management of deer on nature preserves.
8. The DOC Urban Deer Project manager should be consulted for training of personnel and demonstration of methodologies.
9. Serological tests for bluetongue and Lyme Disease must be performed prior to translocation.
10. Deer could not be held more than 24 hours from capture to translocation.

INHS evaluated the removal efficiency (live-trapping and sharpshooting) and costs of the Ryerson program during the first year of herd reduction.

Translocation of metropolitan deer

We contrasted the movements and survival of 11 does that were live-captured, radio-marked and released on the Des Plaines River preserves in northern Cook County, with those of 21 does that were live-captured (from Des Plaines River, Ned Brown Preserve, and Chicago-O'Hare International Airport) in northern Cook County, radio-marked and translocated to the Joliet Army Training Center, Will County. Project objectives were: 1) to monitor the survival of translocated deer during the first year post-release, and 2) to compare the survival and movements of translocated deer to the survival and movements of deer that were captured and marked, but not translocated from metropolitan preserves. An abstract for this project is listed in Results (page 73) and the publication (Jones and Witham 1990) is Appendix G.

Study No. 104-4: Data Management, Analyses, and Reporting

This section is a data management and reporting study segment and is summarized in Results (page 75).

RESULTS

Study No. 104-1: Life History and Ecology of an Urban Deer Herd

Population parameters

Deer abundance on county forest preserves

Deer counts: Cook, DuPage, and Lake counties.-- Deer were counted on 16 of 18 preserves (administrative boundaries) in Lake County on 31 December 1987 and 8 January 1988. Densities ranged from 2 to 23 deer/km^2 with $\geq$18 deer/km^2 on 7 preserves including Ryerson Conservation Area, Daniel Wright Woods, Lyons Woods, Columbia Gardens, Old School, Gander Mountain, and MacArthur Woods (Table 5).

Deer surveys were conducted on 14 forest preserves in DuPage County in 1985, 1987 and 1988 (Table 6). Deer were observed on all preserves except Burlington Park (0.21 ha). Densities were typically less than those observed in Lake County with only 2 preserves (14% of total) with $\geq$ 18 deer/km^2. The latter included Waterfall Glen (22 deer/km^2) and Hidden Lake (20 deer/km^2) preserves. At Waterfall Glen, ungulate density is much higher because free-ranging fallow deer (*Dama dama*) use both the preserve and adjacent Argonne National Laboratory. Deer at Hidden Lake move freely between the preserve and Morton Arboretum.

The majority of INHS deer surveys were conducted in Cook County Forest Preserves (Tables 7-8). We subdivided preserves into smaller units with boundaries that could be determined from the air to help identify where deer were concentrated during winter. Because deer readily move across these boundaries, differences in calculated deer densities among years for a specific site may be a function of local deer movements rather than actual changes in deer abundance. Densities $\geq$18 deer/km^2 in Cook County occurred in

Palos, Ned Brown, and Des Plaines River preserves. The highest deer densities (e.g., 45 deer/km^2) in Cook County each year were in the Des Plaines River preserves. Deer densities remained high in the forested corridor along the northernmost sections of the Des Plaines River during the duration of this study.

Witham, J.H., and J.M. Jones. 1990. White-tailed deer abundance on metropolitan forest preserves during winter in northeastern Illinois. Wildl. Soc. Bull. 18:13-16. (Appendix A).

Abstract: We recalculated deer densities for preserves in Cook, DuPage, and Lake counties based on areas of contiguous property irrespective of administrative boundaries and/or dissecting roads. This evaluation estimates minimum deer densities for preserves that are interconnected. This produced 52 spatially separated preserve areas ranging in size from 0.2 to 34.4 km^2. The majority (79%, n=41) of these preserves were <10 km^2; however, preserves >10 km^2 represented 62% of total area surveyed. The 52 preserves that were surveyed during the 5-year period included 93% (366 km^2) of total forest preserve area in the CMA. Unsurveyed preserves were either small, with few if any deer present, or were located where aerial survey access conflicted with airport flight patterns. We observed deer on 43 of these 52 preserves. Among the 9 preserves where deer were not observed, all were <2.0 km^2 in size and collectively were <3% of the total area of the preserves surveyed. Minimum densities on 52 preserves ranged from 0 to 26 deer/km^2. Minimum densities of deer on 16 preserves (33% of all preserves) exceeded 8 deer/km^2 on at least one survey; 13 (31% of the area surveyed) of these sites had >12 deer/km^2; 7 (14% of the area surveyed) preserves had $\geq$20 deer/km^2 (Table 2 in Appendix A).

Deer count: Kane County.-- In January 1987, a total of 198 deer was counted in Kane County during a 2-day census conducted from a fixed-wing aircraft (Fig. 4). The Kane County landscape west of the Fox River is dominated by cropland and pasture. No deer were observed in relatively barren agriculture fields, which provided little to no cover during winter. All deer were sighted in, or near, woodland cover. Deer concentrations were noted in northeast and far southwest Kane County. Our observations of deer concentrations overlaid areas where deer-vehicle accidents were common (Interstate 90-northeast Kane County) and where damage to agriculture was extensive (Big Rock, southwest Kane County).

Reproductive performance of does

Doe reproductive performance by areas, determined by fetal counts, was summarized for 1984-1985 (Table 9).

Mean fetal counts of doe fawns differed among areas ($P<0.001$, X^2, df=4). All fawns from Ned Brown and Des Plaines fawns were aparous. Singletons were produced by 40 to 43% of the fawns from Palos (4/7), Northwest (6/15), and Non-Cook (10/23). Additionally, twins were produced by 13% (2/15) and 17% (4/23) of fawns from Northwest and Non-Cook, respectively. Mean fetal counts (i.e., fetuses/doe) ranged from 0 (Ned Brown and Des Plaines) to 0.78 (Non-Cook).

A total of 31 yearling females was examined for pregnancy; however, only 4 yearlings were collected from Palos (n=2) and Northwest (n=2) locations. Excluding these 2 locations, fetal rates of yearlings ranged from 0.60 (Ned Brown) to 1.56 (Non-Cook). The percentage of yearling does that were barren varied from 8% (1/13, Des Plaines) to 60% (3/5, Ned Brown). Twins were uncommon among Ned Brown (1/5) and Des Plaines (1/13) yearlings; however, triplets were produced by 1 Des Plaines yearling. Comparatively, the majority (7/9, 78%) of Non-Cook yearlings produced twins.

Most (56/59, 95%) of the adult does examined were pregnant. Adult female fecundity ranged from 1.38 (Ned Brown) to 2.6 (Non-Cook). Fifty-two percent (11/21) of Ned Brown adult females produced singletons. Triplets were produced by adults from Northwest (2/5) and Non-Cook (3/5).

Fetal sex ratios were determined from does that were collected from January-May in 1984 and 1985. Among does $\geq$ 1-year old, fetal sex varied among areas: Ned Brown (0.40 males, n=25), Des Plaines (0.63 males, n=52) and all other areas (0.61, n=54). We expected that nutritionally stressed deer, such as those deer at Ned Brown and Des Plaines, would produce more male than female fawns and that the fetal sex ratio for does with good nutrition would approximate 0.50, or be slightly skewed toward males. Only the fetal sex ratio for the Des Plaines does was consistent with these predictions. However, small sample sizes may have influenced our results during these years, particularly for Ned Brown (n=25 fetuses). The collective (i.e., 1984-1989) fetal sex ratio among Ned Brown does ≥ 1-year old (n=106) was 0.497 male (n=177 fetuses), a 1:1 sex ratio.

Survival rates

One-hundred and three deer were live-captured with rocket nets, marked, and released at the Ned Brown Preserve during winters of 1983-84 and 1984-85. Deer captured included 51 fawns (19 females:32 males), 17 (7 females:10 males) yearlings, and 35 adults (24 females:11 males). Survival rates were estimated for sex and age classes by 6-month intervals corresponding to winter-spring (December-May) and summer-autumn (June-November). Because we captured deer during winter only, we have no data for fawn survival during summer-autumn intervals. To more accurately assess natural mortality, we excluded all mortality that resulted from INHS deer removal activities (i.e., collections for nutrition studies).

Male and female fawn survival was estimated for winter-spring (Dec-May) intervals during 1983-84 and 1984-85 (Table 10). Survival of male fawns (0.85 and 0.87) was comparable between years while female fawn survival was 0.8 and 1.0. The causes of fawn mortality were unknown.

Only 17 yearlings were live captured, however, the yearling sample was resupplemented each year in June by deer that were marked as fawns that survived their first year. Yearling survival was estimated during 3 winter-spring and 2 summer-autumn intervals. All mortality of male yearlings was due to automobile accidents with survival rates of 0.94-1.0 during winter-spring and 0.83-1.0 during summer-autumn. No female yearlings died during summer-autumn, however, some mortality occurred during each winter-spring with survival rates of 0.27, 0.82, and 0.85 (Table 11).

We estimated survival of adult deer during 3 years (i.e., six 6-month intervals). Adult male survival was 0.73-0.83 during winter-spring and 0.69-0.90 in summer-autumn. Notably, adult male mortality rates due to vehicle accidents were 0.1-0.24 during summer-autumn and 0.09-0.27 during winter-spring. Adult males were killed by vehicles during each 6-month interval over 3 years. Survival rates of adult does during winter-spring (0.77, 0.68, 1.0) were comparatively lower than in summer-autumn (1.0, 0.85, 0.94) (Table 12).

Age composition and longevity of deer removed from the Ned Brown Preserve

All deer that were removed from the Ned Brown Preserve by shooting, from 1984 to 1988, were aged by wear and replacement (i.e., fawns and yearlings) or cementum annuli counts (i.e., adults). By backdating, we reconstructed the composite age structure of these deer on 1 June 1984. We recognize that our removals were not randomly collected and we do not imply that data are necessarily representative of true herd age structure. However, we believe that the majority of deer that were alive at Ned Brown on 1 June 1984 were removed by INHS through collections for nutrition research and herd reduction. We counted 293 during winter aerial surveys in 1983-84. A total of 228 deer that would have been alive on 1 June 1984 were collected by INHS. Of these, 219 deer wre either fawns, yearlings, or adults that were aged by cementum annuli counts and received "A" or "B" confidence ratings. Age frequencies for these deer are presented in Table 13. Thirty-seven of 154 (24%) does were $\geq$5 years which is consistent with old-age structure that may be typical for does on CMA preserves which are not hunted. The oldest doe and buck were 13- and 6-years, respectively.

Deer health

Health/condition evaluations

Relative condition of deer on forest preserves.-- Area differences in the morphometry (Table 14) and relative "fatness" (Table 15) among female fawns became more distinctive from autumn to spring. Only 1 index differed significantly (femur/hindfoot, $P=0.0181$, Ned Brown and Des Plaines < Palos and Non-Cook) during autumn; however, 7 of 8 female fawn condition indices differed during both winter and spring. Skeletal measurements of Ned Brown female fawns during winter were smaller ($p < 0.01$) than those in Palos and Northwest. Ned Brown fawns had less girth ($p < 0.0002$) than fawns from all areas and had lower body weight ($p=0.0009$) and fat ($p < 0.0009$) than Northwest fawns. The KFI of Non-Cook fawns was less ($p=0.0002$) than the KFI of fawns in Northwest. Area differences in female fawns were accentuated during spring. Ned Brown fawns were physically smaller and had lowest fat reserves among fawns all areas. Female fawns from Ned Brown and Des Plaines differed only in total length ($P<0.0031$). In contrast, female fawns collected during spring from Northwest were relatively more robust than fawns from Ned Brown, Des Plaines, or Palos.

Area differences in morphometry among male fawns were less pronounced than were differences among female fawns. Although area relationships followed trends similar to those of female fawns (i.e., Ned Brown and Des Plaines < Northwest and Non-Cook), significant differences were detected among extremes only. Ned Brown male fawns were shorter in total length than fawns from Palos and Non-Cook during winter ($P<0.0024$) and spring ($P<0.0377$). The hindfoot of Ned Brown fawns was less than average hindfoot length of fawns from Northwest ($P=0.0014$, winter) and Non-Cook ($P=0.0026$, spring). Area differences in winter hindfoot ($P<0.0278$) and autumn hindfoot ($P<0.0127$) were significant, but Tukey's test could not attribute these differences to specific areas.

Girth, body weight, and fat of male fawns did not differ among areas during autumn; however, surprisingly, the Kistner score and KFI (i.e., fat indices) for Ned Brown males fawns were among the highest values observed. Area differences in the condition of male fawns were most apparent during winter. The body weight of Ned Brown male fawns was less ($P=0.0001$) than the body weight of male fawns from Palos, Northwest, and Non-Cook. Similarly, Des Plaines male fawns weighed less than those in Northwest and Non-Cook ($p=0.0001$). Fat reserves that were relatively abundant during autumn appeared to be used more rapidly by Ned Brown fawns as winter Kistner and KFI scores were lowest among areas ($p=0.0001$). Male fawns from Palos and Northwest scored highest for winter fat indices among areas. Indices for Ned Brown and Des Plaines did not differ significantly during winter. Although area trends were apparent for condition of male fawns during spring, only girth (Des Plaines < Non-Cook, $p=0.0021$) and body weight ($p=0.0005$) differed (Table 17).

The number of female yearlings collected from all areas was small during autumn ($n\leq17$) and winter ($n\leq11$). Area differences in condition indices for yearling females were recorded for summer total length (Ned Brown < Des Plaines, Palos, Northwest, and Non-Cook; $p=0.0006$) and summer femur (Ned Brown < Northwest, $p=0.0507$). Summer and spring femur/hindfoot ratio and spring Kistner score differed among areas; however, the test did not distinguish which areas contributed to these differences (Tables 18 and 19).

Seasonal vulnerability of male yearlings to vehicle accidents influenced sample sizes. More male yearlings were collected during autumn and spring intervals than during summer and winter. Area differences in skeletal indices were apparent during seasons when larger sample sizes were obtained. Autumn femur and femur/hindfoot of Ned Brown yearling males were less than those indices for Des Plaines, Palos, and Non-Cook (p=0.0001), and Northwest (p=0.0572), respectively. The mean femur length for Palos yearling males during autumn was shorter (p=0.0001) than values for Northwest yearling males. Similarly, Ned Brown spring hindfoot differed (p=0.0118) from hindfoot mean values for Des Plaines, Palos, Northwest, and Non-Cook. Non-specific area differences (p=0.0532) in femur measurements occurred during spring. Based on small sample sizes, male yearling girth (Ned Brown < Northwest; p=0.0310) and KFI (Ned Brown < Northwest; p=0.0315) differed during winter (Table 20 and 21).

With 2 exceptions (i.e., Non-Cook total length and Palos hindfoot), adult female skeletal indices increased in order from Ned Brown (lowest values), Des Plaines, Palos, Northwest, to Non-Cook (highest values). The mean femur for Ned Brown adult females was shorter (p=0.0123) than femurs of females from Northwest and Non-Cook (Table 22).

Area effects on fat deposition in adult females were most evident during the spring and summer intervals. During spring, Des Plaines adult females had less girth (p=0.0044) and lower KFI (p=0.0222) than adult females from Northwest and Non-Cook; mean body weight of adult females from Ned Brown and Des Plaines were less (p=0.0005) than the body weight of Northwest adult females; Ned Brown adult females had lower Kistner score (p=0.0001) than adult females from Non-Cook. During summer, Ned Brown adult females had less girth ($p=0.0006$) and lower body weight ($p=0.0033$) than Palos females. Mean girth of females from Ned Brown and Des Plaines were less ($p=0.0006$) than Non-Cook adult female girth during summer. Area differences were significant for summer KFI ($p=0.0239$) and winter girth ($p=0.0261$), however, these differences could not be attributed to specific areas (Table 23).

Area comparisons of adult males were negatively affected by low sample sizes. Skeletal indices, from data pooled among seasons, differed in femur length only (Ned Brown < Northwest, $p=0.0087$). Girth of adult males during summer (Ned Brown < Palos, $p=0.0491$) and spring Kistner scores ($p=0.0136$) differed among areas (Tables 24 and 25).

Body composition/condition evaluation of fawns.-- This report section was published in the Journal of Wildlife Management.

Watkins, B.E., J.H. Witham, D.E. Ullrey, D.J. Watkins, and J.M. Jones. 1991. Body composition and condition of white-tailed deer fawns. J. Wildl. Manage. 55:39-51. (Appendix B)

Abstract: Sixteen white-tailed deer (Odocoileus virginianus) fawns were captured between November and April 1984-86 near Chicago, Illinois, to evaluate relationships between body composition and condition indices. Body fat (bled, ingesta-free basis) of the fawns ranged from 2.3 to 48.9%, dry-matter basis. Of 6 morphometric indices, chest girth had the highest correlations with body mass, gross energy, and fat. Of 45 postmortem indices, carcass mass and composition, viscera mass and composition, Kistner score, kidney fat indices, kidney fat mass, and back fat thickness were related to body fat concentration by logarithmic functions. Kistner score and gastrocnemius fat concentration were each linearly related to body fat concentration. Femur marrow fat and mandible marrow fat concentrations were each related to the negative inverse of body fat concentration. Serum triiodothyronine had the closest relationships with body energy content and body fat concentration of the 11 blood and serum constituents we analyzed. Multiple regression analysis indicated that body gross energy content could best be predicted in live fawns by a combination of live mass and triiodothyronine and postmortem by a combination of viscera mass and live mass or gastrocnemius fat mass, kidney fat mass, or gastrocnemius fat mass and liver mass.

<u>Body composition change of fawns during winter</u>.-- This report section was accepted for publication in the Canadian Journal of Zoology.

Watkins, B.E., J.H. Witham, and D.E. Ullrey. 1992. Body composition changes in white-tailed deer fawns during winter. Can. J. Zool. 00:000-000 (in press). (Appendix C)

Abstract: Body composition was determined for 16 white-tailed deer (<u>Odocoileus virginianus</u>) fawns captured near Chicago, Illinois between November and April to investigate changes in body composition and chemical component distribution as fawns catabolized tissues over the winter. Live weights of the fawns ranged from 16.8 to 41.6 kg., and ether-extractable fat concentration of the bled, ingesta-free body ranged from 2.3 to 48.9%, dry basis. Carcass, viscera, and hide contained, on average, 70%, 21%, and 9% of the bled, whole body fat, respectively. Above approximately 15% whole body fat (dry basis), the percentage of body fat in the viscera increased and the percentage in the carcass declined. Body composition (blood-, ingesta-, and fat-free basis) averaged 72% water, 23% crude protein, and 5% ash; ash and phosphorus concentrations increased and protein concentration decreased over the winter. Sodium concentration tended to decrease. Based on relationships between chemical components and body weight, the composition of weight lost during winter was calculated to range from 12% water, 84% fat, 4% protein, and 0.5% ash during early winter to 73% water, 0.3% fat, 25% protein, and 2% ash during early spring. Calculated metabolizable energy derived from tissue catabolism was a quadratic function of body weight and ranged from 7.7 to 1.1 Mcal/kg of bled, ingesta-free weight loss during early and late periods.

<u>Estimating fawn body composition with deuterium oxide</u>.-- This report section was published in the Journal of Zoo and Wildlife medicine.

Watkins, B.E., D.E. Ullrey, J.H. Witham, and J.M. Jones 1990. Field evaluation of deuterium oxide for estimating body composition of white-tailed deer (<u>Odocoileus virginianus</u>) fawns. J. Zoo and Wildl. Medicine. 21:453-456. (Appendix D)

Abstract: The efficacy of using deuterium oxide dilution under field conditions to predict body composition of free-ranging white-tailed deer (<u>Odocoileus virginianus</u>) was evaluated using 10 fawns captured near Chicago, Illinois, between November 1985 and March 1986. Estimated body water was calculated using the average blood deuterium concentration 1.5 and 2 hr after i.v. infusion. Estimated body water was correlated with true body water (r^2=0.93) but overestimated true body water by 23.8 $\pm$ 1.4%. Including estimated body water in regression models significantly (P>0.05) improved prediction of body composition versus the use of live weight alone. Estimated body water (kg) and live weight (kg) were correlated (P<0.0001) with the ether extract (kg) (r^2=0.93), gross energy (Mcal) (r^2=0.95), and crude protein (kg) (r^2=0.93) content of the ingesta-free body.

Parasites of urban deer

Helminthic and protozoan parasites of urban deer.--This unpublished report was prepared under contract and submitted to INHS.

Cisneros, J.G. 1987. Helminthic and protozoan parasites of white-tailed deer in urban areas of northeastern Illinois. Unpub. Rep. Sub. to Ill. Natural History Survey-Wildl. Sec., Champaign. 15pp. (Appendix E).

Abstract: Fecal samples, from 270 white-tailed deer >1 year from 4 sites (Northwest Cook, Busse, Des Plaines, and Non-Cook) in northeastern Illinois, were examined for helminthic and protozoan parasites using fecal flotation. Seventy-four (28%) deer carried 1 or more parasites. Trichostrongyloids (genera Haemonchus, Ostertagia, and Trichstrongylus) showed highest (11%) prevalence of parasites. Low parasite intensities may have resulted from inherent limitations of the flotation technique and/or the prolonged freezing of samples which ruptured some eggs and oocysts. Largest intensities corresponded to areas and parasite species with the highest prevalences: Des Plaines, E. mccordocki; Busse Woods, trichostrongyloids and P. tenuis. No difference was detected in parasite prevalence (winter=31%, summer=26%, spring=27%, & fall=25%) among seasons. Intensities were uniformly low except for relatively high Eimeria oocyst numbers in spring and fall. Parasites identified in this study included 2 species of nematodes not previously reported for northern Illinois deer (Oesophagostomum venulosum and Capillaria bovis) and 2 species of coccidia (Eimeria mccordocki and E. madisonensis) not previously reported in Illinois deer. However, all parasite species identified in this study are common parasites of white-tailed deer in the United States. The low prevalences and low intensities indicate that none of the deer in this study were not heavily parasitized, nor do they show a threat to the general deer population in terms of parasitic infection.

Histopathology.-- Histopathological analyses were performed on lung, liver, and kidney tissue samples submitted to the Veterinary Diagnostic Laboratory, University of Illinois, Champaign. Because the source of tissues was deer killed by vehicles, the condition of tissues submitted was generally poor, due largely to tissue deterioration between death and postmortem evaluation. We viewed this analyses as a general screening of deer health, only. No visible lesions were present in most specimens.

Several changes were observed in the liver. The most common finding was of mild, nonsuppurative pericholangitis. This consisted of a loose infiltrate of lymphocytes in the connective tissue of the portal triads. This is a common finding in wildlife and represents a long-term, low-grade, nonspecific inflammatory response. In some sections, focal lymphoid aggregates were randomly located in the liver; often the cells were within sinusoids. This could be an artifact or another nonspecific lesion of chronic exposure to a variety of pathogens. One case had a lymphoid aggregate within Glisson's capsule. There was increased connective tissue at this site and the inflammatory cells were in a loose aggregate. Similar changes in livers have been observed from deer taken at the Crab Orchard National Wildlife Refuge in southern Illinois.

Renal lesions were minimal and infrequent. Focal tubular mineralization was observed in only one case. This animal may have eaten a toxic plant. Although this is a common finding in most species , it was unusual in this instance since this was not a feature in any of the other kidneys submitted. Mild nonsuppurative interstitial nephritis was the only other lesion observed.

Three changes were observed in the lungs. Lungs contained scattered, small granulomas which contained morulae or larvae. These were probably Parelaphostrongylus tenuis, although P. andersoni has a similar life cycle. The second major lesion observed was a mild to moderate eosinophilic pneumonitis. This was characterized by a diffuse infiltrate of lymphocytes around and between bronchi, bronchioles, and small to medium sized arteries. Lungs with these lesions rarely contained nematodes or nematode larvae. The changes were similar to those associated with pulmonary or arterial parasites such as Dictyocaulus viviparous or the blood-lung migration pattern of some nematode larvae. A third lesion in the lungs was focal peribronchiolar lymphoid aggregates or nodules. These are common in many species and are a response to chronic, subclinical, infections.

Based on this evaluation, there is no reason to suspect that disease was operating as a major mortality factor in the CMA deer herds. Evidence of chronic malnutrition was apparent in the high density herds of Busse Woods and on the Des Plaines River in northern Cook County. Chronic malnutrition may predispose some individuals to diseases; if malnutrition is prevalent within a herd it is likely that a disease would spread more rapidly and be more intense than in a herd with individuals on a higher nutritional plane.

California encephalitis: Jamestown Canyon virus.-- Blood sera samples from deer live captured during 1984 and 1985 at Ned Brown Preserve (n=44) and at the Des Plaines River preserves (n=43) in northern Cook County were analyzed by Dr. Paul Grimstad (Univ. Notre Dame, South Bend, Ind.) for infection by California encephalitis (Jamestown Canyon virus). Results of this evaluation were:

Preserve Year	No. seropositive / No. deer tested		
	Fawns	Yearlings	Adults
Ned Brown			
1984	0/3	0	4/4
1985	6/18	4/4	15/15
Des Plaines			
1984	0/9	3/4	10/10
1985	4/7	5/5	8/8

Study No. 104-2: Deer Range Evaluation

Effects of deer on forest vegetation

Plant measurements

Busse exclosure and control plot.--Total stem density of herbaceous species was consistently higher in the Busse exclosure and generally exhibited an increase over time with the exception of 1987 values (Table 26). Differences in herbaceous stem densities between the exclosure and control plot were significant for 1986 and 1988 ($\underline{X}^2$= 9.54, p=0.002 and $\underline{X}^2$ =19.85, p=0.0001, respectively), only. Wild garlic (Allium canadense) and wild leek (A. tricoccum) comprised > 35% of the total stem density value for Busse control plot during each spring. These species appear highly unpalatable to deer as we saw little evidence that deer, even at high densities, browsed them; therefore, eliminating these from the herbaceous species total yields consistently higher herbaceous species density in the exclosure for all years (Table 27). Total stem densities of all herbaceous species for 1985-1988 were significantly ($\underline{z}$ >2.61, $p < 0.05$) higher in both plots than during 1984, with the exception of 1987 values. Sampling in 1987 was conducted relatively late in the phenological succession of spring ephemerals and when the latter had substantially declined in numbers. Additionally, 1987 total herb density was significantly ($\underline{z}$=2.61, $\underline{p} < 0.05$) lower than 1986 and 1988 in both, the exclosure and control plot; therefore, the 1987 density value are not directly comparable to other years. However, the ratio of herbaceous stem density in the control plot to the exclosure declined over time (Fig. 5) and strongly indicates a greater disparity between desirable herb density in the exclosure and control.

The total number of species did not increase markedly in either plot over the 6 years. Individual species such as Erythronium albidum, Tovara virginiana, and Trillium recurvatum, which is not an ephemeral and persists into the summer, exhibited a substantial increase in density (Fig. 6).

Significant differences ($\underline{X}^2 \geq 5.26$, $p \leq 0.02$) in density of grasses and sedges in the exclosure and control plot occurred during all years; both were more abundant in the control plot which indicates initial microenvironmental differences between exclosure and control (i.e., topography and soil moisture). Grass/sedge densities did not increase significantly over time (Table 26). Woody species density varied among years but was mostly higher in the control plot; differences were significant ($\underline{X}^2$ =10.81, p=0.001) for 1986 only. Unfortunately, this category included first-year tree seedlings which were, for the most part, < 10 cm. These seedlings were prevalent in the control and comprised the bulk of the woody species stems present in both plots (Table 26, 1989 data). Based on annual measurements in the control plot and exclosure, few, if any, of these seedlings survive 1 year and therefore, contribute little to actual understory regeneration. Mean woody species density was significantly higher in both plots during 1986 and 1988; unfortunately, the inclusion of minute seedlings without distinction as such probably masked interannual differences during subsequent statistical comparisons. However, mean woody stem density (including small seedlings and introduced/exotic species) appeared to increase in the exclosure (Fig. 7).

Percent cover of herbaceous species was significantly ($\underline{X}^2 \geq 27.55$, $p \leq 0.0001$) higher during the springs of 1985-1988 than the summer of 1984 in both plots. Herb cover was significantly ($\underline{z}$ >2.61, p < 0.05) higher in the exclosure during all years, partially due to more extensive coverage by _E. albidum_ and to a lesser extent _T. virginian_, and _T. recurvatum_. Mean percent cover of _Erythronium_ was proportionately less in the control plot over time (Fig. 8); this species appeared to respond most quickly to exclusion from browsing. _Tovara_ and _Trillium_ did not exhibit similar trends over time (Figs. 9 and 10).

Woody cover was significantly ($\underline{z}$ >2.61, p < 0.05) lower in both plots during 1986; sampling in 1986 was prior to full leaf-out of the woody plants. Percent cover of woody species was marginally higher in the exclosure for all years (Fig. 11), but differences were significant in 1985 and 1987 only. Grasses and sedges did not differ significantly over time or between plots. Mean percent cover for all plants was significantly ($\underline{X}^2$ >4.34, $p < 0.04$) higher in the exclosure during 1986 and 1988 only.

Busse Nature Preserve: all plants < 1m.-- Sampling in the nature preserve was conducted during early to mid May in 1986-1989. No significant differences in total, herbaceous, or "other" species density were detected between years (Table 28). Although the total number of herbaceous species encountered in the quadrats increased between 1986 and 1988 (Table 29), slight decreases in density were recorded for some species (i.e., Eythronium albidum, Geranium maculatum, and Geum canadense). Woody stem density was significantly ($\underline{X}^2$ >9.80, $p < 0.002$) higher during 1986 and 1989; however, non-persistent first-year seedlings < 10 cm accounted for 87% and 57% of the total woody stem density in 1986 and 1989, respectively. Total stem density of all plants was markedly, but not significantly, higher in 1987 due to an abundance of sedges (Carex spp.). Reasons for the higher density of sedges in 1987 are speculative but may include favorable weather conditions, variation in random placement of quadrats, and time of sampling (i.e., 1987 sampling was phenologically later than the other years).

Species diversity along line intercepts was consistent after 1986 (Table 30). Trillium grandiflorum which reportedly "carpeted" the nature preserve in the past, was first encountered during our sampling in 1987; Quercus spp. seedlings were first observed in sample units during 1989. Percent cover of all understory plants was ≥ 1.9% higher during 1988 and 1989 than the previous

2 years, but differences between years were not significant ($p > 0.05$) for individual groups of plants (e.g., herbaceous, woody, etc.) or for all plants combined. Wild leek accounted for ≥ 39% of the mean herbaceous cover during 1986, 1988, and 1989 (Table 31). The leaves of wild leek appear early in the spring and disappear prior to the complete development of flower stalks; flower stalks were well developed and leaves were deteriorating during the 1987 sampling which undoubtedly resulted in the lower percent cover of herbaceous (Table 31) or "other" (Table 30) species in 1987.

Similar sampling was conducted in Busse South during April-May 1986-87. Stem densities and percent cover of all understory plants ≤ 1m were higher in Busse Woods South (Tables 32 and 33, respectively) than in the nature preserve. Robust herbaceous plants dominated the Busse South understory; mean percent cover and density values of herbaceous species were markedly higher in Busse South. Woody species density was consistent in Busse South between years, but percent woody cover was higher in 1987 due to differences in phenological time of sampling; Busse South was sampled in April of 1986 prior to full development of leaves on woody plants. The mean density of all plants was not markedly dissimilar between the nature preserve and Busse South during 1987, but first-year woody seedlings, grasses, and sedges were essentially absent in the latter woodlot. This, in conjunction with total percent cover which was considerably higher in Busse South, indicates that more robust plants with greater foliar development were present in the understory and were subjected to less browsing pressure.

Busse Nature Preserve - Shrubs and Saplings > 1m.-- The dominant species, based on stem density, in the < 2.5 cm DBH size class were sugar maple (*Acer saccharum*), ironwood (*Ostrya virginiana*), basswood (*Tilia* *americana*), ashes (*Fraxinus* spp.), and elms (*Ulmus* spp.) for all years (Table 34). Mean total stem density in the smaller size class did not differ significantly ($p > 0.05$) between years, and the number of species encountered during sampling ranged from 12 to 16. Dead and leafless stems dominated this size class and largely outnumbered live stems in 1985 and 1986; however, the mean density of dead stems declined significantly ($X^2 > 6.19$, $p < 0.013$) over the 3 years. The density of live stems < 2.5 cm DBH was markedly lower than stems of 2.5-10.2 cm DBH.

The density of stems in the larger size class averaged between 1,040 and 1,272 stems/ha and did not differ significantly ($p > 0.05$) between years. Dominant species (based on density) were ironwood, basswood, ashes, and elms; the number of species was consistent among years. Dead/leafless saplings comprised ≤ 11% of the average estimated density of all saplings during all 3 years. The mean density of dead stems in this size class also decreased over time but not significantly ($p > 0.05$).

Saplings < 2.5cm DBH were more numerous in Busse Woods South (Table 35) than in the nature preserve; mean density values were 3.5 times higher in Busse South. Live stem density was 4.3 times greater than standing dead/leafless sapling density which was opposite of the relationship of dead to live stems observed in the nature preserve. The number of sapling species < 2.5 cm was 12-15 in Busse South, and sugar maple samplings were the most abundant. Other important species were basswood, prickly ash (*Xanthoxylum americanum*), common buckthorn (*Rhamnus carthartica*), ironwood, and elms.

Fewer species in the 2.5-10.2 cm DBH class were encountered in Busse South (i.e., n = 8-9) than in the smaller size class or the nature preserve. Estimated sapling (2.5-10.2 cm DBH) density in Busse South was similar to the nature preserve. Sugar maple was most prevalent in this size class also, followed by ironwood, basswood, and elms. Sugar maple sapling density comprised ≥43.8% of the mean density for all saplings < 2.5cm DBH and ≥ 27.7% of the total density of saplings in the 2.5-10.2 cm DBH class.

After the winter of 1985-86, field workers found several elm saplings in the nature preserve that had been damaged by deer; the bark on several trees had been stripped to heights of 1.5m smaller trees were girdled, and larger exposed roots were also stripped. More extensive damage was observed during late winter 1986-87. Additionally, several sugar maples had been completely stripped of bark by squirrels during the same winter. Bark stripping by the 2 species was somewhat unexpected since there was a relatively abundant red oak acorn corp during the previous fall. However, the large mast crop may have supported more animals through the winter, and the competition by 2 high density herbivore populations for available mast may have resulted in late winter depletion of this food resource and necessitated use of subsistence foods. A subsequent inventory of all deer damaged trees yielded the following: all of the stripped trees were elms, 256 damaged elms were found and marked, ≥ 90% were concentrated in an area of approximately 3 ha in the northwest corner of the nature preserve, > 95% were less than 10.2 cm DBH, and > 10% were less than 2.5 cm DBH. In August 1987, 250 of the damaged elms were relocated to determine survival. Out of 180 (72%) trees that were girdled, 163 (91%) had died and 16 (9%) had much reduced foliage (i.e., smaller and fewer leaves than undamaged trees). Similar bark stripping of elms and hawthorns (Crataegus spp.) was observed in other sections of the nature preserve during the fall of 1989 (C. Anchor, Cook Co. For. Pres. Dist., pers. commun. 1989).

Busse Nature Preserve vs. Busse Woods South.-- The 34-ha Busse South woodlot exists on soils categorized as well drained upland soils of 2-5% slope (i.e., Morley silt loam); only 4 separate soils were identified in Busse South. Soil types in the 130 ha nature preserve are well drained upland (61.6%), poorly drained upland (34.3%) and poorly drained lowland (4.1%) soils. Eleven soil types were identified in the nature preserve.

Twenty-one canopy tree species (i.e., DBH > 10.2 cm) were identified in the nature preserve, and 18 were encountered in Busse South. Dominant canopy trees differed among the 2 areas (Table 36). The nature preserve is dominated by large oaks, but large sentinel oaks are fewer in Busse South. The latter woodlot seems to be dominated by more shade-tolerant species (i.e., sugar maple, basswood, and elms); however, both woodlots had elms as major components of the lower canopy strata. Mean percent canopy closure ≥ 1.5m above ground level was 93.1% and 88.3% in Busse South and the nature preserve, respectively.

Deer habitat evaluations

Witham, J.H., E.A. Cook, and J.M. Jones. No date. White-tailed deer habitat change in metropolitan northeastern Illinois. Unpub. manuscript., Ill. Natural History Survey-Wildl. Sec., Champaign. 14pp. (Appendix F)

Abstract: Landsat Thematic Mapper satellite data collected in 1985 and 1988 were used to evaluate white-tailed deer (Odocoileus virginianus) habitat in the 4-county (5,929 km^2) Chicago Metropolitan Area (CMA). Thirteen land cover classes were combined into 5 general deer habitat categories for each date. In 1988, CMA landscape was 6.7% nondeveloped forest, 49.3% heavily vegetated residential and cropland, 3.3% maintained grass, 39.1% urban and nondeer habitat, and 1.6% water. County-owned green belt systems, comprising 7.2% of the metro area, provide permanent habitat where deer concentrate. Percent development varied from highly urbanized Cook County (75.9%) to more rural Kane County (29.5%). Less developed Kane and Lake counties sustained highest net losses (>8%) and net degradation (17-27%) of deer habitat during 1985-1988. Less developed counties have the greatest opportunity to plan for future wildlife habitat; more developed counties are closer to minimum threshold levels of deer habitat and should focus on how deer will be managed

on extant habitats.

Addendum: Although not included in the manuscript referenced above, figures 12-15, based on 1988 data, were added to this report to enable the reader of this report to visualize relative deer habitat by county.

Changes in land use: Insularity of the Ned Brown Preserve

Using aerial photographs from 1949, 1964, 1970, and 1985, we evaluated changes in land use within a buffer zone extending 5 km in each direction from the edges of the Ned Brown Preserve. Cells corresponded to 1-ha and were evaluated individually through a lighted image enlarger for development, roads, vegetation, and water.

Trends in "development" categories was most revealing (Table 37). In 1949, 83% of the study area was undeveloped with 10% low density housing (i.e., 1-2 house units per cell). All other development categories (i.e., medium and high density housing, large buildings/paved areas and construction) totalled 7% of the landscape. Most developments centered in the older community of Arlington Heights; villages of Elk Grove Village and Rolling Meadows were not present. In 1985, these relationships had reversed with only 25% of cells remaining undeveloped (Ned Brown Preserve was included in this total) and 5% in low density housing. Intensive development dominated 70% of landscape in 1985. Analyses of roads follows a similar pattern. Cells with no roads in 1949 (78%) decreased to 44% by 1985 (Table 38). This change resulted almost entirely from an increase in secondary roads from 1949 (10%) to 1985 (44%).

Agriculture dominated landscape in 1949 (80%) declined to 5% by 1985 (Table 39). Agriculture was treated as a subset of the "no development" classification, which, as previously stated, declined from 83 to 25% during this same period. Urban development (i.e., urbanization/suburbanization) clearly supplanted rural landscape over this 36-year period. Increases in grass (5 to 29%) and mixed vegetation (14 to 40%) resulted primarily from ornamental and recreational landscaping in residential areas and suburban community facilities.

Small changes in the percentage of water resources are probably more significant than are similar changes among the other 3 classification types. A slight increase (from 2 to 5%) in shoreline/open water was accompanied by a small decline (from 8 to 4%) in streams. Cells classified as "no water" varied by small amounts (86%, 92%, 89% and 90%) among years examined (Table 40).

Deer-vehicle accidents

Accident costs

Average costs of deer-vehicle accidents investigated by the Cook County Sheriff's Police 1984 were not different (t-test, df=134, p=0.59) from costs of deer-vehicle accidents that occurred in 13 other Cook County municipalities. Because no difference was detected, all 1984 questionnaires (CCSP and municipalities) were pooled as one data set. Questionnaires during subsequent years (i.e., 1985-1988) were sent only to persons involved in deer-accidents that were investigated by CCSP.

The average total cost of a deer-vehicle accident in Cook County during 1988 was $ 1,600.18. Among the 5 years surveyed (1984-1988), this value is second only to 1986 ($1,611.77). The latter was influenced by several accidents where vehicles were irreparably damaged; the highest loss for a single accident among 541 responses received over 5 years was $14,050.00 during 1986. The highest loss sustained by a single accident victim in 1988 was $10,157.00.

Several trends were apparent in the average costs of deer-vehicle accidents by category type from 1984 to 1988 (Table 41). First, values varied substantially within cost categories for individual years; therefore, standard errors associated with means were relatively high. Secondly, medical costs per accident were always $\leq$ \$1,500.00; these were unexpectedly low maximum values. The percentage of accidents with injuries where medical treatment was required was < 10% of the respondents within each year. The occurrence of a major injury involving long-term medical care and loss of wages, or loss of human life, would have increased average cost estimates substantially during any single year. Apparently few major injuries occurred in Cook County during our evaluation, and our responses did not include a human fatality. Finally, in absence of a human fatality, the relative percentages of each cost category within years remained consistent among years (Table 42). Average annual repair costs ranged from 91-94% of the average annual total cost of a deer-vehicle accident.

<u>Distribution of accidents and regional trends</u>

The locations of deer-vehicles accidents that occurred during 1975, 1981 and 1987, on state-numbered highways, were obtained from the Illinois Department of Transportation. In each of the 4-county study area, the rise in the frequencies of deer vehicle accidents (Table 43) has been accompanied by wider distribution of accidents (Figs. 16-19). In 1975, accidents in Lake County were recorded in only 2% of the 1,276 km^2 cells that we examined. In contrast, 13% of cells had a least 1 accident during 1987. A similar increase in the dispersion of accidents was documented within Cook County where occurrence of accidents in cells rose from 1% to 10% from 1975 to 1987. In both Kane (<1% to 5%) and DuPage (1% to 5%) counties, a greater distribution of deer-vehicle accidents, was also noted. The percentage of cells in which >1 accident occurred was negligible in 1975 (range 0 to 0.3%), but was substantially higher (range 1.8% to 4.5%) by 1987.

Deer-vehicle accidents from 1978 to 1986 showed highly significant exponential trends in accident frequencies for Cook (F=97.6, P=0.0001), DuPage (F=42.5, P=0.0006), Kane (F=167.2, P=0.0001), and Lake (F=71.4, P=0.0002) counties.

Study No. 104-3: Management Strategies and Experimental Control

Experimental deer herd reductions

Deer reduction at Ned Brown Preserve

Deer at the Ned Brown Preserve were counted annually from aircraft (i.e., initially 2X with fixed-wing, thereafter by helicopter) during 1983 to 1989 (Table 8). Minimum herd size during the first winter (i.e., 1983-84) was 293 deer with the majority (n=258) of animals concentrated on the north half of Ned Brown near Busse Forest Nature Preserve. Thirty-five deer were collected for research purposes (i.e., condition evaluations and translocation survival study) from the Ned Brown Preserve during 1983-84 and 1984-85, prior to initiating formal herd reduction. From 1985-86 to 1987-88, a total of 334 deer was removed from the northern section of the Ned Brown Preserve (Table 44). The target density of 8 deer/km^2 was reached for the entire preserve in 1986-87 and for north half of Ned Brown (including Busse Forest Nature Preserve) in 1987-88; representing the second and third year, respectively, in which deer were removed to reduce population size.

The removal rate using a .243 caliber rifle during the first year (winter 1985-86) of herd reduction at Ned Brown was 62.5 minutes/deer ± 51.5

st.dev. (n=75). Removal rates between the first and second year (58.8 minutes/deer, n=115, winter 1986-87) were not different (p>0.05). However, during the third year of reduction, as deer numbers declined and the surviving deer were more wary, the removal rate was significantly higher ($\underline{x}$=108.1 minutes/deer, n=59, p<0.0001) than during either of the 2 previous years.

The 3 principal objectives of herd reduction at Ned Brown were to: 1) reduce browsing pressure to enable regeneration of forest trees and understory plants, 2) improve average physical condition of the deer herd, and 3) significantly reduce the number of deer-vehicle accidents on nearby roads.

Vegetation analyses at Ned Brown are reported on pages 53-60. Briefly, some responses of plants to lower browsing pressure were evident but the period of evaluation covered during this study was insufficient in length to detect significant recovery of impacted plant communities. It is unknown at this time whether the damage caused by deer to the composition and structure of the understory has permanently altered the system. We can conclude, however, that the plant communities for which Busse Forest Nature Preserve gained ecological recognition, as a dedicated state nature preserve and registered federal natural landmark, have been seriously compromised by the selective foraging of deer.

We monitored selected deer "health" indices by postmortem evaluations of deer that were killed during herd reduction at Ned Brown. Prior to herd reduction, deer at Ned Brown were in the poorest condition among local herds that we evaluated, which suggests that available nutrition at Ned Brown was limiting. Even without substantive recovery of understory plants, we expected average health of deer to increase following herd reduction because available forage would be shared by fewer animals. With the exception autumn 1984-85 where several condition indices exceeded 1986 postreduction values (male fawn, Kistner score and KFI, p<0.02; adult female, KFI, p=0.0161; adult male KFI, p=0.0331), the preponderance of data demonstrated significant increases in deer health (i.e., fat depot) after herd reduction was initiated. Relative to condition indices from female fawns examined prior to herd reduction (i.e., 1984-85), postreduction female fawns during autumn had greater body weight (1987, p=0.0001) and chest girth (1987, p=0.0046); winter female fawns had more fat (1986 & 1987, Kistner scores, p=0.0001), larger girth (1986, p=0.0002), and greater body weight (1986 & 1988, p=0.0001); and spring female fawns during 1986 were heavier (p=0.0122). Post reduction male fawns during winter had greater body weight (1988, p=0.0016), more fat (1986,1987 & 1988 Kistner scores, p=0.0001), and larger girth (p=0.0033), than did prereduction male fawns. In most cases, the sample sizes for male and female yearlings were insufficient for detecting differences in condition among years. Only the KFI for male yearlings during 1986 was significantly greater (p=0.0002) than that of prereduction male yearlings. Post reduction adult females had greater body weight during winter (1986, p=0.0249) and more fat during winter (1986 Kistner score and KFI, p=0.0001) and spring (1986 and 1988 Kistner score, p=0.0001; 1986 KFI, p=0.0001), than prereduction females.

We evaluated deer vehicle accidents on state numbered highways near Ned Brown Preserve, northwest Cook, Des Plaines, and Palos, for 1982 to 1988. Highway lengths, deer-vehicle accident frequencies, and accident rates (deer accidents/1 km highway) are presented in Table 46. Three general trends in accident rates were apparent. In northwest Cook deer-vehicle accidents increased and then stabilized over the 6-year period. Accident rates in both Palos and Des Plaines were relatively stable and vascilated around an average;

years with higher rates were offset by lower rates in subsequent years and visa versa. Deer-vehicle accidents associated with the Ned Brown Preserve herd declined from 1.45 accidents/km in 1982 to 0.42 accidents/km in 1988. The observed decline in accident rate for the Ned Brown area was the only area that was negatively correlated ($r = -0.79$) with the combined total number of deer accidents for the other 3 areas (Table 47). In general, the deer vehicle accident rate at Ned Brown declined by a minimum of 50% during the herd reduction. Additionally, on 2 highway segments that lie adjacent to the area where most deer were removed, accident totals declined from 19 (1985 and 1986) to 4 (1987 and 1988).

Deer Reduction at Chicago-O'Hare International Airport

During autumn 1987, O'Hare Airport administrators committed to the deer reduction plan proposed by INHS (Table 3) and selected a low residual deer population goal (i.e., ≤10 deer remaining on site). A DOC deer removal permit was issued to the Director of the Department of Aviation Safety. Ten potential shooting and capture site were baited with corn and elevated blinds were established at 3 locations where elevated dirt or landfill mounds (i.e., burmes) were present. Burmes were used as backstops to safely stop discharged bullets. After a 15cm snowfall which provided excellent contrast for observability, 66 deer were counted by helicopter on 7 January 1988. Based on this count, our goal was to remove a minimum of 56 deer leaving ≤10 deer on airport property.

Rocket nets were used to live-capture 12 deer. Eight of these deer were translocated to Will County as part of the INHS study on the survival and movements of translocated deer (Jones and Witham 1990). The remaining 4 deer were euthanized by shooting while restrained under the net. Sharpshooters killed 38 deer from elevated blinds and from elevated positions on burmes. Four deer were shot from vehicles at locations where the bait site was positioned near a burme. One additional subadult deer was wounded (1/43, 2% wounding rate) and not recovered after it moved into a location where the discharge of a second bullet would have been unsafe. A total of 54 deer was removed using rocket nets and sharpshooters.

From 1-3 sharpshooters were at bait sites a total of 112.25 hours (25 separate episodes). The removal rate for the entire period was 0.37 deer/hour. Removal rates, determined for 5 consecutive 20-hour intervals, declined sharply after 60 hours (0.35, 0.7, 0.7, 0, and 0.15 deer/hr) (Fig. 20). The regression of the cumulative number of deer killed by sharpshooters on cumulative shooting hours was best described by the power function $y=0.746X^{0.86}$, $r^2=0.94$, df=23 (Fig. 21)

The sex and ages (cementum annuli counts and wear/replacement methods were used to age adults) of deer removed from the airport indicated that most deer on site were < 2 years old. The oldest deer removed were a buck and a doe that were both aged at 6 years (Fig. 22). Age specific fetal rates were determined from counts of fetuses during postmortem evaluations. All 9 female fawns were aparous. One yearling doe carried twin fetuses. The fetal rate for 14 adult does was 2.14. Based on these data, the female deer removed from the airport (i.e., live capture and shooting) would have produced 42 fawns during May-June 1988.

The carcass of 1 yearling doe was given under IDOC permit to the Field Museum of Natural History for mounting and display. INHS personnel performed postmortem examinations on the remaining 45 carcasses. Forty-four carcasses were processed for fees totalling $2,033. by a state-licensed meat packing plant. The 44 deer produced 2,164 lbs of ground venison that was donated to the Chicago Food Depository for distribution to the needy of Chicago. Market value of the ground venison was $ 8,115.00 (based on $3.75/lb retail value of commercial ground venison, 4/14/88, Czimer Foods, Lockport, Ill.). One deer with a fractured and infected foreleg was unfit for human consumption and was buried.

O'Hare personnel participated in the live capture, handling, and transport of deer. The Department of Aviation Director assisted in counting deer during 1 aerial census. O'Hare personnel baited sites and shot 1 deer from an elevated blind. Chicago Animal Control personnel visited the INHS field office to discuss deer capture, and visited bait sites at O'Hare.

A helicopter census was conducted on 7 April 1988 under conditions of poor observability; no snow cover was present. Five deer were observed in 1 group and were relatively easy to distinguish; however, it would have been difficult to detect deer that remained motionless in cover.

Deer reduction at Ryerson Conservation Area

Deer numbers at Ryerson were reduced by live capture and shooting during 14 February to 1 May 1989. Five Stephenson box traps were used each day to live capture deer, except during the first 2 days when only 3 traps were available and during 10-14 March when trapping was temporarily suspended. Sharpshooters shot deer during 21 nights from 22 March to 16 April. Records were incomplete on efforts to capture deer by remote chemical injection; however, no deer were darted on 3 occasions during 2-8 March. Three (19-23 March) attempts to capture deer using a drive net were unsuccessful.

A total of 34 captures were made in box traps. Six does (5 fawns and 1 yearling) were radio-collared and released on site. Two of the marked does were recaptured once and 1 was recaptured twice. Three deer escaped from traps before they could be restrained by handlers. Twenty-one deer were considered for translocation. Among these deer, 2 does (1 fawn and 1 adult) died during handling and 1 adult doe that tested positive for Lyme disease was euthanized. The remaining 18 deer were translocated to the Wildlife Prairie Park enclosure near Peoria, Illinois. Post release deaths within the enclosure were 2 deer (1 male fawn, 1 adult doe) at < 1 week, 1 adult male at < 1 month, and 1 adult female at 4 months. At least 2 deer that were translocated as fawns escaped from the enclosure and were killed during autumn 1989; a yearling doe with a bullet wound (before hunting season) was dispatched by state personnel in September and a yearling buck was legally taken by an archer in October. Nine translocated does (6 adult, 2 yearling, 1 fawn) survived through the May-June fawning period and potentially could have given birth. Known births by does within the enclosure during 1989 were 3 live and 1 stillborn fawns.

Excluding deer that escaped or were recaptured, mean trapping success was 0.08 deer/trap night. This value was reduced because trapping was continued well after its effectiveness declined. A more representative trapping rate, based on 191 trap nights during which all deer were captured, was 0.14 deer/trap night. A logarithmic function [$Y = -6.48 + 6.18 (\ln(x))$, $r^2=0.94$, $df=74$], best describes the relationship between the cumulative number of deer captured and cumulative trap nights, indicating that the effectiveness of live capture declined over time (Fig. 23). We evaluated this change in trapping success by determining trapping rates for consecutive intervals of 20 trap nights. Rates declined from 0.33-0.35 to 0.05 deer/trap night during the first 5 intervals (i.e., 100 trap nights), stabilized during the next 4 intervals at 0.10-0.05 deer/trap night, and then dropped to zero (Fig. 24). Over 50% of deer were captured by the 36th trap night and 90% of captures were made by trap night 136.

Sharpshooters started on 22 March following a decrease in trapping success. Deer were shot during early mornings and late evenings when the preserve was closed to the public. Thirty-nine deer were killed during 100.5 hours ($\underline{x}$=0.39 deer/shooting hour) and none were wounded. The regression of the cumulative number of deer shot on cumulative shooting hours was a power function ($y=0.145X^{1.407}$, r^2=0.97, df=20), indicating that shooting efficiency increased over time (Fig. 25). The rates of deer removed by sharpshooters during 5 consecutive 20-hour (range 19-22 hours) intervals ranged from 0.20 to 0.75 deer/hour (Fig. 26).

Removal rates varied depending on whether 1 or 2 sharpshooters were used. One sharpshooter ($\underline{x}$=0.567 deer/hr) was more efficient than 2 sharpshooters ($\underline{x}$=0.308 deer/hr). Although there was no difference between the average number of deer removed daily by 1 ($\underline{x}$=1.85 SE 0.45 deer/day, n=13 days) or 2 sharpshooters ($\underline{x}$=1.88 SE 0.58 deer/day, n=8 days), the mean number of hours/day combined for 2 sharpshooters ($\underline{x}$=6.44 hrs/day) was 71% greater than for 1 sharpshooter ($\underline{x}$=3.77 hrs/day). Thus, a single sharpshooter was more efficient than 2 sharpshooters because he took the same number of animals per day in less time than 2 sharpshooters combined.

Age specific fecundity was assessed from fetal counts of does that were field dressed or autopsied. Among 13 adult does, 12 had twins and 1 had triplets ($\underline{x}$=2.08 fetuses/adult doe). Each of 2 yearlings produced singletons and no fawns were pregnant. The fetal sex ratio for all does examined was 1:1 (15 females:14 male fetuses, 0.517 female).

First year costs for the live capture of deer were divided between the forest preserve district and the plaintiffs by court agreement. Live capture required 1,046 LCFPD staff hours (average wages and benefits = $16.45/hr) totalling $17,206.70, or $627.29 for each of the 27 deer that was captured and handled. Exact expenditures by the plaintiffs were not available; however, a minimum of $15,000.00 was spent on veterinarian services, transport of blood samples for analysis, contractual services for an animal transport specialist, equipment, and supplies (LCFPD pers. commun.). On a per deer basis, estimated minimum cost to the plaintiffs was either $555.56 (n=27) or $714.29 per deer.

The cost of shooting 39 deer was $11,192.15, or $287.98/deer. This total is a composite of 3 cost categories; LCFPD staff hours averaging 10.87 hours/deer (62%), contractual services for 2 sharpshooters (23%), and processing of carcasses in a state-inspected meat packing plant at $0.50/lb dressed weight (15%). The estimated value ($3.75/lb) of the 2,513 lbs of ground venison that was donated to local charities was $ 9,423.75. A minimum of $43,402.96 was spent by the LCFPD and the plaintiffs to live trap, translocate, and shoot deer on Ryerson during winter 1989.

The Chicago media (i.e., print, radio, and television) produced >100 reports on various aspects of the Ryerson deer program during a 19-month period (November 1987 to May 1989). The majority of reports coincided with the height of controversy (i.e., public demonstration, litigation, and initial deer herd reduction) during January-March 1989.

<u>Translocation of Metropolitan Deer</u>

Jones, J.M., and J.H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildl. Soc. Bull. 18:434-441. (Appendix G).

Abstract: We evaluated the survival and movements of white-tailed deer captured in the Chicago Metro area and translocated to a more rural site in

Will County, Illinois. Most deer were captured with rocket nets, excepting 2 with drive nets, and 1 by remote chemical injection. Translocated does (N=25) were radio marked and moved in individual transport crates or collectively in a darkened horse trailer. Translocated bucks (N=25) were treated similarly except marking was by ear tags only. Metro resident does (N=12) were live captured, radio marked, and released on site. Estimated annual survival of resident adults (0.73, n=12) was higher ($\underline{z}$=2.01, p=0.02) than for translocated adults (0.34, n=12). The annual survival of translocated doe fawns (0.44, n=10) was not different ($\underline{z}$=0.43, p=0.33) from the survival rate of translocated adult does. Twelve (48%) translocated bucks were known to have died during the first year post-release; 11 of these were shot by hunters. Translocated does had higher, but not significantly different (p>0.05) mean values for annual area of use, activity radius, and longest distance from the release site than the resident does. Seven (32%, 5 fawns and 2 adults) of 22 translocated does moved >5 km from the release site during the first year post-release. The longest movement was by a fawn, captured in southeast Cook County, which in 2 months traveled >43 km (straight line) from the release site to within 4 km of it's capture site. The principal reason for translocating deer from metro preserves to rural locations is to reduce local abundance without killing deer. Translocation may result in the deaths of >50% of these deer during the first year post-release. If reduction of deer numbers is warranted at specific sites in northeastern Illinois, alternative methods of herd reduction should be evaluated. Evaluation of live trapping and translocation should consider the probability of deer survival relative to the reasons for selecting this method.

<u>Alternatives: Population Control and Damage Abatement</u>

Deer management and damage abatement alternatives have been comprehensively reviewed previously (Cypher and Cypher, 1988; Ellingwood and Caturano, 1988; Mich. St. Univ. Deer Damage Comm., 1989; Minn. River Valley Deer Manage. Task Force, 1990; Brush and Ehrenfeld, 1991). Although each review includes some differences, most deer management alternatives are typically divided into 8-10 general categories (after Minn. River Valley Deer Manage. Task Force 1990):

<u>Indirect</u>	<u>Direct</u>
Fences/exclusion	Fertility control
Repellants	Trap and transfer
Habitat manipulation	Trap and kill
Artificial feeding	Hunting
No action	Sharpshooting
	Reintroduce predators

Other literature have focused on selected alternative methods. Rongstad and McCabe (1984) and Scanlon and Brunjak (1984) summarized techniques used to capture and immobilize whitetails, respectively. Various methods used to remove and handle large mammals including deer were discussed by Riney (1982). Criteria for translocating deer were defined by Nielsen (1988) and Rongstad and McCabe (1984). Kirkpatrick and Turner (in press?) reviewed fertility control as a means for regulating deer abundance. Population management, repellents, and fences to reduce deer depredations to agriculture have been described extensively (Caslick and Decker 1977, McAninch et al. 1983, Matschke et al. 1984, Craven and Hygnstrom 1988, and others).

No single method will achieve deer management objectives for all situations that occur in metro environments--each method has advantages and limitations which must be considered relative to site objectives. Although many management options can be effective when conditions enable reliable access to deer (e.g., confined deer populations in zoological institutions or special study areas), the efficacy of each option declines (at different rates) when the ability to remove, capture or treat deer is restricted by factors such as increased size of an area, complex physiography (e.g., rugged topography) or vegetation (e.g., swam or marsh communities), regular immigration from nearby refugia, economics, societal preferences and/or legal mandates.

