# Evaluation of a Trap-Sterilize-Release Program for White-tailed Deer Management in Highland Park, Illinois, 2002-2005

## Prepared for the Highland Park City Council

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**by**


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## Executive Summary

In 2001, after 10 years of discussion regarding white-tailed deer management, the City of Highland Park chose to study the use of surgical sterilization of female white-tailed deer as an alternative means of controlling its deer population. No previous attempts have been made by wildlife ecologists to assess the efficacy of surgical sterilization to control urban deer populations. Preliminary data on the efficacy of sterilization, as a means of controlling deer on the grounds of the Milwaukee County Zoo, Milwaukee, WI, suggested that this technique held promise for small geographic areas. In 2002, the Illinois Department of Natural Resources approved a Scientific Permit for