We found it useful to consider alternative methods of deer management and damage abatement in 2 ways. The first approach (Appendix H), developed by J.M. Jones (unpub. report), divided alternatives into 4 primary categories based on whether the method is for population control and/or damage abatement and whether deer are killed. The latter is included because killing deer is perceived as a major threshold action among metro residents. Exclusive of this emphasis on mortality, this approach is similar to other reviews of deer management options and was written for nontechnical audiences (e.g., publics, landowners, board members) who have rudamentary knowledge of deer biology and wildlife management. The second approach divides deer management options into more discrete segments using a step-down or outline format (Table 48). The primary objective is to develop a comprehensive list of deer control methods for agency or professional reference. New references are added as studies are published. Reviews of deer management options are sometimes criticized on the basis that all potential methods were not considered. We believe that maintenance of an open and ongoing review of deer management options will help to negate criticism because there is opportunity for anyone to provide examples (i.e., citations) that support the inclusion of additional methods. This places responsibility on the complainant to provide information, is nonthreatening, and reduces conflict.

Study No. 104-4: Data Management, Analyses, and Reporting

Database management and transfer of records to IDOC.

The INHS Urban Deer Research Program overlapped the initiation of the IDOC Urban Deer Project which was designed to: 1) implement INHS preliminary recommendations on a short term basis, 2) be the IDOC specialist on urban deer management in northeastern Illinois, and 3) define long-term direction for the IDOC on urban deer issues. The IDOC Urban Deer Project established their office within the same building (i.e., Cook County Forest Preserve District-New Division Headquarters) as the INHS Urban Deer Research Program. This enabled equipment, data, reports, and other INHS research information, to be transferred directly to the IDOC for varied uses in urban deer management.

The INHS Urban Deer Research Program started in 1983 using an Apple IIE personal computer. Some of the original data files are still retained on 5.25" floppy diskettes formated for the Apple IIE which was transferred to the inventory of the IDOC Urban Deer Project manager. We upgraded the field office computer to an IBM AT/XT-286 in FY87, and then again in FY89, to an IBM PS-2. The latter remains as the principal office computer for the IDOC Urban Deer Project. Some research data sets were analyzed by the University of Illinois Statistical Laboratory, Champaign, under contractual services. The university main frame computer was needed to analyze selected, large, data sets that were developed early in the research program. However, this situation was less than satisfactory as we experienced numerous problems in communicating our needs to statistical consultants and much time was spent checking both data entry and data analyses for errors. The current database management and statistical analyses capabilities of personal computers and software, has reduced this problem to an insignificant level for the IDOC Urban Deer Project. The IDOC Urban Deer Project manager can access INHS data as needed or desired, although all such records were not retained in a standardized database management format.

Transfer of project information to organizations and publics

The number of organizations, publics, and media contacts made by INHS personnel over the course of this study is uncountable. A partial list of contacts included:

Print media: Associated Press (2), Chicago Sun Times (6) Chicago Tribune (13), Chicago Department of Aviation Public Relations (4), Chicago Reader (3), Daily Herald (17), Elgin Courier (1), Glencoe News (1), Hammond Times (2), Illinois Game and Fish Magazine (2), In Vermont (1), Joliet Herald (1), Lake Geneva Chronicle (1), Lerner publications (1), Life Newspaper (1), Outdoor Notebook (3), Pioneer Press (7), Southtown Economist (2), Waukegan News Sun (5), World Book Encyclopedia (2), Contact name not recorded (27), Radio media: WBBM (1), WIND (1), WGN (1)

Television media: Channel 2-CBS (3), Channel 5-MAQ (5), Channel 7-WLS (3), Channel 9 (2), Channel 32 (2)

Presentations: Auroraland Bowhunters (1), Barrington Natural Historical Society (2), Cook County Forest Preserve District (2), Chicago Botanical Society (1), Governors State University (2), INHS/IDOC Pittman-Robertson meeting (4), INHS Urban Deer Project Community Liaison Committee (3), Illinois Nature Preserves Commission (2), Issac Walton League (1), Lake County Forest Preserve District (2), Maine Township High School Southfest (1), McHenry County Conservation District (1), Midwest Deer and Turkey Study Group (1), National Urban Wildlife Symposium (1), Natural Areas Conference (1), Ninth Great Plaines Animal Damage Control Conference (1), Northeastern Illinois University (3), Prairie Woods Audubon Society (1), Triton College (1), Wildlife Society-Illinois Chapter (1), Organizations not recorded (7)

Reports produced from this study:

Quarterly progress reports (18), Annual progress reports (6), INHS Reports (1), Project Completion Report (1),

Cisneros, J.G. 1987. Helminthic and protozoan parasites of white-tailed deer in urban areas of northeastern Illinois. Unpub. Rep. Sub. to Ill. Natural History Survey-Wildl. Sec., Champaign. 15pp.

Witham, J.H., and J.M. Jones. 1987. Cooperative urban deer management in Cook County, Illinois. Ill. Natural History Survey-Wildlife. Unpub. rep. 36pp.

Witham, J.H., and J.M. Jones. 1987. Recommendations for deer management on O'Hare International Airport. Ill. Natural History Survey-Wildlife. Unpub. rep. 21pp.

Witham, J.H., E.A. Cook, and J.M. Jones. No date. White-tailed deer habitat change in metropolitan northeastern Illinois. Unpub. manuscript. 14pp.

Publications produced from this study:

Jones, J.M., and J.H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildl. Soc. Bull. 18:434-441.

Watkins, B.E., D.E. Ullrey, J.H. Witham, and J.M. Jones 1990. Field evaluation of deuterium oxide for estimating body composition of white-tailed deer (Odocoileus virginianus) fawns. J. Zoo and Wildl. Medicine. 21:453-456.

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DISCUSSION

Deer health and insular preserves

Numerous workers have evaluated the relative health or condition of deer at 2 or more rural locations separated by distance (Rosen and Bischoff 1952, Weckerly et al. 1957, and others) or by barriers (Klein 1964). Geographically separated subpopulations may differ substantially in average morphometry, physiological status and/or reproductive performance if interchange by deer between areas is restricted and if areas vary in habitat quality. Such interregional differences in size, health, and productivity of deer typically result from site-specific nutrition which varies by location within and among years. Deer on a chronic submaintenance diet will be physically smaller, accrete less fat, catabolize fat reserves earlier, and produce fewer offspring than will deer on a higher nutritional plane.

Because soils are fertile and diets are frequently augmented by cultivated crops (e.g., corn, soybeans) high in digestible energy, white-tailed deer in the midwest agricultural region typically have rapid growth, seasonally abundant fat stores, and high fecundity (Gladfelter 1984). The morphometry of deer in Northwest Cook County and Non-Cook counties (i.e., Lake, DuPage, and Kane), and to a lesser degree in Palos, were similar to those of robust farmland deer. For example, mean winter girth and hindfoot of deer from Palos/Northwest/Non-Cook, approximated measurements reported by Nixon (1989) for male (girth = 81.2 cm, hindfoot = 45.4 cm) and female (girth = 78.6 cm, hindfoot = 43.8 cm) fawns that were live captured on central Illinois farmland habitat during winter. Mean autumn/winter total body weights of robust CMA fawns and yearlings were comparable to weights of fawns (male=45 kg, female=41 kg) and yearlings (male=74 kg and female=62kg) in Iowa (Kline 1967). Reproductive performance of midwestern whitetails has been reviewed extensively (Harder 1980, Gladfelter 1984, and Stoll and Parker 1986) and is a function of doe nutrition. Higher level nutrition increases pregnancy rates of fawns and fetal rates (fetuses/doe) of yearlings and adults. Fawn pregnancy and fetal rates for Palos/Northwest/Non-Cook areas were 43-61% and 43-78%, respectively. Collectively for Palos/Northwest/Non-Cook areas, fetal rates were 1.46 (19 fetuses/13 does) for yearling and 2.19 (35 fetuses/16 does) for adult does. Fetal rates of these adult does were within ranges of fecundity of does from higher quality habitats in Ohio (Stoll and Parker 1986). Furthermore, the 16% (6/38) twinning rate by fawns and triplets produced by 5 of 10 adult Northwest/Non-Cook does are findings consistent with deer on a high nutritional plane.

The relatively poor quality of deer on Ned Brown and Des Plaines Preserves contrasted significantly with the more robust attributes of deer on Palos/Northwest/Non-Cook. These differences were acute among fawns, the cohort most sensitive to nutritional deficiency. Skeletal measurements, body weight and girth of fawns in Ned Brown/Des Plaines were always ≤ those of Palos/Northwest/Non-Cook. Ned Brown fawns had ample fat depots during autumn; however, these energy reserves were depleted more rapidly by winter-spring than were fat reserves of fawns from other areas. Obligate lipogenesis, an overwintering survival strategy of whitetails in northern latitudes, may occur during autumn among deer on submaximal diets. The cost of this strategy is reduced physical growth resulting in relatively fat, smaller deer with better odds for surviving winter than those of larger leaner deer. Low body fat, girth, and body weight of Ned Brown/Des Plaines prepartum adult does during winter-spring was consistent with relatively poor nutrition which may have contributed to the small size of fawns through lower weight of fawns at birth, later parturition, or reduced lactation. Stoll and Parker (1986) listed ranges of fecundity for fawn (0.06-0.18), yearling (1.27-1.56), and adult does (1.27-1.80) on poor quality habitat. Fecundity of Ned Brown/Des Plaines does were at the lower end of these ranges; no fawns conceived, multiple fetuses for yearling does were rare (3/18 does), and about one-half (22/43) of the adult does had ≤1 fetus.

The disparity in "relative health" among deer on adjacent CMA preserves should be considered when developing management strategies for CMA deer. At the time of this evaluation, CMA deer were products of a "do nothing" strategy (i.e., letting Nature takes its course). This passive approach among deer management alternatives relies on natural limiting factors (e.g., weather, nutrition, pathogens, density dependence) and existing indirect human influences (e.g., vehicle accident mortality, land use) to regulate deer abundance within limits of human tolerances. If a specific level of deer health is a management objective for deer on metro preserves (e.g., no starvation, maintaining suboptimal condition of does to effect lower recruitment) then a "do nothing" strategy may not achieve this objective.

Our results demonstrating substantial differences in health and reproductive performance among deer from areas in close proximity, suggest that workers developing deer demographic profiles for regional population models should be cautious when making comparisons. Selection of data from one site may be skewed relative to more representative regional averages.

Most urban environs typically lack the normal complement of natural mechanisms that limit deer abundance. Local habitats have been extensively altered by humans, and surprisingly, many of these perturbations favor deer survival. In such settings, choices made by individuals and communities are the fundamental causes of deer-human conflicts.

Insular refuges are a paradox of preservation and development. County forest preserves form the principal deer habitat in urban northeastern Illinois. Counties have acquired large areas of non-developed and rural landscape for the "purpose of protecting and preserving the flora, fauna, and scenic beauties...in their natural state and conditions (Wendling et al. 1981). Because of their aesthetic quality and/or higher economic value, private lands around many urban forest preserves have been extensively developed for residential, commercial, and industrial uses. Deer concentrate on preserves, but readily cross highways seeking resources on adjacent private properties. Urban forest preserves will only become more insular over time, thereby, contributing to the escalation of deer-human conflicts.

Demographic responses of deer on quasi-insular preserves are similar to those of deer that are protected from natural predators and hunting. In the

CMA, large predators are absent. Winter weather is harsh but within the normal limits of the northern range of the white-tailed deer. In these metro preserves, deer survival and productivity fluctuate predominately under the constraints of weather and interannual variations in available nutrition. In rural settings, temporal increases in deer abundance are more likely to be offset by a combination of dispersal and hunter harvest. However, on relatively small, non-hunted, insular sanctuaries the negative consequences of increased deer abundance are acutely accentuated. High deer numbers on metro preserves will decline only as a result of dieoffs triggered by severe weather or disease, or both; or from reductions caused by protracted submaintenance nutrition resulting from degraded plant resources caused by foraging deer. Eventual reduction of numbers of deer by malnutrition best characterizes the conditions that existed at Ned Brown and Des Plaines preserves. Our evaluation of observed deer densities in the CMA suggest current concern for at least 12 of the 52 preserves surveyed that represent $92km^2$ (25%) of the total preserve area.

Prognosis: Plant recovery at the Ned Brown Preserve

Understory recovery in Busse exclosure

Our analyses were hampered by the phenological stage of the understory at the time of sampling; spring ephemerals were gone in 1984 and declining in 1987, and woody plants did not have fully developed leaves in 1986. Although visual comparison of the exclosure and control plot reveals obvious differences and substantial regeneration within the former, stem density and percent cover data show few trends indicating substantial recovery of desirable herbaceous and woody species over the years. In hindsight, measurement of the height, size, and/or robustness of the understory plants, excluding unimportant species such as woody seedlings and unpalatable plants, would have been desirable. The latter measurements would have complimented density measurements and made possible quantification of differences between plots. Plants within the exclosure were of increased vigor and stature, a fact only hinted at by percent cover data. The measurements presented herein do not convey that the palatable plants within the control plot tended to be short (i.e., generally < 15 cm); however, the inverse relationship of woody stem density to woody percent cover in the exclosure, as compared to the control plot, indicates the small stature of woody plants (i.e., woody seedlings) in the latter. Percent cover measurements were selected initially with the hope that they would reflect differences in plant size but they more sensitive to differences in time of sampling and the phenological stage of plants during the spring development than density measurements.

Despite these limitations, some signs of regeneration in the understory vegetation were evident. The ratio of herbaceous stem density within the control plot to the herb stem density in the exclosure showed a definite decline over time for all herbaceous species, excluding grasses, sedges, and Allium spp., and for individual species (i.e., woodland knotweed). Percent cover data exhibited a similar proportional trend for white adder's tongue which was the first plant to rapidly increase in size and abundance upon exclusion of deer browsing.

Although detection of trends that would indicate marked regeneration of desirable understory species was complicated by phenological considerations, this lack of notable regeneration lends urgency to the criteria used for identifying the need to reduce deer numbers and browsing intensity. It is apparent that regeneration of the heavily browsed Busse Woods understory will be slow under the closed canopy and in the absence of an extensive, and probably costly, understory restoration program. The full extent of understory recovery possible in the absence of deer browsing has probably not been realized in Busse Exclosure to date; full potential for recovery is impossible to predict at this time. Only continued monitoring will provide answers to questions on what species will return or will never return, how long the return to a "normal" successional pattern will take, and will more aggressive exotic species become a problem. Understory vegetation is inherently limited and determined by sunlight penetration of the canopy, and successional encroachment of sugar maple into oak-dominated woodlots can cause marked changes in understory species composition, structure, density, distribution, etc. (McIntosh 1957). It is apparent that if closed canopy woodlots, similar to Busse Nature Preserve, are allowed to be extensively degraded through excessive browsing, reduction of deer numbers in itself will not result in a rapid increase in the number, vigor, and distribution of understory plant species. Based on the Busse exclosure data, it appears that even in the absence of browsing, understory recovery will be a slow increase in the size of the remnant woody seedlings and basal sprouts and a slightly quicker increase in the stature, numbers, and distribution of some herbaceous species. There is little evidence that the unpalatable species (i.e., wild garlic, wild leek, grasses, and sedges) or exotic species (i.e., buckthorn, *Rhamnus cathartica*) will become more widespread or dominant in the understory. Although undoubtedly given a competitive advantage over species heavily browsed by deer, the unpalatable species are under similar constraints of sunlight penetration and habitat requirements. This may not be the case with more tenacious exotic species (i.e., garlic mustard, Alliaria officinalis) which may be an "increaser" species in degraded forest understories (i.e., overbrowsed) even under an essentially closed canopy; fortunately this species has not, thus far, become well established in the nature preserve.

Development of methods/indices that will eliminate or minimize interannual phenological differences is required; a simplistic ratio of control plot measurements divided by similar parameters measured in the exclosure shows some promise in analyzing trends (e.g., in stem density of herbaceous species) over time. Regeneration of the understory vegetation after exclusion may follow the theoretical curves shown in Figure 26. As an example, the stem density of the understory plants should be the same for the exclosure and control plot if the basic premise of similarity of the 2 plots, essential for use of exclosures, is fulfilled. Therefore, at the time of elimination of browsing pressure upon the enclosed vegetation, the ratio of control plot to exclosure stem density would approximate one. Continued browsing pressure upon the control plot vegetation and regeneration within the exclosure would cause a greater disparity between the stem densities of the 2 plots, and resultantly the ratio declines over time. The decline would be finite as the exclosure vegetation recovered to the fullest extent possible under current environmental conditions and previous impacts of degradation (i.e., some species may have been extirpated due to browsing). Thus, a leveling of the theoretical line would be expected (Line A on Figure 26). However, the reduction of deer numbers outside the exclosure, such as performed at Busse Woods, would presumably allow some eventual regeneration of the control plot plants (Line B on Figure 26) and decrease the disparity between plots. Since the control plot would be open to continued (but less intense) browsing by deer, plant recovery would not mirror that of the exclosure and would be relatively prolonged. Conversely, a woodlot with a more open canopy or intensively managed for understory regeneration (e.g., prescribed burning to stimulate growth and to eliminate saplings of shade-tolerant species such as sugar maple, and reintroduction/seeding of former understory constituents) would probably exhibit understory recovery more quickly (Line C, Figure 26). However, efforts to stimulate understory development in the absence of management of deer numbers may provide less than desirable results (Behrend and Patric 1969); deer densities as low as $10.4/km^2$ (Behrend and Patric 1969) and $15.4/km^2$ (Tilghman 1989) may suppress tree seedling development in forests extensively managed for understory development and regeneration. Delaying deer reduction programs until forests are severely degraded only increases eventual expenditures, not only for deer removals, but also any subsequent understory restoration projects.

Establishing an exclosure in a woodlot exhibiting the initial stages of overbrowsing (i.e., prior to the selective elimination, or reduction in vigor, of more palatable species and creation of a browseline) can be beneficial. The disparity between understory vegetation between the exclosure and the overbrowsed control plot would increase rapidly as deer numbers, and presumably browsing pressure upon the control plot, increased and the exclosure vegetation recovered relatively quickly due to early protection. However, the use of exclosures to document deer damage to native vegetation may be too slow to determine an immediate need to reduce deer numbers. Vegetation analyses that focus on key indicator species, endangered or threatened plants, or on relative comparisons between overbrowsed areas and similar areas nearby that are not being impacted by deer may more quickly identify immediate management needs.

Methods of analyzing deer-vegetation interactions must be realistically evaluated in light of the clearly stated objectives for implementing such studies. For example, the use of exclosures as educational tools can be immeasurably beneficial in situations where the actual impact deer are having upon their food resources is questioned, but the size and shape of exclosures for educational purposes and qualitative assessments only would not necessarily be the same as those designed for quantitative measurements. The size, maintenance, and monitoring frequency of deer exclosures is also contingent upon time, personnel, and monetary constraints. Further, the community or vegetation types and the objectives of the vegetation analyses should be considered when determining the size, shape, and sampling of an exclosure. Size of homogenous areas in terms of microenvironmental factors of topography, soil moisture, soil type, drainage, leaf litter depth, canopy closure, and proximity to forest edge or human disturbances will partially dictated the size and orientation of the exclosure and a comparable control plot. If the exclosure study is to emphasize comparison of key indicator species, the parameters to be measured and the characteristics (e.g., growth form, distribution, clumping) of these species will be important considerations.

Interannual comparisons of the distribution, abundance, and size of understory plants is complicated by differences in weather between years. Problems with using spring ephemerals as indicator species are further compounded by the need to catch them at nearly the same phenological stage each year. Subjective evaluation of the understory during the spring may be more accurately predicted by augmenting such observations with cumulative weather data (Abrami 1972).

Busse Nature Preserve - plants < 1m

No information exists on the former herbaceous species (e.g., composition, cover, abundance, density) in the nature preserve prior to the obvious impacts of excessive deer browsing upon the understory. This lack of previous quantitative measurements, and the unknown regenerative capacity of herbaceous species that have been continuously and heavily browsed (i.e., foliage and flowers removed annually), preclude hypotheses on the expected recovery of the understory to a former "natural" state, similar to Busse Woods South. However, the lack of definite increases in the percent cover and density of plants < 1m in the nature preserve over 4 years of reduced browsing pressure indicates that regeneration of the lowest stratum of the understory will take many years. Although some herbaceous species appear capable of increasing in distribution (e.g., T. grandiflorum) under the current browsing pressure and herbaceous species numbers increased between 1986 and 1987, the extent and speed (and species capable) of recovery can only be determined by continued monitoring while maintaining deer at current numbers. Based on 6 years of data on the control plot in Busse Woods North, herbaceous plants exhibit minimal changes under the current browsing regime.

Loss of "normal" seedling/sapling recruitment, selective inhibition of more palatable woody understory species, and the resultant alternation of natural successional trends by high deer numbers, or low-moderate numbers over many years, has been well documented in a variety of forest types (Behrend and Patric 1969, Harlow and Downing 1970, Ross et al. 1970, Marquis and Grisez 1978, Anderson and Loucks 1979, Hanley and Taber 1980, Shissler and Seidel 1984, Strole 1988, Tilghman 1989). Ross et al. (1970) determined that regeneration of the understory in a red pine (Pinus resinosa) forest was inhibited by estimated deer densities of 15-29 deer/km^2 for $\geq$ 10 years; normal successional trends and recruitment of saplings into the understory only occurred after several years of total exclusion. Tilghman (1989) found that the number of tree seedlings (> 0.3 m and < 0.9m) species declined in uncut Allegheny forest plots as deer densities increased. Preferential browsing by deer may hasten the encroachment of sugar maple in oak-dominated woodlots in central Illinois and prevent tree seedlings from growing into larger size classes (Strole 1988). Shissler and Seidel (1984) found that heavily browsed woodlots of $\geq$ 50% canopy closure exhibited "reversed secondary succession" as woody recruits were nonexistent and grasses dominated the understory. If high densities of deer are sustained by mild winters and abundant mast crops, tree seedling/sprout composition, abundance, and recruitment is reduced; preferred species may be eradicated and all species, even those presumed to be of low palatability, are impacted. In Busse Nature Preserve, successional invasion by sugar maple and other shade-tolerant species has been interrupted; however, it appears that high deer densities also curtailed the potential spread and increase in abundance of unpalatable exotic woodies (i.e., Rhamnus cathartica).

The loss of woody species recruitment for > 6 years will undoubtably have a profound effect upon the future composition and structure of the nature preserve. Although small first year seedlings of elms and ashes are periodically abundant, observations indicated that these seedlings survived <1 year under lower deer densities and provided no woody recruits. Observations of large localized groups of oak seedlings in 1988 and 1989 can be viewed optimistically as an initial sign of understory recovery; lowering deer numbers may allow some acorns to germinate, as opposed to being quickly consumed by deer (or squirrels) and allow some seedings to be unbrowsed. Based on the observed regeneration of understory species in our deer exclosure, it is evident that once a closed-canopy woodlot is allowed to be severely degraded by deer, recovery will be slow and will be predictably delayed even under light browsing pressure. If the deer herd is maintained at the current density and herbaceous browse alternatives do become more abundant, seedling/sapling recruitment may gradually exceed current levels.

Busse Nature Preserve - Shrubs and Saplings > 1m

Previous vegetational surveys in Busse Nature Preserve, as part of the 1976 Natural Areas Inventory, estimated 5,600 and 5,400 shrub/sapling stems > 10 cm DBH per hectare in the dry-mesic upland and mesic upland forest types, respectively. Dominant species were *Fraxinus pennsylvanica*, *Corylus americana*, and *Viburnum rafinesquianum* in dry-mesic forest, and sugar maple dominated (i.e., 50% of stems encountered) the mesic upland forest. Estimated densities of woody stems < 10.2 cm DBH in Busse Woods South were 4,624/ha in 1985 and 3,934/ha inn 1986; the dominant species was sugar maple during both years. Stem densities in the nature preserve (i.e., ≤ 2,088 live stems/ha) were much lower during 1985-87 than the previous NAI estimates and concurrent estimates for Busse South. Although sugar maple and ash are still dominant understory constituents, dead and leafless shrubs and saplings are most abundant within the nature preserve. The abundance of small (i.e., < 2.5 cm DBH) dead stems cannot be directly attributed to overbrowsing by deer; shading and other forms of natural attrition may be partly responsible. Leafless, and obviously browsed stems were not distinguished from dead stems during data entry in the field, but their presence further exemplifies the impact deer had upon the normal woody recruitment/successional patterns in the nature preserve.

Estimated woody stem densities for the < 1m, > 1m and <2.5 cm DBH, and 2.5-10.2 cm DBH size classes were 32,000-33,000/ha, 2,827-3,360/ha, and 1,107-1,264/ha, respectively, in Busse Woods South. This typical inverse relationship between stem density and size class was not observed in the nature preserve; density values (per hectare) in Busse Nature Preserve were 23,000-36,000 shrubs/saplings < 1m (excluding first year seedlings), 648-816 live shrubs/saplings > 1m and <2.5 cm DBH, and 1,040-1,272 live saplings between 2.4 and 10.2 cm DBH.

Although both, Busse Woods South and the nature preserve, can be considered mature second growth with some history of disturbance in the past, Busse South appears to be successionally older. The high importance value of sugar maple in Busse South is probably indicative of advanced succession; oak-dominated mesic woodlots in northeastern Illinois that were historically maintained by periodic fires exhibit successional trends of canopy oaks being replaced by more mesic sugar maples (Stearns and Kobringer 1975) with a shade tolerant understory of sugar maple, basswood, and ironwood. Percent canopy closure, number of canopy species, or forest soil types were not markedly different between woodlots; these seemingly minor difference fail to explain the obvious lack of understory vegetation in the nature preserve. Conversely, the greater number of soil types and the slightly more open canopy and less shading of the understory vegetation due to sugar maple being less prevalent in the nature preserve would presumably allow a greater diversity and abundance of understory plant species and greater woody regeneration in the latter.

High deer numbers have apparently caused the lack of seedlings/sprouts ≤ 2.5 cm DBH (especially those with canopies within the deers reach) in the nature preserve directly by causing the mortality of individual plants via excessive and continual browsing of leaves and twigs and indirectly by suppressing recruitment from smaller size classes. The same holds true for the larger sapling class (2.5-10.2 cm DBH); direct and selective bark peeling kills saplings directly and the lack of potential replacement saplings will affect the future composition of the lower canopy trees. Deer related sapling mortality is undoubtedly augmented by natural causes such as shading and harsh weather.

The openness that currently characterizes the nature preserve's understory may be perpetuated under the present browsing pressure due to the degraded forage base. Loss of desirable shrubs and saplings accessible to deer and continued growth of larger saplings out of the deer's reach will exacerbate the open appearance of the understory. Natural attrition among the canopy trees amy allow localized resurgence of shrubs and saplings, but the species composition cannot be predicted at this time. In the absence of an understory management or restoration program, recovery will probably involve the most browsing resistant species; normal successional patterns may never return if exotic species are allowed to dominate.

On urban deer management: the role of a state wildlife agency

Moralistic and humanistic characteristics that predominate urban public values (Kellert 1980) affect the selection of methods used to control local deer numbers. In general, urban publics strongly favor nonlethal techniques; however, those methods have demonstrated only limited effectiveness in reducing and controlling deer abundance. In contrast, lethal methods of deer control have been more effective but less acceptable to urban publics. The inverse relationship between effectiveness and general acceptability of methods of deer control creates polarization between government agencies and the general public.

The resolution of suburban deer conflicts requires cooperation among the state wildlife agency, local governments, the affected individuals or landowners, and public groups with special interests. None of these parties can resolve deer issues independently. The state wildlife agency regulates the use of wildlife resources as defined by legislative mandated laws, whereas, land-use established by property owners and zoning, is the principal determinant of wildlife abundance and population quality (Smith and Coggin 1984). Because deer, and often times deer habitat, are resources held in public trust, interested citizens can profoundly influence management decision through socio-political processes.

The Illinois Department of Conservation has no direct control over land-use decisions in the CMA; landowners must therefore assume a direct participatory role in urban deer management. State wildlife regulations can only set the boundaries from which options for deer management can be selected. County commissioners and other officials of local government, as elected extensions of the various publics, are ultimately responsible for making specific decisions. The state wildlife agency must clearly distinguish between technical solutions and value judgments; questions of human values cannot be resolved technically and must be reconciled on a local level. Inherent in this responsibility is the need to balance human interests against the welfare of the natural resources within limitations of the available management options. The role of state government in this process is informational. Local public officials and landowners need unbiased information on deer biology, ecology, and deer management alternatives. They also need professional expertise to design, implement, and evaluate site-specific deer management programs. These management programs will necessarily be continuous, long-term programs as deer numbers change within and among years.

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Table 1. Agencies and organizations with representatives serving on the Community Liaison Committee for the Chicago Urban Deer Study.

American Humane Association
Brookfield Zoo
Cook County Forest Preserve District
DuPage County Forest Preserve District
Fund for Animals
Great Lakes Outdoor Writers
Illinois Audubon Society
Illinois Department of Conservation
Illinois Natural History Survey
Illinois Nature Preserves Commission
Illinois Wildlife Federation
Kane County Forest Preserve District
Lake County Forest Preserve District
Max McGraw Wildlife Foundation
Morton Arboretum
Chicago-O'Hare International Airport
Sierra Club
U.S. Department of Agriculture

Table 2. Outline of deer reduction plan for the Ned Brown Preserve, Cook County, Illinois.

I. Problem statement - The number of white-tailed deer in the Ned Brown Preserve has exceeded the ability of the vegetaion to support them on a sustained basis. Deer, through browsing, have substantially decreased forest regeneration and have severely reduced understory vegetation. The deer herd (1985) is a phase of "destructive overshoot"--a situation where deer have impacted not only palatable plants but also many of the less palatable species. Such conditions are not compatible with maintaining and preserving the diverse array of plant and small animal species that are indigenous to this site. Chronic malnutrition among Ned Brown deer is apparent and the frequency of deer-vehicle accidents reported on adjacent roads is high.

II. Objectives

A. To reduce deer-browsing pressure to a level that enables the regeneration of forest trees and understory plant species in the Busse Woods Nature Preserve and adjacent areas of the Ned Brown Preserve.

Evaluation: Vegetation measurements (XX)

B. To significantly reduce the number of reported deer-vehicle accidents on roads adjacent to Ned Brown.

Evaluation: Monitor frequency of deer-vehicle accidents on state numbered highways adjacent to Ned Brown.

C. To significantly improve average physical condition of the deer herd.

Evaluation: Postmortem examinations (condition indices, physical measurements, and reproductive performance)

III. Decision Rule: Deer will be removed from the Ned Brown Preserve if deer density exceeds 8 deer/km^2 of deer habitat.

Evaluation: Helicopter counts of deer during winter.

Table 3. Outline of key elements of the O'Hare Airport deer reduction plan.

Problem statement: The mission of Chicago-O'Hare International Airport is to provide safe and efficient air transportation facilities and services. Undeveloped airport property near active runways provides habitat that supports relatively large numbers of white-tailed deer. These deer range freely and are observed near active runways causing immediate danger to aircraft in transition. Presence of deer on O'Hare property is incompatible with airport mission safety. Live-trapping by O'Hare over 4 years was ineffective. Implementation of more effective methods of herd reduction are warranted.

Program goal: To reduce probability of deer-aircraft collisions and other deer-runway incidents to an acceptable level as defined by O'Hare Aviation Safety Department.

Objectives:

1) To define the maximum number of deer that O'Hare will accept on airport property. This maximum number will be used as a decision rule above which reduction will be implemented.

2) To select a deer management strategy from long and short term options that recognizes the need for periodic, perhaps annual, control efforts.

3) To provide the economic, logistic, and political support needed to implement deer management during autumn 1987.

4) To reduce deer numbers to a level below the defined decision rule threshold before 1 April 1988.

5) To provide regular and effective evaluations of deer numbers, and to maintain numbers at or below the specified decision rule indefinitely.

6) To minimize negative publicity and intra-agency controversy.

Decision rule: INHS identified 4 levels of deer abundance including no maximum population size, moderate to high residual population ($\leq$20 deer), low residual population ($\leq$10 deer), and remove all deer. O'Hare selected a low residual population because it was unlikely that all deer could be removed from the site.

Methods selected from short- and long-term management options

1) Live-trapping and translocation
2) Live-trapping and euthanasia
3) Sharpshooting from elevated stands near baited sites

Program evaluation: Helicopter count during winter

Table 4. Summary of Lake County Forest Preserve District plan for deer management at Ryerson Conservation Area.

I. Problem statement- The primary site objectives are to preserve, protect, and maintain the biological diversity of existing natural communities on both a short-term basis. Browsing by deer has caused a rudimentary browse line and an apparent decline in key indicator spring ephemeral plants creating a visible change in the forest understory. Deer appear in excellent condition and to be increasing in abundance. The number of deer on Ryerson must be regulated if sensitive components (i.e., most palatable plant species and animals dependent on those species) within existing natural communities are to maintained. The Lake County Forest Preserve District has no operational plan for management of deer at Ryerson.

II. Program goal - to develop a deer management program that is effective, regards human safety with priority, provides humane treatment of deer, enhances public education, and minimizes the total number of deer killed, handled, or treated over time.

III. Program objectives

A. To develop and implement a short-term strategy that will reduce the total number of deer on Ryerson Conservation Area to 12 animals (i.e., 15 deer/mile^2) by 15 March 1989.
B. To develop and implement a long-term strategy that will maintain deer numbers at a level that minimizes negative effects to key indicator plant species such as white trillium (<u>Trillium grandiflora</u>).
C. To promote opportunities for community education, information exchange, and public involvement in deer management activities through organized volunteer participation.

IV. Site description and resource inventories
A. Draft master plan (Nuzzo 1988)
1. Description of 9 natural communities
2. Description of rare and endangered species
B. Illinois Natural Heritage database records

V. Documentation of adverse effects on resources

A. Qualitative assessments
1. Current and historic photographs of site vegetation
2. Department of Conservation evaluation of botanical risks
B. Quantitative assessments
1. Aerial counts of deer
2. Preliminary analysis of plant density, percent cover, and frequency of occurence within the deer exclosure/control plot

VI. Review of alternate methods of deer control

A. Outline of alternative methods of deer control
B. Citations of literature reviewed

cont.

Table 4 (cont.)

VII. Permits required

VIII. General methods, strategies, and evaluations.*

A. Objective A - to reduce total number of deer to 12 by 15 March 1989
   1. Live capture, radio collar, and release 12 deer on site.
   2. Remove all unmarked deer
      a. Live capture and translocate
      b. Live capture and euthanize
      c. Sharpshooters
B. Objective B - develop a long term strategy that will maintain deer numbers at a level that minimizes negative effects to key indicator plant species.
   1. Determine local movements of deer on/near Ryerson
   2. Determine reproductive performance of Ryerson does.
   3. Identify and monitor key indicator plants that are sensitive to browsing by deer. Define threshold levels of browsing on key plant species that can be sustained over time and estimate the maximum deer density that will maintain these levels.
   4. Evaluate advantages/disadvantages of fencing and/or contraception to maintain desired deer densities.
C. Objective C - to promote community eduction, accurate information exchange, and public involvement in deer management.
   1. Develop a public education program on deer biology and management
   2. Designate a single project spokesperson who is knowledgable and who will be accessible to the media and publics
   3. Use volunteers to help capture and monitor radio marked deer
   4. Assess need for hiring additional personnel

IX. Evaluations

A. Objective A - count deer by helicopter
B. Objective B
   1. Monitor local deer movements with radio telemetry
   2. Determine fetal rates from postmortem examinations of does that are killed during herd reduction
   3. Contract plant ecologist to develop vegetation monitoring program
   4. Contract deer antifertility work to assess feasibility.
C. Objective C - evaluate community support of program

Table 5. Minimum winter density of white-tailed deer on selected forest preserves in Lake County, Illinois.

Location	Area (km2)	No. of deer counted	Density (Deer/km2)
Columbian Gardens	0.91	17	19
Ryerson Cons. Area	2.23	52	23
Daniel Wright Wds. & Lloyds Wds.	2.54	55	22
MacArthur Wds. & N. of MacArthur	2.05	37	18
Old School	2.10	40	19
Wilmot Wds.	4.97	44	9
Riverhill	1.68	26	15
Gurnee Wds.	3.24	10	3
Wadsworth	4.53	25	6
Van Patten Wds.	4.38	30	7
Cuba Marsh	2.25	5	2
Countryside Golf C.	1.99	0	0
Lakewood	5.62	44	8
Gavin Bog & N.P.	2.23	15	7
Spring Bluff	1.01	6	6
Lyons Wds.	1.09	22	20
Greenbelt	2.15	1	0
Gander Mt.	1.24	22	18

[a] Counts made by 2 observers in Bell Long Ranger helicopter on 31 Dec 87 and 8 Jan 88.

Table 6. Minimum winter density of white-tailed deer on selected forest preserves in DuPage County, Illinois.[a,b,c]

Location	Area (km2)	No. of deer counted 1985	1987	1988	Density (deer/km2)
Blackwell	4.53	14	13	12	3
Burlington Park	0.21	0	0	0	0
Churchill Wds.	0.98	0	2	2	0 - 2
Greene Valley	5.83	29	21	19	3 - 5
Herrick/Danada	6.24	6	19	17	1 - 3
Hidden Lake	1.58	11	13	31	7 - 20
McDowell Grove	1.68	0	1	17	0 - 10
Pratt's Wayne Wds.	5.18	2	11	15	0 - 3
Springbrook	7.20	0	0	9	0 - 1
Timber Ridge	2.46	19	19	28	8 - 11
Waterfall Glen	9.84	71	217	221	7 - 22
W. Branch DuPage River	7.04	23	22	13	2 - 4
West DuPage	1.89	3	0	2	0 - 2
Winfield Mounds	1.37	4	6	3	2 - 4

[a] Counts made by 2 observers in fixed-wing Cessna 172 on 30 Jan 85 and 16 Feb 85.

[b] Counts made by 2 observers in Bell Long Ranger helicopter on 21 Jan 87 and 22 Jan 87.

[c] Counts made by 2 observers in Bell Long Ranger helicopter on 7 Jan 88 and 27 Jan 88.

Table 7. Minimum winter density of white-tailed deer on selected forest preserves in southern Cook County, Illinois.

Location	Area (km2)	No. of deer counted 1983[a]	1985[b]	1988[c]	Density (deer/km2)
Sag Valley Division					
E. Willow Rd.	7.49	41	48		5 - 6
W. Willow Rd.	9.30	71	119		8 - 13
Tampier Lake	4.87	24	33		5 - 7
McGinnis Slough	4.40	22	22		5
Palos Division					
W. Willow Rd.	12.46	78	60	125	5 - 10
E. Willow Rd.	12.38	113	273	247	9 - 22
Black Partridge Wds.	1.37	0	0		0
Salt Creek Division					
W. Rt 45/S. 31st	4.45	13	17		3 - 4
22nd to 31st	2.05	11	4		2 - 5
Zoo & DesPlaines R.	4.45	0	0		0
Lake Ida	2.38	23	13		5 - 10
Calumet Division					
Eggers Grove	0.70	0	0		0
Burnham Wds. Golf C.	1.24	0	0		0
Beaubien Wds.	1.01	0	0		0
Calumet-Sag Channel	3.00	3	0		0 - 1
Dan Ryan Wds.	0.85	0	0		0
Calumet Playfield	0.80	0	0		0
Sand Ridge Nat. Cent.	2.10	0	1		0
Tinley Creek Division					
N. of 151st	13.49	19	31		1 - 2
104th Ave. property	3.24	9	6		2 - 3
S. of 151st	20.88	34	42		2
Thorn Creek Division					
N. Glenwood-Dyer	11.66	35	33		3
S. Glenwood/N.Linc.	3.57	13	17		4 - 5
S. Lincoln Highway	5.67	25	18		3 - 4
Plum Creek	4.38	13	23		3 - 5

[a] Counts made by 2 observers in fixed-wing Cessna 172 on 30-31 Dec 1983 and 4 Jan 1984.

[b] Counts made by 2 observers in fixed-wing Cessna 172 on 15 Jan, 28-30 Jan, and 19 Feb 1985.

[c] Counts made by 2 observers in Bell Long Ranger helicopter on 29 Jan 1988.

Table 8. Minimum winter density of white-tailed deer on selected forest preserves in southern Cook County, Illinois.

Location	Area (km2)	No. of deer counted 1983[a]	1985A[b]	1985B[c]	1986[d]	1987A[e]	1987B[f]	1988B[g]	Density (deer/km2)
New Division									
Poplar Ck. W. Sutton	5.02	23	23						5
Poplar Ck. E. Sutton	11.01	12	15						1
Spring Lake N. Dundee	8.91	27	56						5 - 6
Spring Lake S. Dundee	6.79	40	32						3 - 6
Crabtree N. C.	4.69	37	34						7 - 8
Deer Grove	6.79	8	22						1 - 3
Paul Douglas	5.18	20	30						4 - 6
Bakers Lake	1.14	0	0						0
DesPlaines River									
Madison - North	1.42			8	4	2			1 - 6
North - Belmont	1.09			0	0	0			0
Belmont - Irving Pk.	2.38			34	60	21			9 - 25
Irving Pk. - Lawrence	1.94			21	23	29			11 - 15
Lawrence - I/90	1.86			38	30	35			16 - 20
I/90 - Devon	0.85			16	6	7			7 - 19
Devon - Touhy	0.88			13	9	5			6 - 15
Touhy - Oakton	0.70			19	8	10			11 - 27
Oakton - Golf	1.27			21	21	13			10 - 17
Golf - Central	0.83	28		30	25	28			30 - 36
Central - Lake	2.90	130		53	106	91			18 - 45
Lake - Palatine	2.31	24		60	53	29		34	10 - 26
Palatine - Dundee	3.73	80		119	120	51		86	14 - 32
Dundee - Lake/Cook	1.84	58		73	53	47		69	26 - 40
Skokie Division									
S. Oakton	2.90	1		7	4	8		6	0 - 3
Oakton - Golf	4.43	6	8	13	8	4		11	1 - 3
Golf - Willow	10.98	25	8	12	46	26		52	1 - 5
Willow - Dundee	8.78	74	36	54	71	92		64	4 - 10
Dundee - Lake/Cook	4.95	20	8	15	21	10		5	1 - 4
West of I/94	5.41	35	15	46	69	42		61	3 - 13
Ned Brown Preserve									
N. Rt. 72	6.89	258	167	207	154	85	58	47	7 - 37
S. Rt. 72	7.95	35	44	46	36	33	41	56	4 - 7

[a] Fixed-wing Cessna 172 on 12/27/83, 12/30/83, 12/31/83, & 1/13/84

[b] Fixed-wing Cessna 172 on 1/05/85, 1/27/85, and 1/30/85

[c] Bell Long Ranger helicopter on 1/21/85 and 1/22/85

[d] Bell Long Ranger helicopter on 2/11/86

[e] Bell Long Ranger helicopter on 3/16/87

[f] Bell Long Ranger helicopter on 1/03/88, 1/05/88, and 1/06/88

Table 9. Reproductive performance of does from 5 locations within the Chicago metropolitan area, 1984-85.

Female age class by area	No. of does examined (N)	No. of does				Fetuses/N
		Aparous	Singleton	Twin	Triplet	
Fawn						
Ned Brown	15	15	0	0	0	0
Des Plaines	16	16	0	0	0	0
Palos	7	4	3	0	0	0.43
Northwest Cook	15	7	6	2	0	0.67
Non-Cook	23	9	10	4	0	0.78
Yearling						
Ned Brown	5	3	1	1	0	0.60
Des Plaines	13	1	10	1	1	1.15
Palos	2	1	1	0	0	0.50
Northwest Cook	2	0	0	2	0	2.00
Non-Cook	9	2	0	7	0	1.56
Adult						
Ned Brown	21	1	11	9	0	1.38
Des Plaines	22	2	8	12	0	1.45
Palos	6	0	1	5	0	1.83
Northwest Cook	5	0	1	2	2	2.20
Non-Cook	5	0	0	2	3	2.60

Table 10. Cause specific mortality and survival of fawn white-tailed deer captured, marked, and released on the Ned Brown Preserve, Cook County, Illinois.

Interval	Interval Days	No. of Survival Days	Survival Rate	95% CI	Cause of Death		
					Roadkill	Collected	Unknown
Male							
Dec 83-Jun 84	181	2,688	0.873	0.722-1.000	0.000	0.000	0.127 (1)
Dec 84-Jun 85	180	997	0.694	0.419-1.000	0.000	0.153 (1)	0.153 (1)
Female							
Dec 83-May 84	181	864	0.809	0.534-1.000	0.000	0.191 (1)	0.000
Dec 84-Jun 85	180	820	0.801	0.518-1.000	0.000	0.000	0.200 (1)

Table 11. Cause specific mortality and survival of yearling white-tailed deer captured, marked, and released on the Ned Brown Preserve, Cook County, Illinois.

Interval	Interval Days	No. of Survival Days	Survival	95% CI	Cause of Death		
					Roadkill	Collected	Unknown
Male							
Jan 84-May 84	152	486	1.000		0.000	0.000	0.000
Jun 84-Nov 84	183	2,944	0.830	0.672-1.000	0.170 (3)	0.000	0.000
Dec 84-May 85	182	2,795	0.937	0.824-1.000	0.063 (1)	0.000	0.000
Jun 85-Nov 85	183	1,065	0.840	0.598-1.000	0.000	0.159 (1)	0.000
Dec 85-Apr 86	151	199	0.218	0.026-1.000	0.000	0.782 (2)	0.000
Female							
Jan 84-May 84	152	117	0.271	0.021-1.000	0.000	0.000	0.729 (1)
Jun 84-Nov 84	183	915	1.000		0.000	0.000	0.000
Dec 84-May 85	182	1,132	0.851	0.621-1.000	0.000	0.000	0.149 (1)
Jun 85-Nov 85	183	1,139	1.000		0.000	0.000	0.000
Dec 85-May 86	182	738	0.476	0.206-1.000	0.175 (1)	0.349 (2)	0.000

Table 12. Cause specific mortality and survival of adult white-tailed deer captured, marked, and released on the Ned Brown Preserve, Cook County, Illinois.

Interval	Interval Days	No. of Survival Days	Survival	95% CI	Cause of Death: Roadkill	Cause of Death: Collected	Cause of Death: Unknown
Male							
Dec 83-May 84	183	972	0.828	0.572-1.000	0.172 (1)	0.000	0.000
Jun 84-Nov 84	183	1,768	0.901	0.736-1.000	0.098 (1)	0.000	0.000
Dec 84-May 85	182	1,768	0.734	0.517-1.000	0.266 (3)	0.000	0.000
Jun 85-Nov 85	183	3,413	0.687	0.520-0.907	0.224 (5)	0.000	0.089 (2)
Dec 85-May 86	182	1,600	0.634	0.406-0.990	0.091 (1)	0.183 (2)	0.091 (1)
Jun 86-Nov 86	183	1,001	0.694	0.417-1.000	0.153 (1)	0.153 (1)	0.000
Female							
Dec 83-May 84	183	2,055	0.765	0.565-1.000	0.000	0.000	0.235 (3)
Jun 84-Nov 84	183	2,667	1.000		0.000	0.000	0.000
Dec 84-May 85	182	2,374	0.681	0.487-0.953	0.191 (3)	0.000	0.127 (1)
Jun 85-Nov 85	183	3,328	0.848	0.703-1.000	0.152 (3)	0.000	0.000
Dec 85-May 86	182	2,427	0.591	0.400-0.872	0.000	0.409 (7)	0.000
Jun 86-Nov 86	193	1,704	0.471	0.269-0.822	0.076 (1)	0.454 (6)	0.000

Table 13. Age structure of deer removed from the Ned Brown Preserve based on backdating ages to 1 June 1984. Ages of deer of fawns and yearlings were determined by wear and replacement; adults were aged by counting cementum annuli.

Ages	Females	Males
0-1	31	31
1-2	22	19
2-3	37	3
3-4	27	8
4-5	14	2
5-6	8	0
6-7	4	2
7-8	4	0
8-9	4	0
9-10	2	0
10-11	0	0
11-12	0	0
12-13	0	0
13-14	1	0

Table 14. Seasonal and site variation of physical measurements of female fawn whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Total length			Hind Foot			Femur			Femur/HF		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Autumn												
16	7	1437.9	36.7	13	412.9	4.2	10	224.4	3.2	9	0.54	0.00
3	4	1403.8	35.4	6	408.3	8.8	6	220.0	2.6	5	0.53	0.01
11	6	1367.7	44.1	7	399.4	8.3	8	213.5	4.8	7	0.54	0.01
7	8	1345.4	40.1	8	408.3	9.6	8	214.3	4.8	5	0.52	0.01
6	6	1374.7	33.7	6	406.0	8.8	5	210.4	5.2	5	0.52	0.00
	(P = 0.4676)			(P = 0.7459)			(P = 0.1476)			(P = 0.0181)		
										6, 7 < 11, 16		
Winter												
16	3	1458.0	56.6	4	429.3	8.6	3	220.3	1.5	3	0.52	0.00
3	7	1523.3	29.5	8	440.3	6.4	8	234.4	4.3	8	0.53	0.01
11	2	1511.0	1.4	2	442.5	1.5	2	231.0	3.0	2	0.52	0.01
7	5	1438.4	47.9	6	429.3	8.6	5	223.2	5.3	5	0.52	0.00
6	10	1355.9	8.8	15	409.5	3.4	12	210.6	4.6	11	0.51	0.01
	(P = 0.0012)			(P = 0.0011)			(P = 0.0099)			(P = 0.0943)		
	6 < 3, 11			6 < 3, 11			6 < 3, 11					
Spring												
16	13	1527.3	18.1	20	441.7	5.8	22	237.1	2.6	19	0.54	0.00
3	8	1573.4	32.8	11	444.5	4.5	9	244.1	3.4	8	0.55	0.01
11	6	1512.5	53.5	6	433.7	6.2	7	229.9	4.5	6	0.54	0.01
7	11	1453.7	21.6	13	424.2	4.7	10	217.6	3.2	9	0.51	0.01
6	3	1349.7	58.2	2	403.0	2.0	3	206.7	3.2	2	0.51	0.00
	(P = 0.0031)			(P = 0.0187)			(P = 0.0001)			(P = 0.0017)		
	6 < 7,11,3,16 7,11,16 < 3			6 < 11,3,16			6,7 < 11,16,3 11 < 3			6 < 11,16,3 7 < 16,3		

[a] Areas:

Northwest Cook County = 3   Palos-Sag Valley = 11   Ned Brown = 6
Non-Cook County = 16   Des Plaines = 7

Table 15. Seasonal and site variation of measurements of the condition of female fawn whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Girth (mm)			Whole Body Weight (kg)			Kistner Evaluation			Kidney Fat Index		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Autumn												
16	4	740.8	29.3	8	40.2	1.9	7	65.7	3.7	12	1.07	0.15
3	6	743.8	19.9	4	37.4	3.4	8	60.0	10.4	6	1.09	0.39
11	4	727.8	19.5	5	36.4	3.6	6	59.2	5.1	7	1.32	0.32
7	7	729.7	29.0	7	32.3	3.2	9	47.2	7.5	9	0.97	0.23
6	6	734.5	9.9	6	34.2	2.3	6	62.5	5.0	6	1.51	0.17
	(P = 0.9862)			(P = 0.2804)			(P = 0.2180)			(P = 0.5688)		
Winter.												
16	2	792.0	22.0	2	34.2	2.5	2	30.0	0.0	3	0.26	0.06
3	7	813.3	21.9	6	41.1	3.1	8	63.8	7.5	7	1.47	0.26
11	2	803.0	2.0	2	39.2	0.2	2	35.0	5.0	2	0.58	0.21
7	3	771.3	22.3	3	36.7	1.6	5	43.0	7.2	6	0.61	0.11
6	10	684.8	13.3	9	24.8	2.0	8	13.8	7.0	10	0.31	0.10
	(P = 0.0002)			(P = 0.0009)			(P = 0.0008)			(P = 0.0002)		
	6 < 7,11,3,16			6 < 3			6 < 3			6, 16 < 3		
Spring												
16	11	771.2	10.0	15	40.9	1.5	20	33.0	3.8	18	0.39	0.14
3	6	787.5	23.3	8	44.8	3.3	9	40.6	4.8	10	0.31	0.06
11	4	682.3	14.6	4	34.1	4.1	6	26.7	9.3	6	0.27	0.08
7	8	707.8	12.2	9	28.2	1.9	12	17.9	3.7	9	0.15	0.02
6	3	686.0	13.2	3	25.9	0.8	3	13.3	8.3	3	0.11	0.03
	(P = 0.0001)			(P = 0.0001)			(P = 0.0144)			(P = 0.6099)		
	11,6,7 < 16,3			6, 7 < 3, 16			6 < 3					

[a] Areas:

Northwest Cook County = 3
Non-Cook County = 16
Palos-Sag Valley = 11
Ned Brown = 6
Des Plaines = 7

Table 16. Seasonal and site variation of physical measurements of male fawn whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

	Total length			Hind Foot			Femur			Femur/HF		
Area[a]	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Autumn												
16	8	1486.0	21.3	12	440.4	5.3	11	233.5	3.6	10	0.54	0.00
3	7	1444.0	25.7	8	430.5	5.6	8	234.0	2.7	8	0.54	0.00
11	8	1405.6	23.1	9	412.8	8.2	9	218.1	4.1	7	0.53	0.00
7	9	1431.9	23.0	11	429.4	6.1	11	225.9	3.1	10	0.53	0.01
6	5	1405.8	35.1	5	430.4	9.0	5	219.4	6.5	5	0.51	0.01
	(P = 0.1565)			(P = 0.0605)			(P = 0.0127)			(P = 0.0324)		
											6 < 3	
Winter												
16	4	1606.3	13.0	5	444.0	11.5	6	237.3	7.0	5	0.53	0.01
3	5	1558.2	29.1	9	453.2	5.8	8	239.5	4.0	8	0.53	0.01
11	2	1601.5	36.5	4	448.5	6.2	3	230.0	5.8	3	0.51	0.01
7	10	1487.0	20.6	13	432.4	4.9	14	223.2	3.3	12	0.52	0.00
6	10	1437.3	30.7	16	428.3	5.3	14	218.6	2.6	12	0.51	0.01
	(P = 0.0024)			(P = 0.0278)			(P = 0.0014)			(P = 0.1783)		
	6 < 11,16						6 < 3					
Spring												
16	22	1636.5	13.7	24	459.9	12.1	28	252.6	2.1	23	0.57	0.04
3	6	1524.7	109.3	7	454.1	6.9	6	242.5	5.8	6	0.53	0.01
11	3	1534.3	81.6	4	458.0	17.7	5	240.4	6.7	4	0.53	0.01
7	17	1513.4	28.3	21	447.4	4.8	20	238.3	2.7	19	0.53	0.00
6	4	1517.3	68.3	4	454.5	13.0	5	228.8	15.0	4	0.53	0.01
	(P = 0.0377)			(P = 0.9082)			(P = 0.0026)			(P = 0.7528)		
	6 < 11,16						6 < 16					

[a] Areas:

Northwest Cook County = 3   Palos-Sag Valley = 11   Ned Brown = 6
Non-Cook County = 16   Des Plaines = 7

Table 17. Seasonal and site variation of the condition of male fawn whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

	Girth (mm)			Whole Body Weight (kg)			Kistner Evaluation			Kidney Fat Index		
Area[a]	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Autumn												
16	7	800.0	19.9	8	41.8	1.3	8	64.4	2.0	12	1.16	0.23
3	8	844.4	21.7	6	45.0	1.9	7	62.9	5.2	9	1.07	0.19
11	5	795.2	17.9	5	36.8	3.3	6	58.3	5.4	8	1.46	0.26
7	4	790.8	18.1	9	41.0	1.7	9	65.6	3.8	8	1.50	0.26
6	5	756.2	26.5	5	36.8	2.5	5	69.0	4.8	5	1.63	0.57
	(P = 0.0899)			(P = 0.0657)			(P = 0.5716)			(P = 0.5921)		
Winter												
16	3	842.3	19.1	4	47.3	1.2	6	50.0	8.5	8	0.86	0.21
3	4	826.8	23.8	5	47.5	2.7	7	61.4	6.0	7	1.31	0.28
11	1	783.0		2	45.4	0.9	2	62.5	17.5	3	1.52	0.32
7	8	752.1	21.8	8	36.0	2.3	9	27.8	6.6	13	0.46	0.11
6	12	718.3	12.7	10	28.9	1.4	10	11.5	3.4	10	0.28	0.05
	(P = 0.0017)			(P = 0.0001)			(P = 0.0001)			(P = 0.0001)		
				6 < 11,16,3 7 < 16,3			6 < 16, 3 11 7 < 3, 11			6, 7 < 3, 11		
Spring												
16	13	847.1	10.2	20	50.8	1.4	22	32.3	2.9	23	0.19	0.02
3	7	811.1	13.8	6	43.8	2.8	6	25.8	6.4	7	0.15	0.02
11	3	800.3	35.0	3	42.3	5.1	3	21.7	6.0	3	0.16	0.05
7	13	756.1	14.3	17	38.7	1.9	18	22.2	2.5	15	0.17	0.02
6	4	795.3	48.2	4	39.1	7.2	4	18.7	7.2	2	0.11	0.03
	(P = 0.0021)			(P = 0.0005)			(P = 0.0969)			(P = 0.7227)		
	7 < 16											

[a] Areas:

Northwest Cook County = 3
Non-Cook County = 16
Palos-Sag Valley = 11
Ned Brown = 6
Des Plaines = 7

Table 18. Seasonal and site variation of physical measurements of female yearling whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Total length n	x̄	SE	Hind Foot n	x̄	SE	Femur n	x̄	SE	Femur/HF n	x̄	SE
Summer												
16	12	1602.5	14.7	14	458.7	4.1	13	252.1	1.9	12	0.55	0
3	2	1659.5	21.5	2	463.5	14.5	2	258.0	5.0	2	0.56	0.03
11	4	1621.5	11.6	5	437.4	5.9	5	249.4	2.8	5	0.57	0.01
7	6	1598.5	16.7	5	464.6	9.5	6	244.5	3.0	5	0.53	0.01
6	3	1476.7	6.1	3	444.7	6.5	2	240.0	8.0	2	0.55	0.01
	(P = 0.0006) 6 < 3,7,11,16			(P = 0.0640)			(P = 0.0507) 6 < 3			(P = 0.0325)		
Autumn												
16	9	1581.0	31.7	9	446.4	9.7	9	243.8	6.0	8	0.55	0.01
3	1	1470.0		2	448.5	28.5	1	256.0		1	0.54	
11	1	1544.0		1	471.0		2	258.0	5.0	1	0.56	
7	0			2	447.0	5.0	2	250.0	0	2	0.56	0.01
6	3	1642.3	91.5	3	463.3	10.5	3	316.3	74.3	3	0.68	0.14
	(P = 0.5858)			(P = 0.8328)			(P = 0.4375)			(P = 0.5812)		
Winter												
16	2	1575.5	18.5	2	467.0	1.0	2	253.5	4.5	2	0.54	0.01
3	1	1660.0		1	462.0		1	250.0		0		
11	1	1612.0		2	474.0	2.0	2	251.5	5.5	2	0.53	0.01
7	3	1542.0	21.0	4	458.5	2.7	3	245.7	7.4	3	0.54	0.01
6	1	1518.0		2	462.0	5.0	3	240.7	7.2	2	0.52	0.02
	(P = 0.1726)			(P = 0.0824)			(P = 0.7250)			(P = 0.7403)		
Spring												
16	11	1575.1	19.1	13	454.6	4.2	11	244.4	3.8	11	0.54	0.01
3	7	1568.3	35.4	7	443.4	7.1	6	246.5	4.3	6	0.55	0.02
11	1	1494.0		2	445.0	21.0	1	247.0		1	0.53	
7	6	1548.2	38.7	7	458.4	10.9	6	249.0	4.6	6	0.54	0.01
6	5	1525.8	34.7	6	454.7	6.3	5	231.0	1.9	5	0.51	0.01
	(P = 0.7125)			(P = 0.6367)			(P = 0.1020)			(P = 0.0367)		

[a] Areas:
Northwest Cook County = 3; Palos-Sag Valley = 11; Ned Brown = 6
Non-Cook County = 16; Des Plaines = 7

Table 19. Seasonal and site variation in the condition of female yearling whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Girth (mm) n	$\bar{x}$	SE	Whole Body Weight (kg) n	$\bar{x}$	SE	Kistner Evaluation n	$\bar{x}$	SE	Kidney Fat Index n	$\bar{x}$	SE
Summer												
16	8	814.4	15.1	11	49.3	2.7	14	50.6	4.8	9	0.40	0.14
3	2	849.0	61.0	2	49.2	5.2	1	30.0		1	0.14	
11	0			4	51.0	4.9	5	62.0	5.6	3	0.60	0.26
7	5	854.6	26.1	4	50.3	4.7	6	64.2	6.2	6	0.89	0.26
6	2	774.0	11.0	3	45.7	0.8	3	46.7	4.4	3	0.28	0.10
	(P = 0.2669)			(P = 0.9420)			(P = 0.1607)			(P = 0.2786)		
Autumn												
16	5	799.8	52.9	7	56.2	1.8	8	74.4	2.9	9	1.23	0.24
3	1	850.0		1	44.9		2	77.5	7.5	1	3.02	
11	1	906.0		1	52.6		1	80.0		1	1.56	
7	1	886.0		2	55.8	0.5	2	67.5	2.5	2	1.44	0.73
6	3	920.3	23.9	3	54.6	6.7	3	70.0	7.6	3	1.85	0.39
	(P = 0.5674)			(P = 0.6307)			(P = 0.7038)			(P = 0.2630)		
Winter												
16	2	898.0	44.0	2	54.7	8.8	1	70.0		2	1.77	0.80
3	1	926.0		0			1	75.0		1	0.97	
11	2	904.0	6.0	2	56.0	2.0	2	85.0	5.0	2	2.77	0.81
7	1	859.0		3	54.9	3.5	1	70.0		4	1.33	0.27
6	0			1	40.4		1	85.0		2	1.53	0.64
	(P = 0.7694)			(P = 0.4548)			(P = 0.5519)			(P = 0.3971)		
Spring												
16	7	808.4	8.3	7	50.5	4.7	11	54.1	5.4	11	0.33	0.05
3	6	801.2	17.5	7	49.9	3.6	7	50.7	6.4	7	0.45	0.17
11	1	803.0		1	44.0		1	35.0	15.5	1	0.15	
7	4	797.3	29.4	6	50.2	3.1	6	45.8	3.0	5	0.24	0.07
6	5	785.6	28.6	6	40.3	2.1	6	24.2	6.0	4	0.14	0.05
	(P = 0.9446)			(P = 0.2758)			(P = 0.0117)			(P = 0.3666)		

[a] Areas:
Northwest Cook County = 3 Palos-Sag Valley = 11 Ned Brown = 6
Non-Cook County = 16 Des Plaines = 7

Table 20. Seasonal and site variation in the condition of male yearling whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Girth (mm) n	Girth (mm) $\bar{x}$	Girth (mm) SE	Whole Body Weight (kg) n	Whole Body Weight (kg) $\bar{x}$	Whole Body Weight (kg) SE	Kistner Evaluation n	Kistner Evaluation $\bar{x}$	Kistner Evaluation SE	Kidney Fat Index n	Kidney Fat Index $\bar{x}$	Kidney Fat Index SE
Summer												
16	2	917.0	38.0	4	67.2	3.7	5	63.0	5.4	2	0.41	0.18
3	5	879.4	23.0	5	61.9	6.1	5	54.0	8.9	3	0.24	0.05
11	1	980.0		1	62.6		1	65.0		1	0.55	
7	3	899.0	12.0	3	60.5	3.0	3	56.7	6.7	2	0.34	0.18
6	1	905.0		0			1	55.0		2	0.43	0.09
	(P = 0.4230)			(P = 0.8252)			(P = 0.8870)			(P = 0.6269)		
Autumn												
16	6	1000.0	27.8	8	76.2	2.5	9	71.7	6.3	12	1.21	0.18
3	5	1004.0	27.1	4	79.5	6.4	4	78.8	6.3	8	1.27	0.27
11	2	893.0	9.0	4	71.2	3.3	5	76.0	4.3	5	1.33	0.41
7	2	918.0	89.0	5	66.6	4.2	5	74.0	4.6	11	1.36	0.24
6	3	856.7	50.6	3	67.9	6.2	4	82.5	7.5	4	1.59	0.51
	(P = 0.0602)			(P = 0.1977)			(P = 0.7749)			(P = 0.9373)		
Winter												
16	0			0			1	50.0		1	0.39	
3	1	920.0		1	56.2		1	75.0		1	1.09	
11	0			1	64.0		0			1	0.81	
7	0			0			0			1	0.56	
6	3	834.7	7.7	2	43.1	5.9	2	27.5	27.5	3	0.19	0.05
	(P = 0.0310)			(P = 0.4230)			(P = 0.7082)			(P = 0.0315)		
	6 < 3									6 < 3		
Spring												
16	10	857.8	14.6	11	53.1	1.1	14	43.6	4.8	15	0.21	0.03
3	3	883.7	25.8	4	54.4	4.2	4	37.5	6.0	4	0.21	0.03
11	1	904.0		1	65.8		1	45.0	23.7	1	0.24	
7	2	897.0	75.0	2	51.5	9.8	3	31.7	11.7	4	0.44	0.22
6	2	823.5	7.5	2	51.0	0.2	2	40.0	5.0	3	0.22	0.06
	(P = 0.5416)			(P = 0.3392)			(P = 0.8302)			(P = 0.3129)		

[a] Areas:
Northwest Cook County = 3 Palos-Sag Valley = 11 Ned Brown = 6
Non-Cook County = 16 Des Plaines = 7

Table 21. Seasonal and site variation of physical measurements of male yearling whitetails collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

	Total length			Hind Foot			Femur			Femur/HF		
Area[a]	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Summer												
16	4	1706.0	26.6	5	498.2	10.4	3	274.3	5.7	3	0.55	0.01
3	5	1665.2	50.1	5	479.2	15.7	5	270.6	7.2	5	0.57	0.01
11	1	1542.0		1	481.0		1	261.0		1	0.54	
7	3	1658.0	47.5	4	469.0	5.6	4	256.5	3.9	4	0.55	0.01
6	1	1747.0		1	461.0		2	255.5	13.5	0		
	(P = 0.5169)			(P = 0.4906)			(P = 0.3454)			(P = 0.3971)		
Autumn												
16	9	1749.7	38.1	14	489.1	5.4	15	275.6	1.7	13	0.57	0.01
3	6	1750.5	38.4	7	482.7	5.4	7	283.9	3.4	4	0.58	0.01
11	3	1686.7	24.7	6	476.7	11.3	6	263.8	4.0	5	0.55	0.02
7	5	1699.4	50.1	8	472.9	5.2	7	271.9	3.2	6	0.57	0.01
6	3	1644.7	55.7	4	474.0	13.9	4	250.3	11.7	4	0.53	0.01
	(P = 0.6211)			(P = 0.4163)			(P = 0.0001) 6 < 3,7,16 11 < 3			(P = 0.0572) 6 < 3		
Winter												
16	1	1744.0		1	479.0		1	274.0		1	0.57	
3	1	1665.0		2	489.0	6.0	1	263.0		1	0.53	
11	0			1	504.0		1	267.0		1	0.53	
7	0			0			0			0		
6	2	1638.5	33.5	3	476.3	8.3	2	255.5	1.5	2	0.53	0.01
	(P = 0.4805)			(P = 0.4047)			(P = 0.1690)			(P = 0.3346)		
Spring												
16	13	1632.8	30.7	16	482.7	4.5	15	261.7	2.9	13	0.54	0.01
3	4	1659.8	31.7	4	486.5	6.1	3	261.7	5.8	3	0.54	0.02
11	2	1821.0	0	2	480.0	6.0	2	262.5	6.5	2	0.55	0.01
7	3	1710.0	96.3	4	483.3	12.0	3	255.3	8.8	3	0.53	0
6	2	1627.5	9.5	3	440.7	6.0	4	238.5	9.6	3	0.55	0.02
	(P = 0.4653)			(P = 0.0118) 6 < 3,7,11,16			(P = 0.0532)			(P = 0.8119)		

[a] Areas:
Northwest Cook County = 3 Palos-Sag Valley = 11 Ned Brown = 6
Non-Cook County = 16 Des Plaines = 7

Table 22. Site variation of physical measurements of female whitetails >2 years old collected from 5 locations in the Chicago Metropolitan Area.

	Total length			Hind Foot			Femur			Femur/HF		
Area[a]	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
All Seasons												
16	18	1638.1	13.1	22	468.1	3.9	24	255.7	1.5	19	0.55	0
3	9	1710.8	17.3	13	467.7	6.1	12	255.4	2.7	11	0.55	0.01
11	15	1676.3	21.7	16	470.5	6.4	19	251.5	1.8	16	0.54	0.01
7	52	1650.9	11.8	59	464.3	2.5	63	250.7	1.1	55	0.54	0
6	30	1644.4	15.1	40	462.2	2.8	39	246.6	2.8	38	0.53	0.01
	(P = 0.1390)			(P = 0.5666)			(P = 0.0123)			(P = 0.1275)		
							6 < 3,16					

[a] Areas:
Northwest Cook County = 3
Non-Cook County = 16
Palos-Sag Valley = 11
Ned Brown = 6
Des Plaines = 7

Table 23. Seasonal and site variation in the condition of female whitetails >2 years old collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Girth (mm) n	Girth (mm) $\bar{x}$	Girth (mm) SE	Whole Body Weight (kg) n	Whole Body Weight (kg) $\bar{x}$	Whole Body Weight (kg) SE	Kistner Evaluation n	Kistner Evaluation $\bar{x}$	Kistner Evaluation SE	Kidney Fat Index n	Kidney Fat Index $\bar{x}$	Kidney Fat Index SE
Summer												
16	1	1030.0		2	60.8	2.7	5	58.0	6.2	5	0.41	0.07
3	0			0			0			0		
11	2	955.5	10.5	2	69.6	4.8	3	68.3	6.7	2	0.37	0.29
7	8	868.3	14.3	11	59.3	1.6	13	46.9	4.9	8	0.17	0.03
6	3	807.3	1.7	4	49.0	2.9	4	52.5	7.5	3	0.14	0.03
	(P = 0.0006) 6 < 11,16; 7 < 16			(P = 0.0033) 6 < 11			(P = 0.2051)			(P = 0.0239)		
Autumn												
16	2	990.0	0	4	64.2	1.2	4	77.5	4.3	5	2.12	0.36
3	2	954.0	18.0	2	65.3	2.2	2	80.0	5.0	3	2.42	0.84
11	2	886.0	19.0	3	57.8	2.4	3	71.7	4.4	3	0.88	0.17
7	3	946.7	15.7	4	66.1	1.6	3	78.3	3.3	5	1.30	0.41
6	4	925.3	22.4	5	65.7	3.8	4	76.3	5.9	3	3.39	1.60
	(P = 0.1045)			(P = 0.3208)			(P = 0.8446)			(P = 0.2044)		
Winter												
16	2	973.0	2.0	3	63.0	4.3	4	66.3	12.5	5	1.16	0.27
3	2	914.0	36.0	2	57.2	0.5	1	80.0		3	0.85	0.40
11	4	927.3	26.3	5	66.5	4.7	5	74.0	8.6	5	1.25	0.32
7	6	873.3	18.0	6	53.9	3.1	7	72.9	8.2	9	1.34	0.24
6	7	893.9	17.3	8	52.4	2.0	9	51.7	7.6	10	0.59	0.13
	(P = 0.0261)			(P = 0.2849)			(P = 0.1000)			(P = 0.1149)		
Spring												
16	4	916.5	9.9	7	59.4	2.9	8	47.5	6.2	4	0.53	0.14
3	4	917.5	31.2	5	66.0	3.3	5	51.0	8.1	6	0.46	0.11
11	4	860.3	18.6	5	57.3	2.6	6	50.8	3.5	5	0.32	0.06
7	25	835.6	10.8	27	52.3	1.6	27	31.9	3.2	19	0.33	0.07
6	15	845.5	10.7	15	49.6	1.5	16	9.7	2.5	12	0.12	0.01
	(P = 0.0044) 7 < 3,16			(P = 0.0005) 6,7 < 3			(P = 0.0001) 6 < 16			(P = 0.0222) 7 < 3,16		

[a] Areas:
Northwest Cook County = 3; Non-Cook County = 16; Palos-Sag Valley = 11; Ned Brown = 6; Des Plaines = 7

Table 24. Site variation of physical measurements of male whitetails >2 years old collected from 5 locations in the Chicago Metropolitan Area.

Area[a]	Total length			Hind Foot			Femur			Femur/HF		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
All Seasons												
16	10	1839.6	38.7	15	493.0	4.5	15	278.3	5.0	11	0.56	0.01
3	7	1848.4	44.1	10	510.9	4.9	9	283.7	5.1	9	0.56	0.01
11	6	1867.2	34.9	8	497.3	6.4	9	276.1	4.2	8	0.55	0.01
7	18	1781.5	29.7	21	490.9	3.1	19	271.9	2.2	17	0.55	0.01
6	19	1739.5	26.6	29	493.9	4.4	28	266.7	2.2	26	0.54	0
	(P = 0.0614)			(P = 0.0958)			(P = 0.0087)			(P = 0.0818)		
							6 < 3					

[a] Areas:
Northwest Cook County = 3
Non-Cook County = 16
Palos-Sag Valley = 11
Ned Brown = 6
Des Plaines = 7

Table 25. Seasonal and site variation in the condition of male whitetails >2 years old collected from 5 locations in the Chicago Metropolitan Area during 1984-1985.

Area[a]	Girth (mm)			Whole Body Weight (kg)			Kistner Evaluation			Kidney Fat Index		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Summer												
16	0			0			0			0		
3	0			1	107.5		1	95.0		1	1.60	
11	2	1092.0	36.0	2	108.2	7.9	2	92.5	7.5	1	1.54	
7	0			1	112.5		0			0		
6	2	804.5	55.5	3	54.4	11.3	3	55.0	29.3	2	0.71	0.15
	(P = 0.0491) 6 < 11			(P = 0.0910)			(P = 0.5912)			(P = 0.2366)		
Autumn												
16	4	1071.8	33.0	4	97.6	10.5	3	73.3	16.7	6	1.38	0.38
3	0			2	109.8	5.4	2	85.0	5.0	3	1.62	0.60
11	1	1060.0		1	80.3		1	80.0		1	1.14	
7	7	1046.4	36.5	6	94.3	6.4	5	68.0	11.8	6	1.74	0.56
6	1	995.0		5	78.3	5.1	5	70.0	6.7	5	1.95	0.50
	(P = 0.8793)			(P = 0.1617)			(P = 0.8997)			(P = 0.9205)		
Winter												
16	1	1108.0		0			1	40.0	12.0	1	0.52	
3	3	981.0	54.9	2	69.6	20.2	1	40.0	12.0	3	0.21	0.10
11	1	1010.0		1	89.8		1	10.0		2	0.39	0.09
7	2	927.5	32.5	2	59.6	1.9	4	38.8	17.6	4	0.59	0.18
6	11	939.8	20.5	10	59.7	4.5	11	15.0	5.9	12	0.29	0.14
	(P = 0.2389)			(P = 0.2868)			(P = 0.4167)			(P = 0.7163)		
Spring												
16	1	980.0		4	80.3	7.9	4	48.8	10.7	4	0.34	0.06
3	3	967.7	16.3	2	65.8	8.2	3	53.3	6.7	3	0.26	0.07
11	1	872.0		1	56.7		1	5.0		1	0.17	
7	5	857.0	14.1	5	51.0	3.0	6	15.0	6.6	5	0.18	0.04
6	3	978.0	90.6	3	74.1	13.5	4	47.5	8.8	5	0.24	0.05
	(P = 0.2751)			(P = 0.1033)			(P = 0.0136)			(P = 0.3286)		

[a] Areas:
Northwest Cook County = 3 Palos-Sag Valley = 11 Ned Brown = 6
Non-Cook County = 16 Des Plaines = 7

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Table 26. Mean densities (stems/m^2) of plants <1m in Busse Woods exclosure (BEX) and adjacent control plot (BCP), 1984-89 (N=48 1m^2 quadrats per plot per year unless otherwise noted).

SPECIES	1984 (August)		1985 (May)		1986 (April)		1987 (May)		1988 (May)		1989 (May)	
	BEX	BCP	BEX	BCP	BEX	BCP	BEX	BCP	BEXa	BCP	BEX	BCP
a) herbaceous species												
Allium canadense	0	0	0.8	17.3	16.7	23.7	7.9	23.4	8.9	16.2	0.4	12.4
A. tricoccum	0	1.0	1.6	0.3	0.7	7.8	0.1	0.4	T b	4.0	0.5	4.6
Allium sp.	0.1	0	0	0	0	0	0	0	0	0	0	0
Anemone spp.	0.5	0.4	0	0	0	0	0	0	0	0	0	0
A. quinquefolia	0	0	0	0	T	0	T	0.1	0	0	0	0
A. virginiana	0.2	0.5	0	0	0	0	0	0	0	0	0	0
Anemonella thalictroides	0	0	T	0	0	0.1	0	0	0	0	0	0
Ariseama dracontium	0	0	0.4	1.5	0	T	0.2	0.2	0.2	0.2	0.2	0.1
A. triphyllum	0.2	0.3	3.3	7.8	1.0	3.2	2.1	6.4	1.6	4.1	1.6	4.3
Aster spp.	0	0	0.2	T	T	0	0.1	0	0.1	T	0	0
Cardamine douglassi	0	0	T	1.4	0	4.4	0	1.6	0	6.5	0	5.1
Circaea quadrisulcata	0.9	0.1	0.9	0.2	0.4	0.1	1.8	0.3	2.3	0.8	2.4	0.1
Claytonia virginica	0	0	3.4	0	0.9	3.0	0	0	2.0	0.8	2.0	1.5
Commelina spp.	0	0	0.2	0	0	0	0.3	0	0	0	0	0
Dentaria laciniata	0	0	0	0.1	0	0.6	0	0.1	0	0.6	0	0.5
Erigeron spp.	0	0	0	T	0	0	0	0	0	0	0	0
Erythronium albidum	0	0	50.1	3.4	107.3	21.6	2.8	1.7	85.1	11.3	129.3	8.7
Floerekia proserpinacoides	0	0	0	0	0	0	0	T	0	0.6	0	2.1
Fragaria virginiana	0	T	0	T	0	0	0	0	0	0	0	0
Galium spp.	0.1	0.1	0.3	0.5	0	T	0.3	0.1	0.1	0.1	1.0	T
Geranium maculatum	T	T	0.1	0.8	0	0.7	0	0.6	0	0.3	0	0.2
Geum canadense	0	0	0.4	0.9	0.4	0.3	0.7	0.3	0.7	0.2	1.3	0.3
Habernaria viridis	0.2	0	0	0	0	0	0	0	0	0	0	0
Hackelia virginiana	0	0	0	0	0	0	0	0	0	0	0.2	0.1
Hydrophyllum virginianum	0	0	0	0	0	0	0	0	0	T	0	0
Hypericum spp.	0	0.1	0	0	0	0	0	0	0	0	0	0
Lactuca spp.	0	0	0	0	0	0	T	T	T	0.3	0	T
Oxalis spp.	0.2	0.2	0.3	0.2	T	0.1	0.2	T	0.2	0.2	T	0.2
Phlox divaricata	0	0	0.3	0.8	0.3	0.2	0.2	0.4	1.0	0	0.2	0.8
Podophyllum peltatum	0	0	0	0	0.1	0	0.1	0	0.2	0	0	0
Polygonum spp.	0	0	0	T	0	0	0	0	0	0	0	0
Prenanthes alba	0	0	0	0	0	0.1	0	0.1	0	0	0	0
Ranunculus spp.	0	0	0.2	0	0.2	T	0.1	0.3	1.1	0.3	0.3	0.3
Smilacina racemosa	0	0.1	0.7	0	0.6	0.3	0.3	T	0.3	0.1	0.1	0.4
Solidago spp.	0.2	0.3	0.3	0.1	0.2	0.2	0.1	0.2	0.7	0.2	0.3	0.3
Taraxacum officinale	0	0	0	0	0	0	0	T	0	T	T	0
Tovara virginiana	3.0	3.6	6.1	3.9	3.4	0.9	5.6	0.9	4.8	0.6	1.7	0.2
Trillium recurvatum	0	0	3.5	0.5	4.1	1.5	2.3	0.5	8.2	1.7	3.0	1.5
Urtica spp.	0	0.5	0	0	0	0	0	0.4	0	0.4	0	0
Viola spp.	0.3	0.3	0.3	0.4	T	T	0.1	0.2	0.1	0.1	0.4	0.3
Number of species	12	15	22	23	18	22	21	25	20	25	20	22
Mean density	11.0	7.5	73.6	40.0	136.4	68.9	25.4	38.3	117.6	49.9	145.1	44.2
Relative density (%)	76.9	56.5	93.8	47.7	94.7	65.3	86.1	51.6	88.5	48.7	87.7	51.7

cont.

Table 26. (cont.)

SPECIES	1984 (August) BEX	1984 (August) BCP	1985 (May) BEX	1985 (May) BCP	1986 (April) BEX	1986 (April) BCP	1987 (May) BEX	1987 (May) BCP	1988 (May) BEX[a]	1988 (May) BCP	1989 (May) BEX	1989 (May) BCP
b) woody species												
Acer saccharum	0.1	T	0.3	0	0.1	T	T	T	8.1	14.2	0	0
Carya spp.	T	0	0	0	T	0	T	0	0.1	0	T	0
Crataegus spp.	0.1	0.1	0.1	0.1	T	T	0.1	0	0	T	T	0
Fraxinus spp.	T	0.3	T	0	T	T	T	0	T	0	1.0	1.5
Ostrya virginiana	0	0	T	0	T	0	0.1	0.2	0.2	0.1	0.5	T
Parthenocissus quinquefolia	0.1	0.1	T	T	T	0	T	0	T	0	T	0
Prunus spp.	0	0	0	0	0.2	0	0.2	0	T	0	0	0
Quercus spp.	T	T	0	0	0	T	0	0	0	0	0	0
Rhamnus cathartica	0.3	0.5	0.4	0.2	0.5	0.3	0.3	T	0.1	0.1	0.2	0.3
Ribes spp.	0.1	T	0	T	0	0.1	0	0	0	0	0	0
Rubus spp.	0	0	0	T	0	0	0	0	0	0	0	0
Smilax spp.	0.1	0.1	0.3	T	0.1	T	0.2	T	T	0	0	0
Tilia americana	T	T	0.1	0.1	0.4	0.2	0.6	0.3	1.8	0.8	0	0
Toxicodendron radicans	0.2	0.4	0.5	1.0	0.1	0.1	0.2	0.3	1.2	2.9	0.5	1.5
Ulmus spp.	0	0.3	0	2.1	3.6	8.4	T	T	0.1	0.3	0.9	0
Vitis riparia	0	0	T	0	0	T	T	0	0	0	T	0
Woody seedlings (i.e., first year)					3.8	8.7					13.5	13.9
Number of species	11	10	10	9	12	11	13	7	11	7	10	6
Mean density	1.1	1.8	1.6	3.5	5.1	9.3	1.8	0.8	11.5	18.3	18.2	17.1
Relative density (%)	7.6	13.4	2.0	4.1	3.5	8.8	6.1	1.1	8.7	17.9	11.0	20.0
c) other species												
Sedges (i.e., Carex spp.)	0	0	0.2	34.5	2.0	24.1	1.3	28.4	2.7	28.7	1.1	19.8
Grasses (e.g., Sphenopholis spp., Poa spp., and Glyceria spp.)	1.4	3.4	0	2.4	0.1	1.3	0.3	5.5	0.3	5.3	0.2	4.3
Unknowns	0.8	0.6	3.1	3.6	0.4	1.9	0.2	1.2	0.7	0.2	0.7	0.2
Number of species	2	2	3	6	3	6	3	3	3	3	2	4
Mean density	2.2	4.1	3.2	40.5	2.5	27.3	2.3	35.1	3.7	34.2	2.0	24.1
Relative density (%)	15.5	30.2	4.1	48.2	1.8	25.9	7.8	47.3	2.8	33.4	1.2	28.2
d) all plants												
Number of species	25	27	35	38	33	33	37	35	34	35	33	32
Mean density	14.3	13.5	78.4	84.0	144.0	105.3	29.5	74.2	132.9	102.4	165.4	85.4

[a] Only 8 permanent line intercepts were usable due to fallen trees.

[b] Trace amounts of <0.05 stems/m^2.

Table 27. Mean densities (stems/m^2) of plants <1m in Busse Woods exclosure (BEX) and adjacent control plot (BCP), 1984-89 (N=48 1m^2 quadrats per area per year unless otherwise noted).

PLANT TYPE	1984 (August) BEX	1984 (August) BCP	1985 (May) BEX	1985 (May) BCP	1986 (April) BEX	1986 (April) BCP	1987 (May) BEX	1987 (May) BCP	1988 (May) BEX[a]	1988 (May) BCP	1989 (May) BEX	1989 (May) BCP
Herbaceous	10.9 (11)[b]	6.6 (14)	71.2 (20)	22.5 (21)	119.1 (16)	37.3 (20)	17.4 (19)	14.6 (23)	108.7 (18)	29.7 (23)	144.2 (18)	27.2 (20)
Woody	0.8 (10)	1.3 (9)	1.3 (9)	3.3 (3)	4.6 (11)	9.0 (10)	1.5 (12)	0.8 (6)	11.4 (10)	18.2 (6)	18.0 (9)	16.8 (5)
First-year "seedlings"	NR[c]	NR	NR	NR	3.8	8.7	NR	NR	NR	NR	13.5	13.9
Exotic Woody	0.3 (1)	0.5 (1)	0.4 (1)	0.2 (1)	0.5 (1)	0.3 (1)	0.3 (1)	T[d] (1)	0.1 (1)	0.1 (1)	0.2 (1)	0.3 (1)
Others[e]	2.3 (3)	5.1 (3)	5.6 (5)	58.0 (8)	19.9 (3)	27.3 (5)	10.3 (5)	58.8 (6)	12.7 (5)	54.5 (5)	3.0 (5)	41.1 (6)
Total	14.3 (25)	13.5 (27)	78.4 (35)	84.0 (38)	144.0 (33)	105.3 (38)	29.5 (37)	74.2 (35)	132.9 (34)	102.4 (35)	165.4 (33)	85.4 (32)

[a] Only 32 permanent quadrats were usable due to fallen trees.

[b] Number of species shown in parentheses.

[c] Not Recorded during sampling.

[d] Trace amounts of <0.05 stems/m2.

[e] The "others" category includes grasses, sedges, *Allium canadense*, and *A. tricoccum*.

Table 28. Mean densities (stems/m^2) of plants <1m in Busse Nature Preserve during May 1986-1989; number of species shown in parentheses.

Plant Type	1986	1987	1988	1989
Herbaceous	32.4 (20)	38.5 (24)	32.7 (27)	28.2 (28)
Woody	17.3 (14)	3.7 (15)	5.7 (15)	7.5 (15)
First-year[a] "seedlings"	15.9	NR (b)	NR	4.8
Exotic Woody[c]	0.8 (1)	0.5 (2)	0.4 (2)	0.9 (1)
Others[d]	24.4 (5)	50.6 (4)	19.0 (5)	16.0 (5)
Total	75.0 (40)	93.4 (45)	57.8 (48)	52.6 (48)

[a] Also included in the "Woody" category.

[b] Not Recorded.

[c] Includes *Rhamnus cathartica* and *Viburnum opulus*.

[d] Includes grasses, sedges, mosses, unidentifiable species, and other obviously unpalatable species (i.e., *Allium canadense*, *Allium tricoccum*, *Sanicula canadensis*, and *Eupatorium rugosum*).

Table 29. Mean densities (stems/m^2) of plants <1m in Busse Nature Preserve, 1986-89 (N=50 1m^2 quadrats per plot per year).

SPECIES	1986(May)	1987(May)	1988(May)	1989(May)
a) herbaceous species				
Allium tricoccum	6.3	3.0	4.4	3.9
Anemone quinquefolia	2.5	2.0	1.1	2.0
Arisaema dracontium	0	0	T	0.1
A. triphyllum	1.8	1.4	0.7	1.2
Boehmeria cylindrica	T (a)	T	0.2	0
Caulophyllum thalictroides	1.4	0.1	2.8	1.3
Cardamine douglassii	0.9	0.7	1.2	1.0
Chenopodium album	0	0	0	T
Circaea quadrisulcata	0	8.1	T	T
Claytonia virginica	2.6	4.0	1.5	8.4
Dentaria laciniata	10.8	5.2	15.6	6.2
Epipactis helleborine	0	0	0	0.1
Eupatorium rugosum	0	0	0	0.1
Erythronium albidum	7.8	6.8	5.8	5.0
Galium spp.	0.6	0.2	1.0	0.1
Geranium maculatum	1.4	1.8	1.1	0.7
Geum canadense	0.5	0.2	0.2	0.1
Hackelia virginiana	0	0	0	0.1
Hydrophyllum virginianum	0.2	0.2	T	0.1
Impatiens spp.	0	0	T	0.1
Iris virginica	0	0	T	0
Isopyrum biternatum	0	0	0.1	0
Lactuca spp.	0	0.1	T	0
Oxalis spp.	0	0.1	T	0.1
Phlox divaricata	0.4	0	0	0
Polygonum spp.	0	1.8	0	0
Potentilla canadense	0	0	0	T
Prenanthes alba	T	0	0	0
Ranunculus spp.	0.1	0.4	0.3	0.4
Sanicula sp.	0	0	0.2	0
Smilacina racemosa	0.2	0.3	0.1	0.1
Solidago spp.	0.1	0.1	T	0.1
Thalictrum dioicum	0	3.8	0.1	0.3
Tovara virginiana	0.6	1.0	0.1	0.1
Trillium grandiflorum	0	0.1	0.1	0
T. recurvatum	0.3	0.3	0.6	0.4
Viola spp.	T	T	T	T
Number of species	21	25	29	28
Mean density	38.7	41.8	37.3	32.3
Relative density (%)	51.8	44.8	64.5	61.4

cont.

Table 29: Mean densities (stems/m^2) of plants <1m in Busse Nature Preserve, 1986-89, continued.

SPECIES	1986(May)	1987(May)	1988(May)	1989(May)
b) woody species				
Acer saccharum	0.1	0.5	1.9	0.3
Carya spp.	T	T	T	T
Cornus spp.	T	0	0	0
Crateagus spp.	0.1	0.1	0.1	0.1
Euonymous atropurpurea	T	0.2	0.3	0
Fraxinus spp.	0.4	0.1	0.1	2.2
Lonicera spp.	0.8	0.2	0.3	0.1
Ostrya virginiana	0.1	0.5	1.9	0.3
Parthenocissus quinquefolia	0.1	0.3	0.1	0.9
Prunus serotina	0.9	0.2	0.5	0.5
Quercus spp.	0	0	0	0.1
Rhamnus cathartica	0.8	0.5	0.3	0.9
Ribes missouriense	0	0	0	T
Smilax spp.	0	T	T	T
Staphylea trifolia	0	T	0	0
Tilia americana	0.1	0.2	0.3	0.6
Toxicodendron radicans	0.2	0.5	0.8	0.5
Ulmus spp.	14.5	0.3	0.4	1.9
Viburnum spp.	T	T	T	0
Vitis riparia	0	T	T	0.1
First-year "seedlings"	15.9			4.8
Number of species	15	17	16	16
Mean density	18.2	4.3	5.8	8.4
Relative density (%)	24.3	4.6	10.4	16.0
c) other species				
Sedges (i.e., Carex spp.)	10.8	40.6	4.2	6.2
Grasses (e.g., Glyceria spp., Poa spp., Sphenopholis spp.)	6.9	5.9	9.9	5.0
Unknowns	0.4	1.2	0.4	0.9
Number of species	4	3	3	4
Mean density	18.1	47.7	14.5	12.1
Relative density (%)	24.1	51.1	25.1	23.0
d) all plants				
Number of species	40	43	48	48
Mean density	75.0	93.4	57.8	52.6

[a] Trace amounts of <0.05 stems/m^2.

Table 30. Mean percent cover of plants < 1m in Busse Nature Preserve during May 1986-1989; number of species shown in parentheses.

Plant Type	1986	1987	1988	1989
Herbaceous	1.9 (20)	1.8 (28)	2.9 (27)	2.9 (28)
Woody	0.3 (14)	0.5 (13)	0.4 (13)	0.5 (13)
First-year[a] "seedlings"	0.2	NR (b)	NR	0.2
Exotic Woody[c]	T (d)	T	T	T
Others[e]	2.5 (5)	1.8 (6)	3.3 (6)	3.2 (7)
Total	4.7 (40)	4.1 (48)	6.7 (48)	6.6 (49)

[a] Also included in the "Woody" category.

[b] Not Recorded.

[c] Includes *Rhamnus cathartica* and *Berberis thunbergii*.

[d] Trace amounts of <0.05%.

[e] includes grasses, sedges, mosses, unidentifiable species, and other obviously unpalatable species (i.e., *Allium canadense*, *Allium tricoccum*, *Sanicula canadensis*, and *Eupatorium rugosum*).

Table 31. Mean percent cover of plants <1m in Busse Nature Preserve, 1986-89 (N=25 20m line intercepts per year).

SPECIES	1986(May)	1987(May)	1988(May)	1989(May)
a) herbaceous species				
Allium canadense	T (a)	T	T	T
A. tricoccum	2.0	T	1.9	2.4
Anemone quinquefolia	0.1	0.1	0.1	0.1
Arisaema dracontium	0	0	0	T
A. triphyllum	T	0.1	T	0.1
Boehmeria cylindrica	0	0.1	T	0
Caulophyllum thalictroides	0.4	0.7	0.6	0.5
Cardamine douglassii	T	T	T	T
Chenopodium album	0	0	0	T
Circaea quadrisulcata	0	T	T	T
Cirsium sp.	0	T	0	0
Claytonia virginica	T	T	0.1	0.1
Dentaria laciniata	0.8	0.2	1.4	1.1
Epipactis helleborine	0	0	T	T
Eupatorium rugosum	0	0	0	T
Erythronium albidum	0.2	0.1	0.2	0.3
Galium spp.	T	T	T	0.1
Geranium maculatum	0.1	0.1	0.2	0.1
Geum canadense	T	T	T	0.1
Hydrophyllum virginianum	0	T	0	T
Iris virginica	T	0.1	T	0.1
Isopyrum biternatum	0	0	T	T
Lactuca spp.	0	T	0	0
Oxalis spp.	0	T	0	0
Phlox divaricata	0	0	0	T
Plantago spp.	T	T	0	0
Polygonum spp.	0	T	T	0
Potentilla canadense	0	T	T	0
Podophyllum peltatum	T	0	0	0
Prenanthes alba	0	T	T	T
Ranunculus spp.	T	T	T	T
Sanicula sp.	0	0	T	0
Smilacina racemosa	T	T	T	T
Solidago spp.	T	T	T	T
Taraxacum officinale	0	0	0	T
Thalictrum dioicum	0.1	T	T	T
Tovara virginiana	T	0.1	T	0.1
Trillium grandiflorum	0	0	T	0
T. recurvatum	T	T	0.1	0.1
Viola spp.	T	T	T	T
Number of species	22	30	29	30
Mean % cover	3.9	1.9	4.9	5.4
Relative cover (%)	81.3	46.3	73.1	81.8

cont.

Table 31. (cont.)

SPECIES	1986(May)	1987(May)	1988(May)	1989(May)
b) woody species				
Acer saccharum	T	T	0.1	T
Carya spp.	0	0	T	0
Cornus spp.	T	0	T	T
Crateagus spp.	T	T	T	T
Euonymous atropurpurea	T	T	T	T
Fraxinus spp.	T	T	T	0.1
Lonicera spp.	0.1	0.1	T	T
Ostrya virginiana	T	0.1	T	T
Parthenocissus quinquefolia	T	T	T	0.1
Prunus serotina	T	T	0.1	T
Quercus spp.	0	0	0	T
Rhamnus cathartica	T	T	T	0.1
Rubus spp.	0	0	0.1	0
Smilax spp.	0	T	0	T
Tilia americana	T	T	T	0.1
Toxicodendron radicans	T	T	T	0.1
Ulmus spp.	0.2	0.1	T	T
Viburnum spp.	T	0	0	0
Vitis riparia	T	T	0	0
First-year "seedlings"	0.2			0.2
Number of species	15	14	15	15
Mean % cover	0.4	0.5	0.5	0.5
Relative cover (%)	8.3	12.2	7.5	7.6
c) other species				
Sedges (i.e., Carex spp.)	0.3	0.6	0.7	0.5
Grasses (e.g., Glyceria spp., Poa spp., Sphenopholis spp.)	0.1	0.3	0.3	0.1
Unknowns	0.1	0.1	T	0.1
Mosses		0.8	0.3	
Number of species	3	4	4	4
Mean % cover	0.5	1.7	1.3	0.7
Relative cover (%)	10.4	41.5	19.4	10.6
d) all plants				
Number of species	40	48	48	49
Mean % cover	4.7	4.1	6.7	6.6

[a] Trace amounts of <0.05 stems/m^2.

Table 32. Mean densities (stems/m^2) of plants < 1m in Busse Woods South during April-May 1986-1987; number of species shown in parentheses.

Plant Type	1986 (April) n=30	1987 (May) n=30
Herbaceous	94.5 (18)	80.1 (18)
Woody	3.5 (14)	3.2 (16)
First-year [a]	0.2	NR (b)
Exotic Woody [c]	0.4 (1)	0.2 (1)
Others [d]	20.5 (8)	12.8 (5)
Total	118.9 (41)	98.1 (40)

[a] Included in the "Woody" category also.

[b] Not Recorded during sampling.

[c] includes *Rhamnus cathartica*.

[d] includes grasses, sedges, unidentifiable species, and other obviously unpalatable species (i.e., *Allium canadense*, and *Allium tricoccum*).

Table 33. Mean percent cover of plants < 1m in Busse Woods South during April-May 1986-1987. The number of species found is shown in parentheses. The sample size was 15-20m permanent line intercepts per year.

Plant Type	1986(April)	1987(May)
Herbaceous	5.2 (16)	9.1 (24)
Woody	0.8 (15)	4.5 (16)
Exotic Woody[a]	0.2 (1)	0.6 (1)
Others[b]	0.7 (5)	1.9 (5)
Total	6.9 (37)	16.0 (46)

[a] includes Rhamnus cathartica.

[b] includes grasses, sedges, mosses, unidentifiable species, and other obviously unpalatable species (i.e., Allium canadense, and Allium tricoccum).

Table 34. Estimated average densities (stems/ha) of shrubs and saplings > 1m in 2 diameter (at breast height) classes in Busse Nature Preserve, 1985-1987 (n=50 5X5m quadrats per year).

Species	1985		1986		1987	
	<2.5cm	2.5-10.2cm	<2.5cm	2.5-10.2cm	<2.5cm	2.5-10.2cm
Acer negundo	0	0	0	8	0	8
A. saccharinum	0	16	0	0	0	0
A. saccharum	136	64	264	88	200	80
Carya cordiformis	16	16	0	0	0	0
C. ovata	8	8	8	24	0	32
Cornus racemosa	0	0	24	0	40	0
Corylus americana	48	0	16	0	24	0
Crateagus spp.	88	56	64	64	64	32
Euonymous atropurpurea	0	0	0	24	8	8
Fraxinus spp.	136	176	64	152	80	120
Malus spp.	0	0	8	0	0	0
Ostrya virginiana	96	216	120	368	104	296
Prunus americana	32	8	8	0	0	0
P. serotina	16	0	16	32	16	32
Quercus spp.	0	8	8	16	8	16
Rhamnus cathartica	24	88	32	64	32	80
Tilia americana	56	280	112	288	48	256
Ulmus spp.	96	104	32	144	24	160
Viburnum spp.	0	0	8	0	0	0
Unknowns	0	0	32	0	0	0
Dead/leafless	2432	128	1056	88	648	72
Total live	752	1040	816	1272	648	1120

Table 35. Estimated average densities (stems/ha) of shrubs and saplings >1m in 2 diameter (at breast height) classes in Busse Woods South, 1985-1986 (n=25 5X5m quadrats in 1985 and 30 quadrats in 1986).

Species	1985		1986	
	<2.5cm	2.5-10.2cm	<2.5cm	2.5-10.2cm
Acer saccharum	1472	368	1307	307
Carya cordiformis	16	0	93	0
C. ovata	80	0	53	13
Cornus spp.	48	0	0	0
Corylus americana	16	0	13	0
Crateagus spp.	208	48	93	0
Fraxinus spp.	128	48	107	13
Malus spp.	0	0	13	0
Ostrya virginiana	160	208	120	280
Prunus americana	224	0	0	0
P. serotina	16	16	0	0
Quercus spp.	48	0	0	0
Rhamnus cathartica	128	64	347	80
Tilia americana	448	352	320	200
Ulmus spp.	176	144	67	187
Viburnum spp.	0	0	27	0
Xanthoxylum americanum	192	16	267	13
Dead/leafless	784	160	627	67
Total live	3360	1264	2827	1107

Table 36. Importance value indices (=sum of relative density, dominance, and frequency values) of canopy trees >10.2cm DBH in Busse Nature Preserve (BNP) and Busse Woods South (BWS). Both areas were sampled during 1985; sample sizes were 200 trees for BNP and 100 trees for BWS.

Species	BNP	BWS
Acer spp.	10.3	59.4
Carya spp.	5.4	9.3
Crataegus spp.	12.0	4.2
Fraxinus spp.	37.6	33.7
Juglans nigra	2.5	0
Ostrya virginiana	28.1	9.9
Populus deltoides	1.4	0
Prunus serotina	8.9	0
Quercus spp.	119.3	96.7
Rhamnus cathartica	11.2	2.4
Tilia americana	32.2	33.3
Ulmus spp.	32.1	51.5
Total number of species	21	18
Canopy closure (%)	88.3	93.1

Table 37. Relative percentages of developed landscape within a 225 km^2 study area centered on the Ned Brown Preserve, Cook County, for 1949, 1965, 1970 and 1985.[a, b]

Development Classification	Year 1949	1964	1970	1985
No development	82.6	57.9	49.7	24.8
Low density housing	9.6	10.3	8.6	5.3
Medium density housing	3.6	6.1	8.0	14.9
High density housing	2.1	15.0	16.9	29.2
Buildings/paved areas	1.8	8.2	14.4	24.9
Construction	0.4	2.4	2.2	0.9
Unknown	0	0.2	0.1	0

[a] No development = no development in 1 ha cell, includes agriculture
Low density housing = 1 to 2 houses located in cell
Medium density housing = 3 or 4 houses located in cell
High density housing = 5 or more houses located in cell
Building/Pavement = Contains at least 1 building & associated pavement
Construction = >0.5 of cell area is under construction
Unknown = development type cannot be determined (gravel pit included)

[b] Buildings that could not be distinguished from houses were classified as houses.

Table 38. Relative percentages of road types within a 225 km^2 study area centered on the Ned Brown Preserve, Cook County, for 1949, 1965, 1970 and 1985.[a, b]

Road Classification	Year 1949	1964	1970	1985
No roads	77.7	59.0	53.6	44.2
Secondary	10.4	30.8	35.0	43.8
Main	10.8	6.0	6.9	5.9
Major	0.0	1.2	1.4	1.6
Secondary/Main	1.1	2.6	2.4	3.6
Main/Major	0	0.3	0.3	0.6
Secondary/Major	0	0.2	0.3	0.4

[a] Definitions:
- No roads = no roads in cell
- Secondary roads = all roads that are not main or major roads includes RR
- Main roads = 2 or 4 lane roads >5 km in length
- Major highways = roads with > 5 lanes
- Secondary/Main = both types are located in cell
- Main/Major = both types are located in cell
- Secondary/Major = both types are located in cell

[b] Driveways, gravel, and dirt roads were not classified

[c] Roads under construction categorized by type at completion

Table 39. Relative percentages of vegetation types within a 225 km^2 study area centered on the Ned Brown Preserve, Cook County, for 1949, 1965, 1970 and 1985.[a, b]

Vegetation Classification	Year			
	1949	1964	1970	1985
No vegetation	0.1	2.2	5.4	19.3
Agricultural field	79.9	41.5	24.9	5.2
Grass	5.1	24.5	25.1	29.0
Mixed vegetation	13.8	30.4	43.0	39.5
Closed canopy forest	0.9	1.3	1.6	6.4
Unknown	0	0	0	0.1

[a] Definitions:

No vegetation = no dominant vegetation in cell
Agricultural field = at least 0.5 of cell is cropland or pasture
Grass = meadow or grass not associated with agriculture
Mixed vegetation = mixture of grass, shrubs, marsh, and/or trees
Closed canopy forest = entire cell includes closed canopy woodlot
Unknown = type not distinguishable from aerial photograph

Table 40. Relative percentages of water resources within a 225 km^2 study area centered on the Ned Brown Preserve, Cook County, for 1949, 1965, 1970 and 1985.[a, b]

Water Resource Classification	Year 1949	1964	1970	1985
No water	86.1	92.2	88.9	90.2
Stream	7.5	4.6	4.9	3.5
Shoreline	1.2	1.3	2.6	4.7
Open water	1.1	0	0.1	0.5
Marsh shoreline	4.2	1.9	3.6	1.2
Open marsh	0	0	0	0

[a] Definitions:

No water = no water identified in cell
Stream = segment of stream <100 m in width in cell
Shoreline = interface between land and lake, pond, or river >100 m width
Open water = entire cell is open water
Marsh shoreline = interface between land and marsh in cell
Open marsh = entire cell is marsh

Table 41. Mean cost of deer-vehicle accidents in Cook County, Illinois, during 1984 to 1988.[a,b,c]

Cost Category by Year	Mean	SE	Range of Values
1984			
N = 140 usable responses			
Vehicle repair	$ 1,149.44	78.34	0.00 - 6,240.00
Towing	10.40	2.25	0.00 - 150.00
Substitute vehicle	35.25	8.72	0.00 - 600.00
Medical	13.57	10.82	0.00 - 1,500.00
Lost wages	17.35	11.37	0.00 - 1,500.00
Other	0.77	0.47	0.00 - 45.00
Total cost (d)	1,226.78	92.10	0.00 - 7,340.00
1985			
N = 79 usable responses			
Vehicle repair	$ 1,328.71	133.61	0.00 - 8,010.25
Towing	10.65	2.53	0.00 - 125.00
Substitute vehicle	40.84	11.76	0.00 - 565.00
Medical	26.61	13.49	0.00 - 752.00
Lost wages	33.38	19.83	0.00 - 1,500.00
Other	6.13	4.93	0.00 - 384.00
Total cost (d)	1,446.32	156.65	55.00 -10,387.25
1986			
N = 94 usable responses			
Vehicle repair	$ 1,470.66	183.33	0.00 -13,200.00
Towing	13.55	2.71	0.00 - 115.00
Substitute vehicle	83.00	22.26	0.00 - 1,700.00
Medical	18.37	8.03	0.00 - 500.00
Lost wages	28.14	11.78	0.00 - 800.00
Other	9.04	4.66	0.00 - 300.00
Total cost (d)	1,622.77	194.84	0.00 -14,050.00

(cont.)

Table 41. (cont.)

Cost Category by Year	Mean	SE	Range of Values
1987			
N = 118 usable responses			
Vehicle repair	$ 1,247.03	98.36	0.00 - 8,000.00
Towing	9.26	2.41	0.00 - 130.00
Substitute vehicle	57.46	11.25	0.00 - 509.00
Medical	1.56	1.15	0.00 - 131.00
Lost wages	4.15	2.20	0.00 - 150.00
Other	31.66	14.28	0.00 - 1,500.00
Total cost (d)	1,351.13	109.43	10.00 - 8,621.00
1988			
N = 110 usable responses			
Vehicle repair	$ 1,478.38	133.20	0.00 - 8,900.00
Towing	9.65	2.37	0.00 - 125.00
Substitute vehicle	73.18	13.53	0.00 - 825.00
Medical	9.76	5.36	0.00 - 507.60
Lost wages	11.40	6.20	0.00 - 550.00
Other	17.82	12.10	0.00 - 1,300.00
Total cost (d)	1,600.18	144.21	10.00 -10,157.00

[a] Questionnaires were sent to individuals involved in deer-vehicle accidents that were investigated by the Cook County Sheriff's Police.

[b] Responses in 1984 include X deer-vehicle accidents investigated by municipality police departments; total cost of these accidents was not significantly different from costs derived from Cook County Sheriff's Police responses.

[c] Cost in U.S. dollars

[d] Total Cost was determined by averaging the Total Cost of individual responses. Therefore, the Range of Values for Total Cost can have a minimum value > $ 0.00 even though the minimum value for each cost category (e.g., repair, towing etc.) was = $ 0.00.

Table 42. Relative comparison of average costs associated with deer-vehicle accidents in Cook County, 1984-1988.

Year	Cost Categories (%)					
	Repair	Towing	Substitute Vehicle	Medical	Lost Wages	Other Costs
1984	93.7	0.8	2.9	1.1	1.4	0.1
1985	91.9	0.7	2.8	1.8	2.3	0.4
1986	90.6	0.8	5.1	1.1	1.7	0.6
1987	92.3	0.7	4.3	0.1	0.3	2.3
1988	92.4	0.6	4.6	0.6	0.7	1.1

Table 43. Number of deer-vehicle accidents reported on state-numbered highways in northeastern Illinois from 1978 through 1990 (Ill. Dep. Trans.)

	Year												
County	78	79	80	81	82	83	84	85	86	87	88	89	90
Cook	137	112	139	167	260	248	354	379	469	436	494	499	610
DuPage	20	19	19	20	23	31	50	58	76	72	85	74	109
Kane	24	34	36	36	55	68	80	81	124	125	150	190	216
Lake	66	50	53	73	105	126	157	200	250	274	298	359	346
Total	247	215	247	296	443	473	641	718	919	907	1027	1122	1281

Table 44. Sex and age composition of all deer removed by INHS from the Ned Brown Preserve, Cook County, from 1983 to 1988. Methods used included live-capture by rocket net, drive net, and sharpshooting.

Autumn-Winter	Female			Male		
	Fawns	Yearlings	Adults	Fawns	Yearlings	Adults
1983-1984	2	1	7	0	0	0
1984-1985	6	3	9	6	0	1
1985-1986	23	3	42	36	8	13
1986-1987	35	14	40	33	13	7
1987-1988	10	7	15	11	8	10
1988-1989	2	0	2	2	0	0
Totals	78	28	115	88	29	31

Table 45. The minimum number of deer counted during helicopter surveys during winter and the number of deer removed by INHS annually at the Ned Brown Preserve from 1983-84 to 1988-89.

	1983-84	1984-85	1985-86	1986-87	1987-88
Aerial count					
North NB	258	207	154	85	47
South NB	35	46	36	33	56
Minimum density					
North NB	37	30	22	12	7
South NB	4	6	5	4	7
Total NB	20	17	13	8	7
No. deer removed	10	25	125	142	61

Table 46. Annual deer-vehicle accident rates for selected highways from 4 locations in Cook County during 1982-1988.

Area	Length of highways evaluated (km)	Accidents/km						
		1982	1983	1984	1985	1986	1987	1988
Ned Brown	24.1	1.45	1.0	1.41	0.91	0.83	0.46	0.42
Northwest	41.8	0.50	0.62	0.84	0.71	0.93	0.88	0.88
Des Plaines	25.7	0.89	0.58	0.89	1.05	1.05	0.74	0.86
Palos	37.0	0.92	0.60	1.02	0.94	1.13	0.73	0.89

Table 47. Correlation matrix comparing the frequencies of deer-vehicle accidents at locations in Cook County. Accident frequency data were from Illinois Department of Transportation summaries (1982-1988) for selected road sections within each area.

Area	Area: Ned Brown	Northwest Cook	Des Plaines	Palos	Cook
Ned Brown	1.0				
Northwest Cook	-0.63	1.0			
Des Plaines	0.13	0.25	1.0		
Palos	0.24	0.37	0.91	1.0	
Cook[a]	-0.75 (-0.79)	0.90 (0.89)	0.42 (0.39)	0.43 (0.37)	1.0

[a] Correlation coefficients in parentheses were determined by comparing subcounty (e.g., Palos) accident frequencies with those from Cook County that were reduced by the number of accidents in the subcounty of comparison.

Example: (Palos accidents) vs (Cook County total accidents - Palos accidents)

Table 48. Outline of deer management options and selected citations.

1.0.0.0.0.0	Intervention
1.1.0.0.0.0	Demographic intervention
1.1.1.0.0.0	Mortality intervention or translocation
1.1.1.1.0.0	Induce biological control
1.1.1.1.1.0	Introduce predator (4,9,12,13,33,52,60,66,67,88,92)
1.1.1.1.2.0	Introduce pathogen
1.1.1.2.0.0	Live capture and euthanize, translocate, or displace
1.1.1.2.1.0	Box traps
1.1.1.2.1.1	Clover trap (11, 26, 45, 59)
1.1.1.2.1.2	Oregon panel trap
1.1.1.2.1.3	Pisgah box trap (26, 86)
1.1.1.2.1.4	Stephenson box trap (41, 69)
1.1.1.2.2.0	Corral or drive traps (41, 82)
1.1.1.2.3.0	Nets and snares
1.1.1.2.3.1	Drive net (5, 25, 45, 90)
1.1.1.2.3.2	Drop net (14, 76)
1.1.1.2.3.3	Net gun (3, 25, 48)
1.1.1.2.3.4	Rocket or cannon nets (41, 45, 47, 69)
1.1.1.2.3.5	Snare (2, 41)
1.1.1.2.4.0	Manual capture of fawns (17, 29, 32, 37, 43, 91, 103)
1.1.1.2.5.0	Oral sedative in bait (41, 62)
1.1.1.2.6.0	Remote chemical injection (46, 64, 65)
1.1.1.2.6.1	Blowgun (27, 36, 65, 101)
1.1.1.2.6.2	Gun (41, 45, 69)
1.1.1.2.6.3	Bow (1, 10, 41)
1.1.1.2.6.4	Crossbow (41)
1.1.1.2.7.0	Deer drive (e.g., from exclosure) (45, 102)
1.1.1.3.0.0	Regulated public hunting
1.1.1.3.1.0	Archery/crossbow (56, 89)
1.1.1.3.2.0	Firearm (23, 49, 50, 56, 83, 94, 96)
1.1.1.4.0.0	Sharpshooting (i.e., culling) (21, 45, 63, 69, 95, 99)
1.1.1.5.0.0	Toxicants (i.e., poison) (39)
1.1.2.0.0.0	Reproductive intervention
1.1.2.1.0.0	Capture obligate methods
1.1.2.1.1.0	Implant (109, 110)
1.1.2.1.2.0	Ovariectomy (35/elk)
1.1.2.1.3.0	Vasectomy
1.1.2.1.4.0	Mechanical (32, 111)
1.1.2.2.0.0	Non-capture methods
1.1.2.2.1.0	Oral ingestion of chemicals (38, 53, 54, 84)
1.1.2.2.2.0	Remote injection
1.1.2.2.2.1	Immunocontraceptives (112)
1.1.2.2.2.2	Aborticide
1.1.2.2.3.0	Social fertility control (67, 68, 100)

(cont.)

Table 48. (cont.)

1.2.0.0.0.0	Habitat and/or behavior modification
1.2.1.0.0.0	Modify habitat characteristics
1.2.1.1.0.0	Provide supplemental, diversionary, or attractant foods
1.2.1.1.1.0	Provide feed (6,7,22,28,42,68,87,104,105,106,107)
1.2.1.1.2.0	Fertilize (20, 61, 97)
1.2.1.1.2.0	Seed/plant
1.2.1.2.0.0	Road modification (77, 79)
1.2.1.3.0.0	Decrease carrying capacity via silviculture (16, 75)
1.2.2.0.0.0	Modify deer use of habitat resources
1.2.2.1.0.0	Exclusion
1.2.2.1.1.0	Electric fence (8, 18, 44, 51, 58, 71, 73, 98)
1.2.2.1.2.0	Non-electric fence (18, 30, 31, 51, 71, 78)
1.2.2.1.3.0	Mechanical barriers to protect individual plants (24,40,45)
1.2.2.2.0.0	Repellents and warning devices
1.2.2.2.1.0	Area (i.e., smell)
1.2.2.2.1.1	Feather meal (70)
1.2.2.2.1.2	Human hair (15, 89)
1.2.2.2.1.3	Meat meal (70)
1.2.2.2.1.4	Predator odors (57)
1.2.2.2.1.5	Putrescent egg solids
1.2.2.2.1.6	Soap (89)
1.2.2.2.1.7	Tankage (89)
1.2.2.2.1.8	Other
1.2.2.2.2.0	Contact (i.e., taste) (19)
1.2.2.2.2.1	Ammonium soaps of higher fatty acides
1.2.2.2.2.2	Benzyl diethyl methyl ammonium saccharide, thymol
1.2.2.2.2.3	Bone tar oil
1.2.2.2.2.4	Capsaicin (15, 70, 89)
1.2.2.2.2.5	Putrescent egg solids
1.2.2.2.2.6	Thiram
1.2.2.2.2.7	Other
1.2.2.2.3.0	Auditory (i.e., hearing)
1.2.2.2.3.1	Dog (89)
1.2.2.2.3.2	Exploder (18, 89)
1.2.2.2.3.3	Gun discharge (89)
1.2.2.2.3.4	Vehicle whistle
1.2.2.2.4.0	Visual (i.e., sight)
1.2.2.2.4.1	Road mirrors/reflectors (34,72,74,80,81,85,108)
1.2.2.2.4.2	Scarecrow (89)
2.0.0.0.0.0	Nonintervention
2.1.0.0.0.0	Cognizant inaction
2.1.1.0.0.0	Acceptance of problem
2.1.2.0.0.0	Avoidance of decision
2.1.3.0.0.0	Compensation (e.g., monetary) (93)
2.2.0.0.0.0	Incognizance or no recognized problem

(cont.)

Table 48. (cont.)

1) Anderson 1961, 2) Ashcraft and Reese 1957, 3) Barrett et al. 1982, 4) Beasom 1974, 5) Beasom et al. 1980, 6) Brown and Mandery 1962, 7) Carhart 1943, 8) Caslick and Decker 1979, 9) Causey and Cude 1980, 10) Causey et al. 1978, 11) Clover 1956, 12) Connolly 1978, 13) Connolly 1981, 14) Connor et al. 1987, 15) Conover 1984, 16) Conover 1988, 17) Cook et al. 1971, 18) Craven 1983, 19) Crawford and Church 1971, 20) Crouch and Radwan 1981, 21) Dalberg and Guettinger 1956, 22) Dasmann et al. 1967, 23) Dechert 1967, 24) DeVoe and Schaap 1983, 25) DeYoung 1988, 26) Diehl 1988, 27) Dinnes 1982, 28) Doman and Rasmussen 1944, 29) Downing and McGinnes 1969, 30) Falk et al. 1978, 31) Feldhammer et al. 1986, 32) Garrott and Bartmann 1984, 33) Gavitt et al. 1974, 34) Graves and Bellis 1978, 35) Greer 1968 (elk), 36) Haigh and Hopf 1976, 37) Hamlin et al. 1984, 38) Harder and Peterle 1974, 39) Harris 1984:55, 40) Hawthorne 1980, 41) Hawkins et al. 1967, 42) Hubert et al. 1980, 43) Huegel et al. 1985, 44) Hygnstrom and Craven 1988, 45) Ishmael and Rongstad 1984, 46) Jessup et al. 1983, 47) Jones and Witham 1990, 48) Krausman et al 1985, 49) Krefting et al. 1955, 50) Krefting and Erickson 1956, 51) Longhurst et al. 1962, 52) Lowry and McArthur 1978, 53) Matschke 1977a, 54) Matschke 1977b, 55) Matschke et al. 1984, 56) Martin and Krefting 1953, 57) Melchiors and Leslie 1985, 58) McAtee 1939, 59) McCullough 1975, 60) Mech 1984, 61) Mitchell and Hosley 1936, 62) Montgomery and Hawkins 1967, 63) Moore et al. 1977, 64) Nielsen 1982, 65) Nielsen 1989, 66) Nesbitt 1975, 67) Ozoga et al. 1982, 68) Ozoga and Verme 1982, 69) Palmer et al. 1980, 70) Harris et al. 1983, 71) Palmer et al. 1985, 72) Pojar et al. 1975, 73) Porter 1983, 74) Queal 1968, 75) Radwan 1972, 76) Ramsey 1968, 77) Reed 1981, 78) Reed et al. 1974, 79) Reed et al. 1975, 80) Reed and Woodard 1981, 81) Reed et al. 1982, 82) Rempel and Bertram 1975, 83) Roseberry et al. 1969, 84) Roughton 1979, 85) Schafer and Penland 1985, 86) Schilling 1938, 87) Schoonveld et al. 1974, 88) Scott and Causey 1973, 89) Scott and Townsend 1985, 89) Severinghaus 1963, 90) Silvy et al. 1975, 91) Steigers and Flinders 1980, 92) Stout 1982, 93) Strickland 1976, 94) Swank 1962, 95) Taylor and Katahira 1988 (goats), 96) Teer et al. 1965, 97) Thomas et al. 1964, 98) Tierson 1969, 99) Van Etten et al. 1965, 100) Verme et al. 1987, 101) Warren et al. 1979, 102) Wemmer and Stuwe 1985, 103) White et al. 1972, 104) Woebeser and Runge 1975, 105) Wood and Wolfe 1988, 106) Woolf and Harder 1979, 107) Woolfe 1977, and 108) Zacks 1986, 109) Botti 1985, 110) Bell and Peterle 1975, 111) Matschke 1976, 112) Turner et al. 1992.

LIST OF FIGURES

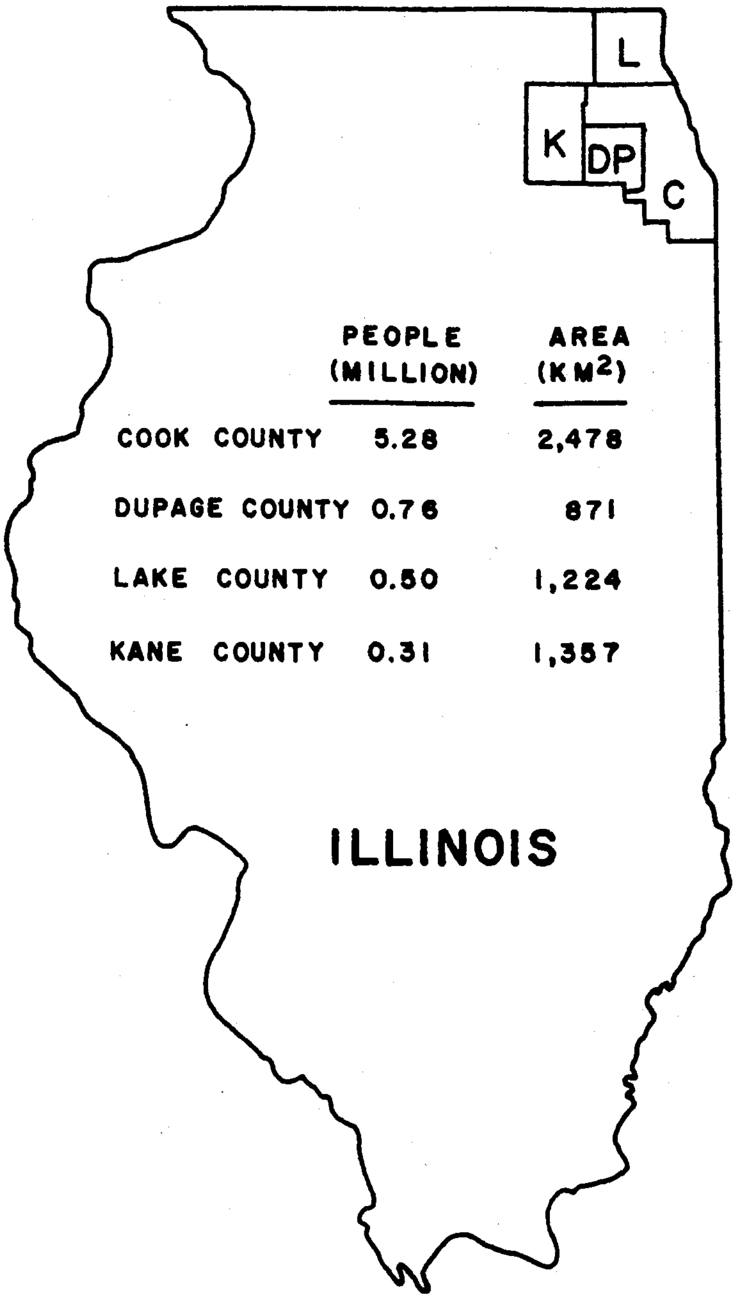


Fig. 1. Four-county study area of the INHS Urban Deer Research Program.

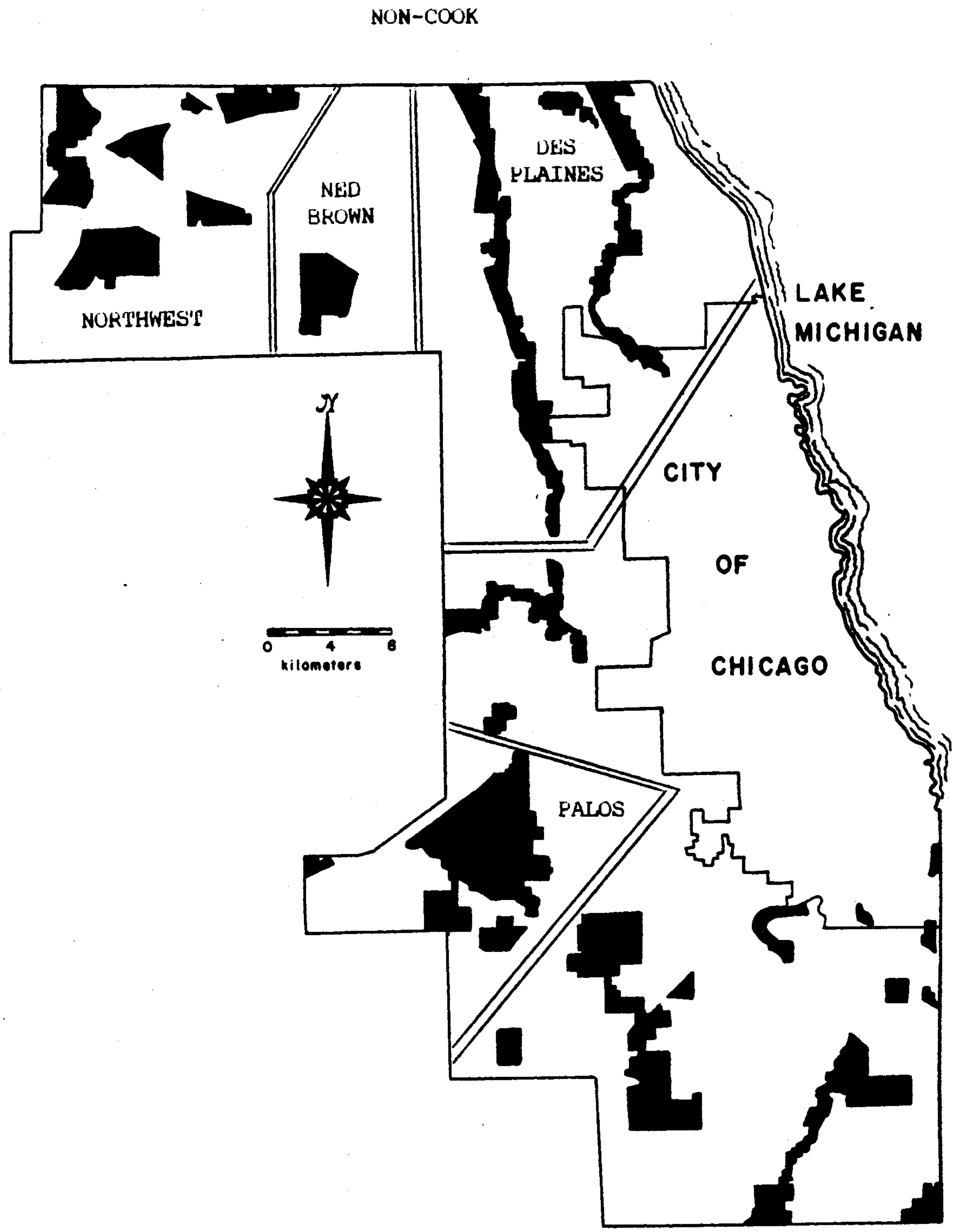
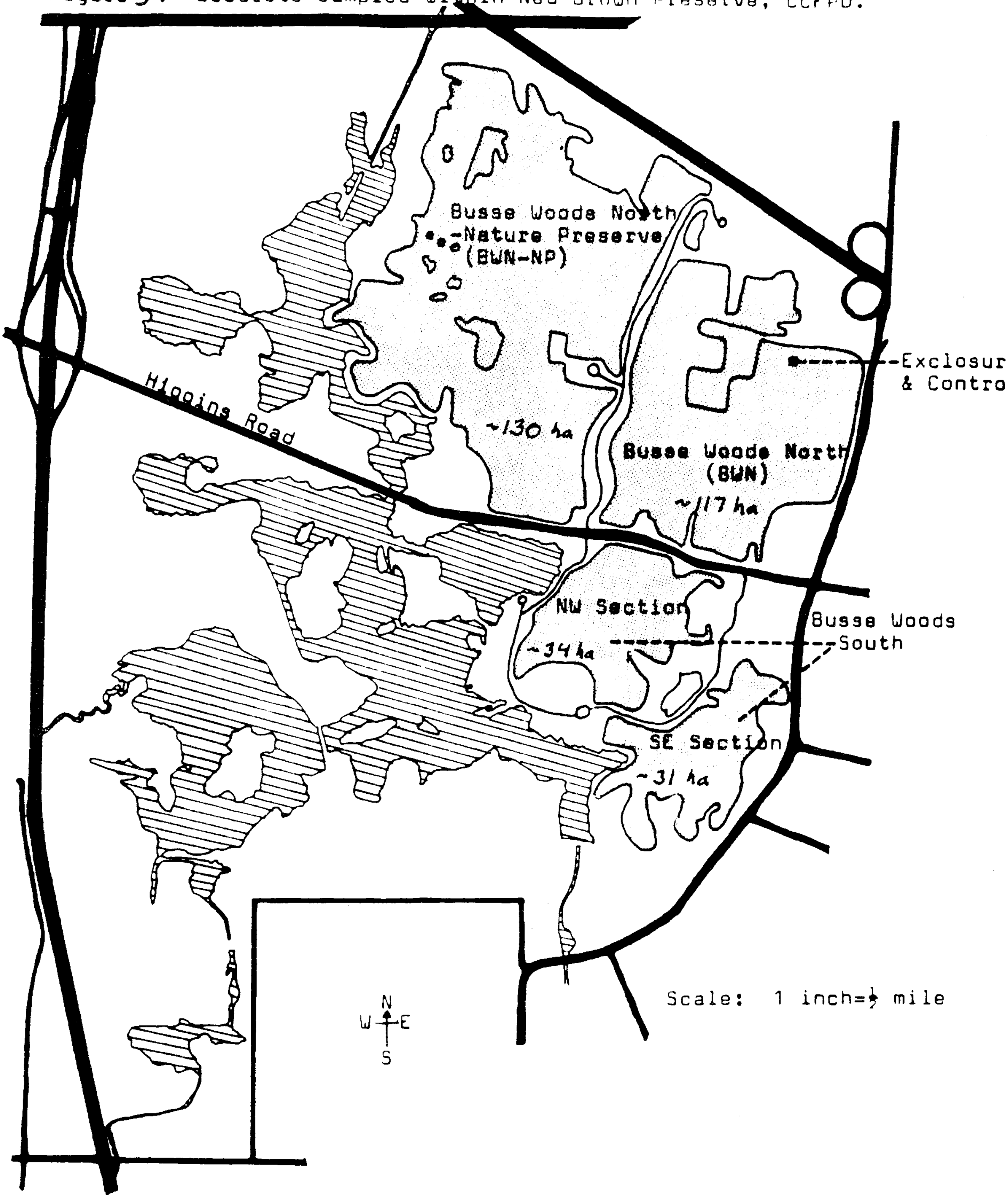


Fig. 2. Deer condition was compared among 5 substudy areas (Des Plaines, Ned Brown, Non-Cook, Northwest, and Palos) in the Chicago metro area.

Figure 3: Woodlots sampled within Ned Brown Preserve, CCFPD.



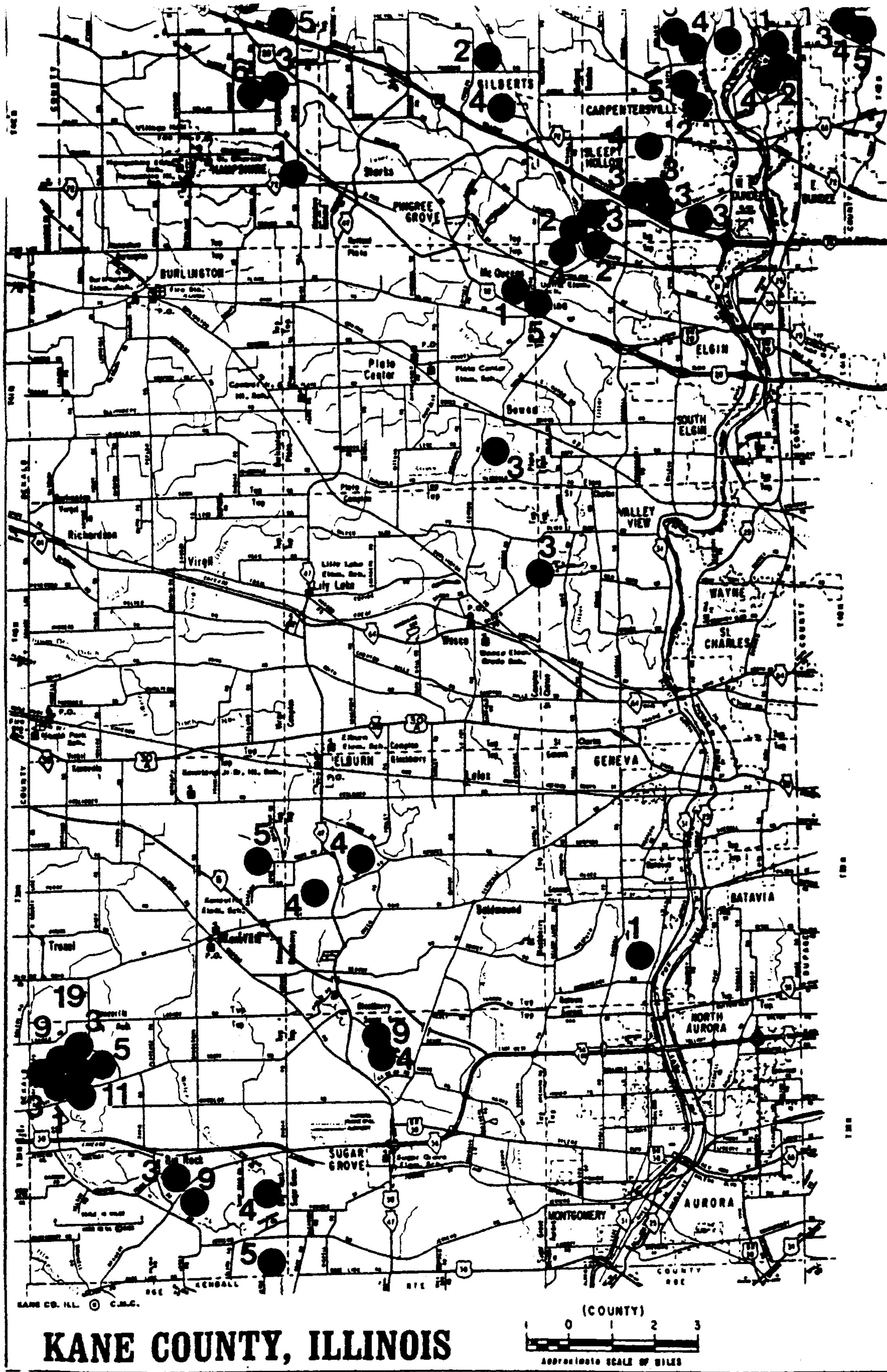


Fig. 4. Distribution of deer sightings in Kane County during a January 1987 aerial count conducted in a fixed-wing aircraft. The number of deer observed in each group are included next to the observation site (i.e., dark circle)

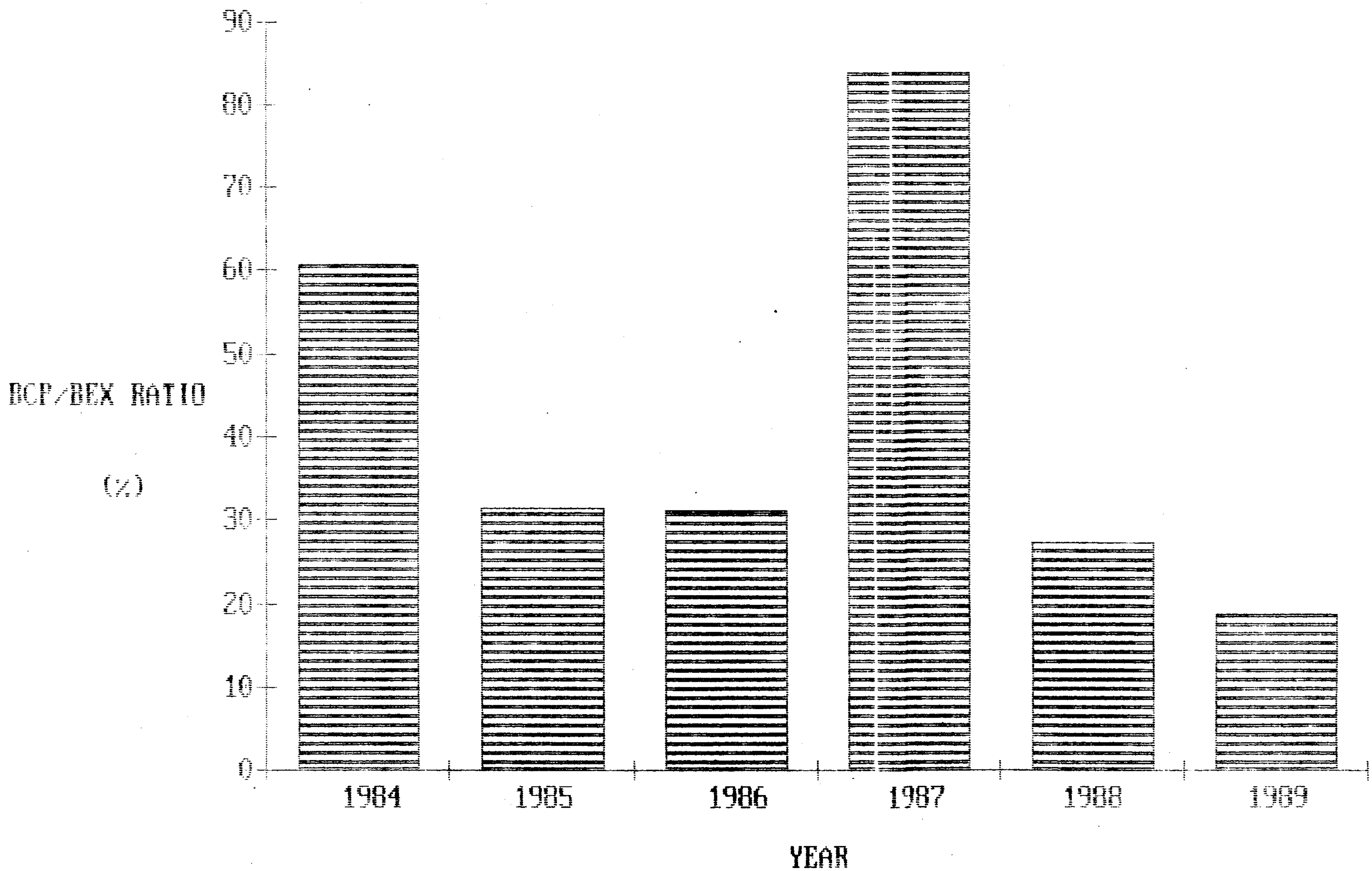


Fig. 5. Mean stem densities of all herbaceous species.

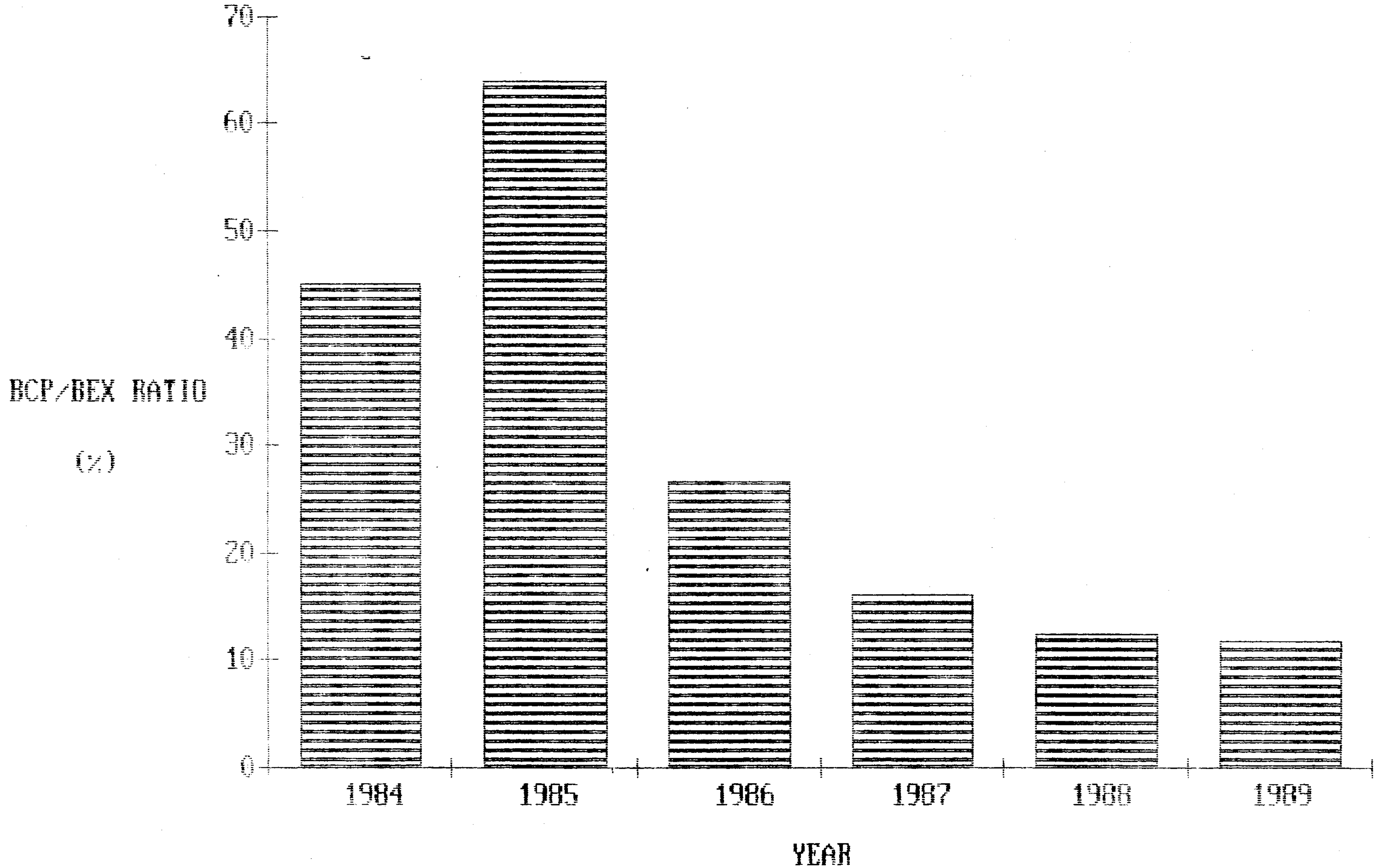


Fig. 6. Mean stem density of woodland knotweed.

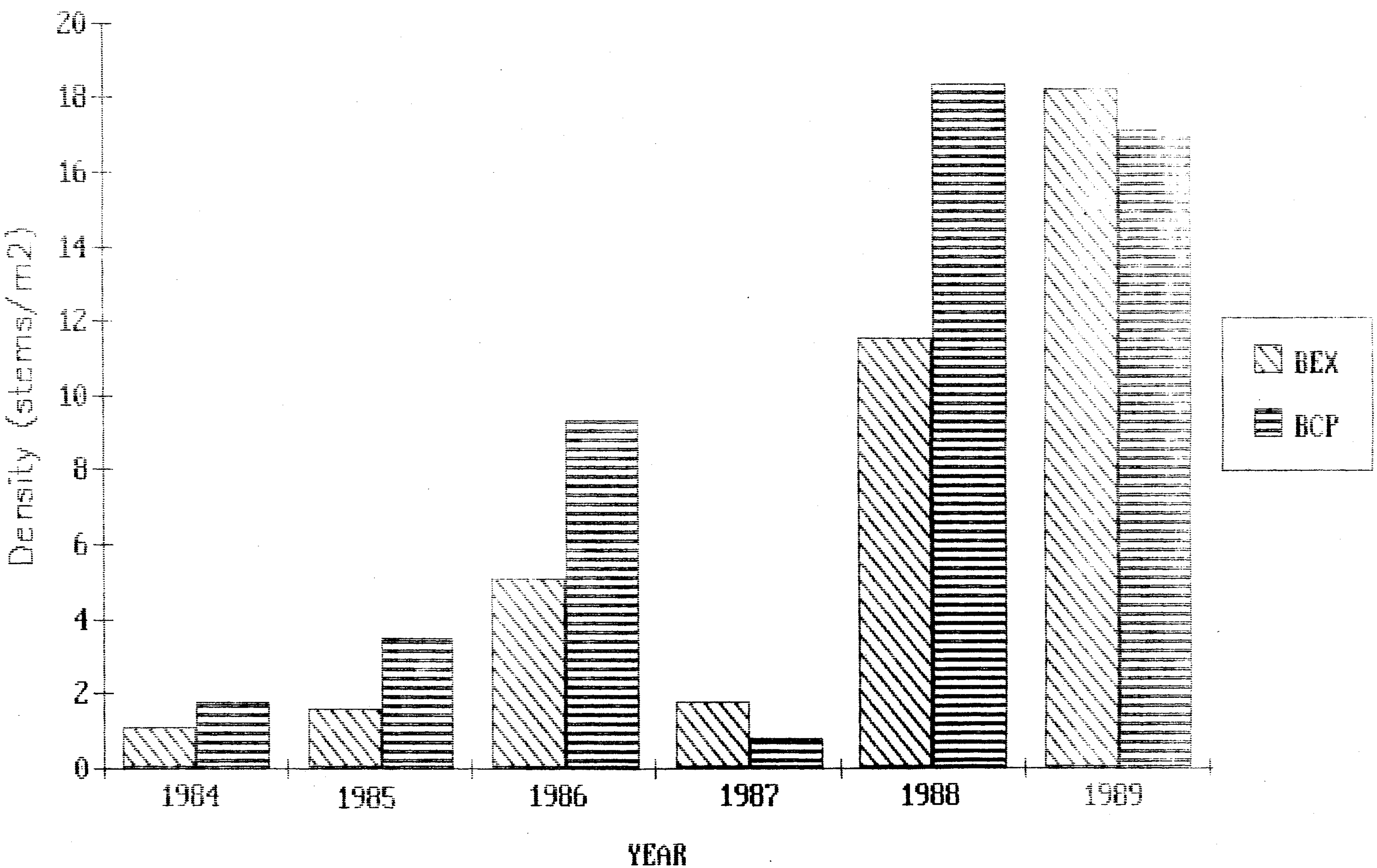


Fig. 7. Mean stem densities of all woody species.

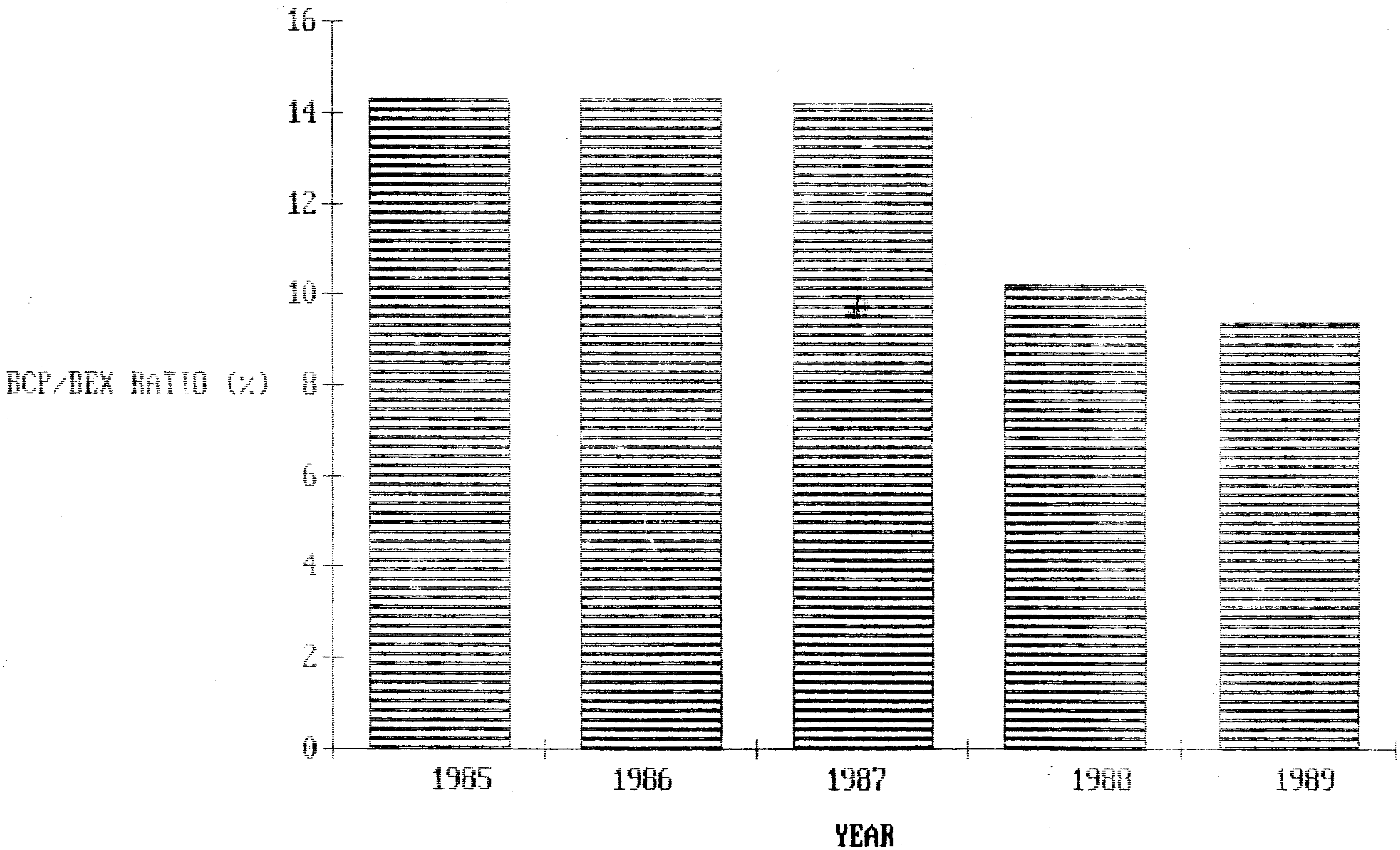


Fig. 8. Mean percent cover of white adder's tongue.

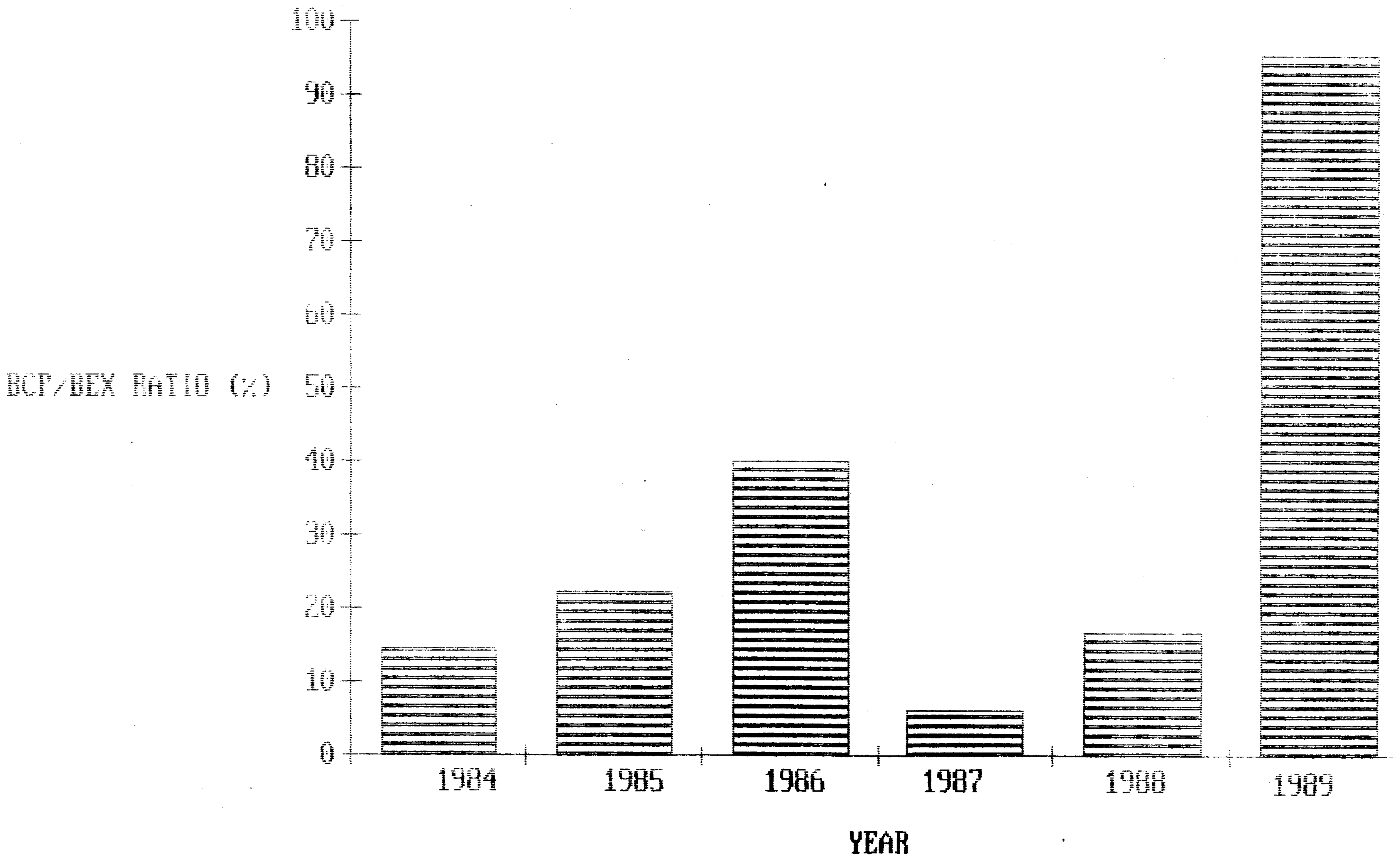


Fig. 9. Mean percent cover of woodland knotweed.

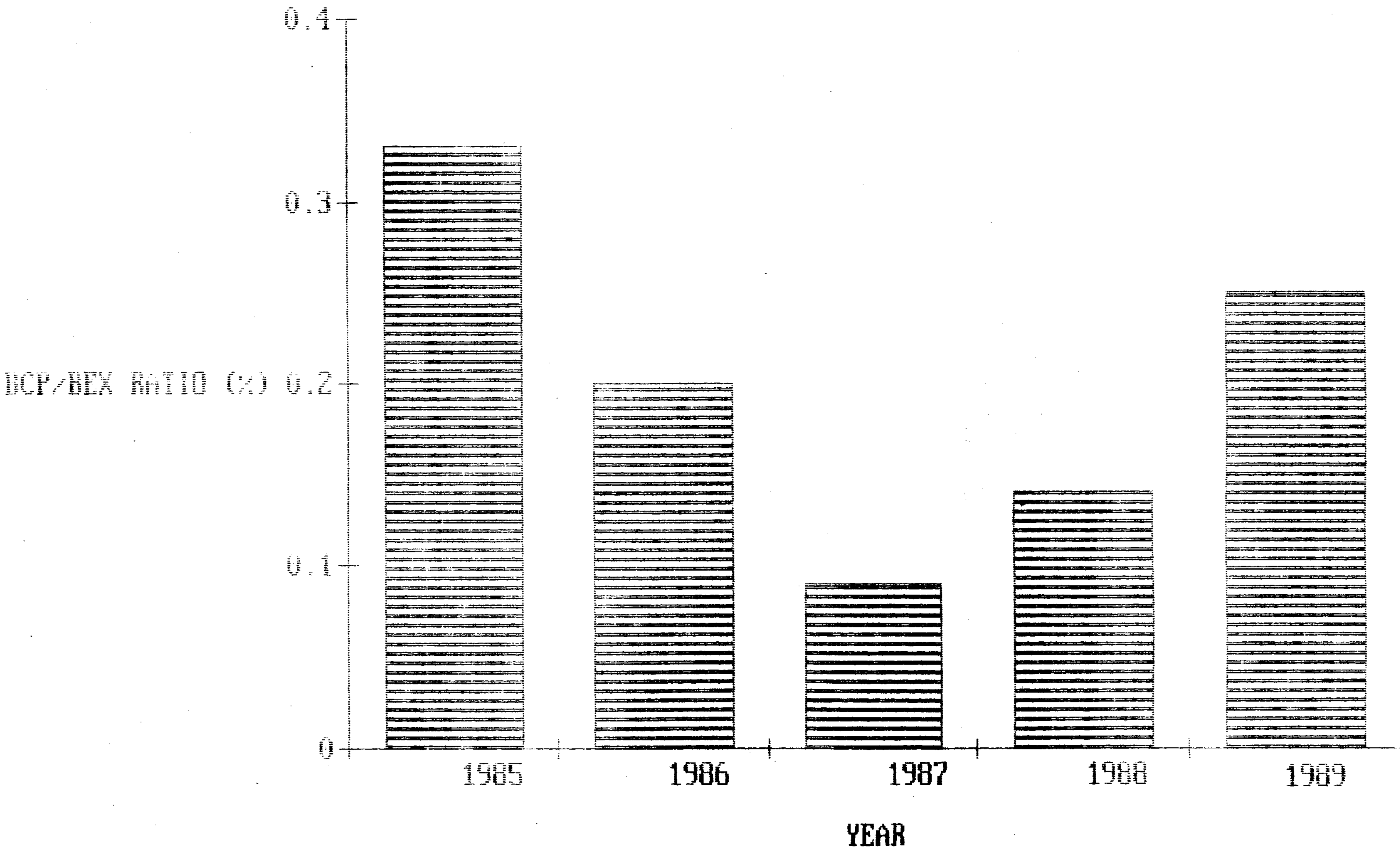


Fig. 10. Mean percent cover of wakerobin.

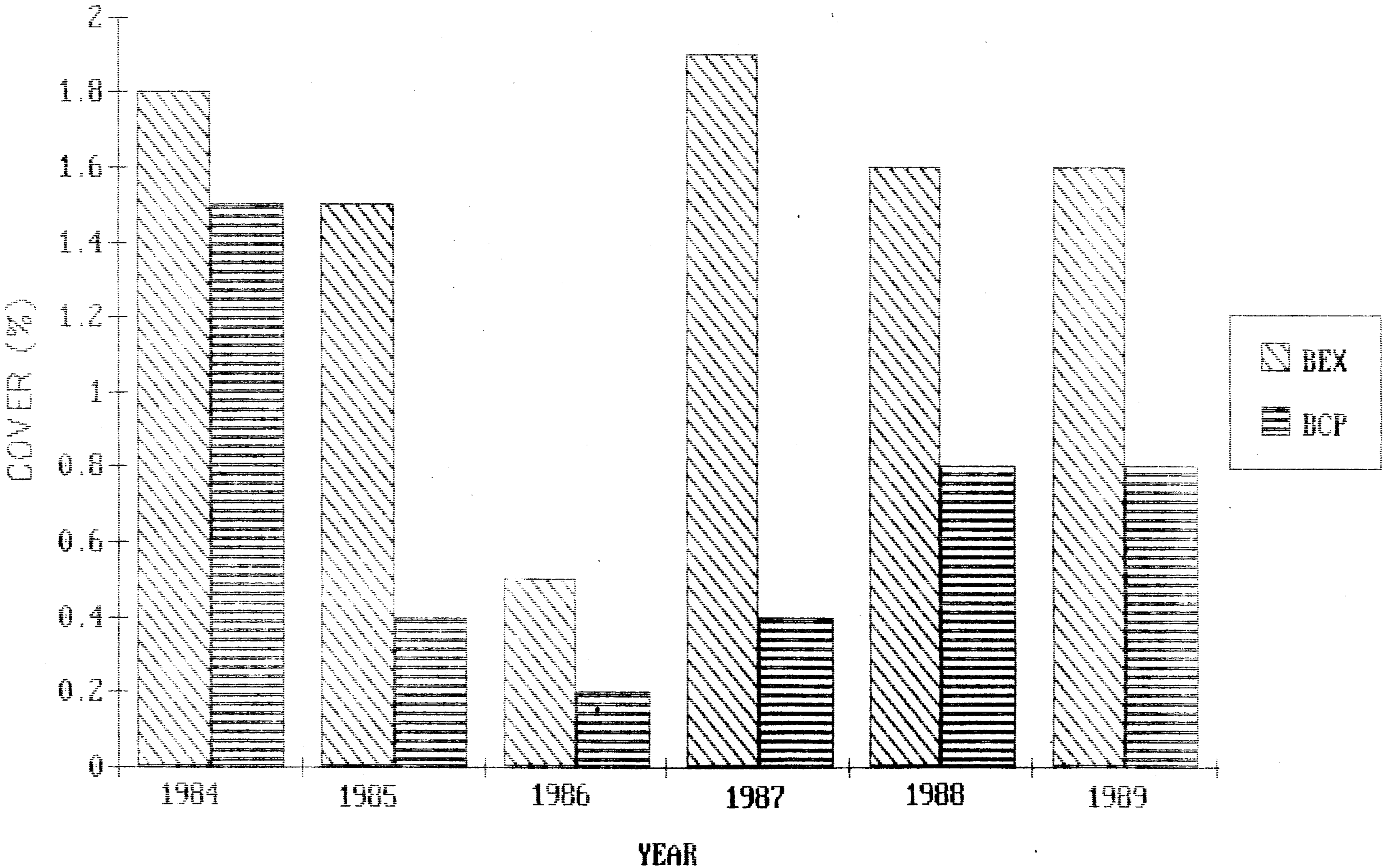


Fig. 11. Mean percent cover of all woody species.

Figs. 12-15. Potential deer habitat in Cook, DuPage, Kane, and Lake counties, based on Landsat Thematic Mapper satellite data collected in 1988. The 5 general categories of deer habitat (different shades on figures) included:

Primary:	Forest and savanna
Secondary:	Residential with trees, nonmaintained grass, cropland, alfalfa and sod
Teritary:	Maintained grass
Nondeer habitat:	Residential-treeless, urban features, and urban water
Water:	Water

Figs. 16-19. Distribution of deer-vehicle accidents on state-numbered highways for Cook, DuPage, Kane, and Lake counties, during 1975, 1981, and 1987. Symbols represent different frequencies of accidents that occurred within 1 km2 cells.

SYMBOL	VALUE
	0
....	1
----------	2
++++++++++	3
**********	4
==========	5
$$$$$$$$$$	6
%%%%%%%%%%	7
##########	9

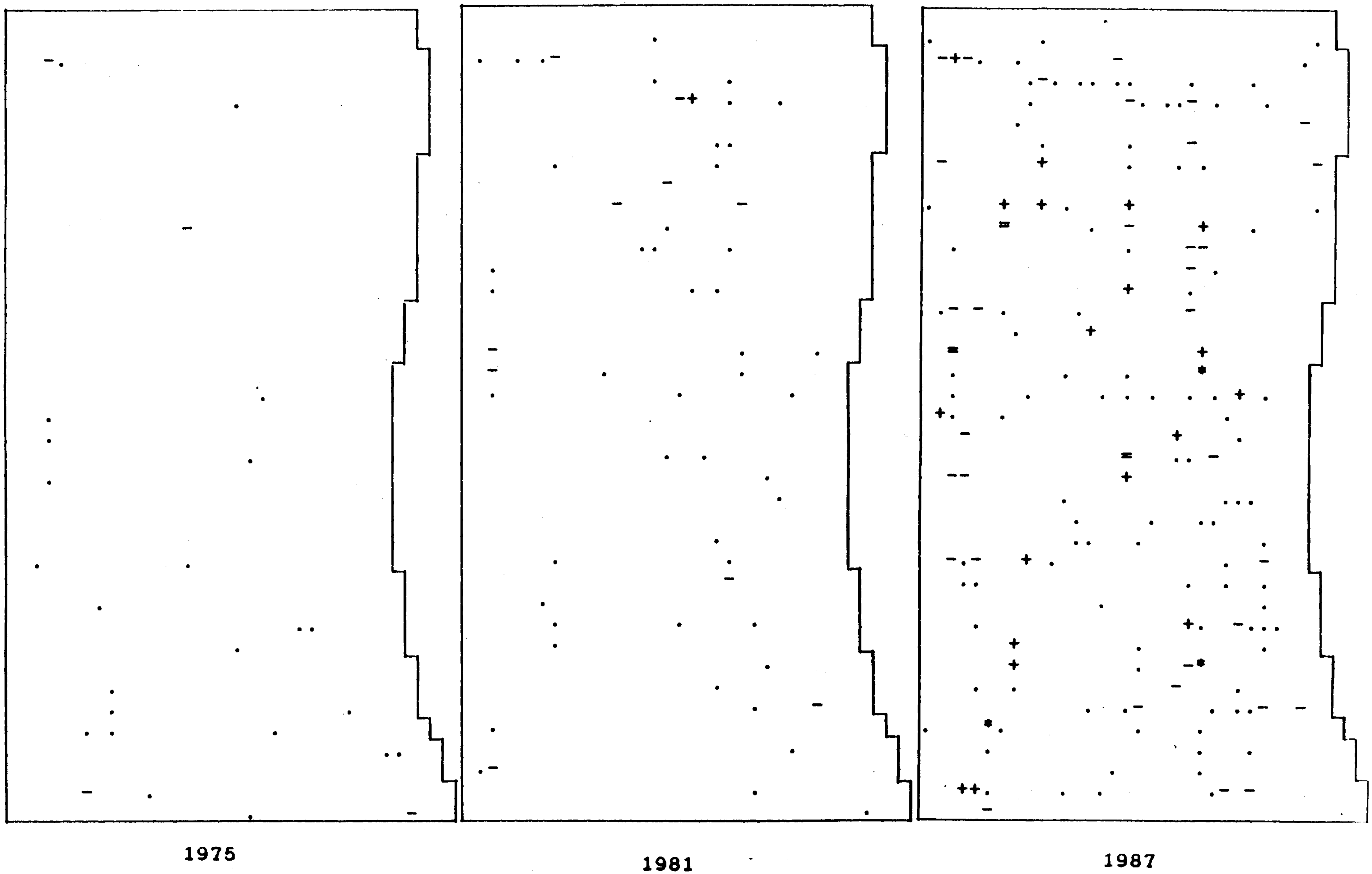


Fig. 16 Lake County

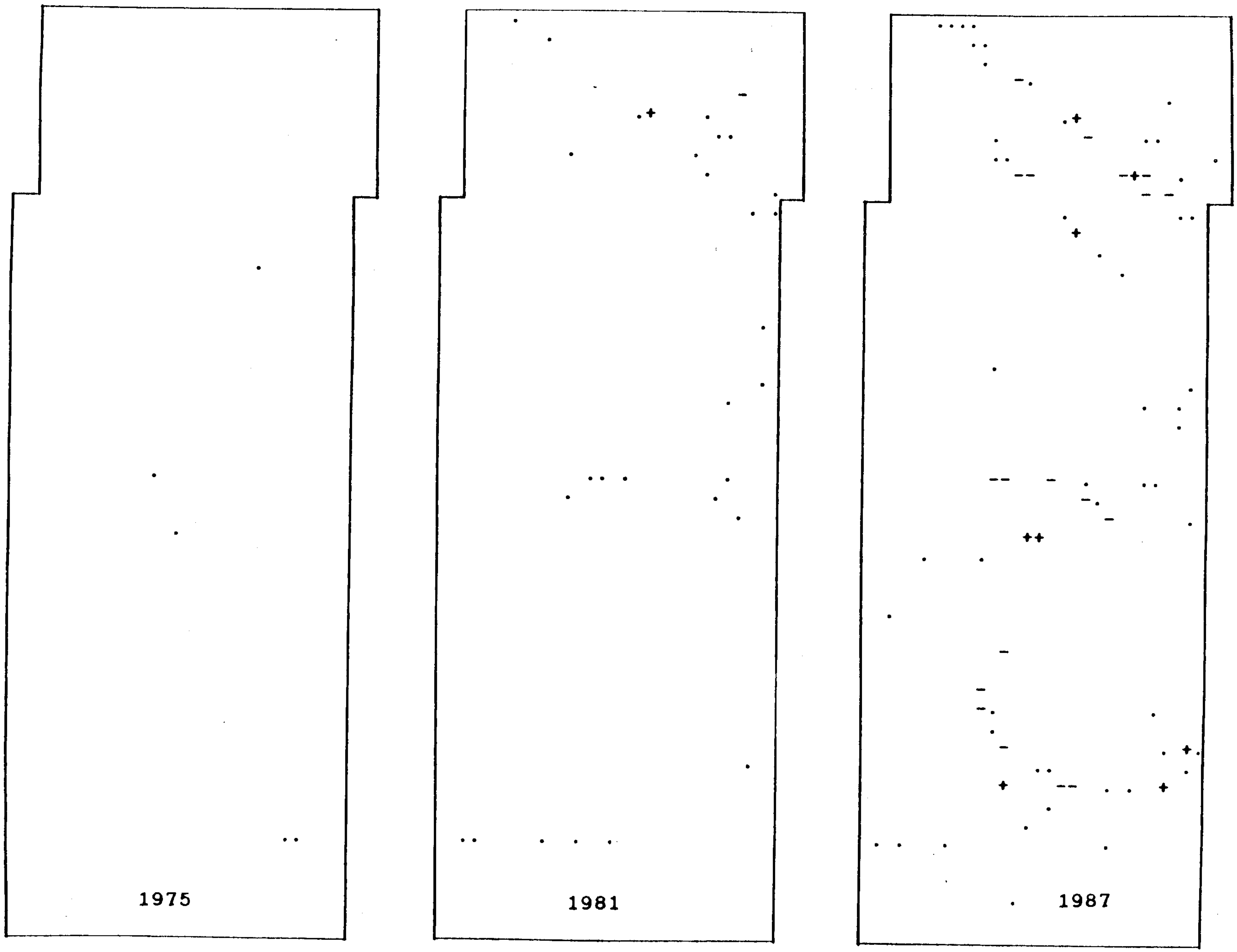


Fig. 17 Kane County

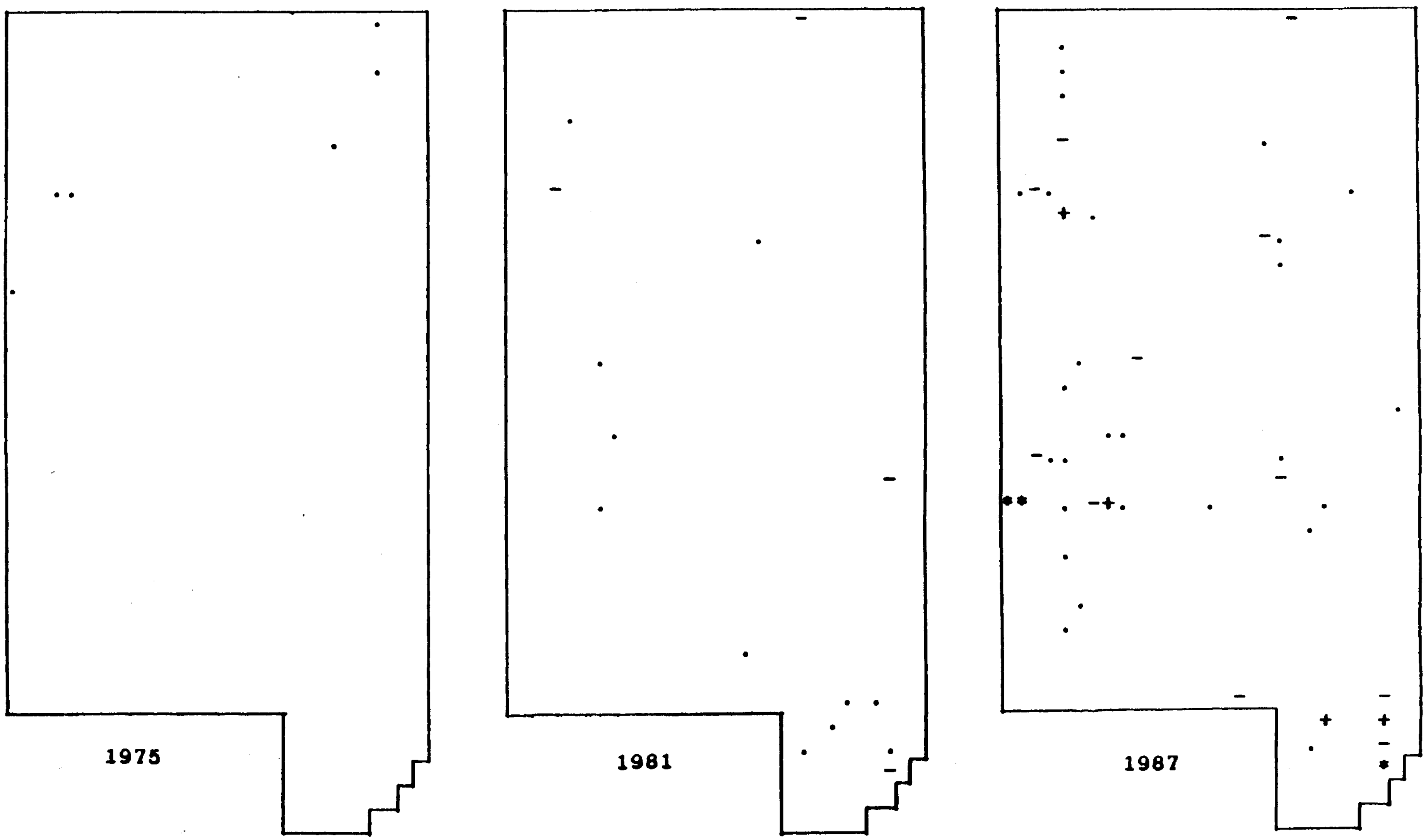


Fig. 18 DuPage County

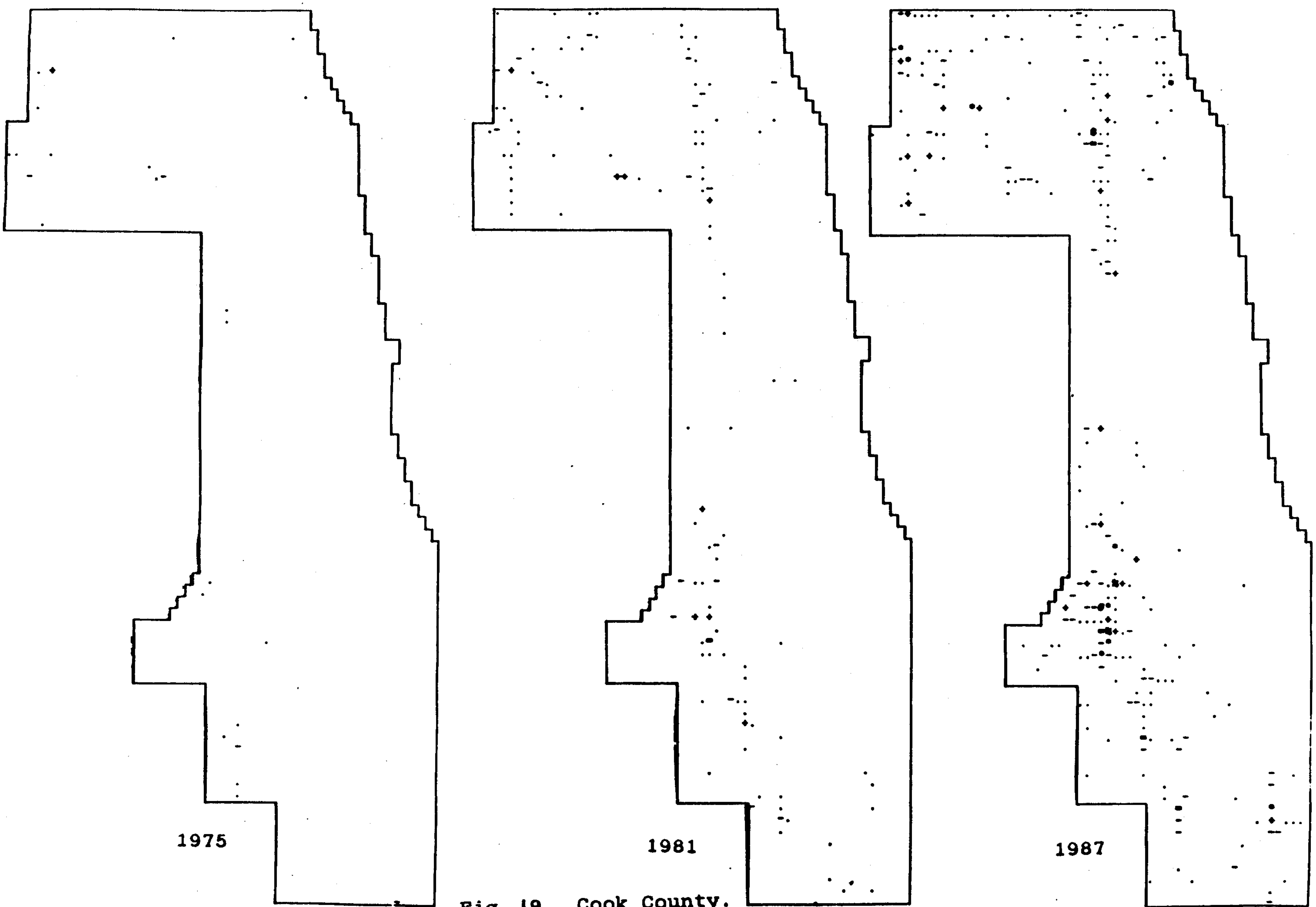


Fig. 19 Cook County.

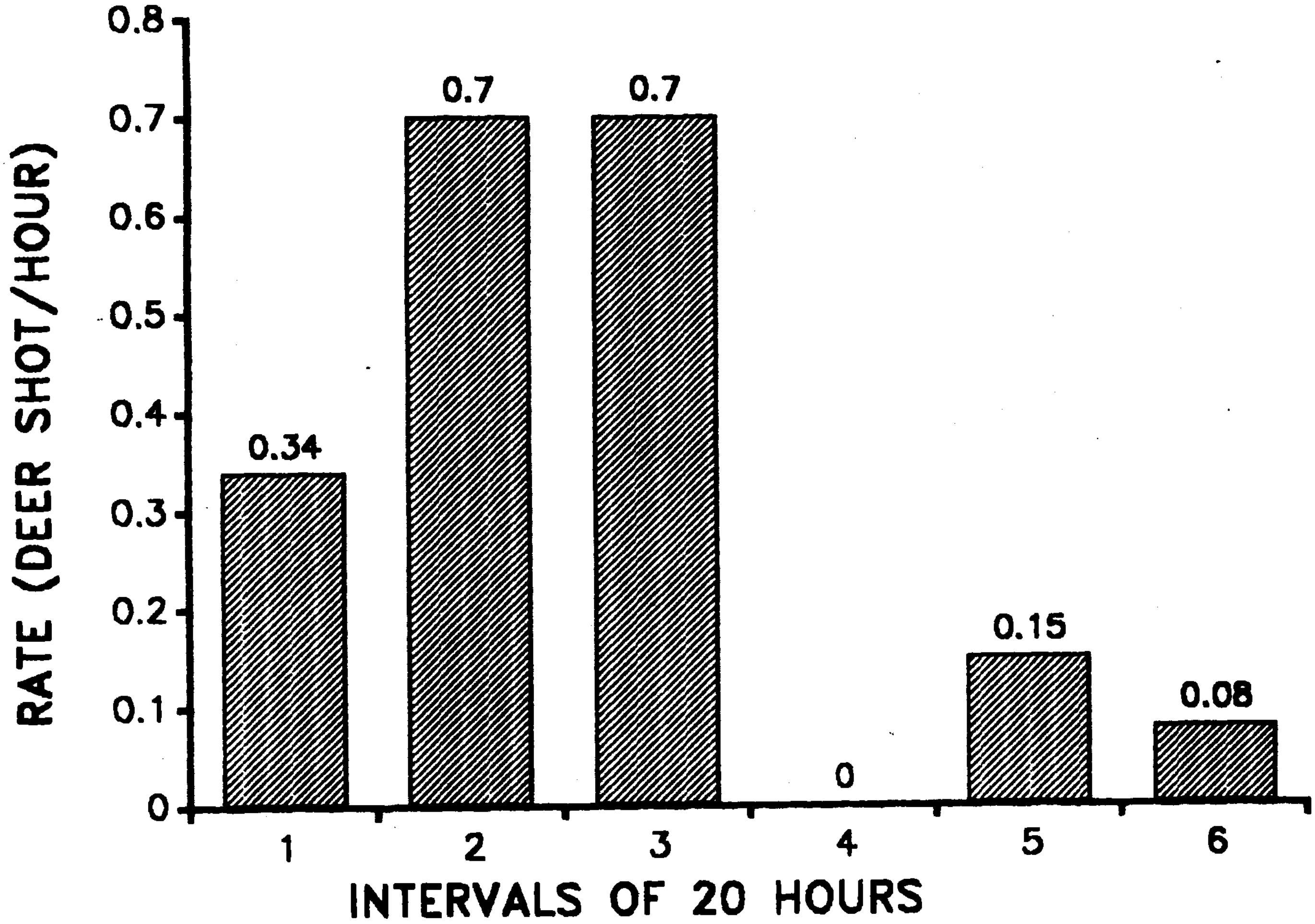


Fig. 20. Deer removal rates in 20-hr increments that were achieved by sharpshooters at O'Hare Airport during winter, 1988.

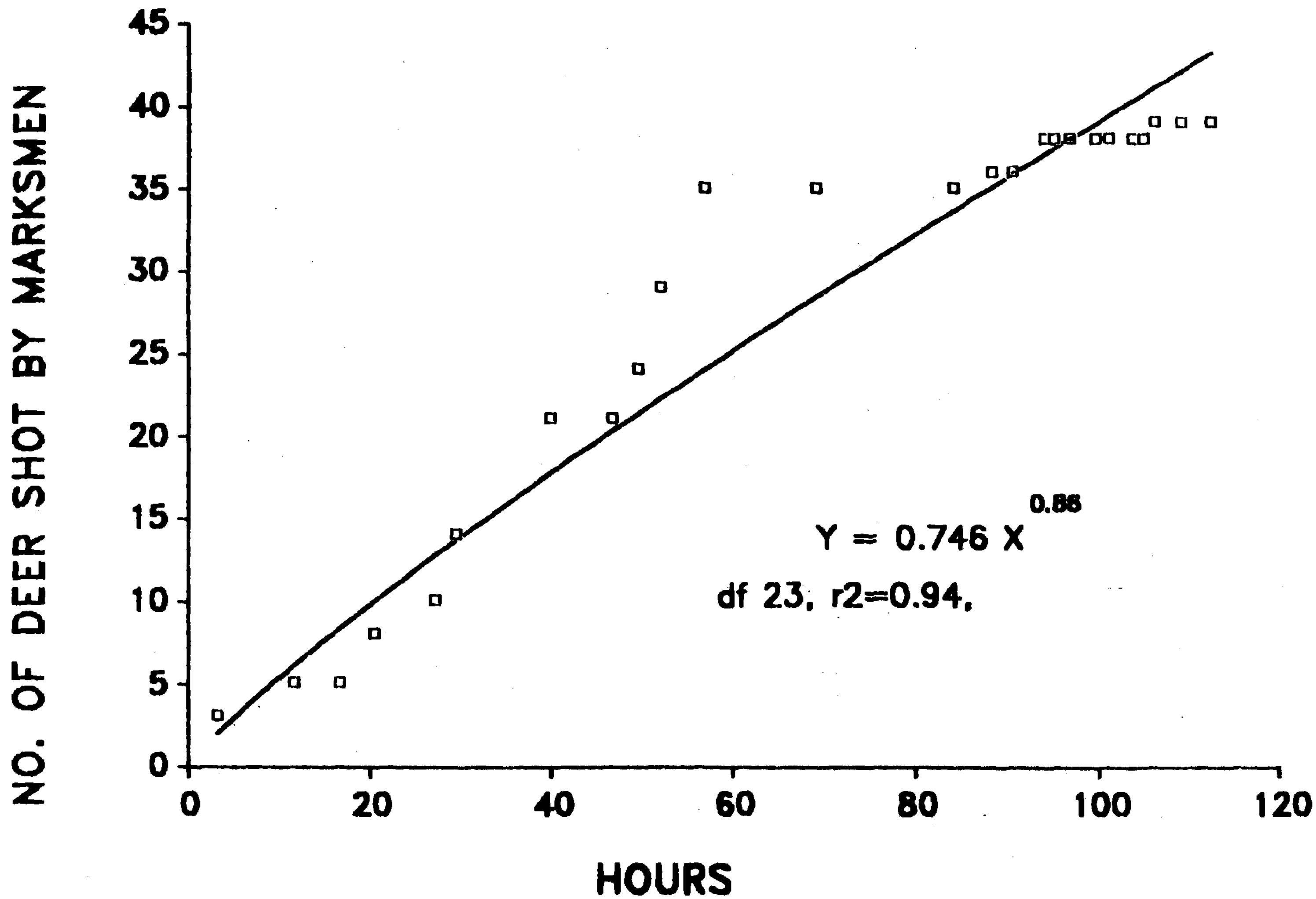


Fig. 21. Regression of deer killed by sharpshooters against effort (hrs. on baited stand) at O'Hare Airport.

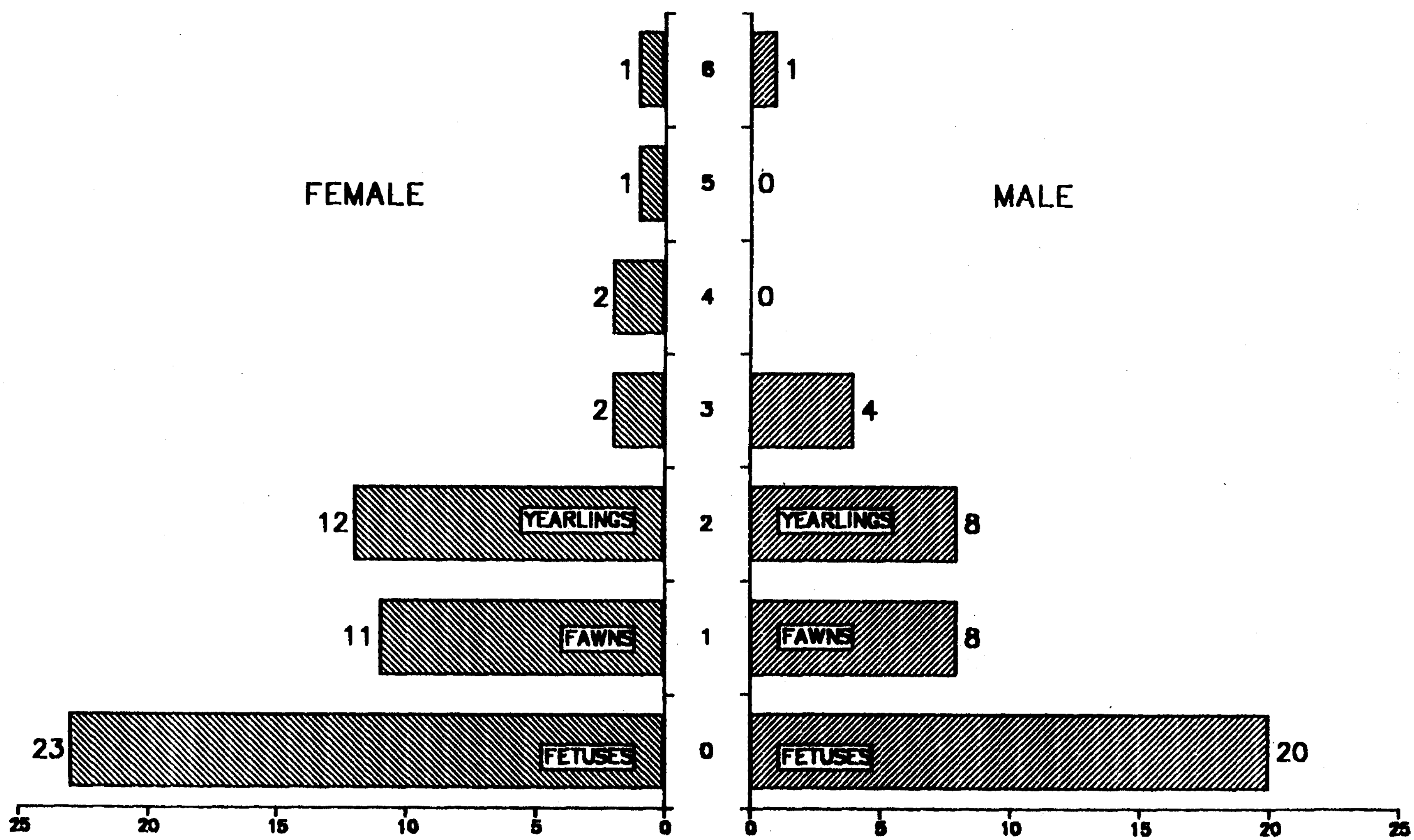


Fig. 22. Sex and age composition of deer removed by INHS from O'Hare Airport during 1988. Four adult deer that were live-trapped and translocated to Will County were not included in this figure.

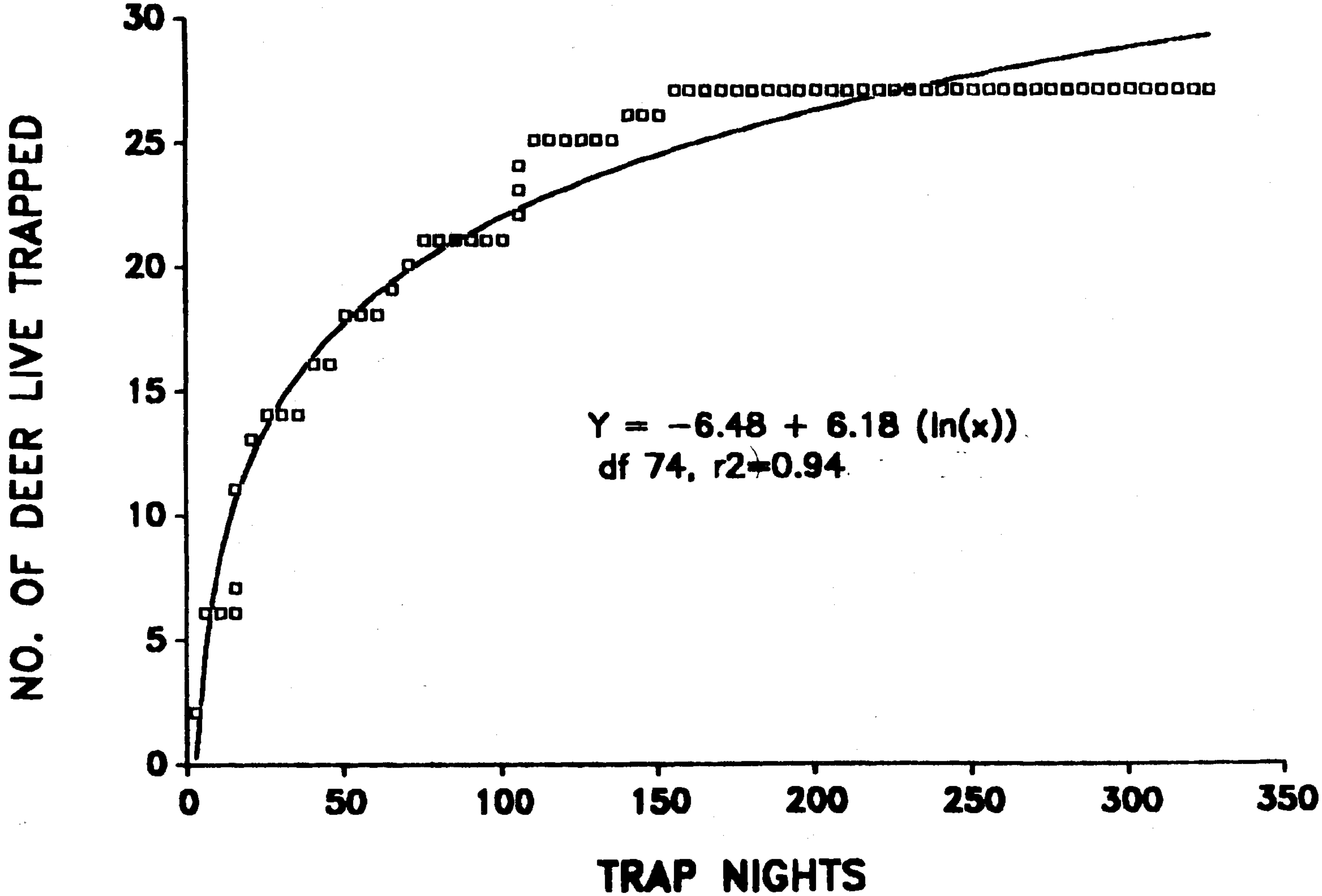


Fig. 23. Relationship between the number of deer live-captured and cummulative trap nights at Ryerson Conservation Area during winter 1989.

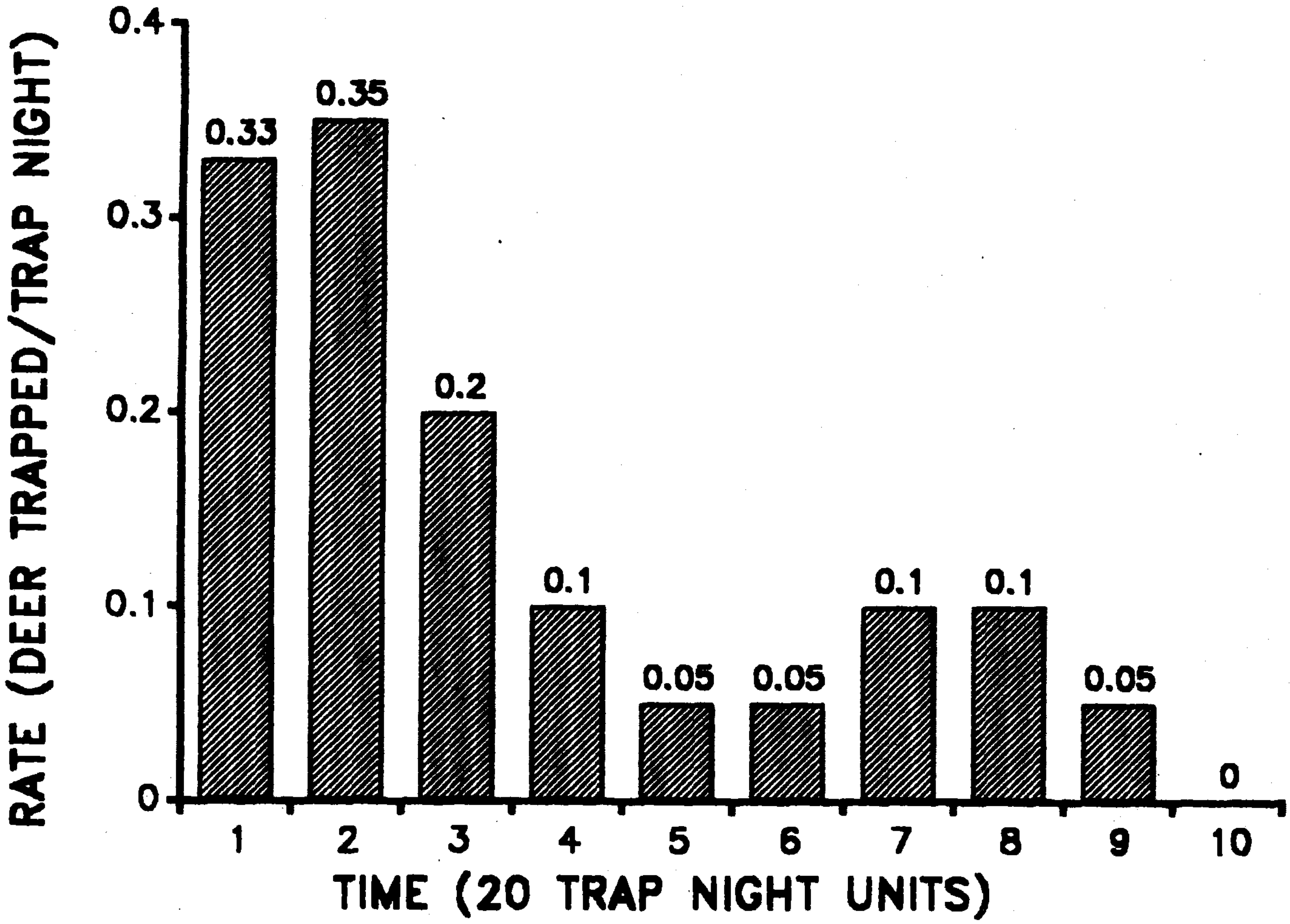


Fig. 24. Live trapping rates over time (i.e., consecutive increments of 20-trap nights) at Ryerson Conservation Area during winter 1989.

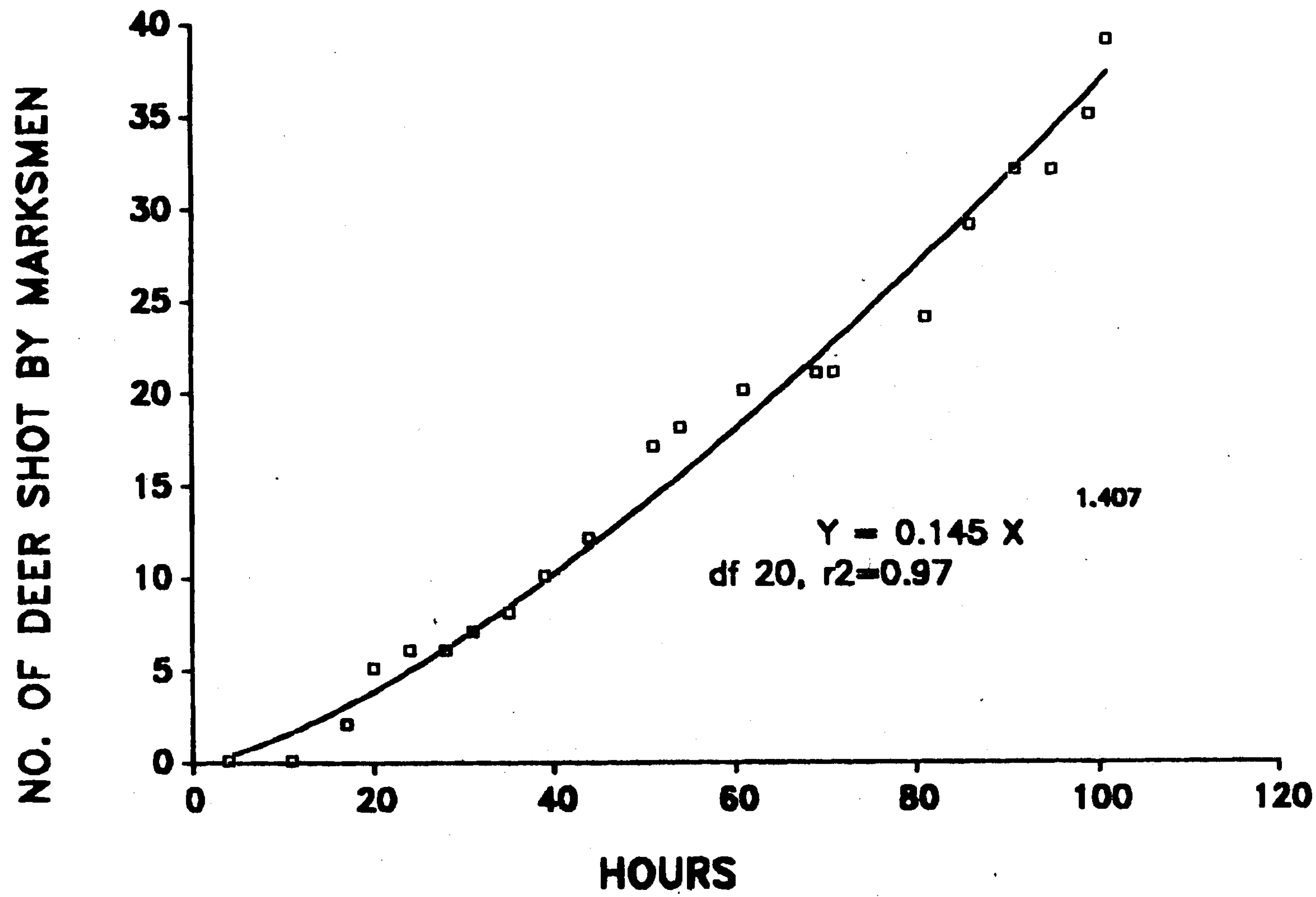


Fig. 25. Regression of deer killed by sharpshooters against effort (hrs. on baited stand) at Ryerson Conservation Area during winter 1989.

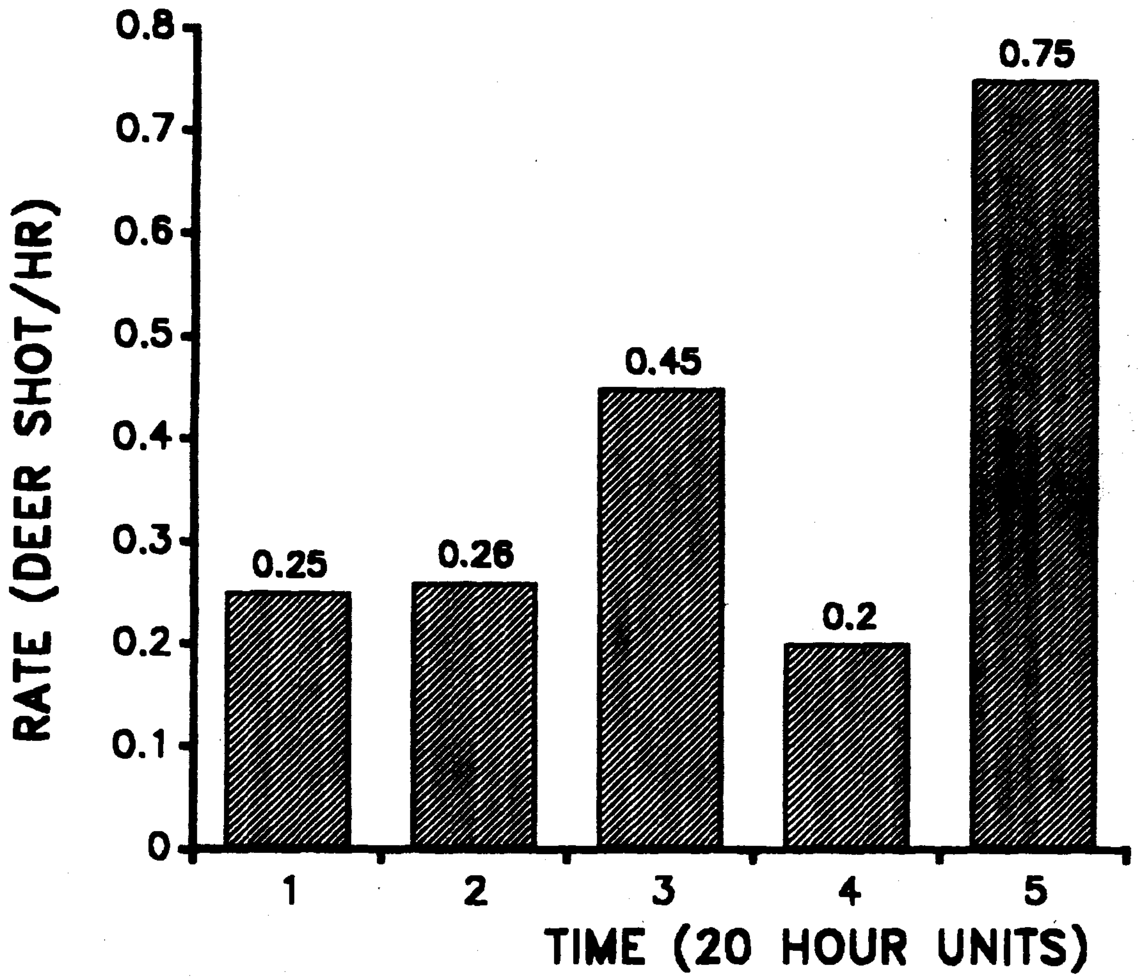


Fig. 26. Deer removal rates in 20-hr increments that were achieved by sharpshooters at Ryerson Conservation Area during winter 1989.

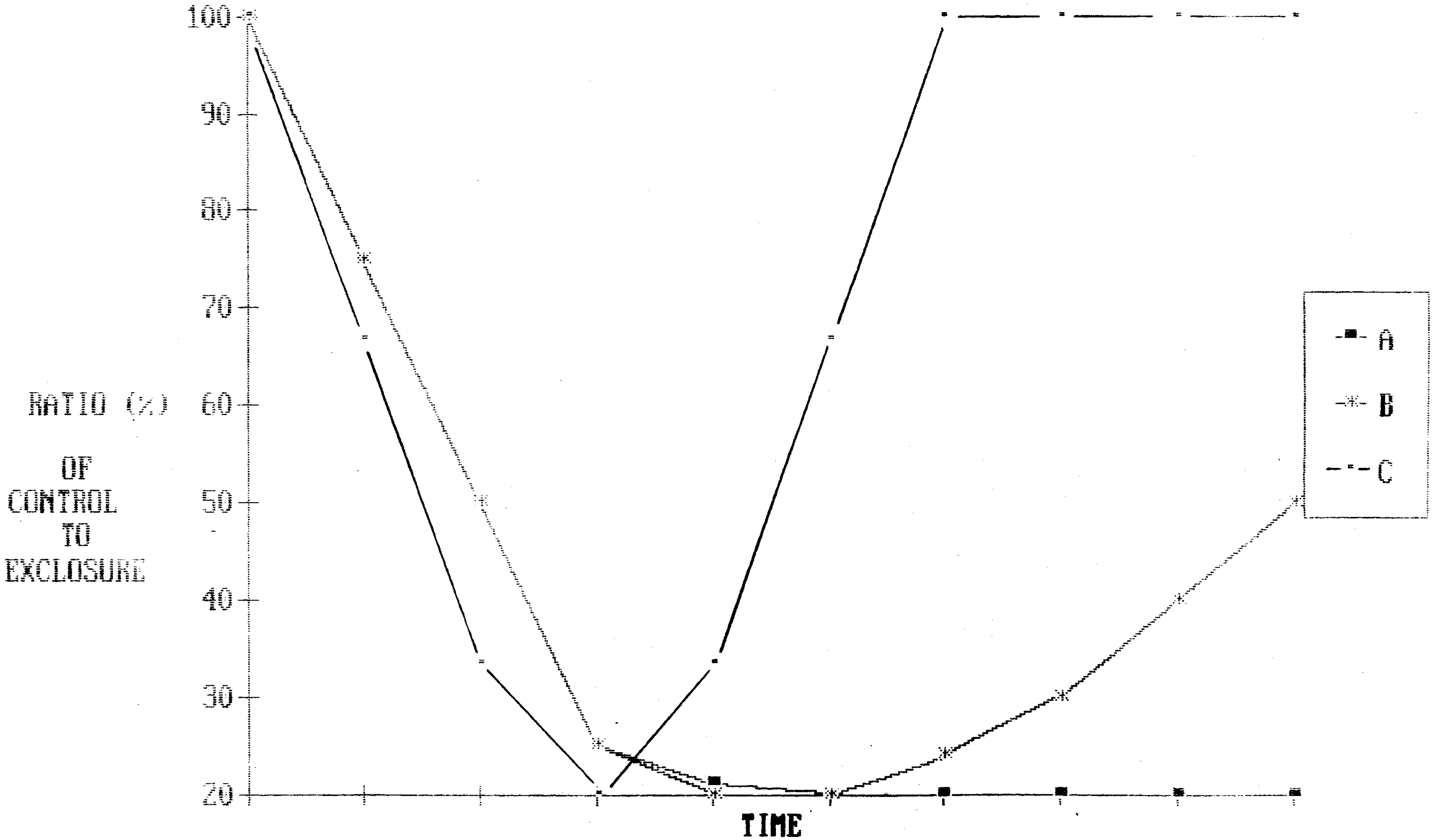


Fig. 27. Hypothetical relationship of plant recovery in a control plot compared to an adjacent deer exclosure.

Appendix A. Witham, J.H., and J.M. Jones. 1990. White-tailed deer abundance on metropolitan forest preserves during winter in northeastern Illinois. Wildl. Soc. Bull. 18:13-16.

Wildl. Soc. Bull. 18:13–16, 1990

WHITE-TAILED DEER ABUNDANCE ON METROPOLITAN FOREST PRESERVES DURING WINTER IN NORTHEASTERN ILLINOIS

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Urban development has expanded beyond the traditional core areas of most major cities. Land-use planners in many metropolitan areas have recognized the value of natural areas for open space and have included them as part of development schemes (McHarg 1969, Hench et al. 1987, Adams and Dove 1989). These natural areas provide habitat for wildlife as well as recreational opportunities for people, thereby increasing the occurrence and diversity of wildlife-human interactions (Bird 1986).

The white-tailed deer (*Odocoileus virginianus*) is the largest wild mammal to inhabit such natural areas in the Chicago Metropolitan Area (CMA) of northeastern Illinois. Principal deer habitat in the CMA is in forest preserves administered by county governments. The many deer that inhabit metropolitan forest preserves, coupled with the progressive insularity of these sites, have led to negative interactions with humans and to locally severe browsing damage to vegetation. For many CMA residents, the cumulative effects of deer-human conflicts have exceeded the residents' willingness to tolerate such damage (Witham and Jones 1987).

We studied white-tailed deer in the CMA for 5 years, 1984–1988. A substudy objective within this program was to determine the minimum number of deer on selected metropolitan forest preserves during winter.

STUDY AREA AND METHODS

The CMA of Cook, DuPage, and Lake counties encompasses 4,521 km^2 in northeastern Illinois with a human population in 1986 of 6.3 million (Table 1). Intermixed on this human-dominated landscape are 393 km^2 of forest preserves representing 8.7% of the total CMA. These preserves are discontinuous in distribution and vary in size and degree of insularity. Vegetation and land-use within forest preserves are diverse and range from extensive recreational developments to inviolate natural areas (Wendling et al. 1981).

Swink and Wilhelm (1979) documented species, associations, and distributions of plants in the Chicago region. In general, the combination of fire suppression and succession has led to preserves dominated by oak/maple/basswood (*Quercus* spp./*Acer* spp./*Tilia americana*) forests of mixed types (i.e., mesic upland, dry-mesic upland, bottomland, and flatwoods). Old-field successional communities, meadows, and regularly mowed recreational fields are interspersed in and around woodlots. Remnant swamp, marsh, bog, fen, and prairie communities also persist (Schwegman 1973:11–14, Wendling et al. 1981).

We defined individual preserves by contiguity of property irrespective of administrative divisions. Unfenced roads that dissected preserves were not treated as boundaries. Areal measurements of sizes of individual preserves in DuPage and Lake counties were provided by their forest preserve districts. Sizes of preserves in Cook County were determined with a dot grid overlaid on forest preserve maps. No adjustments were made for nondeer habitat (i.e., surface water, roads, and maintenance buildings) within preserves.

Deer were counted from a Cessna 172 fixed-wing aircraft during 1984–1985 and from a Bell Long-Ranger helicopter during 1985–1988. The helicopter was favored because of greater maneuverability and improved safety while flying at low altitudes (90–150 m AGL) and reduced speeds (50–60 knots) over developed areas and near major airports. Areas with vegetative cover that was relatively homogeneous were surveyed systematically by flying parallel transects determined by aircraft instrumentation and visual ground references. Transect widths were not measured, but we estimate that they varied from 100 m in mature forests to 300 m for agricultural fields without standing crops. We divided smaller preserves, and areas with heterogeneous vegetative cover types, into subunits with boundaries that were defined by natural features (e.g., changes in vegetation, rivers, lakes) and roads that were visible from the air; we searched these subunits systematically and then totaled all nonduplicate deer counted within each preserve. Individual preserves were surveyed ≤1 time annually and from 1 to 5 times

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Table 1. Chicago Metropolitan Area: human population, and area and size of forest preserves by county.

	Counties			
	Cook	DuPage	Lake	All
Human population ($\times 10^6$)[a]	5.3	0.7	0.3	6.3
County area (km^2)[b]	2,454.5	860.1	1,205.9	4,520.5
Forest preserve area (km^2)	267.9	72.3	52.6	392.8
Percent of county in forest preserve[c]	10.9	8.4	4.4	8.7

[a] 1 July 1986 estimate, U.S. Census Bureau, released December 1987.
[b] Suburban fact book, 1973, Northeast Illinois Planning Commission, Chicago.
[c] 1 January 1988.

during the study. Surveys were conducted during winter when snow depth exceeded 10 cm. Two observers in verbal contact counted deer from 1 side of the aircraft.

Our counts reflect the maximum number of independent observations of deer that we made on each site at the time of the census only. We deleted observations where duplicate sightings may have occurred. These included deer that were disturbed by the aircraft and traveled into areas yet to be surveyed. Most deer observed during surveys remained stationary or moved <50 m toward cover or other deer. Because many factors preclude counting all deer on a site, we refer to data based on our counts as "minimum" numbers or "minimum" densities.

RESULTS

The 52 preserves that were surveyed during the 5-year period included 93% (366 km^2) of the total forest preserve area in the CMA. Unsurveyed preserves were either small, with few if any deer present, or were located where aerial survey access conflicted with airport flight patterns. Individual preserves ranged from 0.21 to 34.37 km^2. The majority (79%, $n = 41$) of preserves in the CMA were <10 km^2; however, preserves >10 km^2 represented 62% of the total area surveyed (Table 2).

We observed deer on 43 of the preserves. Among the 9 preserves where deer were not observed, all were <2.0 km^2 in size and collectively were <3% of the total area of the preserves surveyed.

Minimum densities of deer on the 52 preserves ranged from 0 to 26 deer/km^2. However, deer distribution was typically patchy, with animals often concentrated within preserves on sites of 1 to 3 km^2 at densities >40 deer/km^2. Minimum densities of deer on 16 preserves (33% of all preserves) exceeded 8 deer/km^2 on at least one survey; 13 (31% of the area surveyed) of these sites had >12 deer/km^2; 7 (14% of the area surveyed) preserves had ≥20 deer/km^2 (Table 2).

DISCUSSION

We experienced problems in conducting aerial flights over the CMA that would not have occurred in less developed areas. Airspace was rigidly controlled by airport control towers. Thirteen pilots were used in this study; all were competent, but varied greatly in their attention to detail and enthusiasm. Pilots experienced stress caused collectively by intense concentration necessary to detect other aircraft in the congested airspace of the CMA, complex communications with air traffic controllers, presence of residential and commercial buildings, and flight at low altitudes that required standardization and precision to count deer. Because emergency medical service (EMS) is the priority mission of state-owned helicopters, deer counts were sometimes aborted in flight because of EMS requests. Collectively, these factors, among others, contributed to our decision early in the study to conduct only direct counts of deer.

Direct counts produce limited information on the distribution of deer, minimum abundance, and minimum density. Population trends cannot be inferred from these data and low numbers of deer observed on a site are of

Table 2. Number of white-tailed deer counted during aerial surveys on individual forest preserves in the Chicago Metropolitan Area conducted during winters, 1984–1988. Counts represent the minimum number of deer on a preserve during each respective survey only.

Area of preserve (km²)	Number of deer counted					Range of minimum deer densities (deer/km²)
	1984	1985	1986	1987	1988	
0.21		0		0	0	0
0.70	0	0				0
0.80	0	0				0
0.85	0	0				0
0.98		0		2	2	0–2
1.01					6	6
1.01	0	0				0
1.09					22	20
1.14	0	0				0
1.24	0	0				0
1.24					22	18
1.37	0	0				0
1.58		11		13	31	7–20
1.68		0		1	17	0–1
1.99					0	0
2.10					40	19
2.10	0	1				0
2.15					1	0
2.23					15	7
2.25					5	2
2.38	23	13				5–10
3.00	3	0				0–1
3.14					69	22
3.24	9	6				2–3
4.38	13	23				3–5
4.40	22	22				5
4.53		14		13	12	3
4.59					97	21
4.69	37	34				7–8
5.18	20	30				4–6
5.18		2		11	15	0–3
5.41	35	46	69	42	61	6–13
5.62					44	8
5.72		26		25	33	4–6
5.83		29		21	19	3–5
6.24		6		19	17	1–3
6.79	8	22				1–3
7.04		23		22	13	2–3
7.20		0		0	9	0–1
8.69		101	117	87		10–13
9.84		71		217	221	7–22
10.95	24	21				2
14.84.	293	253	190	118	103	7–20
15.31		404	401	281		18–26
15.70	67	88				4–6
16.03	35	38				2
18.80					135	7
20.90	73	68				3
21.66	136	200			372	6–17
24.84	191	333				8–13
32.04	126	101	150	140	138	3–5
34.37	53	73				2

value as distributional records only. However, the documentation of high minimum deer densities is important to metropolitan land managers who must prioritize their deer management activities among the expansive preserves that exist within the CMA. Deer densities observed in the CMA suggest that managers should be concerned in at least 13 of the 52 preserves surveyed. Those 13 preserves represent 114 km² (31%) of the total area of forest preserves in the CMA.

Our conservative counts of deer are remarkable primarily because they indicate an extensive distribution of large numbers of deer across a major metropolitan landscape with high human densities. The abundance of deer in the CMA is a direct result of historic land-use decisions, which preserved habitat sanctuaries (Forest Preserve District of Cook County 1918) on the periphery of a major city that continued to expand. Deer abundance is dynamic, and the location and severity of site-specific conflicts are already diverse and will continue to change over time. The extensive distribution of forest preserves and the large number that interface private and municipal properties in the CMA will require the development of site-specific evaluations with clearly defined deer management objectives. Some will require intensive management, but in others greater acceptance or tolerance of damages caused by large numbers of deer may be necessary.

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BODY COMPOSITION AND CONDITION EVALUATION OF WHITE-TAILED DEER FAWNS

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Abstract: Sixteen white-tailed deer (*Odocoileus virginianus*) fawns were captured between November and April 1984–86 near Chicago, Illinois, to evaluate relationships between body composition and condition indices. Body fat (bled, ingesta-free basis) of the fawns ranged from 2.3 to 48.9%, dry-matter basis. Of 6 morphometric indices, chest girth had the highest correlations with body mass, gross energy, and fat. Of 45 postmortem indices, carcass mass and composition, viscera mass and composition, Kistner score, kidney fat mass, and gastrocnemius protein had the highest correlations with body mass and composition. Kidney fat indices, kidney fat mass, and back fat thickness were related to body fat concentration by logarithmic functions. Kistner score and gastrocnemius fat concentration were each linearly related to body fat concentration. Femur marrow fat and mandible marrow fat concentrations were each related to the negative inverse of body fat concentration. Serum triiodothyronine had the closest relationships with body energy content and body fat concentration of the 11 blood and serum constituents we analyzed. Multiple regression analysis indicated that body gross energy content could best be predicted in live fawns by a combination of live mass and triiodothyronine and postmortem by a combination of viscera mass and live mass or gastrocnemius fat mass, kidney fat mass and kidney mass, or gastrocnemius fat mass and liver mass.

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Accurate assessment of body condition of white-tailed deer is essential for understanding the interactions that occur between deer populations and their environment and, in turn, for successful management. Although extensive literature is available on ungulate condition indices (Kirkpatrick 1980, Franzmann 1985), few attempts have been made to determine relationships between indices and the attributes they are intended to reflect (Robbins 1983:222).

Condition indices related to (1) body mass and morphometry, (2) body composition, and (3) metabolic status have received widespread attention in white-tailed deer. Commonly-used gravimetric and morphometric indices include live mass, dressed-carcass mass, and various linear and circumferential measurements (e.g., Smart et al. 1973, Roseberry and Klimstra 1975, Weckerly et al. 1987). Commonly-used body composition indices include bone marrow fat concentration, the kidney fat index (KFI), and visual scoring methods (e.g., Ransom 1965, Baker and Leuth 1966, Kistner et al. 1980). Indicators of metabolic status include blood urea nitrogen, serum nonesterified fatty acids (NEFA), and triiodothyronine (T3) (e.g., Kirkpatrick et al. 1975, Seal et al. 1978, Bahnak et al. 1981). We believe all 3 types of indices are required for accurate condition assessment, because body mass, body composition, and metabolic status can have dynamic interrelationships, i.e., different body compositions for the same body mass, and vice versa, or different metabolic states for the same body mass and composition. For example, fawns with restricted food intake or fed a poor quality diet can accumulate substantial fat reserves during autumn even though their body mass is reduced (Verme and Ozoga 1980*a*,*b*; Watkins 1980). An index related only to body fat concentration might not be sufficiently sensitive to differentiate these fawns from larger, well-nourished fawns.

Our objective was to determine how various indices were related to body size, body composition, and metabolic status of white-tailed deer fawns. We thank P. Whetter, M. E. Keeffe, J. W. Seets, R. Dobbins, G. Sanderson, and W. Edwards for their assistance. Our research was supported by the Illinois Natural History Survey, with contributions from the Federal Aid in Wildlife Restoration Project (W-87-R), the Illinois Department of Conservation, and the U.S. Fish and Wildlife Service.

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METHODS

Between November and April 1984–86, 16 white-tailed deer fawns (10 M, 6 F) were captured by rocket net on county forest preserves near Chicago, Illinois. Two deer were collected in November, 4 in December, 2 in January, 7 in March, and 1 in April. Immediately after capture, animals were manually restrained, aged as fawns based on the absence of the third molar, sampled for blood by jugular puncture, and euthanized by injection of T-61 solution (National Laboratories, Somerville, N.J.).

Body Processing

The fawns were transported from the field to a laboratory and processed within 1 hour after death. Each animal was weighed and measured as described by Feldhamer et al. (1985), except that right shoulder height was measured from the plantar surface of the hoof. Animals were bled from the neck over a tared polyethylene bag and eviscerated. Contents of the digestive tract (ingesta) were removed, and urine contained in the bladder was discarded. The skin with hair and dew claws intact (hide) was carefully removed with a minimum of adherent muscle and fat. Carcass fat, musculature, and visceral fat were visually scored (Kistner et al. 1980). The thyroid lobes were removed and trimmed to remove extraneous tissue. The M. gastrocnemius muscle from the point of insertion of the tendon of Achilles to the points of origin on the lateral and medial heads of the femur was removed from the right leg. Marrow plugs (about 3 cm long) were taken from the center of the right femur and from the center of the right mandible. The heart was removed from the pericardium and sliced to remove blood. The kidneys were removed along with all adherent fat and weighed. In very fat animals, fat associated with the kidney was differentiated from that associated with the peritoneum based on the most obvious discontinuity. Perirenal fat was trimmed as described by Riney (1955), and the mass of the kidney and remaining fat was determined. The kidney was then decapsulated and weighed. We calculated kidney fat masses (including the mass of the fibrous capsule) based on total and trimmed perirenal fat. Kidney fat masses were not obtained for 3 animals. Two kidney fat indices were calculated for each kidney and for both kidneys combined: total KFI = (total kidney fat mass × 100)/kidney mass; trimmed KFI = (trimmed kidney fat mass × 100)/kidney mass. An index (Conindex) based on fresh femur fat concentration and left trimmed KFI was calculated following Connolly (1981:334). Back-fat thickness was determined by making a cut perpendicular to the backbone just caudal to the last sacral vertebra and measuring fat depth (mm) at the thickest point.

The trachea, larynx, diaphragm, esophagus, and all contents of the pleural and peritoneal cavities exclusive of ingesta were combined (viscera). All other tissues exclusive of the viscera and hide were combined (carcass). Mass of the blood drained from the neck, blood and fluid from the pleural and peritoneal cavities, blood retained in the heart, and blood obtained by venipuncture (blood) was determined for 14 of the deer.

Body components <6 kg were weighed to the nearest 0.1 g; body components ≥6 kg were weighed to the nearest gram. All tissues were double-bagged in air-tight polyethylene liners and stored at −20 C until ground or analyzed. Carcass (exclusive of the gastrocnemius, thyroids, and marrow plugs), viscera, and hide were ground twice with a large, auger grinder with 1-cm plate openings. Random samples (about 1.2 kg carcass and viscera, and about 0.2 kg hide) of the mixed, ground tissues were placed in tared, aluminum pans, bagged, and frozen at −20 C for chemical analysis. Gastrocnemius muscles were ground twice with a table-top auger grinder and frozen at −20 C for chemical analysis.

Blood samples obtained by venipuncture were placed on ice immediately after collection and then refrigerated at approximately 7 C. After 20–24 hours, blood in nonheparinized tubes was centrifuged, and serum was collected. Serum samples were stored at −23 C until analyzed. Blood collected in heparinized tubes was refrigerated for 20–24 hours until hematological analyses were performed.

Analytical Methods

Blood and tissue samples were freeze-dried and ground in a blender into homogeneous mixtures. Dry matter, gross energy, crude protein, fat, and ash were determined as described by McCullough and Ullrey (1983). Serum samples were analyzed for NEFA following Falholt et al. (1973), for urea nitrogen (SUN) with a commercial diacetylmonoxine procedure (Sigma Chemical Co., St. Louis, Mo.), and for protein with a refractometer. Serum thyroxine (T4) was measured as described by Watkins et al. (1983). Serum T3 was determined with a solid-phase radioimmunoassay (Gammacoat, Clinical Assays, Travenol-Genentech Diagnostics, Cambridge, Mass.) validated for deer serum (T3 recovery = 105.6 ± 2.4 [SE]; parallelism [expected–observed ng/mL]: 0.57–0.54, 1.14–1.12; 2.85 at serum volume used in assay, 5.7–5.4, 9.12–7.51). Hematocrit (PCV) was determined with microcapillary tubes, and hemoglobin (Hgb) was measured by the cyanomethemoglobin method. Red blood cell counts (RBC) were made with a Coulter Counter. Mean erythrocyte cell volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were calculated with standard formulas.

Statistical Methods

We used the SPSS/PC+ statistical program (Norusis 1988:B-197–B-243) to analyze body composition (Y_i) relationships with each index (X_{i1}) and sex (X_{i2}) (0 = M, 1 = F) based on the following model:

$$Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + B_3X_{i1}X_{i2} + e_i.$$

When B_2 and B_3 did not differ significantly ($P \geq 0.05$) from zero based on a partial F-test, a bivariate model was used. When necessary, dependent and/or independent variables were transformed to achieve linearity. We selected the transformation providing the highest correlation coefficient with the most normal and independent distribution of residuals. Significance for regressions was considered to be $P \leq 0.05$. Forward multiple regression analysis was performed on normal and transformed data to determine if the inclusion of more than 1 index variable would significantly ($P \leq 0.05$) improve the regression. A paired t-test was used to test for differences between the right and left kidneys.

Body Composition Basis

Mass and chemical composition of the body were expressed on 3 bases by summing all body components exclusive of (1) ingesta (unbled body); (2) blood and ingesta (body); and (3) hide, blood, and ingesta (skinned body). Statistical analyses were performed with each basis as the dependent variable. Results are presented on a bled, ingesta-free basis unless major differences occurred among the bases or another basis was considered relevant. All concentrations are presented on a dry matter basis unless a fresh mass basis is indicated.

RESULTS

Live masses of the 16 fawns ranged from 16.8 to 41.6 kg, and body fat varied from 2.3 to 48.9% (Table 1). Blood had little influence on overall body composition with all body chemical components highly correlated ($r > 0.99$) with respective unbled body components. Most models for predicting body composition had slightly higher correlations when the skinned body was used as the basis.

Relationships with Body Mass

Carcass, live, and gastrocnemius masses had the highest correlations with body mass (Table 2). Kidney masses were only moderately related to body mass (Table 3). Of the morphometric indices, chest girth showed the highest correlations with live and body masses. Males tended to have greater body mass than females for a given hindfoot length ($P = 0.19$) or total body length ($P = 0.12$).

Relationships with Body Component Concentrations

Carcass and viscera gross energy and fat concentrations had the highest correlations with body gross energy and fat concentrations (Table 4). Kistner score also was highly correlated with body gross energy concentration (Fig. 1).

Indices correlated ($r > 0.9$) with percent body fat and best described by simple linear relationships were Kistner Score, Conindex, and gastrocnemius fat. Indices correlated ($r > 0.9$) with body fat by logarithmic functions included total kidney fat mass, total KFI (Fig. 2), trimmed KFI, and back fat. Females tended to have a higher total kidney fat mass than males for a given body fat concentration ($0.08 < P < 0.17$). Relative to body fat concentration, females had higher right total KFI values than males ($P = 0.03$). Combined total KFI ($P = 0.07$) and left total KFI ($P = 0.18$) also tended to be relatively higher in females. Differences in total or trimmed KFI values between the right and left kidneys were not significant. Indices correlated ($r > 0.9$) with body fat concentration by exponential functions included femur marrow dry matter (%), fresh femur marrow fat (%), mandible marrow dry matter (%), and fresh mandible marrow fat (%).

Table 1. Characteristics of white-tailed deer fawns from northern Illinois, November–May 1984–86.

Characteristic[a]	n	x̄	SE	Range
Live mass (kg)	16	31.1	2.0	16.8–41.6
Total body length (cm)	16	141.7	2.1	129.0–156.0
Chest girth (cm)	16	75.5	0.1	69.0–81.0
Bled, ingesta-free body				
Mass (kg)	16	26.9	2.3	12.9–38.0
Dry matter (%)	16	36.9	1.6	29.4–47.0
Crude protein (%)	16	57.0	3.6	39.2–75.5
Fat (%)	16	24.5	4.7	2.3–48.9
Ash (%)	16	13.8	1.4	6.7–23.0
Gross energy (mcal)	16	62.7	9.2	15.5–115.4
Gross energy (mcal/kg)	16	5.63	0.27	4.0–7.0
Hide (kg)	16	2.1	0.1	1.3–3.1
Viscera (kg)	16	4.2	0.4	1.9–6.4
Carcass (kg)	16	20.4	1.5	9.3–28.5
Ingesta (kg)	14	2.8	0.2	1.7–5.1
Right M. gastrocnemius				
Mass (g)	16	232.5	16.1	90.0–312.3
Dry matter (%)	16	25.6	0.5	23.0–29.1
Crude protein (%)	16	80.6	1.5	73.4–94.2
Fat (%)	16	6.8	1.0	1.3–11.6
Gross energy (mcal/kg)	16	5.50	0.05	5.1–5.8
Kidneys				
Mass (g)	14	75.1	5.1	44.9–111.9
Total fat mass (g)	13	113.7	37.4	3.1–363.0
Total kidney fat index	13	253.2	83.8	10.0–842.0
Kistner score	16	40.0	8.2	0.0–90.0
Triiodothyronine (ng/mL)	16	1.32	0.22	0.1–2.8

[a] All concentrations are on a dry matter basis.

When expressed on a dry matter basis, femur marrow fat (Fig. 3) and mandible marrow fat concentrations were best related to body fat using a $-1/Y$ transformation. Examination of these relationships revealed that dry femur and mandible fat concentrations exceeding 87 and 75%, respectively, were not significantly related to body fat. Below 87 and 75%, femur fat and mandible fat concentrations were related to body fat percent by exponential models: ln(Body fat[%]) = 0.0136(Femur fat[%] + 0.958, $r = 0.92$, $n = 7$, SE = 0.216; ln(Body fat[%]) =

Table 2. Significant ($P \leq 0.0001$) bivariate regression models with body mass as the dependent variable for white-tailed deer fawns from northern Illinois, November–May 1984–86.

Independent variable	Dependent variable[a]	Intercept	Slope	r	SE of estimate	n
Carcass mass (g)	Live mass (kg)	5.390	0.0013	0.993	0.94	16
Gastrocnemius mass (g)	Live mass (kg)	4.210	0.1160	0.952	2.47	16
Chest girth (mm)	Live mass (kg)	−66.400	0.1350	0.916	3.25	16
Live mass (kg)	Unbled body mass (kg)	−4.980	1.0600	0.996	0.83	14
Carcass mass (g)	Body mass (kg)	−0.223	0.0013	0.995	0.85	16
Live mass (kg)	Body mass (kg)	−5.640	1.0470	0.994	0.94	16
Gastrocnemius mass (g)	ln(Body mass) (kg)	2.080	0.0050	0.967	0.09	16
ln(Viscera mass) (g)	ln(Body mass) (kg)	−3.060	0.7610	0.944	0.11	16
ln(Hide mass) (g)	Body mass (kg)	−182.900	27.6000	0.933	3.06	16
ln(Liver mass) (g)	Body mass (kg)	−153.200	28.4000	0.932	2.68	12
Chest girth (mm)	Body mass (kg)	−76.600	0.1430	0.923	3.27	16
ln(Heart mass) (g)	Body mass (kg)	−160.400	33.1000	0.921	3.32	16
Live mass (kg)	Skinned body mass (kg)	−5.580	0.9780	0.994	0.91	16

[a] Body mass = mass of the bled, ingesta-free body.

Table 3. Index relationships ($r \leq 0.9$) with bled, ingesta-free body mass and composition of white-tailed deer fawns from northern Illinois, November–May 1984–86. $P \leq 0.05$ unless indicated by NS (i.e., nonsignificant).

Dependent variable[a]	Independent variable[b] (r) [model type[c]]
Body mass (kg)	Total kidney mass (0.88) [1]; Right kidney mass (0.88) [1]; Total body length (0.85) [1]; Shoulder height (0.81) [1]; Hindfoot length (0.76) [1]; Blood mass (0.70) [3]; Left kidney mass (0.68) [1]; Thyroid mass (0.63) [3]; Ingesta mass (NS).
Body gross energy (mcal/kg)	Live mass (0.87) [4]; Gastrocnemius GE (kcal/g) (0.83) [3]; Blood GE (kcal/g) (0.77) [3]; Hide GE (kcal/g) (0.66) [3].
Body fat (%)	Mandible marrow fat (%) (0.89) [5]; Live mass (0.87) [4]; Hide fat (%) (0.83) [2]; T3 (0.82) [1]; MCHC (−0.79) [6]; chest girth (0.74) [4]; SUN (−0.63) [4]; RBC (0.63) [3]; PCV (0.62) [3]; T4 (0.62) [3]; Serum protein (0.60) [3]; Blood fat (%) (NS); NEFA (NS); Hbg (NS); MCH (NS); MCV (NS).
Body crude protein (%)	Gastrocnemius crude protein (%) (0.82) [2]; Live mass (−0.80) [1]; Hide crude protein (%) (NS).
Body gross energy (mcal)	Gastrocnemius mass (0.88) [4]; chest girth (0.83) [1]; T3 (0.75) [1]; MCHC (0.75) [6]; RBC (0.69) [3]; PCV (0.67) [3]; T4 (0.66) [3]; Serum protein (0.63) [3]; SUN (−0.54) [4]; Hgb (0.52) [3]; NEFA (NS); MCH (NS); MCV (NS).
Body fat (g)	Hide mass (0.88) [1]; Chest girth (0.79) [4].
Body crude protein (g)	Hide mass (0.87) [1]; Liver mass (0.87) [3]; Total kidney mass (0.84) [1]; Viscera mass (0.81) [1].
Body ash (g)	Total body length (0.8) [1]; Hindfoot length (0.66) [1]; Chest girth (0.65) [1]; Carcass mass (0.64) [1]; Live mass (0.6) [1]; Shoulder height (0.58) [1].

[a] Body concentrations are on a dry matter basis.
[b] GE = gross energy; Hgb = hemoglobin (g/dL); MCH = mean corpuscular hemoglobin (pg/RBC); MCHC = mean corpuscular hemoglobin concentration (g/dL cells); MCV = mean corpuscular volume (fL); NEFA = serum nonesterified fatty acids (μm/L); PCV = packed cell volume (%); RBC = red blood cell count ($10^6/mm^3$); SUN = serum urea nitrogen (mg/dL); T3 = serum triiodothyronine (ng/mL); T4 = serum thyroxine (ng/mL).
[c] Model type: [1] $Y = B_0 + B_1X$; [2] $Y = B_0 + B_1\ln(X)$; [3] $\ln(Y) = B_0 + B_1X$; [4] $\ln(Y) = B_0 + B_1\ln(X)$; [5] $Y = -1/(B_0 + B_1X)$; [6] $Y = B_0 + B_1X + B_2(\text{Sex})$.

0.016(Mandible fat[%]) + 0.848, $r = 0.79$, $n = 7$, SE = 0.035).

Carcass and viscera crude protein concentrations were highly related to body crude protein by linear relationships. Gastrocnemius crude protein concentration provided the next best index to body crude protein.

Serum T3 showed the closest relationship with body fat of the blood and serum constituents we analyzed. Sex interacted with mean corpuscular hemoglobin concentration as a predictor of body fat ($P = 0.02$). Serum protein values tended to be higher relative to body fat in females than males ($P = 0.06$).

Relationships with Body Component Quantities

Body gross energy (mcal) was most closely related to viscera mass (kg) (Fig. 4). Kistner

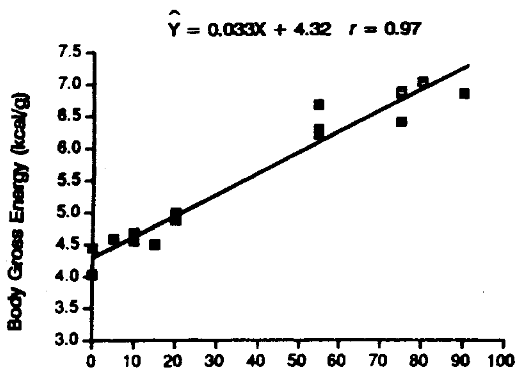

Fig. 1. The relationship between bled, ingesta-free body gross energy (kcal/g, dry basis) and Kistner score (Kistner et al. 1980) for white-tailed deer fawns from northern Illinois, November–April 1984–86.

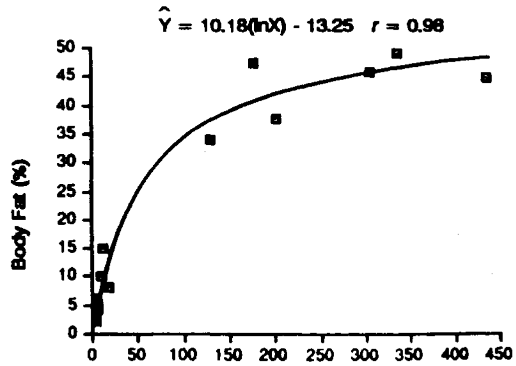

Fig. 2. The relationship between bled, ingesta-free body fat (%, dry basis) and right kidney fat index based on total perirenal fat for white-tailed deer fawns from northern Illinois, November–April 1984–86.

Table 4. Significant ($P \leq 0.0001$) bivariate regression models with body component concentrations as the dependent variable for white-tailed deer fawns from northern Illinois, November–May 1984–86.

Independent variable[a]	Dependent variable[a]	Intercept	Slope	r	SE of estimate	n
Carcass GE (kcal/g)	Body GE (kcal/g)	0.490	0.9500	0.998	0.07	16
Viscera GE (kcal/g)	Body GE (kcal/g)	−0.025	0.8510	0.983	0.21	16
Kistner score	Body GE (kcal/g)	4.322	0.0327	0.973	0.26	16
Carcass fat (%)	Body fat (%)	−0.099	1.0450	0.998	1.13	16
Viscera fat (%)	Body fat (%)	0.960	0.6370	0.997	1.56	16
ln(Total kidney fat) (g)	Body fat (%)	−7.840	9.3800	0.987	3.23	13
ln(Right, total kidney fat) (g)	Body fat (%)	−0.812	9.2800	0.987	3.19	13
ln(Left, total kidney fat) (g)	Body fat (%)	−1.722	9.4500	0.985	3.39	13
Ln(Right total KFI)[b]	Body fat (%)	−13.250	10.1800	0.979	4.10	13
Femur marrow dry matter (%)	ln(Body fat) (%)	0.806	0.0324	0.978	0.24	16
ln(Total KFI)	Body fat (%)	−21.060	10.2840	0.977	4.26	12
ln(Back fat depth) (mm)	Body fat (%)	34.650	3.0240	0.976	4.40	15
ln(Left total KFI)	Body fat (%)	−14.370	10.3500	0.973	4.59	13
Femur marrow fat (%, fresh basis)	ln(Body fat) (%)	1.123	0.0305	0.973	0.26	16
Kistner score	Body fat (%)	2.174	0.5590	0.970	4.73	16
Conindex	Body fat (%)	3.675	0.1880	0.966	5.06	14
ln(Viscera mass) (g)	Body fat (%)	−18.450	2.5620	0.964	0.30	16
ln(Left trimmed KFI)	Body fat (%)	−18.210	12.3200	0.964	5.18	14
Gastrocnemius fat (%)	Body fat (%)	−6.503	4.5510	0.959	5.52	16
Femur marrow fat (%)	−1/Body fat (%)	−0.386	0.0037	0.952	0.04	16
Mandible marrow fat (%, fresh basis)	ln(Body fat) (%)	0.948	0.0419	0.948	0.36	16
Mandible marrow dry matter (%)	ln(Body fat) (%)	0.470	0.0407	0.944	0.38	16
Carcass crude protein (%)	Body crude protein (%)	−2.977	1.0970	0.998	0.07	16
Viscera crude protein (%)	Body crude protein (%)	27.270	0.5620	0.990	2.05	16

[a] Body refers to the bled, ingesta-free body. All concentrations are on a dry matter basis unless fresh basis is indicated. GE = gross energy; KFI = kidney fat index.
[b] Alternate model: Body fat (%) = −10.7 + 9.91 ln(Right total KFI) − 5.16 Sex; $R = 0.987$, SE = 3.38.

score, total kidney fat mass, gastrocnemius fat mass, carcass mass, and gastrocnemius gross energy were also highly correlated with body gross energy (Table 5). Gastrocnemius fat mass tended to be higher relative to body gross energy in females than males ($P = 0.07$). Live mass and chest girth had the highest correlations with body gross energy content of the indices obtainable from a live animal.

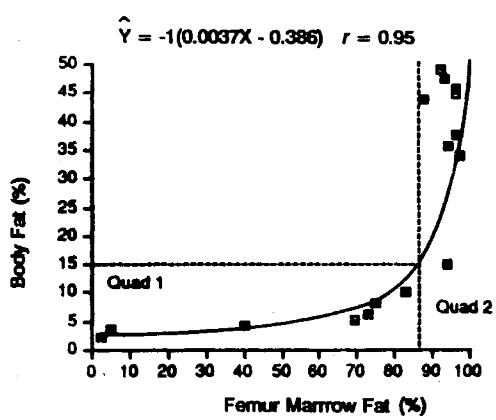

Fig. 3. The relationship between bled, ingesta-free body fat (%, dry basis) and femur marrow fat (%, dry basis) for white-tailed deer fawns from northern Illinois, November–April 1984–86. Quad 1 indicates the range of femur fat that shows a relationship with body fat. Quad 2 indicates the range of femur fat that cannot be used to reliably predict body fat.

Viscera mass, total kidney fat mass, and gastrocnemius fat mass had the highest correlations with body fat mass. Combined, total kidney fat mass had the highest correlation with skinned body fat mass ($r = 0.98$). Differences in total or trimmed fat masses between the right and left kidneys were not significant. Live mass had the highest correlation with body fat mass among the indices obtainable from a live animal.

Carcass mass, live mass, and gastrocnemius mass (Fig. 5) had the highest correlations with body crude protein mass. Females tended to have a lower gastrocnemius mass for a given body crude protein mass than males ($P = 0.14$). Gastrocnemius crude protein mass was lower relative to body or skinned body crude protein masses in females than males ($P < 0.01$). Of the morphometric indices, total body length showed the highest correlation with body crude protein mass. Males tended to have a greater body crude protein mass per total body length ratio than females ($P = 0.17$).

Total body length provided the best index to

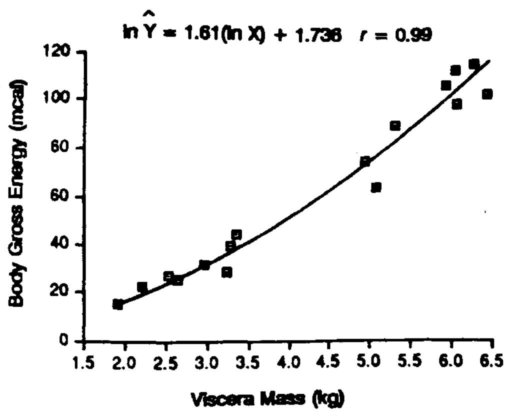

Fig. 4. The relationship between bled, ingesta-free body gross, energy (mcal) and viscera mass (g) for white-tailed deer fawns from northern Illinois, November–April 1984–86.

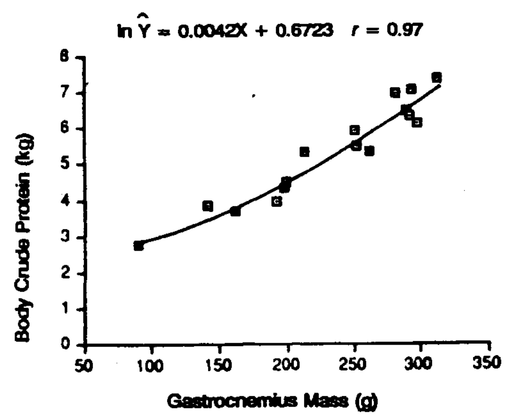

Fig. 5. The relationship between bled, ingesta-free body crude protein (kg) and right M. gastrocnemius mass (g) for white-tailed deer fawns from northern Illinois, November–April 1984–86.

Table 5. Significant ($P \leq 0.0001$) bivariate regression models with body component amounts as the dependent variable for white-tailed deer fawns from northern Illinois, November–May 1984–86.

Independent variable[a]	Dependent variable[a]	Intercept	Slope	r	SE of estimate	n
ln(Viscera mass) (g)	ln(Body GE) (mcal)	−9.387	1.6100	0.987	0.11	16
Kistner score	Body GE (mcal)	18.630	1.1020	0.979	7.81	16
ln(Total kidney fat) (g)	Body GE (mcal)	0.220	18.7800	0.975	8.98	13
ln(Right, total kidney fat) (g)	Body GE (mcal)	14.330	18.5600	0.974	9.08	13
ln(Left, total kidney fat) (g)	Body GE (mcal)	12.410	18.9300	0.975	9.03	13
Body mass (kg)	ln(Body GE) (mcal)	1.810	0.0793	0.968	0.18	16
Gastrocnemius fat (g)	ln(Body GE) (mcal)	3.039	0.1950	0.965	0.18	16
Live mass (kg)	ln(Body GE) (mcal)	1.383	0.0823	0.955	0.21	16
Carcass mass (g)	ln(Body GE) (mcal)	1.833	0.0001	0.945	0.23	16
Gastrocnemius GE (kcal)	ln(Body GE) (mcal)	2.013	0.0058	0.938	0.24	16
ln(Hide mass) (g)	Body GE (mcal)	−864.200	122.0000	0.922	14.78	16
Viscera + ingesta mass (g)	ln(Body GE) (mcal)	1.325	0.0004	0.903	0.31	14
ln(Viscera mass) (g)	ln(Body fat) (g)	−23.370	3.7000	0.980	0.32	16
ln(Total kidney fat) (g)	Body fat (g)	−2,039.000	1,587.0000	0.975	754.00	13
ln(Right, total kidney fat) (g)	Body fat (g)	−847.000	1,569.0000	0.975	759.00	13
ln(Left, total kidney fat) (g)	Body fat (g)	−1,008.000	1,600.0000	0.975	761.00	13
ln(Gastrocnemius fat) (g)	ln(Body fat) (g)	5.695	1.4060	0.969	0.40	16
Back fat depth (mm)	Body fat (g)	746.600	283.5000	0.955	972.00	15
ln(Body mass) (kg)	ln(Body fat) (g)	−6.965	4.3940	0.938	0.56	16
Live mass (kg)	ln(Body fat) (g)	1.638	0.1820	0.910	0.67	16
Carcass mass (g)	ln(Body fat) (g)	2.591	0.0002	0.909	0.68	16
Carcass mass (g)	Body CP (g)	972.400	0.2146	0.970	343.00	16
Live mass (kg)	Body CP (g)	102.800	168.4000	0.968	352.00	16
Gastrocnemius mass (g)	ln(Body CP) (g)	7.580	0.0042	0.968	0.07	16
ln(Gastrocnemius CP) (g)[b]	ln(Body CP) (g)	5.481	0.8030	0.964	0.08	16
Body mass (kg)	Body CP (g)	1,104.000	157.5000	0.953	426.00	16
Total body length (mm)	Body CP (g)	−16,538.000	15.4400	0.932	512.00	16
ln(Heart mass) (g)	Body CP (g)	−25,224.000	5,409.0000	0.910	584.00	16
Chest girth (mm)	Body CP (g)	−11,453.000	23.2300	0.907	593.00	16
ln(Gastrocnemius CP) (g)[c]	ln(Skinned body CP) (g)	5.010	0.8790	0.976	0.07	16
Gastrocnemius mass (g)	ln(Skinned body CP) (g)	7.317	0.0045	0.969	0.08	16

[a] Body mass is on a bled, ingesta-free basis. GE = gross energy, CP = crude protein.
[b] Alternate model: ln(Body CP) (g) = 5.00 + 0.915 ln(Gastrocnemius CP) (g) + 0.141 Sex; $R = 0.988$, SE = 0.047.
[c] Alternate model: ln(Skinned body CP) (g) = 4.57 + 0.981 ln(Gastrocnemius CP) (g) + 0.128 Sex; $R = 0.985$, SE = 0.04.

body ash mass. Live mass and body mass were poor predictors of body ash mass.

Serum T3 concentration showed the closest relationship with body gross energy content of the blood and serum constituents we analyzed. Sex interacted with mean corpuscular hemoglobin concentration as a predictor of body gross energy ($P = 0.04$). Serum protein values tended to be higher relative to body gross energy in females than males ($P = 0.06$).

Multiple Regression Models

In live animals, live mass and T3 were the most useful variables for predicting body gross energy content and body fat concentration with multiple regression models (Table 6). Regressions for predicting body gross energy (mcal) in live animals were significantly improved by including Hgb and mean corpuscular hemoglobin concentration. These models were recalculated with Hgb and mean corpuscular hemoglobin concentration eliminated because of the questionable value of the hematological values. Postmortem, viscera mass, live mass, gastrocnemius fat mass, Kistner score, total kidney fat mass, kidney mass, and liver mass were useful for predicting body gross energy (mcal).

Comparing aggregate profiles of blood and serum constituents to body fat or gross energy had little advantage over using individual constituents. Multiple regression analysis indicated a combination of T3 and serum protein provided the best prediction of body fat concentration and body gross energy (mcal).

DISCUSSION

Body Mass Indices

It is often impractical to weigh deer in the field. In our study, chest girth provided the best premortem prediction of live mass. Our model for predicting live mass from chest girth has a steeper slope than models presented by Weckerly et al. (1987) for fawns in Tennessee. Including very fat and very lean animals in our sample might account for this difference. Carcass mass and gastrocnemius mass appear to be useful indices for predicting body mass postmortem.

Indices of Body Component Concentrations

Since the 1940's, femur marrow fat has been used widely as an ungulate condition index. To eliminate errors that might result from desiccation before analysis, femur fat concentration is often expressed on a dry matter basis. Our data indicate that femur fat (dry matter basis) has limited usefulness as an index because it is not mobilized by fawns until body fat declines to about 15%. The body fat concentration of the fawns in our sample having >87% femur fat could not be differentiated based only on femur fat concentration; e.g., a fawn having 15% body fat could have the same percentage of femur fat as a fawn having 49% body fat. Below 87% femur fat, large differences in femur fat concentrations reflected only small differences in body fat concentrations.

Mandible marrow fat concentration has been reported to reflect a wider range of body fat than percent femur fat (Baker and Lueth 1966) and to separate deer into more distinguishable condition classes (Nichols and Pelton 1974). Mandible marrow also can be collected more easily from hunter-killed animals. From our results, mandible fat offers no advantage over femur fat for predicting body fat concentration in white-tailed deer. Femur fat and mandible fat concentrations are highly correlated, and the relationship between mandible fat and body fat is basically the same, although weaker, as that for femur fat. Mandible fat was not mobilized by the fawns until body fat declined to approximately 12%. The body fat concentrations of fawns in our sample having >75% mandible fat could not be differentiated based only on mandible fat concentration.

Because of its predictable relationship with marrow fat concentration, marrow dry matter percentage, as determined by oven-drying or reagent methods (Neiland 1970, Verme and Holland 1973), is sometimes used instead of ether extraction for estimating the fat concentration of marrow. Our results suggest that marrow dry matter concentration, particularly for the femur, might actually be a better index of body fat concentration than marrow fat percentage. Similar to marrow fat, marrow dry matter concentration cannot be used to discriminate among animals with a high body fat concentration. However, the less curvilinear relationship observed between femur marrow dry matter and body fat suggests that body fat concentrations up to approximately 30% might be accurately predicted with femur dry matter concentrations up to 80%. These relationships would be applicable only to fresh marrow samples that have not desiccated prior to analysis.

Unlike the exponential relationships shown by

Table 6. Multiple regression models ($Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3$) for predicting body gross energy and fat of white-tailed deer fawns from northern Illinois, November–May 1984–86.

		Independent variables[b] and coefficients									
Y[a]	B_0	X_1	B_1	X_2	B_2	X_3	B_3	R	Adj. R^2	n	SE of estimate
GE	−33.100	Live mass (kg)	4.380	T3 (ng/mL)	9.370	Hgb (g/dL)	2.950	0.98	0.94	16	9.25
GE	−64.000	Live mass (kg)	3.580	T3 (ng/mL)	12.200			0.96	0.91	16	10.90
GE	5.430	Chest girth (mm)	0.411	MCHC (g/dL cells)	7.430	T3 (ng/mL)	12.000	0.96	0.91	16	11.90
GE	−272.000	Chest girth (mm)	0.428	T3 (ng/mL)	19.300			0.92	0.83	16	15.20
ln(GE)	0.384	ln(T3) (ng/mL)	0.403	ln(SP) (g/dL)	1.920			0.85	0.68	16	0.38
ln(GE)	−6.420	ln(Viscera mass) (g)	1.154	Live mass (kg)	0.026			0.99	0.99	16	0.08
ln(GE)	−5.890	ln(Viscera mass) (g)	1.150	ln(Gastro. fat) (g)	0.254			0.99	0.99	16	0.07
ln(GE)	2.130	ln(Kistner score)	0.465	ln(Gastro. fat) (g)	0.234			0.99	0.98	16	0.09
ln(GE)	−0.529	ln(Total KFM) (g)	0.205	ln(Kidney mass) (g)	0.891			0.99	0.98	13	0.08
ln(GE)	−1.390	Gastro. fat (g)	0.139	Liver mass (g)	0.746			0.99	0.96	12	0.11
Fat	−29.100	Live mass (kg)	1.257	T3 (ng/mL)	11.030			0.92	0.85	16	7.93
Fat	−136.800	T3 (ng/mL)	16.200	HF length (mm)	0.328			0.90	0.78	16	8.77
Fat	−75.800	T3 (ng/mL)	15.870	ln(SP) (g/dL)	42.610			0.88	0.75	16	9.49
ln(Fat)	−7.770	ln(Left total KFM) (g)	0.414	ln(MF) (%, dry)	2.180			0.99	0.99	13	0.09
ln(Fat)	0.613	Femur dry matter (%)	0.022	ln(Left total KFI)	0.220			0.99	0.98	13	0.17
Fat	−23.500	Viscera mass (kg)	0.006	ln(Total KFI)	5.013			0.99	0.97	13	3.27

[a] GE = bled, ingesta-free body gross energy (mcal), Fat = bled, ingesta-free body fat (%, dry matter basis).
[b] Gastro = right gastrocnemius, Hgb = hemoglobin, KFI = kidney fat index, KFM = kidney fat mass, MF = mandible fat, MCHC = mean corpuscular hemoglobin concentration, SP = serum protein, T3 = triiodothyronine.

marrow fat, each of the kidney fat indices had a logarithmic relationship with body fat. Finger et al. (1981) similarly reported a logarithmic relationship between total KFI and body fat concentration in white-tailed deer, but also found a linear equation fit their data equally well. These authors concluded that deer with a higher percentage of body fat would be required in their sample to determine the true nature of the relationship. Body fat of deer in their sample ranged between 3.4 and 18.1%. Our study included deer with a much wider range of body fat concentrations (i.e., 2.3–48.9%) and a logarithmic relationship is clearly indicated. Above about 35% body fat, small differences in body fat resulted in large differences in the total KFI, whereas below about 20%, large differences in body fat made little difference in the total KFI. The commonly accepted method of trimming the perirenal fat to standardize the KFI (Riney 1955) appears to have little justification. Both total KFI and trimmed KFI methods yielded highly significant regressions, but the total KFI was slightly better correlated with body fat than the trimmed KFI. Although Anderson et al. (1972) reported right, trimmed KFI to be significantly greater in mule deer, we did not find significant differences between right and left KFI values.

Implicit in the KFI is the assumption that kidney mass reflects lean body mass. For the fawns in our study, only moderate relationships existed between kidney mass and body or skinned body crude protein masses, suggesting that this assumption is not entirely valid. Asynchronous changes in kidney mass and body mass reported in mule deer (*O. hemionus*) (Anderson et. al 1990) further indicate that kidney mass is not a constant proportion of lean body mass in deer.

Total perirenal fat mass had the highest correlation with body fat concentration of the indices investigated. However, because total kidney fat mass does not take into account lean body mass, it should be used with caution to predict body fat concentration. Kidney fat mass is better used to predict body fat mass.

Because kidney fat is depleted before femur fat, indices that combine femur fat and KFI have been proposed to evaluate the condition of deer over a wider range (Ransom 1965, Connolly 1981). Our data indicate that one such index, the Conindex, is highly correlated with body fat concentration over a wide range, and the relationship is more linear than those for fresh femur fat concentration or trimmed KFI alone. However, because the KFI component of the Conindex assumes that kidney mass reflects lean body mass, the Conindex has little advantage over the KFI for predicting high fat concentrations. For example, 1 fawn had a body fat percentage considerably higher than that predicted by the Conindex (i.e., 47 vs. 33%) due to the relatively large size of its kidneys.

The use of back fat measurements to predict body fat concentration of deer is limited by the early depletion of subcutaneous fat (Harris 1945, Riney 1955). For fawns in our study, measurable back fat disappeared somewhere between 34 and 15% body fat, making this index of limited value for evaluating the condition of thin to moderately fat animals.

The Kistner technique (Kistner et al. 1980) of visually scoring body musculature and fat depot sites has been widely used for postmortem condition evaluation in deer. Our data indicate the Kistner score provides a reasonable index to body fat concentration for fawns. Unlike the curvilinear relationships exhibited by femur and mandible fat concentrations, KFI, and back fat depth, the Kistner score is related to body fat concentration by a simple linear equation that almost passes through the origin. The Kistner score also provided the best prediction of body gross energy concentration. The Kistner technique has the disadvantage that scores are subjective and might vary among evaluators.

Although less correlated to body fat concentration than some other indices, gastrocnemius fat concentration provided a useful index for predicting body fat concentration in the fawns. Ringberg et al. (1981) reported a similar relationship between gastrocnemius fat and carcass fat in lean reindeer (*Rangifer tarandus*).

Indices of Body Component Quantities

Similar to other researchers (e.g., Robbins et al. 1974, Hout 1982, McCullough and Ullrey 1983), we found high correlations between live mass or body mass and the amounts of gross energy, water, crude protein, and fat. Although body mass can provide useful information regarding condition in deer, reliance on body mass alone to predict body composition can yield spurious conclusions. For example, 1 fawn that weighed 26 kg contained 10% body fat, whereas another that weighed 24 kg contained 44% body fat. Use of body mass to predict body composition, therefore, is best relegated to multivariate models that include at least 1 independent variable related to fat.

Gastrocnemius fat mass and gross energy (kcal) may provide the most practical single indices of body gross energy (mcal) even though viscera mass, Kistner score, and total kidney fat mass showed stronger relationships. The high correlation between viscera mass and body gross energy probably reflected a relationship between lean viscera mass and lean body mass, and the importance of the viscera as a fat storage site. Use of viscera mass as a practical index is limited by the laborious task of removing the ingesta. Including ingesta mass with the viscera substantially diminished the accuracy of predicting body gross energy. We do not recommend Kistner score as a single index of body gross energy content because no consideration is made for body size. Total kidney fat mass should be used with caution because its relationship with body gross energy is highly curvilinear. Using the gastrocnemius has the advantages that it can be collected in the field with relative ease, gastrocnemius mass is related to body mass, and the relationship between body gross energy and gastrocnemius gross energy content is only moderately curvilinear.

Viscera mass and total kidney fat mass also had the highest correlations with body fat mass. Similar to the prediction of body gross energy content, the labor required to remove the ingesta and the highly curvilinear relationship between kidney fat mass and body fat mass limit the practicality of these indices for predicting body fat mass. Again, gastrocnemius fat mass might be a more practical index.

Live mass, carcass mass, and gastrocnemius mass were the most practical single indicators of body crude protein mass. Expressing crude protein content on a skinned body basis has the advantage of eliminating the influence of keratin proteins from the pelage. Gastrocnemius crude protein mass provided the best prediction of skinned body crude protein mass. Ringberg et al. (1981) reported a linear relationship between gastrocnemius mass and total muscle mass in lean reindeer. In our study, relationships between gastrocnemius mass and body or skinned body crude protein mass were slightly exponential, indicating that relatively less body protein is associated with the gastrocnemius in larger animals. The lower crude protein content of the gastrocnemius relative to body crude protein in females may reflect a greater skeletal muscle mass in males. When it is not possible to obtain live mass or gastrocnemius mass, total body length appears to provide a fair index to body crude protein mass.

Metabolic Status

Several studies on the effects of diet composition, food intake, and starvation on blood and serum characteristics of white-tailed deer have indicated the potential efficacy of serum urea nitrogen, nonesterified fatty acids, and the thyroid hormones (particularly T3) for discriminating metabolic status (e.g., Seal et al. 1978, Bahnak et al. 1979, Watkins et al. 1982). In our study, serum T3 had the highest correlations with body fat and gross energy of the blood and serum constituents evaluated. Although T3 would appear to be a useful index of metabolic status, little is known about the factors that can influence this hormone. A negative energy balance can cause serum T3 to decline in white-tailed deer and other animals (Watkins et al. 1982). However, in a study of fawns restricted to 50% of ad libitum intake during the fall, a decrease in serum T3 did not occur even though the growth rate of the restricted fawns was significantly reduced (Watkins 1980). This suggests that during the period of obligate lipid deposition, T3 levels will not necessarily decline even though fawns are energy-restricted and stunted in size. In addition, because of the small circulating reservoir of T3 and low binding affinity of serum proteins, serum T3 levels might be easily influenced by short-term perturbations (Watkins et al. 1983).

Most of the other blood and serum constituents showed only moderate relationships with body fat or gross energy. Serum T4 was less related to body fat than T3. Unlike T3, serum T4 in white-tailed deer is strongly influenced by season (Watkins et al. 1983), and this may have partially obscured its relationship with body composition. Serum urea nitrogen was related inversely to body fat, indicating that muscle catabolism was fueling an increasing proportion of the energy requirement as body fat concentration declined. Serum nonesterified fatty acids were not related to body fat or gross energy. Responses of serum nonesterfied fatty acids to energy restriction in captive deer have been inconsistent (e.g., Seal et al. 1978, Warren et al. 1982, Card et al. 1985) suggesting that the factors influencing fatty acids of metabolic origin in the blood may be too complex for practical value. The reported effects of dietary protein and/or energy intake on hematological values of white-tailed deer have also been conflicting (e.g., Seal et al. 1978, Warren et al. 1982, DelGiudice et al. 1987). These inconsistencies make the use of hematological values questionable for condition assessment.

MANAGEMENT IMPLICATIONS

Condition Evaluation

Because many relationships between indices and body composition are not linear, we think predicted body composition rather than index values should serve as the basis for evaluating the condition of deer. Predicted body gross energy (mcal), within sex and age classes and within seasons, would provide the most practical single basis for evaluating condition. This measure takes into account body mass and composition and provides a representation of the amount of metabolic fuel available to the animal. Ideally, predicted body gross energy should be used in combination with an index of metabolic status. Although T3 is the most promising metabolic indicator we evaluated, it appears to give only a very broad indication of metabolic status. Factors independent of diet that might influence T3 need further study.

The applicability of our data to other age classes and to other times of the year is not known. Additional research is required to establish if indices show similar relationships to body composition when deer are in an anabolic state.

Assessing Condition Premortem.—Live mass and T3 offer the greatest potential for assessing the condition of live fawns during winter in terms of body gross energy (mcal). When it is not possible to obtain live mass, a combination of chest girth and T3 appears to provide a fair prediction of body gross energy.

Assessing Condition Postmortem.—A combination of viscera mass and live mass or gastrocnemius fat mass provided the best postmortem predictions of body gross energy (mcal) in the fawns. Excluding viscera mass, body gross energy was best predicted by a combination of total kidney fat mass and total kidney mass, or gastrocnemius fat mass and liver mass. As a single index, the gastrocnemius holds promise as a useful indicator for evaluating the condition of deer because it can be collected in the field and used to predict body mass, body gross energy, body crude protein mass, and body fat mass and concentration.

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Body composition changes in white-tailed deer fawns during winter

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Body composition was determined for 16 white-tailed deer (*Odocoileus virginianus*) fawns captured near Chicago, Illinois between November and April to investigate changes in body composition and chemical component distribution as fawns catabolized tissues over the winter. Live weights of the fawns ranged from 16.8 to 41.6 kg, and ether-extractable fat concentration of the bled, ingesta-free body ranged from 2.3 to 48.9%, dry basis. Carcass, viscera, and hide contained, on average, 70%, 21%, and 9% of the bled, whole body fat, respectively. Above approximately 15% whole body fat (dry basis), the percentage of body fat in the viscera increased and the percentage in the carcass declined. Body composition (blood-, ingesta-, and fat-free basis) averaged 72% water, 23% crude protein, and 5% ash; ash and phosphorus concentrations increased and protein concentration decreased over the winter. Sodium concentration tended to decrease. Based on relationships between chemical components and body weight, the composition of weight lost during winter was calculated to range from 12% water, 84% fat, 4% protein, and 0.5% ash during early winter to 73% water, 0.3% fat, 25% protein, and 2% ash during early spring. Calculated metabolizable energy derived from tissue catabolism was a quadratic function of body weight and ranged from 7.7 to 1.1 Mcal/kg of bled, ingesta-free weight loss during early and late periods.

Introduction

Knowledge of body composition is important for evaluating the condition of deer and for understanding the effects of environmental factors on deer populations. White-tailed deer in northern latitudes normally undergo seasonal anabolic-catabolic cycles with concomitant changes in body composition. In a study of white-tailed deer in Quebec, Hout (1982) found seasonal differences not only in fat content but also in fat-free body composition. Most studies on the body composition of white-tailed deer (Robbins et al. 1974, McCullough and Ullrey 1983, Rumpler et al. 1987) have not investigated seasonal changes.

Net tissue catabolism by deer is critical for winter survival when food quantity and quality are inadequate. Few attempts have been made to determine the composition of winter weight loss in deer. Based on relationships between body composition and body weight in white-tailed deer fawns during winter, Hout (1982) concluded that body protein and ash losses were relatively constant at 22% and 3-4% of weight lost, respectively, whereas the rates of fat catabolism and water loss decreased and increased, respectively, as fawns lost weight. Using isotope dilution, Torbit et al. (1985) reported protein losses accounted for 20-34% of the body energy catabolized by captive mule deer (O. hemionous) during winter. Also using isotope dilution, Delgiudice et al. (1990) reported weight lost by adult, captive white-tailed deer averaged 24% water, 56% fat, 18% protein, and 3% ash.

Our objectives were (1) to investigate changes in body composition and chemical component distribution as fawns underwent net catabolism during the winter, and (2) to calculate the composition and energy content of lost weight based on changes in body composition with decreasing weight.

Methods

Sixteen free-ranging white-tailed deer fawns (10 males, 6 females) were captured by rocket net near Chicago, Illinois between 1984 and 1986 during late November (N = 2), December (N = 4), January (N = 2), March (N = 7), and early April (N = 1). Each animal was immobilized with a combination of ketamine hydrochloride and xylazine hydrochloride (Watkins et al. 1990a), sampled for blood by jugular venipuncture, and euthanized by injection of T-61 solution (Watkins et al. 1982). Animals were processed as described by Watkins et al. (1990b). The animals were bled from the neck over a tared container and then eviscerated. The contents of the stomach, intestines, and cecum were removed and weighed (ingesta). The hide, including skin, hair, and dewclaws, was removed with a minimum of adherent fat and muscle. The M. gastrocnemius muscle was removed from the right leg, the heart was removed from the pericardium, kidneys were decapsulated and weighed without perirenal fat, and thyroid gland lobes were trimmed of fat. All contents of the pleural and peritoneal cavities, exclusive of ingesta, were combined with the trachea, larynx, esophagus, diaphragm, and thyroid glands (viscera). All tissues exclusive of the hide and viscera were combined (carcass). Tissues were double-bagged in air-tight polyethylene liners and stored at -20 C until ground twice using a large, auger-type grinder. Tissue and blood samples were freeze-dried and analyzed as described by McCullough and Ullrey (1983). Fat was determined by extraction with diethyl ether and protein was calculated by multiplying Kjeldahl nitrogen by 6.25.

Blood, ingesta, kidney, liver, and thyroid weights were not determined for 2 animals (a female in November, and a male in April). Blood analyses were not available for 2 other animals.

For analysis, the fawns were divided into two groups: those captured early (i.e., November-January; 6 males, 2 females) and those captured late (i.e., March and April; 4 males, 4 females). An independent $\underline{t}$-test was used to test for differences in body composition and component distribution between periods. Data were analyzed with males and females combined and for males only. Regression analysis was performed using SPSS/PC+ statistical software (Norusis 1988). The following model was used to determine relationships between body components (Y_i and X_{i1}) and sex (X_{i2}; 0 = male, 1 = female):

$$Y_i = \underline{B}_0 + \underline{B}_1 X_{i1} + \underline{B}_2 X_{i2} + \underline{B}_3 X_{i1} X_{i2} + \underline{e}_i.$$

When $\underline{B}_2$ and $\underline{B}_3$ did not differ significantly ($\underline{P} < 0.05$) from zero based on a partial $\underline{F}$-test, a bivariate model was used. When necessary, dependent and/or independent variables were transformed to achieve linearity. The transformation providing the highest correlation with the most normal and independent distribution of residuals was selected. Significance for all analyses was considered to be $\underline{P} < 0.05$.

The composition of weight loss was estimated by (1) using regression analysis to determine the relationships between chemical component weights and bled, ingesta-free body (BIFB) weight, (2) differentiating the equations obtained in step 1 to determine rates of component loss (g) per kg of BIFB loss, (3) standardizing the rates of total component loss to equal 1 kg (i.e., individual component loss/total component loss x 1000), and (4) using regression analysis to determine the rates of standardized component loss relative to BIFB weight. Six fawns (early period: 3 males, 1 female; late period: 1 male, 1 female) were omitted from the analysis because they did not follow a pattern of decreasing fat concentration with decreasing body weight.

Gross energy (GE) and metabolizable energy (ME) were calculated from fat (i.e., ether extract) and protein (i.e., crude protein) using coefficients of 9.5 kcal GE per g of fat, 5.65 kcal GE per g of protein, 9 kcal ME per g of catabolized fat, and 4.4 kcal ME g of catabolized protein (based on a nitrogen-correction factor of 7.45 kcal/g of urinary nitrogen). The mean BIFB GE of the fawns calculated using coefficients was 61.4 Mcal versus 62.7 Mcal determined by bomb calorimetry.

Results

Body Weight Relationships

Live and BIFB weights of the fawns ranged from 27-41.6 and 23.8-38 kg, respectively, during the early period and from 16.8-31.1 and 12.9-26.4 kg during the late period (Table 1). Body and body component weights generally decreased between periods whereas the weight of stomach contents increased. Viscera weight decreased relative to BIFB weight but relative liver, kidney, and thyroid weights did not change between periods. Heart and gastrocnemius weights increased relative to BIFB weight but not relative to fat-free BIFB weight.

Blood weight (g) was moderately related to IFB weight (kg):

[1] $\ln \text{Blood weight} = 0.73(\ln \text{IFB wt}) + 4.64$, $\underline{r} = 0.72$, SEE = 0.24.

Ingesta weight was not related to IFB weight ($\underline{P} = 0.9$).

Fat, Protein, and Mineral Distribution

BIFB fat, dry matter basis (DMB), varied from 34-48.9% during the early period and from 2.3-15% during the late period (Table 2). On the average, carcass, viscera, and hide contained 69.7% ± 2.4, 21% ± 2, and 9.3% ± 2.9 of the BIFB fat, respectively. As BIFB fat (DMB) increased up to approximately 15%, the percentage of BIFB fat contributed by the carcass increased, the percentage contributed by the viscera remained fairly constant (14.1% ± 0.7, $\underline{N} = 8$), and the percentage contributed by the hide decreased (Fig. 1). Above approximately 15% BIFB fat (DMB) the percentage of BIFB fat contributed by the carcass gradually decreased, the percentage contributed by viscera gradually increased, and the percentage contributed by the hide remained fairly constant (1.7% ± 0.1, $\underline{N} = 8$).

Protein distribution did not differ between periods. The relative ash content of the carcass and hide increased and decreased, respectively, between periods. The relative sodium content of the carcass and viscera decreased and increased, respectively, between periods.

Dry matter and GE concentrations in the blood declined between periods (Table 3).

<u>Changes in Fat-Free Body Composition</u>

On a fat-free IFB or BIFB basis, fawns collected during the early period had lower ash and P concentrations, and a higher percentage of protein than those collected in March-April (Table 4). Fat-free BIFB Na (% DMB) tended to be higher in November-January than in March-April ($\underline{P} = 0.07$).

Expressed as a percentage of ash, Ca and Na decreased between periods (29.0% ± 1.1 Ca *vs* 23.3% ± 1.2; 5.2% ± 0.8 Na *vs* 2.8% ± 0.1) whereas P did not change (14.4% ± 0.7 *vs* 14.4% ± 1.5).

Relationship Between Chemical Components

BIFB fat was highly correlated with BIFB GE (Table 5). Below 30.2% BIFB fat (DMB), the greatest proportion of BIFB GE was in protein. Above 30.2% BIFB fat (DMB), fat was the predominant form of energy storage.

BIFB water concentration (%) was inversely related to and highly correlated with BIFB fat concentration (%, FWB) whereas the amount of BIFB water (g) was only moderately related to the amount of BIFB fat (g). Conversely, BIFB water (%) was only moderately related to BIFB protein (%, FWB) but BIFB water (g) was highly correlated with BIFB protein (g).

Composition of Lost Weight

BIFB weights of the 10 fawns used to calculate the composition of lost weight ranged from 12.9 to 36.1 kg and BIFB fat ranged from 2.3 to 47.2% (DMB). Chemical component amounts (g) were related to BIFB weight (kg) by the following equations (X = BIFB weight [kg]):

[2] Water weight = 10710.9(ln X) - 18272.7, r = 0.99, SEE = 597

[3] ln Fat weight = 0.197(X) + 1.891, r = 0.99, SEE = 0.25

[4] Protein weight = 3608.6(ln X) - 6286.8, r = 0.98, SEE = 281

[5] ln Ash weight = 0.322(ln X) + 6.04, r = 0.71, SEE = 0.124.

Differentiating these equations and standardizing component losses to sum to 1 kg resulted in the following equations relating the rate of component loss (g/kg of BIFB weight lost) to BIFB weight (kg):

[6] Water loss = $24.357(X) - 1.035(X^2) + 586.79$

[7] Fat loss = $-34.106(X) + 1.431(X^2) + 205.28$

[8] Protein loss = $7.966(X) - 0.345(X^2) + 201.36$

[9] Ash loss = $1.783(X) - 0.0507(X^2) + 6.57$

BIFB fat (%, DMB) was related to BIFB weight (kg) as follows:

[10] ln Fat = $0.136(X) - 1.009$, $r = 0.98$, SEE = 0.25.

As BIFB weight decreased, the rate of fat catabolism decreased and the rates of water loss and protein catabolism increased (Fig. 2). Between 36.1 and 25 kg of BIFB weight, the rate of protein loss increased rapidly from 0.04-0.19 kg/kg. Between 25 and 12.9 kg, protein loss gradually increased from 0.19-0.25 kg/kg. The rate of ash loss remained fairly constant for BIFB weights between 12.9 and 25 kg (i.e., 19-22 g/kg of weight loss), but between 25 and 36.1 kg, decreased to 5 g/kg of weight loss. Based on the rates of fat and CP losses, the amount of ME catabolized (Mcal) per kg of BIFB weight loss was calculated to range from 7.7 to 1.1 for the fawns in the study:

[11] Catabolized ME (Mcal) = $-0.272(X) + 0.0114(X^2) + 2.7335$.

Catabolized ME derived from fat (Mcal) ranged from 7.5 to 0.03 (Mcal) per kg of BIFB weight loss and comprised 97.8% of the total catabolized ME at 36.1 kg and 2.8% at 12.9 kg BIFB weight:

[12] Catabolized ME from fat (Mcal) = $-0.307(X) + 0.1288(X^2) + 1.8475$.

The percentage of catabolized ME derived from body protein can be estimated by subtracting eq. 12 from eq. 11, dividing the result by eq. 11 and multiplying by 100. The percentages of catabolized ME derived from body protein were related to the body fat:body protein ratios (BFPRs) of the 10 fawns used in the analysis by the following equation:

[13] ln Percent of Catabolized ME from Protein = -2.755(BFPR) + 4.2156,

$\underline{r}$ = -0.98, SEE = 0.263.

Discussion

Body Composition: General Aspects

Fat concentrations in our study covered a wider range for a single age class than previous reports for white-tailed deer (Robbins et al. 1974, Finger et al. 1981, Hout 1982, McCullough and Ullrey 1983, Rumpler et al. 1987). The animal with the lowest BIFB fat concentration in our study (i.e., 0.68%, FWB; 2.3%, DMB) collapsed under the capture net and made no attempt to struggle. By its response and extremely emaciated appearance, this animal's body fat concentration, as determined by ether extraction, was probably approaching the minimum that can occur in a living fawn. Hout (1982) found fawns in Quebec averaged 1.2% BIFB fat (FWB) during February and March at which time several fawns had been found dead or incapable of standing. BIFB fat concentrations as low as 0.1% (FWB) were reported by Hout (1982) between mid-April and mid-June. Depperschmidt et al. (1987) reported 1.1% shaved BIFB fat (FWB), as determined by methanol-chloroform extraction, to be the lowest fat level observed in starved pronghorns (*Antilocapra americanus*). Conversely, the highest BIFB fat concentration observed in our study (22% FWB; 48.9% DMB) exceeded the highest fat concentration for a white-tailed deer fawn yet reported (Robbins et al. 1974, Hout 1982, McCullough and Ullrey 1983).

The very low body fat concentrations measured in some deer in our study and by Hout (1982) indicate that ether extract represents a mobilizable lipid reserve that can be depleted to very low levels. Extraction of animal tissues with diethyl ether will not remove covalently-bound membrane phospholipids. However, as pointed out by other researchers (Hout 1982, McCullough and Ullrey 1983, Rumpler et al. 1987), ether-extractable lipids should provide a reasonable estimate of total mobilizable lipid reserves because only a relatively small quantity of covalently-bound lipids would be expected to be catabolized.

To better represent metabolically active tissues, body composition is often reported on a hair-free basis to remove the effect of metabolically inert keratin proteins. In our study, approximately 17% of the BIFB protein was contributed by the hide (skin + hair) during both early and late periods. The consistent contribution of the hide indicates that hair probably did not have a major influence on body composition relationships in this study. Emaciated fawns had very thin skins indicating net catabolism of dermal and epidermal proteins.

Body Ca and P concentrations during the early period were lower than Ca and P concentrations reported by McCullough and Ullrey (1983) for white-tailed deer from the George Reserve, Michigan. However, Na concentration was over 2 times higher than that reported for the George Reserve deer (i.e. 0.44% vs 0.2%, DMB). In the areas where we collected the fawns, roads are frequently salted in the winter and deer were commonly observed feeding along roadsides. It is likely that the Illinois fawns had greater Na concentrations due to this supplemental source. Vegetation in the Great Lakes region is naturally low in Na and it is doubtful that deer can consume adequate Na to meet the requirements established for domestic ruminants by feeding solely on terrestrial vegetation not amended with Na (Watkins 1983). The difference in body Na between the Illinois and Michigan deer may reflect the potentially marginal Na status of deer in the Great Lakes region that do not have access to supplemental Na.

Body Weight Relationships

When fawns from both periods were combined, mean ingesta weight expressed as a percentage of live weight (i.e., 9.6%) was similar to reports for captive white-tailed deer (Robbins et al. 1974, Rumpler et al. 1987). However, in our study the percentage of ingesta differed almost 2 fold between periods. This difference was due primarily to the weight of stomach contents and probably resulted from the consumption of poorly digestible foods during late winter and early spring. Accurate prediction of ingesta weight from live weight was not possible.

Blood weights obtained in our study accounted for a lesser percentage of IFB weight than reported by McCullough and Ullrey (1983) for captive white-tailed deer of various ages bled during the fall. This difference may be due in part to seasonal differences in plasma volume (Jacobsen 1978) but probably relates primarily to methodology. McCullough and Ullrey (1983) determined blood weights by bleeding animals immediately upon death. In our study, up to 1 hour elapsed after death before the animals were bled. This delay likely resulted in more blood being retained in the tissues. On a dry matter basis, blood comprised approximately 2% of IFB weight. Even with 50% blood retention, the error in BIFB composition would be minimal and would relate primarily to protein.

Expressed relative to metabolic body weight (body weight$^{0.75}$), liver and gastrointestinal weights in cattle and sheep typically decrease with decreasing energy intake (Keenan et al. 1969, Johnson et al. 1990). This relationship may have been obscured in the fawns in our study because of the emaciated condition of the some of the late period fawns.

Fat, Protein, and Mineral Distribution

Except at extremely low body fat concentrations, the carcass was the major site of body lipids in the fawns. Above approximately 15% BIFB fat (DMB) the viscera became an increasingly important site for lipid storage. Subcutaneous fat is often reported to be the last site of fat accretion and the first site of fat depletion in deer (Riney 1982). Our data indicate that when subcutaneous fat is being mobilized, relatively more fat is being utilized from visceral deposits.

The similar distributions of protein in the carcass and viscera between early and late periods indicate protein was mobilized from skeletal muscle and viscera in fairly constant proportions over the winter. Because the hide is a combination of skin and noncatabolizable hair and scurf, the fairly constant distribution of body protein in the hide indicates the catabolism of skin proteins over the winter.

The carcass contained the majority of ash, Ca, P, and Na in the body during both periods. Of the minerals studied, Na showed the greatest change in distribution between periods. The increase in the proportion of Na in the viscera during the late period suggests a decrease in the extracellular, exchangeable sodium concentration of skeletal muscle as tissues were catabolized.

Changes in Fat-Free Body Composition

Mean composition of the fat-free BIFB of fawns in our study was similar to that reported for white-tailed deer in other studies (Robbins et al. 1974, Hout 1982, McCullough and Ullrey 1983). The higher ash and phosphorus content and lower protein content of the dry, fat-free BIFB of fawns collected in March and April probably resulted from body protein catabolism occurring at a faster rate than ash loss during winter. Hout (1982) found a similar seasonal variation in dry, fat-free BIFB ash and protein composition of white-tailed deer fawns in Quebec. Calcium concentration of the fat-free body did not increase over the winter suggesting a differential loss of calcium compared to other minerals possibly related to a decrease in activity.

The tendency for fat-free BIFB Na concentration to be higher during the early period suggests that excess extracellular Na is excreted over the winter as tissues are catabolized and plasma volume decreases. Watkins (1983) hypothesized that Na "wash-out" occurs during winter in wild ruminants in temperate regions similar to starvation induced natriuresis observed in humans. Deer would therefore be at highest risk of Na deficiency during late spring and early summer when consuming new growth and switching from net catabolism to net anabolism.

Relationships Between Chemical Components

Close inverse relationships between the concentrations of body water and fat such as those found in our study have been reported previously for white-tailed deer (Robbins et al. 1974, Hout 1982, McCullough and Ullrey 1983, Rumpler et al. 1987). Our finding of only a moderate relationship between the amount of body water and fat is similar to that of Rumpler et al. (1987) for deuterium-estimated body water in adult does. Rumpler et al. (1987) also reported a close relationship between the amount of body water and protein similar to that found in our study. Correlations between the concentrations of body water and protein have not previously been reported for white-tailed deer. Our data indicate only a moderate relationship between these variables. Relationships between body water and body ash were similar to those between body water and body fat in that the correlation between concentrations was considerably higher than that between amounts. Similar results were reported by Rumpler et al. (1987). The different relationships between body water expressed as a percentage of live weight or as an amount and the fat, protein, or ash percentage or amount in the body is probably due to inconsistencies between the relative and absolute amounts of these components. For example, even though its body water concentration would be lower, a large animal with a high fat content could contain a higher absolute amount of water than a small deer with a low fat content.

Composition of Weight Lost

Body weight alone cannot be used to predict the composition of weight loss. The body weight relationships in our study only apply to fawns having a similar relationship between body weight and BIFB fat concentration. The relationship between body weight and fat concentration can be highly variable. For example, the fawns omitted from the analysis included an animal that had an ingesta-free body weight of 23.8 kg with 43.9% fat (DMB) and another that weighed 38 kg with 37.5% fat (DMB).

Our method for estimating the composition of lost weight assumes that the different fawns in our sample would be representative of the changes in body composition that would have occurred if a longitudinal study of the same animals had been made as they lost weight. Although we cannot prove this condition was met, the following discussion indicates our data are reasonable based on available information. All of the fawns used in the analysis were collected from the western suburbs of Chicago and should have been subjected to similar nutritional and environmental conditions. Again, our results must be qualified based on the observed relationship between BIFB weight and BIFB fat concentration.

Changes in the composition of weight loss are determined by metabolic responses to energy and protein deprivation. The metabolic responses of protein-energy deficient animals generally follow a predictable sequence (Hoffer 1988). Initially, glycogen reserves are quickly depleted and labile proteins are catabolized to support gluconeogenesis. Subsequently, lipolysis and ketogenesis increase and tissues adapt to metabolizing ketones and fatty acids. After the initial rapid loss of labile body proteins, protein catabolism decreases but continues at a rate necessary to prevent ketoacidosis and allow for obligatory turnover of body protein. As fat reserves decline, protein catabolism increases to help satisfy energy requirements. Once fat reserves are essentially exhausted, protein is rapidly catabolized until muscles are critically depleted and death results.

Below approximately 25 kg BIFB weight, protein and ash loss rates calculated from our data were similar to loss rates reported by Hout (1982). However, unlike the fairly constant loss rates reported by Hout (1982), our data indicate rates of protein and ash loss accelerated rapidly as weight decreased from 36 to about 25 kg BIFB weight. Rates of water and fat loss calculated in our study also followed different relationships than those described by Hout (1982). Although our methods for calculating the composition of weight loss were similar, Hout (1982) (1) did not eliminate fawns that did not follow a pattern of decreasing fat concentration with decreasing body weight, (2) used power regressions to calculate all relationships, and (3) calculated the rate of fat loss by difference.

It is well established that the composition of weight loss in humans and other animals depends on the body composition of the individual (Forbes 1987: 237). Fat individuals catabolize less protein than those that are thin. With the exception of Hout (1982), previous studies with deer have not attempted to relate weight loss composition with changes in body composition. Our data indicate that the composition of catabolized tissues is a function of the body fat to body protein ratio. Torbit et al. (1985) reported undernourished adult mule deer with BFPRs between 0.73 and 0.3 derived 18-31% of their catabolized energy from protein (based on our ME coefficients). In comparison, eq. 13 predicts 9.1-29.6% of catabolized ME is derived from body protein for the same range of BFPRs. DelGiudice et al (1990) reported weight loss in undernourished adult white-tailed deer with BFPRs between 0.63 and 0.5 averaged 23.5% water, 55.9% fat, 17.6% protein, and 2.9% ash. Using our

ME coefficients, body protein would have accounted for an average of 13.3% of their catabolized ME. Equation 13 predicts 11.9-17% of catabolized ME from body protein for the same range of BFPRs.

There is relatively little information on the composition of weight loss in domestic ruminants. It is often assumed that the composition of weight loss is approximately the same as the composition of weight gain over the same range of body weights. Keenan et al. (1969) found underfed sheep with an average BFPR of approximately 0.8 derived 14% of their catabolized energy from protein (calculated using our ME coefficients). Blaxter (1962: 93) noted that body protein accounted for as little as 8% of the tissue energy catabolized by fat, adult sheep. Equations presented by Wright and Russel (1984) based on the body composition of cattle losing and gaining weight predict that weight change in adult non-lactating, non-pregnant cattle varies from 14% water, 81% fat, and 4% protein, and 0.7% ash at 600 kg IFB weight to 36% water, 50% fat, 13% protein, and 2% ash at 300 kg IFB weight. Using our ME coefficients, body protein would account for 2.3 and 10.9% of catabolized energy at these weights, respectively.

Based on body composition and minimum required protein and fat masses, the maximum proportions of catabolizable energy that can be derived from body fat and protein can be calculated. Extremely emaciated animals can nearly deplete ether-extractable fat but will retain a relatively large protein mass. This protein mass consists of non-catabolizable proteins such as hair as well as the minimum structural and functional proteins required to sustain life. The body of the most emaciated fawn we collected had 2.8 kg of protein and 88 g of fat. This was the lowest protein mass observed by more than 1.1 kg. From the very weak condition of this animal, it was likely approaching its critical protein mass required for survival. Assuming a typical critical protein mass of 2.5 kg, the average early period fawn in our study could have derived a total of 23% of its catabolizable ME from protein. At this rate of protein catabolism, the ratio of body fat to catabolizable protein would remain constant as fat and catabolizable protein would be depleted simultaneously. In our study, fawns during the early period had calculated fat:catabolizable protein ratios ranging from 2.1 to 1.1 whereas late period fawns had ratios ranging from 0.4 to 0.29. The decrease in this ratio between periods indicates that protein catabolism must occur at a considerably slower rate than the overall maximum (i.e., 23% of catabolizable ME) when substantial fat reserves are available. These calculations suggest the rates of long-term protein catabolism in deer with substantial fat reserves (e.g., BFPR > 0.5) must be lower than those reported by Torbit et al. (1985).

If it is assumed that the composition of catabolized tissues would be similar during protein-energy deficiency and fasting, fasting weight loss could be predicted by dividing the energy density of catabolized tissues by daily energy requirements. Based on an average winter maintenance ME requirement of 125 kcal/kg $BW^{0.75}$/day (Thompson et al. 1973) and a BIFB/live weight ratio of 0.85, the percentage of BIFB weight that would be lost daily to meet energy requirements during starvation would change exponentially and vary from 6.5 to 0.75% for the smallest and largest fawns, respectively, used in our analysis:

[14] ln BIFB weight lost per day (%) = -0.093(X) + 3.072,

were X = BIFB weight (kg). For a 41 kg fawn (35 kg BIFB wt) with 40% BIFB fat (DMB), predicted weight loss expressed as a percentage of initial BIFB weight would be,

[15] Percent of initial BIFB weight = -0.400(t) - 0.0228(t^2) + 97.01,

where t = starvation time in days. At 10 and 20 days of starvation, the percentages of initial weight predicted by the above equation compare closely with percentages calculated from the data of deCalesta et al. (1975) for mule deer fawns in excellent condition starved during winter (i.e., 90.7% vs 91.9% and 79.9% vs 83.8% of initial weight, respectively). At 30 days of starvation, eq. 15 predicts greater weight loss than observed in the mule deer (64.5% vs 75.7% of initial weight). This disparity is consistent with the decline that occurs in fasting metabolic rate relative to metabolic body weight (i.e., body weight$^{0.75}$) during prolonged negative energy balance (Kleiber 1961, Blaxter 1962, Keenan et al. 1969). Decreased activity during an energy deficit further reduces maintenance energy requirements relative to metabolic body size. For example, Keenan et al. (1969) reported sheep fed at one-third maintenance for 4 weeks lost 14% of their metabolic body weight while maintenance energy requirements decreased by 32%. Therefore, the overprediction of weight loss by our model follows the trend expected when a constant metabolic rate unadjusted for the effects long-term fasting is used to predict energy requirements.

Changes in the composition of catabolized tissues can have profound effects on the energetics of overwintering deer populations. Our data emphasize the importance of winter fat reserves in deer and the potential errors that can result from assuming a constant caloric content for weight loss in deer energetics models.

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Table 1. Live, ingesta-free body (IFB), bled IFB (BIFB), and body component weights and weight relationships in white-tailed deer fawns during early and late winter.

	Weight (kg)					Percent of											
	Early[b]		Late[c]			Live weight			IFB weight			BIFB weight			Fat-free BIFB[e]		
Component[a]	x̄	SE	x̄	SE	P[d]	Early	Late	P	Early	Late	P	Early	Late	P	Early	Late	P
Live weight	37.3	1.6	24.9	1.7	**(*)	100	100	-	-	-	-	-	-	-	-	-	-
IFB	34.7	1.9	21.1	1.9	**(*)	93.2	84.5	**(**)	100	100	-	-	-	-	-	-	-
BIFB	33.7	1.6	20.1	1.6	**(**)	90.4	80.4	**(**)	96.5	95.3	*(NS)	100	100	-	-	-	-
Fat-free BIFB	27.6	1.3	19.6	1.5	**(**)	74.1	78.6	*(**)	79.2	93.3	**(**)	82.0	97.8	**(**)	100	100	-
Carcass	25.2	1.3	15.6	1.4	**(*)	67.3	61.9	*(NS)	71.6	72.9	NS(*)	74.5	76.9	NS(**)	75.5	77.0	NS(*)
Gastrocnemius	0.28	0.01	0.19	0.02	**(NS)	0.74	0.75	NS(*)	0.79	0.87	NS(**)	0.82	0.92	*(**)	0.97	0.94	NS(NS)
Viscera	5.7	0.2	2.8	0.2	**(**)	15.5	11.1	**(**)	16.9	13.4	**(*)	17.2	13.9	**(*)	14.8	13.9	NS(NS)
Heart	0.34	0.02	0.25	0.01	**(NS)	0.9	1.0	NS(NS)	0.97	1.18	*(NS)	1.0	1.25	**(*)	1.22	1.28	NS(NS)
Liver	0.7	0.05	0.51	0.03	*(NS)	1.89	1.89	NS(NS)	1.97	2.18	NS(NS)	2.09	2.29	NS(NS)	2.57	2.35	NS(NS)
Kidney (g)	87.7	6.7	62.5	3.7	**(NS)	0.24	0.24	NS(NS)	0.25	0.28	NS(NS)	0.26	0.3	NS(NS)	0.32	0.31	NS(NS)
Thyroid (g)	4.0	0.7	2.5	0.2	NS(NS)	0.011	0.009	NS(NS)	0.012	0.011	NS(NS)	0.012	0.011	NS(NS)	0.015	0.012	NS(NS)
Ingesta	2.5	0.1	3.1	0.4	NS(*)	6.9	12.8	**(**)	-	-	-	-	-	-	-	-	-
Stomach	1.9	0.1	2.8	0.3	*(*)	5.1	10.5	**(**)	-	-	-	-	-	-	-	-	-
Intestines	0.7	0.1	0.7	0.1	NS(NS)	1.8	2.8	**(*)	-	-	-	-	-	-	-	-	-
Hide	2.5	0.2	1.6	0.1	**(*)	6.8	6.6	NS(*)	7.3	8.1	NS(NS)	7.5	8.3	NS(NS)	8.8	8.2	NS(*)
Blood	1.3	0.1	1.1	0.1	NS(NS)	3.4	4.3	NS(NS)	3.7	5.0	*(NS)	-	-	-	-	-	-

[a] _N_ = 8 for early and late periods with the following exceptions: IFB, kidney, total ingesta, and blood weights, _N_ = 7 for both periods; liver, thyroid, stomach contents, and intestinal content weights, _N_ = 7 for the early period and 5 for the late period.

[b] November-January.

[c] March-April.

[d] * = $P < 0.05$, ** = $P < 0.01$, NS = nonsignificant. Parentheses indicate males only.

[e] Weights of carcass, gastrocnemius, viscera and hide expressed on a fat-free basis.

Table 2. Composition (dry matter basis) of the bled, ingesta-free body (BIFB) and the percentage of each component contributed by carcass, viscera, and hide in white-tailed deer fawns during early and late winter.

	Percent of BIFB weight					Percent Contribution								
	Early[a]		Late[b]			Carcass			Viscera			Hide		
Component	$\bar{x}$	SE	$\bar{x}$	SE	P[c]	Early	Late	P	Early	Late	P	Early	Late	P
Dry matter	42.5	1.1	31.4	0.6	**(**)	73.0	74.5	NS(*)	18.1	10.1	**(**)	8.3	14.7	**(**)
Gross energy (kcal/g)	6.65	0.11	4.61	0.12	**(**)	71.0	70.1	NS(NS)	17.6	9.6	**(**)	7.2	17.0	**(**)
Ether-extract	42.2	2.0	6.9	1.5	**(**)	70.1	68.5	NS(NS)	27.8	14.1	**(**)	1.7	16.9	**(**)
Crude protein	43.8	1.6	70.3	1.7	**(**)	71.3	70.6	NS(NS)	11.9	11.0	NS(NS)	15.8	17.5	NS(NS)
Ash	8.8	0.6	18.8	0.8	**(**)	93.5	95.1	*(**)	3.9	3.2	NS(NS)	2.2	1.6	*(*)
Ca	2.54	0.13	4.38	0.28	**(**)	99.2	99.2	NS(NS)	0.31	0.48	*(NS)	0.27	0.35	NS(NS)
P	1.26	0.10	2.69	0.10	**(**)	96.1	97.1	NS(NS)	2.95	2.21	*(NS)	0.58	0.61	NS(NS)
Na	0.44	0.06	0.53	0.02	NS(NS)	86.0	78.8	*(*)	9.4	14.5	**(*)	5.33	6.50	NS(NS)

[a] November-January. N = 8.

[b] March-April. N = 8.

[c] * = $P < 0.05$, ** = $P < 0.01$, NS = nonsignificant. Parentheses indicate males only.

Table 3. Blood composition (dry matter basis) of white-tailed deer fawns during early and late winter.

	Early[a]		Late[b]		
Component (%)	$\bar{x}$	SE	$\bar{x}$	SE	P[c]
Dry Matter	19.3	0.3	16.9	0.6	**(*)
Gross Energy (kcal/g)	5.62	0.03	5.39	0.06	**(*)
Ether extract	0.83	0.09	1.21	0.18	NS(NS)
Crude Protein	94.8	0.5	93.2	0.8	NS(NS)
Ash	3.6	0.1	3.9	0.4	NS(NS)

[a] November-January. $N = 7$.

[b] March-April. $N = 5$.

[c] * = $P < 0.05$, ** = $P < 0.01$, NS = nonsignificant. Parentheses indicate males only.

Table 4. Composition (dry matter basis) of the fat-free, ingesta-free body (IFB) and bled, ingesta-free body (BIFB) of white-tailed deer fawns during early and late winter.

	Percent of fat-free IFB weight					Percent of fat-free BIFB weight				
	Early[a]		Late[b]			Early		Late		
Component	$\bar{x}$	SE	$\bar{x}$	SE	P[c]	$\bar{x}$	SE	$\bar{x}$	SE	P
Dry matter	27.2	0.6	28.3	0.6	NS(NS)	27.9	0.6	28.9	0.5	NS(NS)
Crude protein	84.2	0.5	79.5	0.6	**(**)	83.3	0.7	78.9	0.6	**(**)
Ash	15.8	0.5	20.4	0.6	**(**)	16.7	0.7	21.1	0.6	**(**)
Ca	-		-		-	4.39	0.20	4.7	0.28	NS(NS)
P	-		-		-	2.17	0.12	2.89	0.10	**(**)
Na	-		-		-	0.77	0.11	0.57	0.02	NS(NS)

[a] November-January. $\underline{N}$ = 7 IFB basis; $\underline{N}$ = 8 BIFB basis.

[b] March-April. $\underline{N}$ = 5 IFB basis; $\underline{N}$ = 8 BIFB basis.

[c] * = $\underline{P}$ < 0.05, ** = $\underline{P}$ <0.01, NS = nonsignificant. Parentheses indicate males only.

Table 5. Relationships between body components (bled, ingesta-free basis) of white-tailed deer fawns from northern Illinois, November-April 1984-86. Concentrations are on a dry matter basis except for water or unless a fresh weight basis (FWB) is indicated. N = 16, $P < 0.01$.

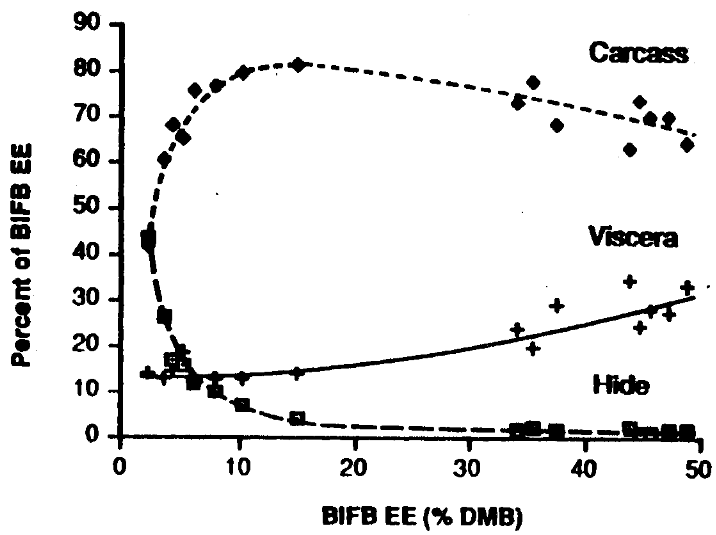
Independent Variable (X)	Dependent Variable (Y)	Intercept	Slope	r	SEE[a]
Fat (g)	Gross Energy (Mcal)	23.81	0.0118	0.989	5.561
Fat (%)	Gross Energy (kcal/g)	4.206	0.058	0.995	0.111
Fat (%)	ln Crude Protein (% of GE[b])	4.613	-0.0232	-1	0.01
Fat (%)	ln Fat (% of GE)	0.985	0.843	1	0.05
Water (g)	Fat (g)	-6639	0.599	0.759	2078
Water (%)	Fat (%, FWB)	95.81	-1.359	-0.982	1.66
ln Water (g)	ln Crude Protein (g)	-1.557	1.043	0.965	0.075
Water (%)	ln Crude Protein (%, FWB)	2.173	0.013	0.757	0.073
Water (g)	Ash (g)	475.6	0.045	0.67	0.005
Water (%)	Ash (%, FWB)	-5.861	0.169	0.838	0.708
Ash (%)	Ca (%)	0.846	0.189	0.921	0.453
Ash (%)	P (%)	0.073	0.138	0.959	0.223

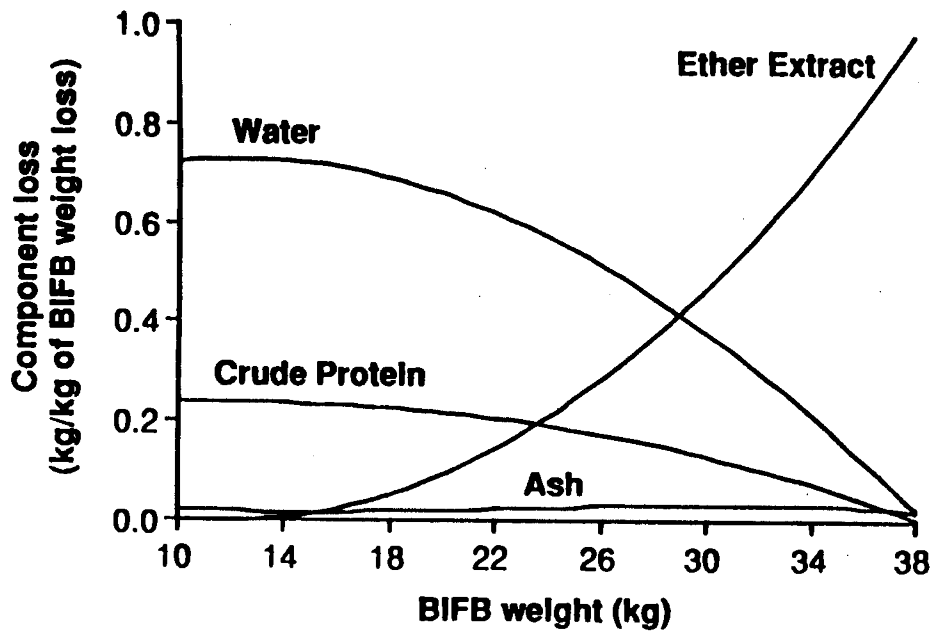
[a] SEE = standard error of estimate.

[b] % of GE = percentage of total gross energy.

Fig. 1. The relationships between bled, ingesta-free body ether extract (BIFB EE) (dry matter basis) and the percentages of BIFB EE contributed by the hide, viscera, and carcass of white-tailed deer fawns during November-April from Northern Illinois, 1984-1986. Lines fitted by eye.

Fig. 2. The relationships between bled, ingesta-free body (BIFB) weight and calculated loss of water, ether extract, crude protein, and ash per kg of BIFB weight loss for white-tailed deer fawns during November-April from Northern Illinois, 1984-1986.


Percent of BIFB EE
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
BIFB EE (% DMB)
Carcass
Viscera
Hide


Component loss
(kg/kg of BIFB weight loss)
1.0
0.8
0.6
0.4
0.2
0.0
Water
Ether Extract
Crude Protein
Ash
10
14
18
22
26
30
34
38
BIFB weight (kg)

Appendix D. Watkins, B.E., D.E. Ullrey, J.H. Witham, and J.M. Jones 1990. Field evaluation of deuterium oxide for estimating body composition of white-tailed deer (Odocoileus virginianus) fawns. J. Zoo and Wildl. Medicine. 21:453-456.

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FIELD EVALUATION OF DEUTERIUM OXIDE FOR ESTIMATING BODY COMPOSITION OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) FAWNS

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Abstract: The efficacy of using deuterium oxide dilution under field conditions to predict body composition of free-ranging white-tailed deer (*Odocoileus virginianus*) was evaluated using 10 fawns captured near Chicago, Illinois, between November 1985 and March 1986. Estimated body water was calculated using the average blood deuterium concentration 1.5 and 2 hr after i.v. infusion. Estimated body water was correlated with true body water ($r^2 = 0.93$) but overestimated true body water by 23.8 ± 1.4%. Including estimated body water in regression models significantly ($P < 0.05$) improved prediction of body composition versus the use of live weight alone. Estimated body water (kg) and live weight (kg) were correlated ($P < 0.0001$) with the ether extract (kg) ($R^2 = 0.93$), gross energy (Mcal) ($R^2 = 0.95$), and crude protein (kg) ($R^2 = 0.93$) content of the ingesta-free body.
Key words: Body composition, condition, deuterium, isotope dilution, *Odocoileus virginianus*, white-tailed deer.

INTRODUCTION

The condition of live free-ranging deer usually is evaluated based on body weight, external morphometry or conformation, and/or blood and serum constituents. None of these methods provide a quantitative measure of body composition. We believe that condition of deer is best expressed in terms of the gross energy content (GE, Mcal) of the ingesta-free body (IFB). Isotope dilution techniques have been used successfully to estimate gross body composition in a variety of live animals,[1,4,6,9] including captive white-tailed deer (*Odocoileus virginianus*).[7] Unlike tritium, deuterium is a stable isotope that can be used safely in the field without special precautions. Isotope dilution using deuterium oxide (D_2O), therefore, offers potential for estimating the body composition of free-ranging animals.

The objective of this study was to evaluate the efficacy of D_2O dilution for predicting body composition of white-tailed deer fawns under field conditions.

MATERIALS AND METHODS

Ten free-ranging white-tailed deer fawns (eight males and two females born during May and June) were captured by rocket net near Chicago, Illinois, in 1985 and 1986 during November ($n = 2$), December ($n = 3$), January ($n = 2$), and March ($n = 3$). Capture locations and capture and handling methods have been described elsewhere.[11] After capture, each deer was immobilized by an i.m. injection of 8 mg/kg ketamine hydrochloride (Vetalar, Parke-Davis, Morris Plains, New Jersey 07950, USA) and 1.2 mg/kg xylazine (Rompun, Haver-Lockhart, Shawnee, Kansas 66201, USA). Three fawns required additional injections (approximately 5 mg/kg ketamine and 1.5 mg/kg xylazine) to maintain adequate anesthesia for 2 hr.

Each of nine fawns was injected via the jugular vein with 10 g of D_2O (DLM-4 deuterium 99.8% D, Cambridge Isotope Laboratories, Inc., Cambridge, Massachusetts 02139, USA) that had been preweighed in

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a 12-cc disposable syringe. One fawn was injected with only 5.4 g of D_2O via the jugular vein because additional D_2O was not available. Blood samples were obtained by jugular venipuncture from the vein opposite the injected vein at 1.5 and 2 hr postinfusion. After the last blood sample was collected, each animal was euthanized by injection of T-61 euthanasia solution (National Laboratories, Somerville, New Jersey 08876, USA). Each animal was bled from the neck, and the weight of the blood was combined with the weight of the previous blood samples. The contents of the stomach (rumen, reticulum, omasum, abomasum) and intestines (small intestine, cecum, large intestine, rectum) were removed and weighed. The entire carcass and viscera from each animal and samples of digesta were double bagged in air-tight polyethylene liners and stored at −20°C. Tissues were ground twice using a large auger grinder. Blood and tissue samples were freeze-dried and analyzed for dry matter, crude protein (CP), ether extract (EE), GE, and ash as described by Rumpler et al.[7] Blood samples were frozen in sealed vacuum tubes for lyophilization. The water fraction of the blood samples was analyzed for deuterium using infrared spectrophotometry.[2] Samples of the stomach and intestinal contents from eight deer were analyzed for water concentration. Water contents of the ingesta of two deer were predicted from the weights of stomach and intestinal contents using the average water concentrations of the eight analyzed samples.

True body water (TBW) was calculated by summing the water contained in the ingesta-free body with that contained in the ingesta, as determined by analysis. Estimated body water (EBW) was calculated based on the ratio between blood deuterium concentration and the amount of injected deuterium.

Linear regression analysis was performed using the SPSS/PC+ statistical program (SPSS, Inc., 444 N. Michigan Ave., Chicago, Illinois 60611, USA). Forward multiple regression was used when inclusion of more than one independent variable significantly ($P < 0.05$) improved the regression. Homogeneity of regression coefficients was tested using an F-test.[8] A paired t-test was used to test for differences between 1.5- and 2-hr blood deuterium concentrations.

RESULTS

Blood deuterium concentrations did not differ significantly between 1.5- and 2-hr postinfusion blood samples and did not allow dilution space to be calculated at the time of infusion. The average of the two samples was used to calculate EBW.

Estimated body water averaged 23.8 ± 1.4% (mean ± SE, $n = 10$) higher than TBW (Table 1). Estimated body water (% of live weight) and TBW (% of live weight) each were correlated with IFB EE (%, fresh weight basis [FFB]) and IFB GE (kcal/g, FWB) (Table 2). The slopes of the regressions did not differ significantly when either EBW or TBW was used as the independent variable.

Ingesta-free body EE (kg), IFB CP (kg), and IFB GE (Mcal) were highly correlated with either EBW (kg) and live weight or TBW (kg) and live weight (Table 3). Prediction of IFB ash (kg) was not significantly improved by inclusion of live weight in the regression when either EBW (kg) or TBW (kg) was used as an independent variable.

DISCUSSION

Rumpler et al.[7] found that D_2O equilibrated with the body water pool within 2 hr postinfusion in adult white-tailed deer does. Based on these results, we selected sampling times of 1.5 and 2 hr postinfusion. The similar D_2O concentrations determined in the 1.5- and 2-hr samples indicate that tracer equilibration had occurred in the fawns within 1.5 hr.

We found EBW averaged almost 24% higher than TBW. Estimated body water always exceeds TBW when a single equilibrated blood D_2O concentration is used to calculate dilution space.[6] Overestimating TBW by more than 20% is not uncommon

Table 1. Characteristics of white-tailed deer fawns collected between November and March from northern Illinois, 1985–1986.

Characteristic	n	$\bar{x}$	SE	Range
Live weight (kg)	10	34.9	1.6	27.1–41.6
IFB[a] weight (kg)	10	32.0	1.8	23.3–39.5
True body water (kg)	8	22.2	0.8	16.7–25.5
True body water (% of live weight)	8	61.1	1.6	55.9–71.2
Estimated body water (kg)	10	27.4	1.1	19.5–31.4
Estimated body water (% of live weight)	10	77.6	2.0	68.7–90.3
Stomach contents (kg)	10	2.26	0.24	1.5–4.1
Stomach water (%)	8	80.1	1.4	73.9–84.7
Intestinal contents (kg)	10	0.71	0.04	0.5–1.0
Intestinal water (%)	8	75.9	1.0	71.8–81.3
Ingesta water (% of true body water)	8	9.4	0.7	6.5–11.8
IFB ether extract (%, DMB[b])	10	32.6	5.0	4.2–48.2
IFB crude protein (%, DMB)	10	51.4	3.8	40.3–75.8
IFB ash (%, DMB)	10	10.8	1.3	6.6–17.8
IFB gross energy (Mcal/kg, DMB)	10	6.15	0.27	4.6–7.0

[a] Ingesta-free body.
[b] Dry matter basis.

in single-point isotope dilution studies.[9] In domestic ruminants, single-point tracer measurements typically result in a calculated dilution space that is 10–20% greater than TBW.[1,6] It is not known why TBW is overestimated to different degrees in different studies. Possible reasons include variable rates of in vivo isotope fractionation (e.g., due to species, age, physiological status, drugs), the use of different sampling intervals after equilibration (i.e., the longer the interval, the greater the overestimate), and incomplete deuterium recovery after vacuum sublimation.[4]

When serial blood D_2O measurements are used to extrapolate to the time of infusion, EBW is generally only 3–7% greater than TBW in ruminants.[1,6,7] In our study, the similarity between the 1.5- and 2-hr samples made extrapolation impossible. Taking more than two samples and extending the interval between samples might improve the accuracy of TBW estimates but may be impractical for some field applications.

Even though EBW overestimated TBW, EBW, in combination with live weight, provided a reasonably accurate prediction of body composition and significantly improved the prediction of body composition over the use of live weight alone. On this basis, our results indicate that D_2O dilution offers a potential nonlethal method for estimating the body composition of deer in the field. Additional studies will be required to determine EBW–body composition relationships for age classes other than fawns. If animals are to be released, sodium chloride should be added to the D_2O to make a 0.85% NaCl solution (physiological saline), and sterile techniques must be used. The

Table 2. Relationships between the percentages of estimated body water (EBW %) or true body water (TBW %) and ingesta-free body (IFB) ether extract or gross energy concentrations for white-tailed deer fawns from northern Illinois. All values are on a fresh basis. $n = 10$, $P < 0.001$.

Regression model	r^2[a]	SEE[b]
IFB ether extract (%) = −1.094(EBW %) + 98.310	0.87	2.91
IFB gross energy (Mcal/kg) = −0.092(EBW %) + 9.541	0.83	0.29
IFB ether extract (%) = −1.353(TBW %) + 98.328	0.97	1.53
IFB gross energy (Mcal/kg) = −0.117(TBW %) + 9.794	0.99	0.08

[a] Coefficient of determination.
[b] Standard error of estimate.

Table 3. Linear regression models for predicting true body water (TBW), ingesta-free body (IFB) ether extract (EE), IFB crude protein (CP), IFB ash, and IFB gross energy (GE) from estimated body water (EBW) or TBW and live weight for white-tailed deer fawns from northern Illinois. All units are in kilograms except GE (Mcal). $n = 10$, $P < 0.0001$ except as noted.

Regression model	R^{2a}	SEE[b]
TBW = 0.670 (EBW) + 3.684	0.93	0.67
IFB EE = 0.918 (live wt) − 0.870 (EBW) − 4.041	0.93	0.85
IFB CP = 0.075 (live wt) + 0.169 (EBW) − 0.997	0.93	0.30
IFB ash = 0.042 (EBW) + 0.127	0.41[c]	0.19
IFB GE = 9.348 (live wt) − 7.332 (EBW) − 48.570	0.95	7.93
IFB EE = 0.907 (live wt) − 1.258 (TBW) + 0.243	0.98	0.51
IFB CP = 0.091 (live wt) + 0.205 (TBW) − 1.497	0.92	0.33
IFB ash = 0.060 (TBW) − 0.051	0.41[c]	0.19
IFB GE = 9.381 (live wt) − 10.937 (TBW) − 9.575	0.99	3.66

[a] Coefficient of multiple determination.
[b] Standard error of estimate.
[c] $P < 0.05$.

combination of ketamine and xylazine used was usually sufficient to keep the deer anesthetized and immobilized for over 2 hr. Captive white-tailed deer can be immobilized repeatedly with ketamine and xylazine with little drug-related mortality.[10] Yohimbine could be used to hasten recovery in ketamine–xylazine-immobilized animals[3,5] after blood samples for D_2O analysis have been collected. Ketamine, xylazine, and yohimbine are not approved for use in food-producing animals and therefore would have restricted use for deer populations harvested for human consumption. It is not known how the use of other drugs (e.g., carfentanil) would influence estimates of D_2O dilution space.

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Helminthic and Protozoan Parasites of White-tailed Deer in Urban Areas of Northeastern Illinois

Final Report

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Helminthic and Protozoan Parasites of White-tailed Deer in Urban Areas of Northeastern Illinois

Jose G. Cisneros

This report is part of the Urban Deer Study of the Illinois Natural History Survey. The project was a determination of the helminthic and protozoan parasites of white-tailed deer (Odocoileus virginianus) through fecal analysis. Animals sampled in this study are part of white-tailed deer herds found in urban locations of northeastern Illinois. Within the text is included detailed methodology, results of examinations, discussion of the significance of these results, and problems perceived in this study with recommendations for improvements.

METHODS

Over one thousand fecal samples were collected by Dr. James Witham during post mortem examinations of road-killed white-tailed deer during a twenty-three month period (December 1983 to October 22, 1985). Samples were frozen and stored for a period of one to three years. For parasitological examination, 270 samples were chosen from four sites: Northwest Cook County, Des Plaines, Busse Woods, and Non-Cook County. Within each location, samples were divided according to season collected - summer, fall, winter, and spring. All samples were from deer over one year of age.

Samples of feces were thawed for one hour before use and were processed for fecal flotation after Samuel and Trainer (1969). One gram of feces was placed into a beaker with 10ml of water. The pellets were broken up completely and the mixture was poured through standard cheesecloth into another beaker. Fecal material in the cloth was pressed with a lab spatula to remove all liquid. The liquid was then poured into a 15ml centrifuge tube and spun at 2200rpm for ten minutes in a clinical centrifuge. The supernatent was discarded and 6ml of Sheather's sugar solution (Levine et al., 1960) was added to the sediment and mixed with a spatula. Sugar solution was added to fill the tube, and the mixture was centrifuged for two minutes at 1100 rpm. After centrifugation, a positive meniscus was created on the tube by adding fresh sugar solution, and a 22mm square coverglass was placed over the top of the tube. After several minutes, the coverglass was removed and transferred to a glass slide. The entire surface of the coverglass was systematically examined for helminth eggs, larvae and coccidial oocysts with the aid of a compound microscope. Data for each sample were recorded on a standardized data sheet. Size was determined with an ocular micrometer. Relevant taxonomic keys and literature utilized in identifying parasites included Kates and Shorb (1943), Becklund (1964), Samuel and Beaudoin (1965), Levine (1968) and Anderson and Samuel (1969).

RESULTS

Two hundred seventy fecal samples from four different areas in northeastern Illinois were examined. Examination revealed five species of nematodes and two species of coccidia. Seventy-four animals (28%) were found to carry one of more parasites which were represented by eggs, first stage larvae and oocysts (Table 1). Anatomical location of parasite in the host, number of deer infected, prevalence, intensity and size range is given for all parasites. Study wide, the trichostrongyloids showed the highest prevalence (11.5%) of all parasites found. (The designation "trichostrongyloids" in the tables includes eggs of the genera Haemonchus, Ostertagia, and Trichostrongylus, and is used due to the difficulties involved in distinguishing the eggs of these three genera. The genera are closely related and species identification based on eggs alone is not feasible. Eggs seen in this study could belong to one or more of the three genera.)

TABLE 1

Parasite prevalence and intensity of Illinois urban white-tailed deer as determined by fecal flotation.

Parasite	# Infected / # examined	Prevalence (%)	Intensity Range	Intensity Mean	Size (μ)
Trichostrongyloids	31/270	11.5	1-29	2.5	60-89x30-50
Oesophagostomum venulosum	5/270	2	1-4	2	70-100x36-55
Nematodirus odocoilei	6/270	2	1-9	3	140-190x53-80
Capillaria bovis	8/270	3	1-3	1.5	40-55x21-32
Parelaphostrongylus tenuis	16/270	6	1-14	3.5	190-350x10-17
Eimeria mccordocki	19/270	7	1-25	3	25-47x15-30
Eimeria madisonensis	3/270	1	1-2	1.5	17-22x17

Overall infection rate for study: 28%

Data for individual locations was separated to characterize the infections present in each. Light infections of three nematode species and one Eimeria species were found in Northwest Cook County (Table 2). Prevalence for Northwest Cook County is 25%.

Three nematode species and two species of coccidia were found in the Des Plaines area deer (Table 3). The Eimeria mccordocki infection rate is the highest for any area. Overall prevalence for the Des Plaines area is 24%.

Four species of nematodes and two species of Eimeria were discovered in Busse Woods samples (Table 4). The largest overall infection rates of this study were from the trichostrongyloid eggs (16%) and the P. tenuis larvae (14%) found in the Busse Woods samples. Prevalence for the Busse Woods collection is 41%.

Only three species of nematodes were found in the Non-Cook County samples, and low prevalences were determined for each (Table 5). The overall prevalence for Non-Cook samples is 11%.

Individual parasite prevalences for all four areas are compared in Table 6.

TABLE 2

Parasite prevalence and intensity for Northwest Cook County white-tailed deer.

Parasite	Prevalence (%)	Intensity	
		Range	Mean
Trichostrongyloids	8 4	1-2	1
Oesophagostomum venulosum	0	--	--
Nematodirus odocoilei	6 3	1-9	4.5
Capillaria bovis	2 1	1	1
Parelaphostrongylus tenuis	0	--	--
Eimeria mccordocki	10 5	1-5	2
Eimeria madisonensis	0	--	--

Animal sample size: 52 Infection rate: 25%
Animals found infected: 13

TABLE 3

Parasite prevalence and intensity for Des Plaines white-tailed deer.

Parasite	Prevalence (%)		Intensity Range	Intensity Mean
Trichostrongyloids	10	6	1-4	2.5
Oesophagostomum venulosum	0		--	--
Nematodirus odocoilei	2	1	1	1
Capillaria bovis	0		--	--
Parelaphostrongylus tenuis	2	1	1	1
Eimeria mccordocki	12	7	1-25	6
Eimeria madisonensis	3.5	2	1-2	1.5

Animal sample size: 58 Infection rate: 24%
Animals found infected: 14

TABLE 4

Parasite prevalence and intensity for Busse Woods white-tailed deer.

Parasite	Prevalence (%)		Intensity Range	Intensity Mean
Trichostrongyloids	16	17	1-29	3
Oesophagostomum venulosum	5	5	1-4	2
Nematodirus odocoilei	0		--	--
Capillaria bovis	5	5	1-3	1.5
Parelaphostrongylus tenuis	14	15	1-14	4
Eimeria mccordocki	6	6	1-2	1
Eimeria madisonensis	1		1	1

Animal sample size: 105 Infection rate: 41%
Animals found infected: 43

TABLE 5

Parasite prevalence and intensity for Non-Cook County white-tailed deer.

Parasite	Prevalence (%)		Intensity Range	Intensity Mean
Trichostrongyloids	7	4	1	1
Oesophagostomum venulosum	0	0	--	--
Nematodirus odocoilei	4	2	1-3	2
Capillaria bovis	4	2	2	2
Parelaphostrongylus tenuis	0	0	--	--
Eimeria mccordocki	0	0	--	--
Eimeria madisonensis	0	0	--	--

Animal sample size: 55   Infection rate: 11%
Animals found infected: 6

TABLE 6

Comparison of parasite prevalences in white-tailed deer from Northwest Cook County, Des Plaines, Busse Woods and Non-Cook County areas.

PREVALENCE

PARASITE	NW Cook	Des Plaines	Busse Woods	Non-Cook
Nematoda:				
Trichostrongyloids	8	10	16	7
Oesophagostomum venulosum	0	0	5	0
Nematodirus odocoilei	6	2	0	4
Capillaria bovis	2	0	5	4
Parelaphostrongylus tenuis	0	2	14	0
Protozoa:				
Eimeria mccordocki	10	12	6	0
Eimeria madisonensis	0	3.5	1	0

Parasite intensities were generally low. Most eggs, larvae, and oocysts were present in numbers less than 10. The largest intensities seemed to correspond to the areas and particular parasite species with the highest prevalences: Des Plaines, E. mccordocki; Busse Woods, trichostrongyloids and P. tenuis.

Seasonal differences in parasite prevalence and intensity were examined between all sites and within each site. Winter samples showed the greatest percentage of infections (31%), but the infection rates of summer, spring and fall were only slightly lower (26%, 27% and 25%, respectively). Intensities were uniformly low except for relatively high Eimeria oocysts numbers in spring and fall and trichostrongyloid eggs and P. tenuis larvae in isolated animals during the summer.

Parasite assemblages also changed with seasons. The greatest number of multiple parasite infections within single deer occurred in the summer and winter seasons. Trichostrongyloid eggs were found most often in spring and summer, and Capillaria bovis eggs were found in the greatest number of animals in the fall. Oocysts of the coccidia Eimeria were found most often in winter samples. Parelaphostrongylus tenuis larvae were found in fecal samples collected at all times of the year (Table 7).

TABLE 7

Seasonal parasite prevalence (%) for Illinois urban White-tailed deer.

	PREVALENCE							
PARASITE	Summer (N=63)	(hw)	Fall (N=78)	(hw)	Winter (N=55)	(hw)	Spring (N=74)	(hw)
Nematoda:								
Trichostrongyloids	19	12	3	2	7	4	16	12
Oesophagostomum venulosum	0		0		3	2	3	2
Nematodirus odocoilei	5	3	5	~~5~~ 4	0		0	
Capillaria bovis	0		8	6	3	2	1	1
Parelaphostrongylus tenuis	5	3	6	5	7	4	5	4
Protozoa:								
Eimeria spp.	8	5	3	2	16	9	4	3

Within locations, Northwest Cook County and Non-Cook County showed the fewest infections during all seasons with relatively little winter and spring parasite activity (Tables 8 and 11). Des Plaines and especially Busse

Woods exhibited parasite infections year-round (Tables 9 and 10). Winter and spring infections at the latter two sites are most conspicuous by their numbers when compared to the Northwest Cook and Non-Cook samples.

TABLE 8

Seasonal parasite prevalence (%) for Northwest Cook County white-tailed deer.

	PREVALENCE			
PARASITE	**Summer**	**Fall**	**Winter**	**Spring**
Trichostrongyloids	20	9	0	0
Oesophagostomum venulosum	0	0	0	0
Nematodirus odocoilei	13	7	0	0
Capillaria bovis	0	7	0	0
Parelaphostrongylus tenuis	0	0	0	0
Protozoa:				
Eimeria spp.	13	0	43	0

TABLE 9

Seasonal parasite prevalence (%) for Des Plaines white-tailed deer.

	PREVALENCE			
PARASITE	**Summer**	**Fall**	**Winter**	**Spring**
Trichostrongyloids	8	0	13	20
Oesophagostomum venulosum	0	0	0	0
Nematodirus odocoilei	0	7	0	0
Capillaria bovis	0	0	0	0
Parelaphostrongylus tenuis	0	7	0	0
Protozoa:				
Eimeria spp.	8	13	20	13

TABLE 10

Seasonal parasite prevalence (%) for Busse Woods white-tailed deer.

PARASITE	PREVALENCE 21 Summer	 18 Fall	 36 Winter	 30 Spring
Nematoda:				
Trichostrongyloids	29 6	11 2	11 4	23 7
Oesophagostomum venulosum	0	0	6 2	7 2
Nematodirus odocoilei	0	0	0	0
Capillaria bovis	0	11 2	6 2	3 1
Parelaphostrongylus tenuis	14 3	17 3	14 5	13 4
Protozoa:				
Eimeria spp.	10 2	0	14 5	3 1

TABLE 11

Seasonal parasite prevalence (%) for Non-Cook County white-tailed deer.

PARASITE	PREVALENCE 14 Summer	 15 Fall	 12 Winter	 14 Spring
Nematoda:				
Trichostrongyloids	14 2	0	0	14 2
Oesophagostomum venulosum	7 1	0	0	0
Nematodirus odocoilei	7 1	6 1	0	0
Capillaria bovis	0	12.5 2	0	0
Parelaphostrongylus tenuis	0	0	0	0
Protozoa:				
Eimeria spp.	0	0	0	0

DISCUSSION

A single published report exists concerning abomasal and intestinal helminths of white-tailed deer in Illinois (Cook et al., 1979), and no published reports are available with respect to protozoa infections. The study by Cook et al. involved the necropsy of eighty-four deer and compared parasite infections in deer from northern and southern regions of the state. Cook's necropsies revealed the nematodes Gongylonema pulchrum, Apteragia odocoilei, Haemonchus contortus, Nematodirus sp., Trichuris sp., and Setaria yehi, and the cestode Moniezia benedeni in the northern sample (Carroll and Jo Daviess counties). Never published separately, Schaeffler and Levine (1968) reported data indicating an approximate 50% infection rate for P. tenuis in Illinois deer. The present study found two species of nematodes not previously reported for northern Illinois deer - Oesophagostomum venulosum and Capillaria bovis.

This study is the first report of protozoans in Illinois deer. Two species of coccidia - Eimeria mccordocki and Eimeria madisonensis, were found in the samples studied.

Although not previously reported in northern Illinois, O. venulosum, C. bovis, E. mccordocki and E. madisonensis, as well as the other parasite species found in this study, are all well known and common parasites of white-tailed deer in the United States. Davidson et al. (1981), the most recent compendium of disease and parasites of white-tails, lists prevalences of all these parasites in the various states where studies have been made. Particular studies which found similar assemblages include: Anderson and Samuel (1969) (samples from Pennsylvania, Texas and Wisconsin); Beaudoin, et al (1970) (samples from Pennsylvania); Samuel and Beaudoin (1965; 1966) (samples from Pennsylvania); Samuel and Trainer (1969) (samples from Wisconsin); and Prestwood et al (1973) (samples from southeastern United States, Texas and the Virgin Islands) and Cisneros (in prep.) (samples from Missouri). In most of the other studies, parasite prevalence was greater than that discovered in Illinois. Several explanations are possible. The most readily apparent is that Illinois deer are not as heavily parasitized as deer in other areas. Data from the northern study site of Cook et al. (1979), however, shows a significantly higher set of prevalence values with infection rates more similar to those found in other states than to those in the current study. This first explanation, therefore, is probably not valid.

A second possible reason for low parasite prevalence is the basic weakness of the fecal flotation procedure in indicating the full extent of an infection. Samuel and Trainer (1969) used fecal flotation to check Wisconsin deer for internal parasites and did identify eggs, larvae, and oocysts of many of the same species found in the present study.

However, their flotation findings were supplemented by necropsy recovery of parasites from deer in the study area. In most cases, necropsies revealed two to three times as many helminth infections as revealed by fecal flotation. In some cases, parasites not found in the flotation work were discovered during necropsy. Although the flotation method is the easiest and fastest way to assess the parasite assemblage within deer, necropsy of fresh kills is still the procedure of choice in order to receive the most accurate estimates of parasite prevalence and intensity. Most of the deer parasite studies previously cited were done by direct necropsy examination.

Finally, low prevalence and intensity figures of this study could have been influenced by prolonged freezing of the samples. The freezing and thawing processes can be very destructive to eggs and oocysts, and in fact, many trichostrongyloid eggs identified in this study were ruptured. Rupture most likely occurred as a result of a period of dessication prior to collection and post-collection freezing and thawing cycles before finally being examined. Ruptured eggs are often not recognizable as eggs and consequently are not counted. In fresh fecal samples, the presence of ten to twenty eggs normally does not indicate a heavy infection. However, due to potential loss of eggs, larvae and oocysts through the freezing process used in this study, infections represented by ten or more eggs, larvae or oocysts may actually indicate a heavy infection with lighter infections represented by only one or two eggs or oocysts. Those infections that are found may be perceived as lighter infections than they truly were, and some lighter or less resistant infections might be totally missed.

The last two factors described above may have contributed significantly to an apparent low parasite prevalence relative to the actual number of infected deer that may exist in the field.

Seasonal variation in parasite prevalence has been noted both between and within study sites. The comparison of overall seasonal prevalences: winter (31%), spring (27%), summer (26%) and fall (25%), indicates that the differences in overall infection rates are not statistically significant. The changing composition of parasite assemblages and the corresponding change in infection rates are noteworthy. Overall, trichostrongyloid prevalence is high in the spring and summer compared to fall and winter months (16%, 19% and 3%, 7% respectively). Eggs of the trichostrongyloid complex require warm temperatures and adequate moisture to develop - conditions most likely to occur during spring and summer. These nematodes continue to produce eggs during fall and winter, but in smaller numbers than when external conditions are favorable. The need for warm, moist conditions is reflected in the trichostrongyloid seasonal prevalence differences. During the winter, the prevalence of Eimeria spp. oocysts is also relatively high. Coccidia oocysts also require heat and moisture to develop outside the deer, but oocysts are none-the -less released fairly continuously in the feces throughout the year. Eimeria spp. oocysts are very resistant to environmental extremes. The summer infection rate of 8% indicates a strong Eimeria presence. The winter rate of 16% shows an even greater presence which is probably related to changing habits of deer in this study. Deer typically have less food and more contact with other deer during winter due to the limited food resources. In the northern states, the deer habit of "yarding up" during the winter can lead to greatly increased contact between deer. Poor nutrition results in a reduced resistance to internal parasites. Coccidia multiply within an animal, and the parasite is spread to other deer feeding in the same area as the infected animal.

The expanded parasite assemblages found in the summer are attributable to the ideal summer growth situations for many parasite species. During winter months, the increased chance of cross transmission and the relatively debilitated state of health of deer result in expanded parasite assemblages.

In terms of each location, Eimeria spp. winter infection rate in Northwest Cook is high (43%) in spite of a small sample size. However, the samples did not indicate a high parasite intensity. The high infection rate may be due to the poor nutritional and overcrowded situation described above. The remainder of the protozoan infection record for Northwest Cook is unremarkable.

Busse Woods shows a year-round parasite presence of all but one of seven parasite species found, indicating a healthy parasite population supported by the conditions of the deer host environment.

Des Plaines and Non-Cook county areas are unremarkable in their seasonal parasite prevalences.

Based on the findings of this study, Northwest Cook county and Non-Cook county areas have the smallest parasite assemblages and the lowest parasite prevalences within their populations. Des Plaines and Busse Woods have significantly larger assemblages and prevalences. Northwest Cook and Non-Cook deer populations are described as low density and high quality with a high nutritional plane. These descriptions are in line with the results of this parasitological study. Low density and good nutrition lead to healthy deer which encounter each other only rarely . These factors are all barriers against parasite transmission and large parasite intensities. High density and poor population quality lead to populations more susceptible to cross-transmission and harboring larger numbers of parasites. Such a situation is seen in Des Plaines and Busse Woods deer.

PARASITE LIFE CYCLES AND ASSOCIATED PATHOGENICITY

Knowledge of each specific parasite's life-cycle will help to explain the influence of seasons and herd density on the occurrences of the parasite.

Ostertagia odocoilei, O. mossi, Haemonchus contortus, and Nematodirus odocoilei are all trichostrongyloids of the abomasum and share a common life cycle. Eggs are deposited in the feces and given the neccessary conditions (i.e. oxygen, moisture and warm temperatures), the eggs hatch within one to two days and the first stage larvae emerge. Still within the feces, the rhabiditiform larvae undergo two molts within the span of a few days. The infective third stage larvae then climbs onto browse where it is ingested by feeding deer. Larvae grow to adults within the gastrointestinal tract.

Pathology associated with trichostrongyloids is blood loss leading to weakness, emaciation and anemia (Davidson et al., 1981; Olsen, 1962). Van Volkenberg and Nicholson (1943) found that deer without adequate browse and under seasonally poor nutritional conditions were susceptible to starvation often accompanied by heavy parasitism, especially by trichostrongyles. Although trichostrongyles contributed to the deaths of a few deer in their study, they claimed that parasite infections were apparently unimportant among deer on ranges with sufficient food.

O. odocoilei, O. mossi and N. odocoilei are all species specific to white-tailed deer. There have been no reports of these parasites in domestic ruminants. There is no threat to humans from any of the parasites due to the very specific biology and ecology of these parasites which restricts them to inhabiting white-tailed deer.

Haemonchus contortus has been reported in cattle (Bos taurus) and sheep (Ovis aries) as well as deer. Some evidence points to the feasibility of cross-transmission between these three hosts. Successful laboratory infections have been produced with sheep being infected with deer H. contortus and vice versa (Samuel, 1968). Prestwood and Pursglove (in Davidson et al., 1981) indicate that although cross-infection has been proven possible in the laboratory and sheep, cattle and deer do all carry H. contortus, much data is still needed to determine whether the parasite infections are exchanged in nature and whether they are a pathogenic threat in all species concerned.

Capillaria bovis, a parasite of the small intestine, is part of the Trichurata and little is known about its life cycle. This species is widely distributed throughout the U. S. and infects cattle as well as deer. Its pathogenicity is unknown. Low infection intensities and low prevalences found in this and other studies (Samuel and Trainer, 1969) would seem to indicate that this species is unimportantant pathologically to white-tailed deer. Low prevalences in deer would indicate a poor potential as parasite reservoirs for domestic ruminants such as cattle. There is no threat to humans from this parasite.

Oesophagostomum venulosum is a strongyle parasite of the colon. Infective third stage larvae develop on the ground five to six days after exposure to optimum conditions of temperature and moisture (Levine, 1968). After ingestion, larvae enter the wall of the intestine and molt to the fourth stage. Seventeen to twenty-two days after infection, these larvae molt to the adult stage. No pathogenic effects have been reported for white-tailed deer. O. venulosum has been reported from a number of wild and domestic ruminants worldwide. In the U.S. this parasite has been reported in cattle, sheep, and goats (Capra hircus) (Shorb, 1939; Whitlock, 1939; Levine, 1963) where it can damage the intestinal wall. The low parasite prevalence and intensity found in this study and in others probably makes white-tailed deer populations poor infection reservoirs from which to infect other ruminants. There is no threat to humans from this parasite.

Parelaphostrongylus tenuis , the meningeal worm which inhabits the brain and spinal cord, has been of some importance in the last twenty years due mostly to its destructive effect on non-natural hosts, in particular moose (Alces alces), reindeer (Rangifer tarandus) and elk (Cervus canadensis) (Anderson, 1965; 1970; Carpenter et al., 1973; Karns, 1967; Prestwood and Smith, 1969). P. tenuis infections are acquired by ingestion of gastropod intermediate hosts containing infective third stage larvae. Eggs develop in the heart and lungs into first stage larvae which are swallowed and passed in feces. First stage larvae penetrate the foot of terrestrial snails where they grow and undergo two molts. The infective third stage larvae is acquired by deer when infected snails are accidentally ingested with browse. Third stage larvae migrate into the nervous system and develop into adult forms finally migrating into the cranium. As a natural host, the pathogenic effect of P. tenuis on the white-tailed deer appears minimal. The prevalence of this parasite can be anywhere between 5% and 86% nationwide. In experimental conditions, heavy infections are accompanied by depression, weakness, ataxia, and posterior paralysis (Davidson et al., 1981). Massive infections, with visible signs, are considered extremely rare under field conditions. P. tenuis infections have been found naturally and have been experimentally established in sheep,and goats (Anderson and Strelive, 1972; Nielson and Aftosmis, 1964). The real threat of this parasite is to other native American ungulates including moose, elk, and caribou and exotics such as fallow deer (Dama dama). Severe neurologic disorder resulting from P. tenuis infiltration of the brain has been documented in all these species. There is no threat to humans from this parasite.

Protozoan infections by Eimeria mccordocki and E. madisonensis are acquired by ingestion of sporulated oocysts. Unsporulated oocysts are passed in feces and exposure to oxygen and moisture outside the host leads to sporulation. Heavy infections are marked by diarrhea, sometimes leading to emaciation, apathy, passage of blood and ultimately death (Davidson, et al., 1981). Evidence suggests infection intensity declines with the deer's age due to acquired resistance resulting from previous infections. As previously discussed, crowded conditions and poor nutrition contribute to Eimeria infections. Anderson and Samuel (1969) report that both E. mccordocki and E. madisonensis are found only in white-tailed deer . These parasite are therefore very species specific and there is little chance of transmission to domestic ruminants and no threat to humans.

SUMMARY AND CONCLUSIONS

The low prevalences and low intensities indicate that none of the deer in this study were heavily parasitized, nor do they show a threat to the general deer population in terms of parasitic infection. In the most general terms, the results of this study can be seen as an indicator that deer of the four study areas, Northwest Cook County, Des Plaines, Busse Woods, and Non-Cook County, are relatively healthy. The deer of Des Plaines and Busse Woods may not be as healthy as those of Northwest Cook and Non-Cook, but this phenomenon may be attributable to the differences in density and nutritional quality of their respective areas. Studies such as those by the Southeast Cooperative Wildlife Disease Study (Eve and Kellogg, 1977) and Demarais, et al. (1983) are attempting to construct deer herd health indices which utilize intensity of parasite infections to show a positive correlation to deer density. The aim is to create an index of correlations so that by checking a relatively small sample of the herd on a regular basis and comparing the parasite count to the established index it is possible to determine the density and health of the herd. This study in no way approaches that level of sophistication, but it does serve to inform the investigator of parasites present in the deer and lend support to any previously suspected trends in the population.

FINAL COMMENTS ON THE EFFECTIVENESS OF THIS STUDY

All samples were processed as one gram of feces so that intensity is measured as number of parasite eggs per one gram of feces. The term "intensity" is relatively useless in terms of parasite eggs and fecal flotations as a whole since adult parasites are capable of producing many eggs. Eggs counted from one animal for a single species of parasite may have been created by one or by a dozen nematodes. There are no rules concerning numbers of males and females; only dissection and extraction can determine exact parasite population numbers. Fecal flotation is useful as a tool to establish parasite assemblages , but not intensities. The exception is when the number of eggs, larvae or oocysts is so large that a heavy infection can be deduced. Such was not the case in this study. There were no indications of heavy or massive infections in any of the samples examined. Samples which did contain parasites contained too few specimens to allow estimation of the number of adult parasites involved.

More infections might have been detected and the accuracy of this study increased if the samples had been stored in 10% formalin rather than frozen for one to three years. Experience shows the condition of parasite eggs and oocysts is significantly better after storage in formalin than after freezing.

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Appendix 1
Infection Data by Specimen
Northwest Cook County

T = Trichostrongyloid
N = Nematodirus
O = Oespohagostomum
C = Capillaria
P = Parelaphostrongylus
E = Eimeria

Data #	UDS #	Season	Confirmed Infection	General Infection Information
1	44	W	x	E (micropyle) 28-30 x 15-20μ, 5 found
2	510	W	x	E (micropyle) 35 x 25 , 1 found
3	43	W		
4	59	W		
5	71	W		
6	520	W		
7	991	F		
8	473	F		
9	912	F		
10	537	W	x	<u>Coccidia</u> egg, 35 x 15μ, 1 found
11	998	F		
12	963	F		
13	979	F	x	N egg, 155-170 x 75μ 9 found
14	983	F	x	Dark bioperculate eggs, 40 x 25μ, 1 found (possible C)
15	454	F		
16	474	F		
17	855	S		
18	428	F		
19	417	F		
20	439	F		
21	003	F		
22	006	F		
23	329	F	x	T egg (ruptured) 80 x 45μ, 1 found
24	866	S		
25	846	S	x	Large, dark coccidian (micropyle present) 50 x 30 μ , 1 found (sheep?); T egg, 75 x 50μ, 1 found; N egg, 165 x 75μ, 1 found
26	256	S		
27	252	S		
28	844	S	x	E 38 x 25 , 1 found; egg-like structure, 35 x 20 μ , 6 - 8 found; N egg (deflated) 160 x 75μ, 2 found; N egg (whole), 155 x 80μ, 1 found
29	814	S		
30	842	S		
31	813	S		
32	856	S	x	T egg (deflated), 80 x 45-50μ, 2 found
33	165	Sp		
34	109	Sp		
35	157	Sp		
36	812	S		
37	816	S	x	T egg, 70 x 40μ, 1 found

38	838	S		
39	135	Sp		
40	835	S		
41	125	Sp		
42	712	Sp		
43	130	Sp		
44	728	Sp		
45	193	Sp		
46	754	Sp		
47	164	Sp		
48	810	S	x	E. (micropyle) 28-30 x 20-22μ, 2 found
49	100	Sp		
50	103	Sp		
51	677	Sp		
52	105	Sp		

Appendix 2
Infection by specimen
Des Plaines

T = Trichostrongyloid
N = Nematodirus
O = Oespohagostomum
C = Capillaria
P = Parelaphostrongylus
E = Eimeria

Data #	UDS #	Season	Confirmed infection	General infection information
53	903	S	x	E, 22 x 17μ, 1 found
54	906	S		
55	890	S		
56	894	S		
57	806	S	x	T, yellow/silver color, ruptured, 75-90 x 30-35μ , 3 found
58	986	F		
59	830	S		
60	911	F	x	E, silver, rough, micropyle, 35-47 x 25 -30μ, 15 found
61	280	S		
62	249	S		
63	824	S		
64	825	S		
65	276	S		
66	289	S		
67	422	F	x	N, ruptured, 190 x 75μ, 1 found
68	443	F	x	P, kinked tail, 225 x 10-15μ, 1 found
69	442	F		
70	448	F		
71	404	F	x	E, micropyle with yellow interior, 35 x 25μ, 1 found
72	392	F		
73	873	S		
74	917	F		
75	455	F		
76	478	F		
77	415	F		
78	689	Sp		
79	185	Sp		
80	649	Sp		
81	353	F		
82	688	Sp		
83	344	F		
84	369	F		
85	213	Sp	x	E, 30-35 x 22-25μ, 25 found
86	679	Sp		
87	181	Sp		
88	676	Sp	x	E, micropyle, 35 x 27μ, 2 found; E, round, 17 x 17μ, 2 found; T, 75-80 x 35-45μ, 4 found
89	172	Sp	x	T, 1 found
90	182	Sp		
91	174	Sp		
92	175	Sp		
93	153	Sp		
94	572	W		
95	041	W		
96	083	W		
97	601	W		
98	666	Sp		

99	542	W	x	T, 3 found
100	496	W	x	T, ruptured, 75 x 35μ, 2 found
101	568	W		
102	552	W		
103	569	W		
104	544	W	x	E, micropyle, 25 x 20μ, 1 found
105	062	W		
106	584	W		
107	585	W		
108	583	W	x	E, 30 x 20-30μ, 2 found
109	149	Sp	x	E, 25 x 20μ, 1 found; T, ruptured, 70 x 30μ, 1 found
110	549	W		

Appendix 3
Infection by Specimen
Busse Woods

T = Trichostrongyloid
N = Nematodirus
O = Oespohagostomum
C = Capillaria
P = Parelaphostrongylus
E = Eimeria

Data #	UDS #	Season	Confirmed infection	General infection information
111	840	S		
112	310	S		
113	239	S	x	T, 82 x 35μ, 1 found; T 65-70 x 40μ, 1 found
114	836	S	x	P, kinked tail, 225-240 x 10μ, 14 found; T, silver gray, 80-85 x 40-45μ, 2 found
115	274	S	x	E, round, 17 x 17μ, 1 found
116	299	S		
117	826	S	x	E, 25 x 20μ, 1 found; T, 70 x 37μ, 1 found
118	892	S		
119	260	S		
120	275	S		
121	886	S		
122	895	S	x	T, ruptured, 80 x 50μ, 2 found
123	802	S		
124	815	S		
125	871	S		
126	888	S		
127	322	S	x	T, 75 x 35-40μ, 1 found
128	2072	W		
129	829	S	x	P, 255 x 10μ, 3 found
130	854	S		
131	2063	W	x	T, ruptured, 60 x 35μ, 1 found; E, micropyle, 30-35 x 25μ, 2 found
132	2064	W		
133	831	S		
134	905	S	x	T, ruptured, 75-85 x 35-42μ, 29 found; T larvae, 6 found; P, kinked tail, 190-225 x 10-15μ, 6 found
135	2049	W		
136	2056	W		
137	557	W	x	T, 80-85 x 40-45μ, 2 found
138	2033	W	x	E, micropyle, 25-27 x 15μ, 1 found
139	2070	W	x	P, 225-250 x 10μ, 7 found; P, (better condition) 350 x 17μ, 1 found; E, 25 x 20μ, 1 found
140	2073	W		
141	030	W		
142	036	W		
143	528	W		
144	602	W		
145	024	W		
146	2020	W	x	O, 70 x 55μ, 1 found; T, 70 x 35μ, 1 found; P, 1 found
147	2027	W		
148	2028	W		
149	2038	W	x	P, 235-250 x 10-15μ, 3 found
150	2059	W		
151	2055	W	x	C, 50-55 x 22-25μ, 3 found
152	2075	W	x	E, 25 x 15μ, 1 found
153	2022	W		
154	2037	W	x	C, 55 x 27μ, 1 found; O, 85-90 x 40μ, 2 found

155	042	W		
156	046	W	x	T, ruptured, 75-85 x 40-42μ, 2 found
157	2046	W	x	E, 25 x 17μ, 1 found; T, 70 x 35μ, 1 found
158	2050	W	x	P, 200-210 x 10-12μ, 2 found
159	038	W		
160	078	W		
161	031	W		
162	051	W		
163	023	W		
164	025	W	x	P, 250-300 x 15μ, 1 found
165	067	W		
166	082	W		
167	2048	W		
168	2117	Sp	x	T, ruptured, 80 x 37μ, 1 found
169	2081	Sp		
170	2086	Sp	x	T, 75 x 32μ, 1 found
171	627	Sp	x	T, ruptured, 75-80 x 32-40μ, 2 found
172	638	Sp		
173	620	Sp		
174	660	Sp	x	T, ruptured, 60 x 35μ, 1 found
175	2095	Sp	x	P, 225 x 15μ, 2 found
176	2114	Sp	x	P, 235-240 x 12-15μ, 2 found
177	2099	Sp		
178	2105	Sp		
179	644	Sp		
180	2125	Sp		
181	2120	Sp	x	P, 220 x 10μ, 2 found
182	2123	Sp	x	P, 205-220 x 10μ, 5 found
183	694	Sp	x	T, 75-85 x 35-45μ, 2 found
184	797	Sp		
185	225	Sp	x	T, 85 x 30μ, 2 found
186	748	Sp		
187	098	Sp	x	O, 90-100 x 47-55μ, 4 found
188	191	Sp		
189	115	Sp	x	O, 98 x 46μ, 2 found
190	150	Sp	x	C, 51 x 25μ, 1 found
191	187	Sp		
192	695	Sp		
193	2005	F	x	T, 70-76 x 37μ, 2 found
194	970	F		
195	331	F	x	T, 87 x 42μ, 1 found
196	378	F		
197	949	F		
198	801	Sp		
199	2006	F	x	C, 53 x 25μ, 1 found
200	2008	F		
201	177	Sp		
202	188	Sp		
203	171	Sp		
204	176	Sp	x	T, 77-79 x 35μ, 2 found; E, 30 x 23μ, 1 found
205	470	F	x	P, 253 x 12μ, 1 found
206	475	F		
207	346	F		
208	2010	F		
209	004	F		
210	2013	F	x	P, 270-276 x 10-13μ, 3 found
211	336	F		
212	2011	F		
213	351	F	x	C, 51 x 25μ, 1 found
214	357	F	x	P, 253-287 x 16μ, 3 found
215	2014	F		

Appendix 4
Infection by Specimen
Non-Cook

T = Trichostrongyloid
N = Nematodirus
O = Oespohagostomum
C = Capillaria
P = Parelaphostrongylus
E = Eimeria

Data #	UDS #	Season	Confirmed infection	General infection information
216	975	F		
217	976	F		
218	400	F		
219	877	S		
220	907			
221	960	F		
222	430	F		
223	449	F		
224	416	F		
225	431	F	x	C, 40-46 x 21-23μ, 2 found
226	460	F	x	N, 150-160 x 70-75μ, 3 found
227	956	F		
228	350	F		
229	425	F		
230	374	F		
231	396	F		
232	526	W		
233	553	W		
234	001	W		
235	2024	W		
236	387	F		
237	536	W		
238	002	W		
239	081	W		
240	504	W		
241	507	W		
242	514	W		
243	541	W		
244	765	Sp		
245	796	Sp		
246	080	W		
247	673	Sp		
248	713	Sp	x	T, 72 x 40μ, 1 found
249	757	Sp	x	T, 75 x 35μ, 1 found
250	202	Sp		
251	742	Sp		
252	818	S		
253	878	S		
254	635	Sp		
255	647	Sp		
256	811	S		
257	819	S	x	T, 72 x 30μ, 1 found; N, 140 x 53μ, 1 found
258	827	S		
259	875	S		
260	847	S		
261	870	S		
262	114	Sp		

263	247	S		
264	321	S		
265	843	S		
266	085	Sp		
267	820	S	x	T, 86 x37μ, 1 found
268	119	Sp		
269	158	Sp		
270	251	S		

Addendum

The original sample inventory submitted for flotation included 274 fecal groups. The final number examined was 270. From the original list, six samples were exempted per your request. Three samples, 963 (Northwest Cook), 78 and 826 (Busse Woods) were found in the sample bags and were analyzed in place of three samples, 969 (Northwest Cook), 73 and 876 (Busse Woods) listed on the inventory, but not found in the bags. Two additional samples (877 and 907, Non-Cook) found in the bags but not listed in the inventory were analyzed.

Appendix F. Witham, J.H., E.A. Cook, and J.M. Jones. No date. White-tailed deer habitat change in metropolitan northeastern Illinois. Unpub. manuscript. 14pp.

30 June 1990
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RH: Metropolitan Deer Habitat . Witham et al.

WHITE-TAILED DEER HABITAT CHANGE IN METROPOLITAN NORTHEASTERN ILLINOIS

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Abstract: Landsat Thematic Mapper satellite data collected in 1985 and 1988 were used to evaluate white-tailed deer (*Odocoileus virginianus*) habitat in the 4-county (5,929 km^2) Chicago Metropolitan Area (CMA). Thirteen land cover classes were combined into 5 general deer habitat categories for each date. In 1988, CMA landscape was 6.7% nondeveloped forest, 49.3% heavily vegetated residential and cropland, 3.3% maintained grass, 39.1% urban and nondeer habitat, and 1.6% water. County-owned green belt systems, comprising 7.2% of the metro area, provide permanent habitat where deer concentrate. Percent development varied from highly urbanized Cook County (75.9%) to more rural Kane County (29.5%). Less developed Kane and Lake counties sustained highest net losses (>8%) and net degradation (17-27%) of deer habitat during 1985-1988. Less developed counties have the greatest opportunity to plan for future wildlife habitat; more developed counties are closer to minimum threshold

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levels of deer habitat and should focus on how deer will be managed on extant habitats.

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Key words: Chicago, habitat, Illinois, metropolitan, *Odocoileus virginianus*, Landsat thematic mapper, urbanization, white-tailed deer.

White-tailed deer persist in many North American metropolitan areas because they habituate to human disturbances and because such areas support diverse plant associations that provide energy and space necessary for deer to survive and reproduce. Contemporary urban land planners often ameliorate wildlife habitat by using open space and natural features in their development concepts (Leedy 1979, Hench et al. 1987); however, many older urban communities also possess similar features that sustain deer populations. Examples of typical metropolitan deer habitat are: riparian corridors with buffer vegetation, widely spaced suburban estates that are heavily vegetated, suburban arboreta, municipal and county nature centers, remnant agricultural fields, and manicured grounds surrounding institutions and corporate buildings.

The Chicago Metropolitan Area (CMA) is comprised of many natural and cultivated plant associations that are largely determined by land ownerships (Schmid 1975, Swink and Wilhelm 1979). White-tailed deer are abundant and widely distributed in the CMA. Greatest concentrations of deer are at suburban-rural fringes and on large county preserves that are bordered by suburban development (Witham and Jones 1990). Because urban development continues to radiate from the city of Chicago, there is a widespread perception among local publics and resource managers that deer habitat in the CMA is decreasing rapidly.

We used satellite imagery data and geographic information system technologies to inventory land cover in 4 counties of metropolitan northeastern Illinois. Our objectives were to estimate percent and total deer habitat in the CMA during 1988 and to evaluate net changes in deer habitat from 1985 to 1988.

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STUDY AREA AND METHODS

The study area of Cook, DuPage, Kane, and Lake counties in northeastern Illinois supported a human population of 6.86 million in 1988 (Northeast. Ill. Plan. Comm. 1989). General characteristics of the study area were described previously (Witham and Jones 1987, 1989). Local climate is predominantly temperate continental with cold winters (January $\bar{x}$ minimum temperature = -10.2 C) and warm, humid summers (July $\bar{x}$ maximum temperature = 28.5 C). Mean annual precipitation and snowfall are 89.7 cm and 101.1 cm, respectively (Natl. Oceanic and Atmospheric Admin. 1987). Soils are derived primarily from glacial drift and were described to the association level by Fehrenbacher et al. (1984). On the basis of similarities in physiographic and biotic communities, Schwegman (1973) included the study area in the Northeastern Morainal Division of Illinois, except for southwest Kane County, which is in the Grand Prairie Division. Swink and Wilhelm (1979) documented species, associations, and distribution of native plants in the Chicago region and Schmid (1975) described urban vegetation. Upland hardwood forests are dominated by bur oak (Quercus *macrocarpa*) and white oak (*Q. alba*) on dry sites and by sugar maple (*Acer saccharum*), basswood (*Tilia americana*), and red oak (*Q. ruba*) on mesic sites; floodplain forests dominants are silver maple (*Acer saccharinum*) and American elm (*Ulmus americana*). Remnant prairie, fen, marsh, and bog communities are interspersed in the study area. The history and ecology of white-tailed deer in the midwest agricultural region (Gladfelter 1984) and specifically in Illinois (Pietsch 1954, Calhoun and Loomis 1974, Nixon et al. 1989) are well documented.

Landsat Thematic Mapper (TM) data collected 27 June 1988 and 5 June 1985 were selected to inventory land cover and short-term change in land cover. TM data have a ground resolution of 30 X 30 m (i.e., pixel size = 0.09 ha) with 7 bands of data ranging in the energy spectrum from visible light, to reflective infrared radiation, to thermal infrared radiation (Iverson and Cook 1988). TM data sets were geographically referenced to Universal Transverse Mercator (UTM) coordinates by the use of identifiable ground control points. A supplemental data set was acquired from Northeastern Illinois Planning Commission which documented the dominant land use (rural, urban residential, or public open space) for each quarter section of the township, range, section map reference system. These data were used to stratify the TM data to aid in classifying land cover. This step and the subsequent processing described below were applied to each TM data set, with 1988 used as an example in the description. An "unsupervised" clustering algorithm, based on means and euclidian distances from the mean, identified 195 spectrally distinct pixel clusters. Aggregation of these clusters into 13 land cover classes was accomplished by studying their spectral characteristics and their locations on aerial photographs. Sample points of each land cover class were field checked. Land cover class descriptions (Table 1) ultimately were based on the commonalities found at the sample points. Ambiguous data were isolated in unique classes to maximize class separation. For example, some confusion existed among alfalfa, sod, and savanna: these mixed clusters were placed in a separate class from areas identified exclusively as savanna. The Illinois Geographic Information System (IGIS, Brigham 1988) was used to subset the data and produce land cover statistics by counties.

Land cover classes were combined into 5 categories (Table 1) based on their relative value as whitetail habitat in metropolitan northeastern Illinois. Nondeveloped forests and savannas were rated as primary deer habitat because they provide year-round concealment, thermal cover, and forage and because they are concentration sites for deer during winter in central and northern Illinois (Nixon et al. 1988). Secondary habitat was land cover that was favorable for deer, but with some limitations. Field crops were considered secondary deer habitat due to seasonal availability of food and cover. Residential estates with tree canopy closure >30% were secondary deer habitat because unrestricted use of estates by deer is precluded by human disturbances, physical barriers, and varying human tolerance for deer. We considered tertiary deer habitat as vegetation that deer would use only if it was proximal to primary or secondary deer habitat. Urban features (e.g., construction, nonresidential buildings, parking lots, residential areas without trees, roads) were regarded as nondeer habitat. Pixels with water signatures were treated independently because of their ambiguity; open water is not usable, whereas a vegetated shoreline associated with suitable habitat would be used by deer. Because we did not censor deer habitat by minimum size or by association with other habitat types, our estimates represent the maximum potential deer habitat in the CMA.

We used IGIS techniques to overlay the 1985 and 1988 deer habitat classifications to detect pixel by pixel changes. The 25 resulting change categories (i.e., a 5 X 5 matrix) were aggregated to represent 6 potential outcomes of habitat change: 1) no change, 2) habitat gain, 3) habitat loss, 4) habitat improvement, 5) habitat degradation, and 6) other. Net change in total deer habitat was defined as:

habitat gain - habitat loss.

Net change in habitat quality was calculated as:

(habitat improvement + habitat gain) - (habitat degradation + habitat loss)

The 1988 satellite data did not cover 2.4% (29.31 km^2) of northeastern Lake County or 0.5% of the 5,929.14 km^2 total study area. This relatively small amount of unclassified area had virtually no effect on estimates of 1988 land cover or changes in cover between 1985 and 1988.

RESULTS

More than 50% of the CMA was classified as primary (6.7%, 394.9 km^2), secondary (49.3%, 2,905.7 km^2), or tertiary (3.3%, 193.0 km^2) deer habitat in 1988. Trees were present on one-quarter (24.7%, 1,457.2 km^2) of the CMA landscape as nondeveloped forests, savannas, or residential areas with canopy closure >30%. Percent forest cover in the most urbanized counties of Cook (29.9%) and DuPage (31.2%) was >2X higher in 1988 than during presettlement in 1820 (Iverson et al. 1989). Secondary deer habitat was 83.2% of all deer habitat; nondeer habitat and water comprised 39.1% (2,308.9 km^2) and 1.6% (97.0 km^2) of the CMA, respectively.

The 4 counties represented a gradient of urbanization. Cook County was most developed with 75.9% (1,880.1 km^2) in forested residential or urban land cover. DuPage (65.5%, 570.6 km^2), Lake (43.6%, 520.2 km^2), and Kane (29.5%, 400.3 km^2) counties were progressively less developed. Percent deer habitat within counties was an inverse gradient of urbanization with values ranging from 44.8% (Cook County) to 77.0% (Kane County). Because it is almost 2X larger than other CMA counties, Cook County had the most area in deer habitat (1,111.1 km^2) despite having the lowest percent deer habitat among counties. Both Lake (819.4 km^2) and DuPage (517.7 km^2) counties had less total deer habitat than Cook or Kane counties (Table 2).

With 1 exception, all counties sustained net reductions in deer habitat and deer habitat quality from 1985 to 1988 (Table 3). Percent net losses of deer habitat were highest in more rural counties of Kane (-8.7%, 117.9 km^2) and Lake (-8.3%, 99.5 km^2) and lowest in DuPage County (-4.7%, 40.84 km^2). An increase in secondary deer habitat in Cook County contributed to a modest net gain (1.4%, 33.7 km^2) in total deer habitat. CMA counties sustained net losses of deer habitat totalling 242.0 km^2 (-4.1% of CMA) during the 3-year period evaluated. DuPage County (-15.3%, 133.3 km^2) and Kane County (-16.2%, 219.6 km^2) experienced moderately high, and Lake County (-27.0%, 323.0 km^2) very high, reductions in deer habitat quality. In Cook County, habitat quality decreased at a more modest rate (-4.9%, 120.7 km^2).

DISCUSSION

Deer habitat classifications used in this study reflect macro habitat types available to deer within the CMA. Such classification does not indicate actual deer use or densities as both will vary within classes because of site specific differences in plant community composition and structure. Other factors such as habitat interspersion, deer behavior, human disturbances, plant phenology, soils, and weather also influence temporal and spatial distributions of whitetails. Thus, our habitat evaluation represents potential deer habitat and is most useful for broad-scale comparisons between relatively distinct types (e.g., forested vs. urban features, developed vs. nondeveloped).

The perception that deer habitat was declining in the CMA was accurate, particularly in the more rural Lake and Kane counties where percent habitat loss and degradation were highest. Rapid loss of deer habitat displaces some deer and may contribute to higher rates of mortality, dispersal or wandering, and/or increased deer densities on suitable remaining habitat. Deer numbers increased statewide in Illinois during the 1980's, but the exponential increase in deer-vehicle accidents (Illinois Dep. Trans., unpub. data), high numbers of complaints of deer browsing damage to ornamental plants, and locally severe degradation of plant communities on remnant natural areas in the CMA (Witham and Jones 1987) may be exacerbated by deer that have been displaced by habitat degradation or loss.

The declining trend in total deer habitat that occurred during 1985-1988 will not result in long term elimination of deer habitat in the CMA because large tracts of natural and restored plant communities are permanently protected in open space properties owned by county forest preserve districts (Wendling et al 1981, Witham and Jones 1987). These forest preserves covered approximately 7% of the CMA in 1988, (11% of Cook County, 9% of DuPage County, 4% of Lake County, and 1% of Kane County). All forest preserves were not suitable deer habitat as some properties were designated for recreational and educational uses. However, deer are able to utilize most of the available resources on preserves that receive intensive human use because they tend to habituate to human disturbances.

Although Kane County ranked highest (77.1%) in percent deer habitat among counties, it was depauperate in nondeveloped forest cover (3.6%) compared to Cook (8.1%) and Lake (8.2%) counties. Differences among counties in the relative amount of primary to seasonal habitats suggest that deer, particularly in Cook and Kane counties, may require different strategies for using resources of these counties. In Illinois, farmland deer concentrate in protected woodlots during winter and then disperse or migrate into agricultural areas during spring and early summer (Nixon et al. 1988, 1989). Most deer are eliminated from agricultural fields and small woodlots in winter by harvest of crops, by regulated hunting, and through annual migrations to more secure habitats. Although firearm hunting is not permitted in Kane County, the dominance of cropland (51%) and limited nondeveloped forest cover creates a similar habitat repletion-depletion cycle where deer must migrate seasonally to and from the larger forests for winter protection.

In contrast to Kane County, Cook County had more nondeveloped forested cover (8.1%) and only limited seasonal cropland (4.7%). Urbanization has increased the insularity of primary deer habitat in Cook County, thus, in many areas deer must negotiate diverse barriers to use disjunct secondary habitats (i.e., cropland). Although dispersal by some subadult whitetails is likely, the limited availability of cropland and the potential costs of injury or mortality incurred by deer attempting to travel through "high risk" urban areas to scattered croplands precludes such movements by most CMA deer. The relatively low mobility of Cook County deer is supported by observations of 12 radio-collared adult and yearling does that were captured and released in Cook County during 1984; none was observed to migrate or disperse (Jones and Witham, unpub. data). Conservative movements by deer in highly developed metropolitan areas, such as Cook County where 5.3 million people reside, may be typical and perhaps selected for through differential survival that favors deer that are more sedentary.

MANAGEMENT IMPLICATIONS

Deer habitat included land use classes with different potentials for development, which may have large scale effects on future distributions and abundance of whitetails in the CMA. Cover for deer on residential areas with >30% canopy closure is predictably more stable than cover on agricultural land in suburban-rural fringe areas which have high potential for conversion to nondeer habitat. In Cook and DuPage counties, secondary deer habitat was mostly (64% and 53%, respectively) forested residential areas. In contrast, secondary deer habitat in more rural Lake and Kane counties was predominantly in less stable cover such as cropland (71% and 90%, respectively).

Counties that are least developed have the greatest flexibility and potential for choosing the amount, distribution, and design of wildlife habitats within their jurisdictions (Hench et al. 1987). Protection of wildlife habitat can be achieved through county and municipal zoning (Bissell et al. 1987) or through purchase of properties for nondevelopment or restoration of natural vegetation. Presently, Kane and Lake counties have the greatest opportunity to plan for wildlife habitat on their developing metropolitan landscapes. Future abundance and distribution of deer in Kane and Lake counties will depend on if, and how, current land use plans (e.g., Byers et al. 1987) are enacted. Concomitant with retention or restoration of wildlife habitat on developing landscapes is recognition that adverse deer-human interactions will increase and will require counties, municipalities, and publics to be more directly involved in local deer management (Witham and Jones 1989).

In contrast, deer habitat in Cook County, and to a lesser degree in DuPage County, is in more permanent cover. Forest preserves comprise 8.7-11% of these counties and provide minimum thresholds of inviolate deer habitat. Secondary deer habitat is predominantly (21.8-25.9% of total county area) in heavily treed residential areas, which tend to become more vegetated over time. Because deer habitat in these urbanized counties is in more stable land use types than in rural counties, fewer opportunities exist for changing such habitats through large scale landscape modifications. Natural resource managers, administrators, and publics in these urbanized counties should clearly define site management objectives for existing habitats and decide how deer and other wildlife species will be managed to meet these objectives.

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Table 1. Land cover classifications used to assess white-tailed deer habitat in metropolitan northeastern Illinois.

Cover types	Description
Primary deer habitat	
Forest, dense	Forest, >70% canopy closure, with understory.
Forest, medium	Forest, 30-69% canopy closure, with understory.
Savanna	Forest, <30% canopy closure
Secondary deer habitat	
Residential, trees	Forested with human structures, estates on large lots, usually mature trees with >30% canopy closure, vegetation > nonvegetation in signature.
Nonmaintained grass	Pasture, hayland, roadsides, small grain cropland, other grassy areas, fallow fields.
Cropland	Mostly corn, soybeans, wheat (rarely baresoil for reasons other than agriculture or roads).
Alfalfa, sod	Alfalfa, sod, waterways, possibly some corn or other grains.
Tertiary deer habitat	
Maintained grass	Manicured urban grassland (i.e., institution grounds, golf courses, cemeteries, grass parklands).
Nondeer habitat	
Residential, no trees	Residential, yards with few or no mature trees, sparse vegetation in signature.
Urban, other	Urban features, cropland within urban areas, quarries, construction sites and other disturbed areas.
Urban features	Roads, buildings, parking lots, nearly all impervious surfaces that are nonvegetated.
Urban, water	Urban features with some water.
Water	Water dominates signature, some sites may be vegetated.

Table 2. Percent and total land cover by county in metropolitan northeastern Illinois, based on Landsat satellite imagery Thematic Mapper data, 27 June 1988.

Cover types	Cook County		DuPage County		Kane County		Lake County[1]	
	% of county	km^2	% of county	km^2	% of county	km^2	% of county	km^2
Primary deer habitat								
Forest, dense	3.95	97.9	3.61	31.4	2.41	33.2	5.04	59.9
Forest, medium	2.75	68.1	1.13	9.8	0.91	12.4	2.05	24.5
Savanna	1.43	35.4	0.65	5.6	0.28	3.8	1.08	12.9
Secondary deer habitat								
Residential, trees	21.79	540.0	25.85	225.1	7.20	97.6	16.71	199.6
Nonmaintained grass	5.96	147.7	9.95	86.6	9.32	126.4	10.05	120.1
Cropland	4.65	115.2	9.25	80.5	50.96	691.3	25.00	298.6
Alfalfa, sod	1.40	34.7	3.38	29.4	3.53	47.9	5.45	65.0
Tertiary deer habitat								
Maintained grass	2.91	72.1	5.78	50.3	2.34	31.8	3.25	38.8
Non deer habitat					22.32	302.7	26.86	320.6
Residential, no trees	20.78	514.9	10.50	91.4	2.46	33.3	4.82	57.6
Urban, other	12.35	306.0	18.27	159.1	17.12	232.3	15.72	187.7
Urban features	14.80	366.8	9.28	80.8	2.03	27.5	3.90	46.5
Urban, water	6.15	152.4	1.63	14.2	0.71	9.6	2.42	28.8
Water	1.08	26.8	0.75	6.5	0.69	9.4	4.55	54.3
Total county area (1 pixel = 0.09 ha)	2,478.10 km^2		870.83 km^2		1,356.63 km^2		1,194.43 km^2	

[1] 2,931 ha (32,568 pixels @ 0.09 pixels/ha) of northern Lake County was not covered by the satellite data file.

Table 3. Percent change in deer habitat from 5 June 1985 to 27 June 1988 for Cook, DuPage, Kane, and Lake counties, Illinois.

Changes in deer habitat during 1985 and 1988	% Change By County			
	Cook	DuPage	Kane	Lake
Habitat gain (GAIN) (non habitat or water ⟶ habitat)	10.45	9.66	4.41	6.28
Habitat loss (LOSS) (habitat ⟶ non habitat or water)	9.09	14.35	13.10	14.61
Habitat improvement (IMPROVED) (tertiary ⟶ secondary or primary) (secondary ⟶ primary)	1.68	4.11	1.73	2.15
Habitat degradation (DEGRADED) (primary ⟶ secondary or tertiary) (secondary ⟶ tertiary)	7.91	14.73	10.06	20.86
Net change in habitat (GAIN - LOSS)	+1.36	-4.69	-8.69	-8.33
Net change in habitat quality (IMPROVED + GAIN) - (DEGRADED + LOSS)	-4.87	-15.31	-17.02	-27.04

Appendix G. Jones, J.M., and J.H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildl. Soc. Bull. 434-441.

Wildl. Soc. Bull. 18:434–441, 1990

POST-TRANSLOCATION SURVIVAL AND MOVEMENTS OF METROPOLITAN WHITE-TAILED DEER

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Problems associated with large concentrations of white-tailed deer (*Odocoileus virginianus*) are accentuated in metropolitan areas where herds are isolated within preserves or parks by urban development. The resultant reduction in plant species richness and structure on these natural areas, adverse effects upon other wildlife species (e.g., ground nesting species), deer-vehicle accidents, and damage to ornamental plants on private properties near preserves can increase to undesirable levels (Decker and Purdy 1988) and can eventually require site-specific population reduction. However, segments of the urban public oppose methods that involve the killing of deer (Heintzelman 1988) and advocate translocating deer from metropolitan environs to more rural settings (Nielsen 1988).

Palmer et al. (1980) and Ishmael and Rongstad (1984) demonstrated that lethal deer pop-

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ulation reduction techniques (i.e., closely regulated public hunting and sharpshooting over bait, respectively) were most effective in terms of manhours and cost per deer removed. However, cost and time required to live capture and translocate deer appear to be secondary concerns to many metropolitan residents who oppose lethal methods and view translocation as a means of "saving" individual deer while addressing the problem of reducing deer numbers. The measurement of "survival" is essential for assessing success if the objective for translocation is to save the lives of individual animals. Studies on the post-translocation survival of nutritionally stressed black-tailed deer (*O. hemionus*) (O'Bryan and McCullough 1985), genetically superior white-tailed deer (McCall et al. 1988), and free-ranging rural white-tailed deer (Hawkins and Montgomery 1969, Pais 1987) indicate that a substantial number of deer will die during capture, translocation, or shortly after release; however, no studies have evaluated the survival of white-tailed deer translocated from metropolitan to rural areas.

As part of a 6-year study of white-tailed deer in the Chicago Metropolitan Area, we monitored the fates of deer captured on metropolitan preserves and translocated to a rural location. The objectives of this study were to monitor the survival of translocated deer during the first year post-release and to compare the survival and movements of translocated deer to the survival and movements of deer that were captured and marked, but not translocated from metropolitan preserves.

STUDY AREAS

Metropolitan Capture Sites

White-tailed deer were captured during the winters of 1984–1988 from 3 locations within Cook County, Illinois: the 1,499-ha Ned Brown Preserve (Ned Brown), the 1,242-ha Des Plaines Preserve (Des Plaines), and the 900-ha Chicago-O'Hare International Airport (O'Hare). Cook County is one of the largest counties (2,480 km²) in Illinois (Neely and Heister 1987) and the most highly populated with >5.2 million residents in 1988 (Northeast. Ill. Planning Comm. 1989). All metropolitan area capture sites were in townships with >77,000 residents (U.S. Census Bureau, unpubl. data). The 18,055 km of roads in Cook County sustain >124.3 million average daily vehicle-kilometers of travel (Ill. Dep. Trans., 1988, unpubl. data). Based on Landsat satellite imagery data, 33% of Cook County was in urban or suburban land use classes in 1985 (E. Cook, Ill. Nat. Hist. Surv., Champaign, pers. commun.).

Ned Brown typifies all capture sites in that major highways dissect or border deer habitat and adjacent properties are extensively developed. Ned Brown sustains intensive public use with >1.5 million visitors annually (Dwyer et al. 1985). Cover types are: 66% in woodlots dominated by oak (*Quercus* spp.), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*), 10% in old field successional stages, wetlands, and mowed grass, 15% in open water, and 9% in roads and other developments. Deer density during the winter of 1984 was >20/km² (Witham and Jones 1990).

Des Plaines differs from Ned Brown in that the former is riparian habitat with woodlots dominated by sugar maple and basswood. O'Hare differs in that deer habitat consists of early second growth (i.e., mostly shrubs and saplings) woodlots and grassy areas or early successional fields adjacent to runways. A minimum of 7.3 deer/km² was initially present on O'Hare (Witham and Jones, unpubl. data).

Rural Release Site

Deer were released on the 1,440-ha Joliet Army Training Center, Will County, Illinois. Will County encompasses 2,197 km² (Neely and Heister 1987) with 17% of the county in urban or suburban land use (E. Cook, Ill. Nat. Hist. Surv., pers. commun.) and a 1988 human population of 346,700 (Northeast. Ill. Planning Comm. 1989); the release site was in a township with 4,820 residents (U.S. Census Bureau, unpubl. data). The 4,470 km of roads in Will County averaged 9.9 million vehicle-kilometers of travel daily (Ill. Dep. Trans., 1988, unpubl. data). Relative to Cook County, Will County had 93% lower human population, 77% less urban/suburban development, and 75% fewer kilometers of roads with 92% less traffic volume.

The Army Training Center is characterized by ≤40% in mature second growth oak woodlots and ≥60% in hawthorn (*Crataegus* spp.) thickets and old fields. Human activity on the training center is restricted to military training exercises, occasional construction activities, a 6-day shotgun harvest of deer (3 days each in Nov and Dec), and a 3-month (Oct–Dec) archery season for deer. Two-lane roads surround most of the training center but have less vehicular traffic than the many 4-lane highways near the capture areas. Limited residential development, industrial complexes situated on large acreages, and a 9,400-ha U.S. Army ammunition plant are contiguous with the training center. Security fences which surround most of the industrial and military areas are partial barriers to deer movements. The training center is ≤80 km (straight line) from the capture sites and had a minimum density of 5 deer/km² during the winter of 1988 (Ill. Dep. Conserv., unpubl. aerial counts).

METHODS

Deer were captured with rocket nets (Hawkins et al. 1968). Exceptions were 2 deer that were captured with drive nets (Silvy et al. 1975) and 1 deer captured by remote chemical injection (Jessup and Hunter 1989). Once captured, deer were manually restrained, blindfolded, and sedated with 8 mg/kg ketamine hydrochloride (Ketaset, Bristol Laboratories, Syracuse, N.Y.) and 1 mg/kg xylazine hydrochloride (Rompun, Miles Laboratories, Shawnee, Kans.). All animals were aged by tooth wear and replacement as either fawns (≤1 year) or adults (>1 year) (Severinghaus 1949). Yearling does were included in the "adults" category due to the small number of yearlings captured. Each doe was marked with a metal ear tag (National Band and Tag Co., Newport, Ken.) in each ear, a numbered white plastic cattle tag (Y-TEX Corp., Cody, Wyo.) in the right ear, and a standard radio collar with a mortality sensor (Telonics, Inc., Mesa, Ariz.). Bucks were marked similarly but were not radio-collared. Deer to be translocated were placed in individual transport crates or collectively in a completely darkened horse trailer. Yohimbine hydrochloride (Sigma Chemical Co., St. Louis, Mo.), which acts as an antagonist of Ketaset and Rompun (Jessup et al. 1983, Mech et al. 1985), was administered intravenously at 0.15 mg/kg prior to transport; animals were alert upon reaching the release site. Resident does released at capture sites in Des Plaines during March–April 1984 were marked similarly but were not sedated nor tagged with cattle tags.

Radio-collared deer were relocated with truck-mounted, paired, 4-element Yagi antennae attached to a portable receiver. A null-peak system was used to determine bearings. Resident does were relocated every 1 to 2 weeks. Translocated does were relocated every 2 weeks during the first 6 months of 1985, but relocation intervals were extended to once a month or every other month when long-distance movements did not occur. Individual animals that moved from the release site were relocated more frequently until it was apparent that the animal had settled into a new area or returned to the release area. Telemetry system accuracy was evaluated by triangulating the locations, unknown to the researcher doing the triangulations, of radio transmitters placed in Ned Brown. The system bias and precision (SD) were calculated according to Lee et al. (1985). The system bias was 0.1° (SD = 8.4°) at ≤2.6 km.

The MICROMORT computer program (Heisey and Fuller 1985) was used to calculate seasonal and annual survival rates for all collared deer and cause-specific mortality rates for translocated does. In order not to violate the assumptions of MICROMORT, the first year post-release was divided into 4 seasons. All translocated animals were released during the winter season (18 Dec–31 Mar) which started after the annual shotgun harvest of deer in December but included the last 14 days of the annual harvest by archers. Subsequent seasons included the spring fawning season (1 Apr–30 Jun), summer (1 Jul–30 Sep), and the autumn hunting season (1 Oct–31 Dec). Accordingly, first year post-release refers to a span of 9–12 months; annual survival calculated for animals translocated in January–March represents a time span less than 1 full year. For the resident deer, the period of capture approximated the spring season described for the translocated animals; therefore, the last seasonal rate evaluated for resident deer was winter of the following year. The number of days per season ranged from 91 to 103 for the translocated does and 90 to 122 for the resident does. Annual survival rates between groups and age classes were statistically compared using "z-scores" as outlined by Heisey (1985). The percent survival of ear-tagged, translocated bucks was empirically calculated based on reports of known mortalities.

The survival of does translocated during 4 consecutive winters was calculated as aggregate seasonal and annual rates. Although seasonal survival rates were significantly different between years (for both fawns and adults), these interannual comparisons were based on very small sample sizes per season (i.e., the number of animals present at the beginning of a season/interval ranged from 0 to 6). However, pooling of seasonal and annual rates was based on the premise that stress incurred during capture and transport and mortality factors specific to the release site were comparable among years. Although 100 firearm deer permits have been issued annually at the Joliet Army Training Center, other known decimating factors at the release site varied among years. The average daily vehicle-kilometers of travel for Will County increased 8% from 1984 to 1988 (Ill. Dep. Trans., 1988, unpubl. data), and annual snowfall ranged from 40.6 cm in 1986 to 94.5 cm in 1985. Average monthly minimum temperatures during the 4 winters ranged from −13.1 C to −7.6 C during January, from −10.6 C to −3.3 C during February, and from −5.7 C to −0.3 C in March.

We used the TELEM computer program (developed by G. Koeln, Ducks Unlimited, Inc., and adapted for use on personal computers by the Geographic Resources Center, University of Missouri–Columbia) to calculate general indices of post-release movement for relative comparisons: noncircular home range/annual area of use, mean activity radius, and longest distance between the release site and subsequent radio locations. The latter value was hand calculated from Universal Transverse Mercator (UTM) coordinates generated by TELEM. Standard transformations of the data failed to approximate normal distributions; thus, movement indices were statistically compared between groups and age classes (release site only) with the Kruskal-Wallis rank test (Proc MRANK; Statistical Analysis System; Sarle 1983).

RESULTS

Twenty-five does (13 adults, 12 fawns) were translocated during December–March 1984–1988. Among these does, 15 were captured at Ned Brown, 5 at Des Plaines, and 4 at O'Hare. One fawn, darted in April 1986 by Chicago Animal Control personnel in southeast Cook County, also was released on the training center. Nineteen does were moved via individual wooden capture crates and 6 were translocated by horse trailer. Twenty-five bucks (7 adults, 4 yearlings, and 14 fawns) were also moved to the center. Twelve resident does (9 adults and 3 yearlings, categorized collectively as adults) were monitored at Des Plaines during 1984–1987.

Survival rates were calculated for 22 translocated does (12 adults and 10 fawns) and 12 resident does. Three translocated deer were dropped from survival analyses due to transmitter malfunction (n = 1 adult doe) and loss of radio collars (n = 2 fawns). Total radio-days per season ranged from 384 to 668 for translocated fawns, from 514 to 729 for translocated adults, and from 861 to 1,095 for resident deer. Accurate determinations of dates and causes of death of translocated does were possible due to prompt reporting by military personnel, hunters, and motorists. Cause-specific mortality rates were not calculated for the resident does because causes of death could not be determined in all cases.

Area of use data were deleted for 5 animals (2 translocated fawns, 2 translocated adults, and 1 resident adult) having <4 radio-fixes each during their first year post-release and for which TELEM could not calculate a noncircular home range from the available telemetry data. Therefore, post-release movements were analyzed for a total of 21 translocated (11 adults and 10 fawns) and 11 resident adult does. Although all radio locations were used for survival analyses, only 153 locations (triangulated) of resident does ($\bar{x}$ = 13 locations/doe, range = 9–17), and 206 locations (triangulated and observed) of translocated does ($\bar{x}$ = 9 locations/doe, range = 4–17) during the first year post-release were usable under the constraints of TELEM.

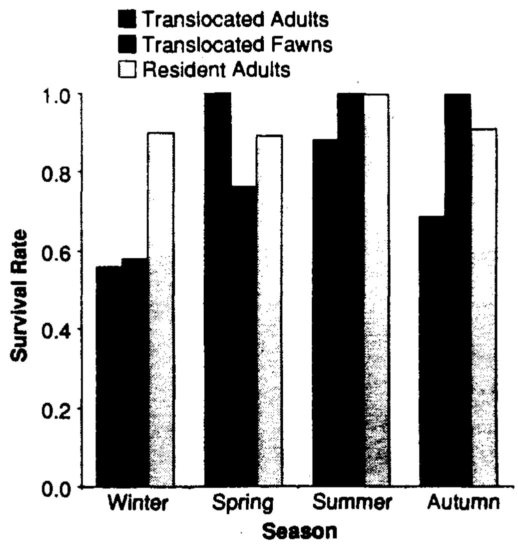

Fig. 1. Seasonal survival for 22 translocated, white-tailed does (12 adults and 10 fawns) of known fates and 12 resident does in the Des Plaines Preserves, Cook County, Illinois. Mortality rates shown were calculated using the MICROMORT computer program (Heisey and Fuller 1985).

Deaths of translocated deer were categorized as vehicle accidents, hunting, and unknown causes (presumably capture myopathy). Each cause contributed to a lower survival rate among translocated deer during the first season post-release; estimated survival rates for translocated adults and fawns during December–March were 0.56 and 0.58, respectively (Fig. 1). Estimated fawn survival increased to 0.76 in the spring (Apr–Jun) followed by no deaths among the fawns (n = 6) surviving the first 6 months post-release. Two of the 7 (29%) translocated adult females that survived the initial translocation and the subsequent spring and summer seasons were killed by hunters during autumn. Three of the 12 resident does died during the first year; the estimated survival rate for resident adults was ≥0.89 during

Table 1. Annual areas of use (AAU), activity radii (AR), and longest distances from capture/release site (DIST) for resident female white-tailed deer (released at their capture site) on a metropolitan forest preserve in Cook County, Ill. and for does translocated from metropolitan preserves to rural habitat in Will County, Ill.

Area/age class	n	AAU (ha)		AR (m)		DIST (m)	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Resident							
Adults	11	253	34	495	45	1,316	154
Translocated							
Adults	11	747	239	698	98	2,411	608
Fawns	10	1,793	442	1,199	179	4,373	901

each season. The estimated annual survival of resident adults (0.73, $n = 12$) was higher ($z = 2.01$, $P = 0.02$) than for translocated adults (0.34, $n = 12$). The annual survival of translocated fawns was 0.44 ($n = 10$) and was not different ($z = 0.43$, $P = 0.33$) from the survival rate of translocated adults. Twelve (48%) translocated bucks were known to have died during the first year post-release; 11 (2 adults, 2 yearlings, and 7 fawns) of these were shot by hunters.

Translocated does had higher but not significantly different ($P > 0.05$) mean values for annual area of use, activity radius, and longest distance from the release site than the resident does (Table 1). The mean annual area of use post-release for resident adults (253 ha) was approximately one-third of the average area used by translocated adults (747 ha) but was highly variable among individuals of each group. Although fawns appeared to exhibit greater movements post-release than older translocated deer, the observed values did not differ ($P > 0.05$).

Seven (32%, 5 fawns and 2 adults) of 22 translocated does of known fates moved ≥5 km from the release site during the first year post-release. The longest movement from the training center was recorded for 1 fawn, captured in southeast Cook County, which in 2 months traveled ≥43 km (straight-line) from the release site to within 4 km of its capture site. Another doe, translocated as a fawn, moved ≥15 km in May–June during 3 consecutive years to a small woodlot near a rural town but returned to the army ammunition plant after the hunting season.

DISCUSSION

Survival of translocated deer (*Odocoileus* spp.) has been documented in other studies (Table 2). Direct comparisons of these studies are complicated by differences between sites, methods of translocation, and methods of calculating and reporting survival rates. These data suggest, however, that the survival of translocated deer is contingent upon capture and handling procedures, the nutritional status of the animals, and the presence of decimating factors at the release site including hunters, vehicular traffic, predators, or a combination of these. Additional considerations are habitat quality, density of resident deer at the release site, and resultant negative interactions (e.g., competition for resources, transmission of diseases or parasites) between translocated and resident deer.

Capture-related stress, accidents with vehicles, and losses to hunters were the major decimating factors that led to lower survival among our translocated does. Capture myopathy can affect animals up to 1 month after live capture (Bartsch et al. 1977, Harthoorn 1977) and was presumably the cause of 3 (12%, 2 adults and 1 fawn) mortalities among our translocated does within 0.8 km of release site during the first month post-release. Site- and

Table 2. Survival of deer (*Odocoileus* spp.) following live-capture and translocation.

Location (citation)	Survival[a] (%)	*n*	Monitoring period (days)	Marking	Comments
A) *Odocoileus hemionus*					
Angel Island, Calif. (O'Bryan and McCullough 1985)	15	13	365	Radio	Nutritionally stressed deer (including 2 bucks). Release site was open to deer hunting, but removal of antlers precluded hunter harvest until next hunting season.
Farmington, N.M. (Temple and Evans, unpubl. data, 1981)	42	33	≤450	Radio	Includes bucks and does. Hunting occurred in, or around, some of the release sites.
B) *Odocoileus virginianus*					
Crab Orchard, Ill. (Hawkins and Montgomery 1969)	32	28	≤502	Radio	Includes 8 bucks. Release site was open to deer hunting.
Freer, Tex. (McCall et al. 1988)	38	13	365	Radio	Genetically superior pen-raised bucks. Release site was open to hunting.
Milwaukee, Wis. (Diehl 1988)	55	11	365	Ear tag	Includes translocated bucks and does of known fates. Release site was open to deer hunting.
River Hills, Wis. (Ishmael, pers. commun., 1989)	45	44	365	Ear tag	Includes bucks and does. Release sites were open to deer hunting.
Ballard Co., Ken. (Pais 1987)	75	35	248	Radio	Percent survival value is the probability that the translocated deer (does) would survive 248 days after release. Release site was closed to hunting during translocation project.
Riverwoods, Ill. (Lake County Forest Preserve Dist., unpubl. data, 1989)	67	18	223	Ear tag	Includes bucks and does that were translocated to a nonhunted deer enclosure/wildlife exhibit. Percent mortality value does not include 2 deer that died due to box-trapping efforts, nor 1 doe that was euthanized due to a positive titer for Lyme disease.
Florida Everglades, Fla. (Fla. Game and Fresh Water Fish Comm., 1983)	33	18	116	Ear tag	Includes nutritionally stressed bucks and does. Deer were translocated to a nonhunted wildlife exhibition park or were pen raised.
Cook Co. For. Preserves, Ill. (Witham and Jones, unpubl. data, 1988)	56	25	365	Ear tag	Includes bucks only. All reported mortalities were due to hunters.

[a] Percent survival values shown are total number of deer that survived the specified time divided by total number of deer translocated, expressed as a percentage, unless noted.

season-specific decimating factors are additive to the initial stress associated with live capture.

O'Bryan and McCullough (1985) identified an initial period during which translocated deer did not avoid potential hazards. During our study, deer-vehicle accidents were the largest single source of mortality among the translocated does and may initially result from unfamiliarity with the release site. Losses to hunters also may be partially attributed to naiveté of translocated deer; the normal evasive behaviors of deer that are reduced in metropolitan situations by habituation to people may initially render translocated deer more vulnerable to hunters than their rural conspecifics.

Typically, fawns suffer higher mortality rates than older age classes in free-ranging white-tailed deer populations (Dahlberg and Guettinger 1956, Nelson and Mech 1986). Although our translocated fawns presumably faced greater exposure to potential mortality factors (i.e., hunters and vehicles) due to greater post-release movements, survival was slightly higher among the fawns. No female fawns, 3 adult females, and 11 (mostly yearlings that had been translocated as fawns) bucks were killed by hunters. The number, sex, and ages of resident deer harvested at the training center were unknown, but the hunter harvest of our translocated deer suggests a preference among hunters at the center for bucks and older (probably larger) does. However, based on the slight differences in survival between fawn and adult does, limiting translocation to younger does in order to improve survival would be contrary to the immediate need to reduce the number of reproductive females during a population reduction program.

The general indices of post-release activity (i.e., area of use, activity radius, and longest distance moved from the release site) were based on minimal numbers of seasonal and annual locations and are insufficient for comparison with other home range studies. However, the distances that the translocated deer traveled from the release site were much less than average movements reported for white-tailed deer occupying seasonal refugia in central Illinois (Nixon 1989). The resident adult does on the high-density, relatively insular, Des Plaines Preserves appeared to exhibit restricted areas of use and distances traveled relative to the movements of translocated does. Areas used by resident does are undoubtedly influenced by habitat availability and degree of urbanization. Although 1 translocated female fawn traveled ≥43 km before it was killed by a vehicle, all other does remained within 15 km of the release site and the majority within 5 km. Fidelity to the release area may have resulted from more favorable conditions at the training center relative to degraded forage conditions that translocated does had experienced previously at Ned Brown and Des Plaines.

The principal reason for translocating deer from metropolitan preserves to rural locations is to reduce local abundance without killing deer. The reality of this choice is that translocation may result in the deaths of more than 50% of these deer during the first year post-release. If a reduction of deer numbers is warranted at specific sites in the metropolitan area, alternative methods of herd reduction should be evaluated in the planning process and during program reviews. The evaluation of live trapping and release should consider the probability of survival of translocated deer relative to the reason(s) for selecting this method. If lower survival among translocated deer, as compared to resident deer, is deemed acceptable, then the effectiveness in achieving population reduction goals, cost per translocated deer, and potential impacts upon resident deer at the release site become paramount considerations.

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Appendix G. Review of deer management alternatives.

The following is condensed from the Deer Population Control and Damage Abatement Technique summary provided to Chicago metro publics by J.M. Jones., DOC Urban Deer Project Manager.

A - NONLETHAL POPULATION CONTROL

1) Passive/nonintervention - Letting Nature take it's course with the hope that excessive deer numbers and related damage are due to temporary disturbance. Tolerance for deer damage.

Advantages: Acceptable to some publics, particularly those not sustaining deer damage. No direct cost to agency because economic losses are borne by landowners.

Disadvantages: Potential for degrading natural area communities protected within metro core area. Potentially large number of damage complaints received by conservation agencies from constituents that sustain economic and/or aesthetic property damage. Deer in poor to moderate health. Absolute number of deer dying annually (natural causes and accidents) is high with potential for dieoffs during winter.

Examples: Boulder, Colo.; National Park Service

2) Habitat modification - Restoration of native plants/food supply on degraded natural areas via planting, seeding, fertilizing, prescribed burning, removal of competing exotic plants, etc. Changing deer abundance by improving or reducing availability of deer habitat (Brush and Ehrenfeld 1991). Includes supplemental or intercept feeding (Wood and Wolfe 1988).

Advantages: Acceptable to some metro publics and natural area ecologists involved in natural area protection. Improved habitat (e.g., food plantings) may temporarily attract some deer to treated areas. Conversely, reducing deer habitat quality may force deer to disperse and forage elsewhere, thereby reducing density near the treated area.

Disadvantages: Cost is high. Food plantings may be ineffective if deer are at high density. Deer health may improve with more food; improved health may increase reproductive performance, survival of fawns, and total deer numbers. Intercept feeding is not practical as a long term alternative. Concentration of deer may promote the spread of diseases.

Examples: Goose Lake Prairie State Park, Morris, Ill.: Utah (Wood and Wolfe 1988)

3) Live capture and translocation - Deer are captured with box traps, corral traps, drive nets, drop nets, net gun, rocket nets, remote chemical immobilization, etc., and moved to a release site.

Advantages: Acceptable to publics, often is the first alternative advocated by individuals that oppose lethal techniques. Initially, deer at high densities can be easily baited and captured. Some translocated deer survive capture and translocation and remain at, or near, the release site.

Disadvantages: First year mortality tends to be >50% because of capture myopathy from handling, deer-vehicle accidents, and hunting. Costs are generally high. Deer become trap wary and are more difficult to capture. Labor intensive at lower densities. Potential for spread of diseases and/or parasites and competition with resident deer for resources. Current DOC guidelines restrict translocations of metro whitetails to not-for-profit zoological institutions.

Regional examples: Ryerson Conservation Area, Lake County Forest Preserve District; Schlitz Audubon Center, Milwaukee, Wis.; Univ. of Wisconsin-Madison, Wis.,; Univ. of Indiana-Purdue, Fort Wayne, Ind.

4) Reproductive intervention - Techniques include mechanical, surgical sterilization (e.g., vasectomies, ovariectomies, tubal ligations; Matschke 1976), chemical reproductive inhibitors (e.g., melengestrol acetate, diethylstilbestrol) administered through treated bait, injection, darting, or surgical implants (Bell and Peterle 1975, Botti 1985, Matschke 1977 and 1980, Roughton 1979). Recent research is directed on immunocontraceptives (e.g., porcine zona pellucidae vaccine) delivered via darts (captive whitetails in Ohio; Turner et al. 1991). Remote injection with prostaglandin to cause abortion in pregnant does is being attempted during a 3-year study from 1989-1992 by Columbus Metro Parks, Ohio, on a 308-ha park (Stanley and Jones, no date).

Advantages: Popular concept because animals are treated but not killed. Experimental use of melengestrol acetate implants have inhibited reproduction in does for >5 years. If effective, removing treated individuals from reproductive pool decreases reproductive potential of localized herd and will reduce the number of individuals treated annually over time. Immunocontraceptive vaccines do not require U.S. Food and Drug Administration approval (J. Turner, pers. commun., 1991).

Disadvantages: Some methods require live capture and are affected by capture limitations mentioned previously. Use of steroidal contraceptives as a management tool (i.e., nonresearch) requires approval by the U.S. Food and Drug Administration. The long term effects of introduced steroidal compounds in deer and the potential effects on consumers of deer meat/organs (e.g., humans, scavengers) is a concern. Distributing chemicals through treated bait affects non-target species and dosages will vary based on individual consumption of bait. Immunocontraceptives presently require an injection with a followup booster. Microencapsulation may reduce this to a single shot procedure which will increase its potential value as a management technique (Turner et al. 1991).

5) Driving deer from impacted area - Used to control deer numbers in a fenced enclosure in Virginia (Wemmer and Stuwe 1985).

Advantages: Efficient and rapid if large number of volunteers are available. Nonlethal.

Disadvantages: Feasible in small enclosures only. Deer problem is being transferred from 1 site to another. Displacement of deer may increase potential for deer-vehicle accidents.

B - NONLETHAL DAMAGE ABATEMENT

1) Repellents and deterrents - this broad category includes olfactory and taste repellents, auditory scare devices, visual scare devices, rubber deterrent ammunition which is designed to inflict nonlethal pain, dogs, and reflectors and high-frequency whistles to reduce deer-vehicle accidents.

Advantages: Repellents may be cost effective for relatively small areas and if plants/crops are of high value (Swihart and Conover 1990, Conover 1987). Auditory and scare devices are generally temporarily effective. Studies show some reduction in deer-vehicle accidents resulting from use of reflectors or mirrors (Schafer and Penland 1985).

Disadvantages: Effectiveness is influenced by deer densities, travel and feeding patterns, availability of other deer foods, and other factors. Some repellents are costly. Reapplication of repellents because of growth of plant or rainfall is sometimes required. Repellents will not prevent antler damage. Deer habituate to manmade disturbances or noises which limits effectiveness of auditory devices. Swareflex reflectors cost about $5,000/mile and require maintenance.

2) Exclusion - includes electric and nonelectric fences, netting, cages or cylinders around individual plants (Byrme 1989, Ellingwood et al. 1985, Hygnstrom and Craven 1988, Palmer et al. 1985, Porter 1983). Nonelectric perimeter fences must be >8′ vertical height with no gaps, although fences >4" may be effective around small garden plots. Electric fences range from multiple strands of high tensile wire mounted on vertical or slanted posts (Selder and McAninch 1987) to a single strand "hot tape" that is erected seasonally prior to anticipated damage. Netting and fencing types are diverse.

Advantages: Fencing is generally the most effective nonlethal means of reducing deer damage and generally very cost effective in protecting valuable crops/plantings.

Disadvantages: Purchase, construction, and maintenance costs can be relatively high.

3) Use plant species avoided by deer - Greatest application with homeowner and ornamental plants. Lists of plants that are preferred and avoided by deer have been compiled (Conover and Kania 1988, Cummings et al. 1963, Feeney 1946, Matthews and Glasgow 1981). Deer are selective feeders and tend to favor the most nutritious plants.

Advantages: May disrupt habitual use of property because deer will forage elsewhere for more palatable plants.

Disadvantages: When deer are at high densities, most plant species are consumed at some level.

C- LETHAL POPULATION REDUCTION

1) Hunting: Legal harvest of deer during seasons; harvest quotas are established by the state wildlife agency.

Advantages: Popular among segments of the public. Principal means for controlling deer numbers over large areas. Harvest strategies are flexible and can be altered to reduce, maintain, or increase deer abundance.

Disadvantages: Opposed by segments of the public. Hunting may not be practical in some urban or suburban areas primarily due to concerns for human safety and conflicts with other users. Some hunters are unwilling to harvest does which reduces the wildlife managers ability to control herd growth.

2) Selective removal by sharpshooters: Uses qualified individuals to remove a specific number of deer with firearms. Good control of sex and age class of deer removed. Can be implemented safely near residential areas if deer are killed from elevated blind.

Advantages: Appears to be acceptable to most publics, except those objecting to all lethal methods. Good control of sex and age class of deer removed. Can be implemented safely near residential areas if deer are killed from elevated blind.

Disadvantages: Costs can be high. Labor intensive. Best suited for controlling deer abundance on relatively small (1000 ha) well-defined areas.

3) Live capture and euthanization: Deer are live captured and then euthanized using American Veterinarian Medical Association euthanasia guidelines (1985). Euthanasia methods further restricted in Illinois to methods that would not contaminate venison for donation to charities.

Advantages: Numerous deer can be captured and removed at one time. Can selectively kill/release for desired removal of specific sex and age classes.

Disadvantages: Same limitations as live capture. Can be labor intensive because of daily baiting and trap checking. Deer become wary of traps over time. Cost of processing meat for donation to charities. Deer stressed by capture prior to euthanasia.

4) Biological control by introducing predator or pathogen: Introduce natural or effective deer predator (e.g., wolf, mountain lion) or disease (e.g., parasite) that induces death.

Advantages: Cost and human intervention would be minimal after initial introduction. Concept of natural control is generally accepted by publics. Greatest probability of success would be on sites where emigration was negligible and where the human population was low (e.g., island refuge).

Disadvantages: Lack of suitable habitat for large predators in human dominated environments. Nonspecificity may impact nontarget animals. Cannot control the numbers or types (sex, age) of deer removed.

5) Poisoning: Killing deer by introducing chemicals into food (e.g., bait) or water supplies.

Advantages: Low cost and potentially effective.

Disadvantages: Nonspecificity--impact on nontarget species. Limited control of numbers or types of deer that are killed. Most poisons are controlled substances that would be illegal to use. Not supported by general publics.

D - LETHAL DAMAGE ABATEMENT

Essentially the same methods as Lethal Population Reduction; however, the focus is on removal of specific problem animals that have habituated to using a specific area, crop, or plant.

1) Hunting:

Advantages: Can be an efficient means of removing a desired number and type (sex & age) of deer. Minimal cost. Landowner concern for liability due for injuries by hunters on their property are protected by the Recreational Use of Land and Water Areas Act (Ill. Rev. Stat., Chap. 70), revised in 1987, which limits landowner liability for accidents/injuries to hunters that are allowed access to their property.

Disadvantages: Hunting may not remove enough deer during normal seasons. Hunting may not be safe in some areas due to proximity to residences or roadways. Municipal ordinance against discharge of firearms may restrict hunting.

2) Removal of "nuisance" deer by state-issued permit outside of regulated hunting season.

Advantages: Allows landowner to remove specific animals causing damage. Deer Removal Permits are generally issued for antlerless only, but restriction can be waived for antler rubbing.

Disadvantages: Labor intensive. Selective removal from one landowner's property alone will not address damage abatement if the problem is one of high deer densities region-wide. Ordinances may preclude the discharge of firearms.

Citations are listed in text LITERATURE CITED SECTION.

Fig. 12. Potential deer habitat in Cook County, 1988.

Fig. 13. Potential deer habitat in DuPage County, 1988.

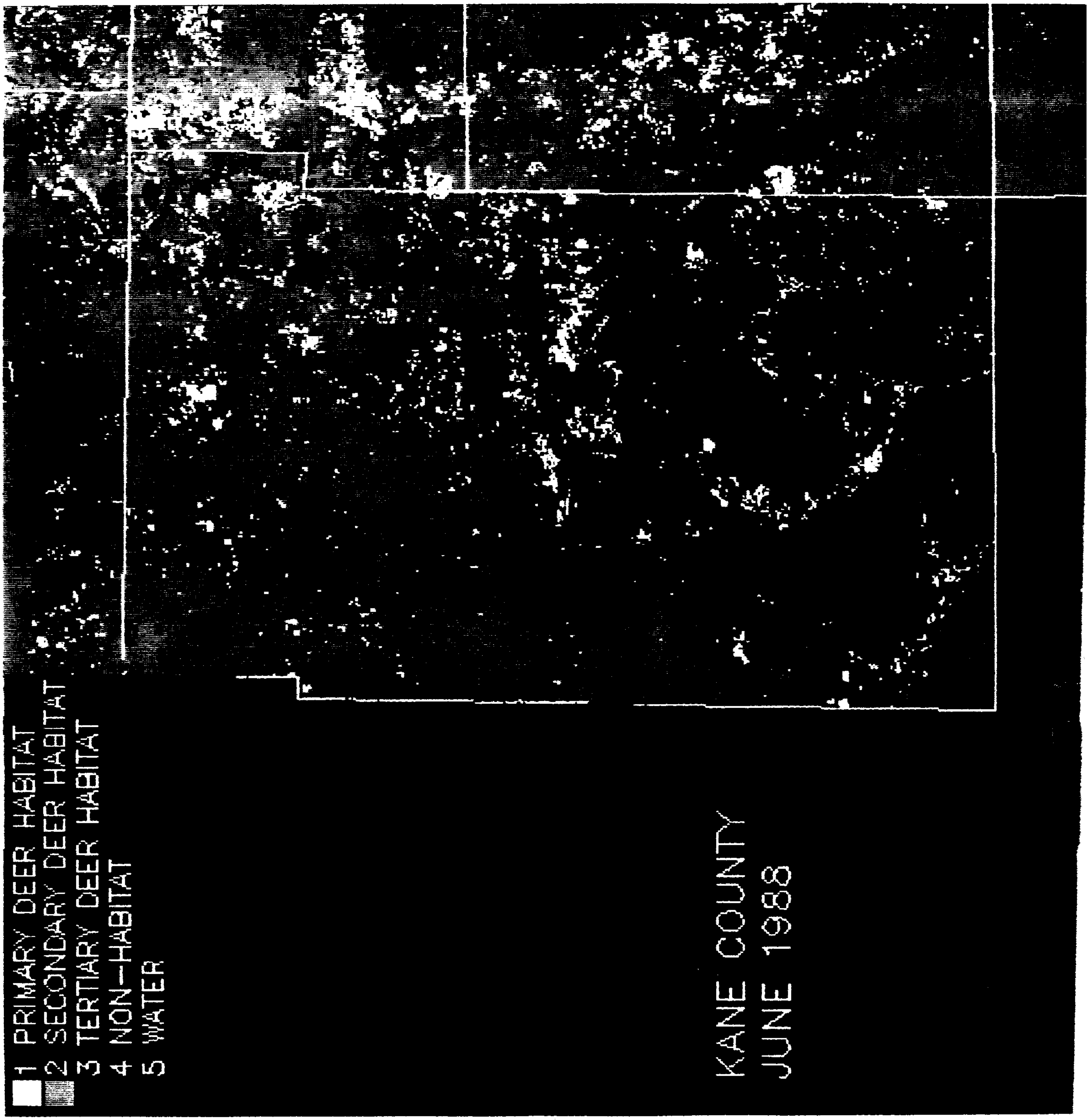

Fig. 14. Potential deer habitat in Kane County, 1988.

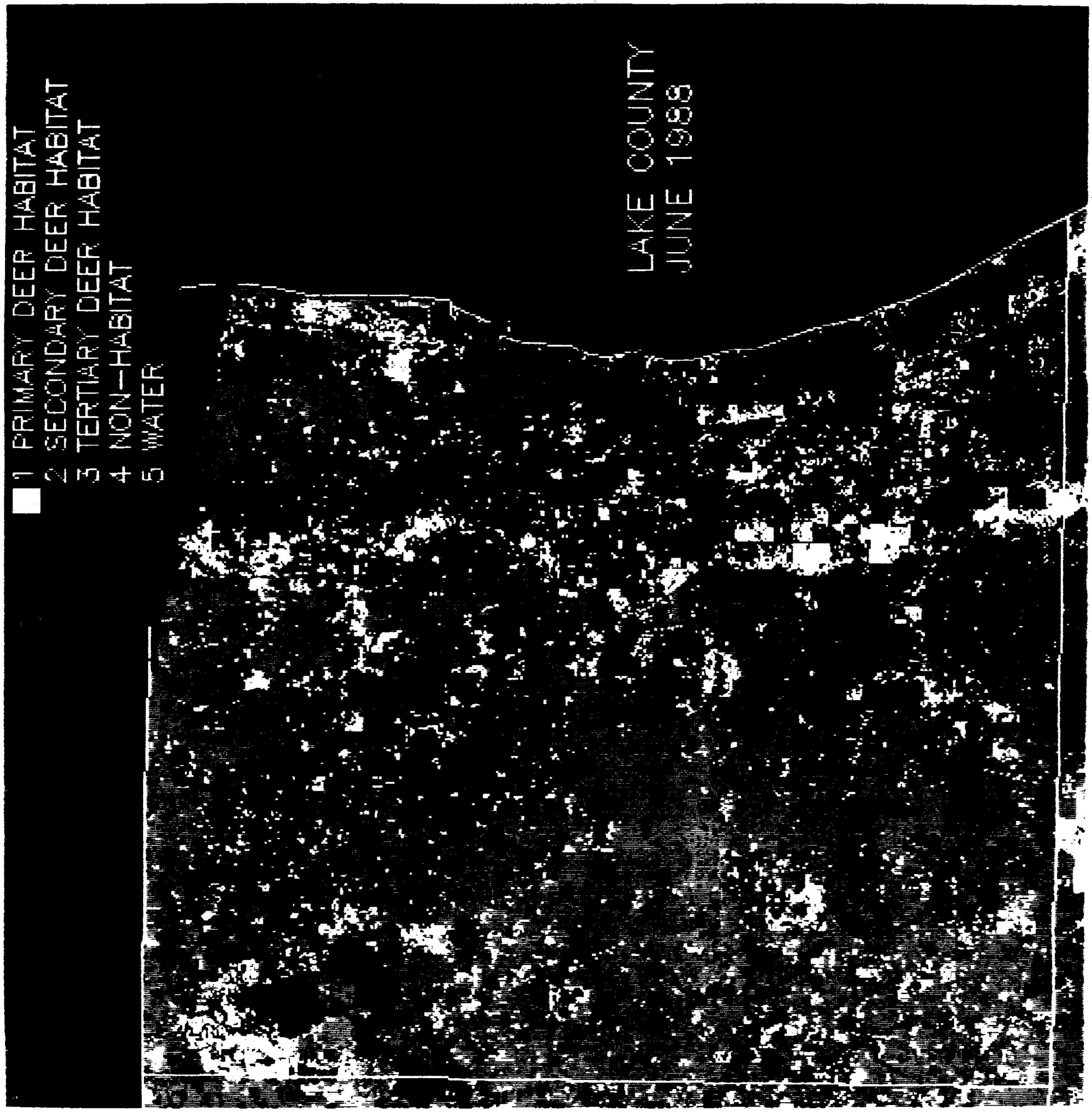

Fig. 15. Potential deer habitat in Lake County, 1988.

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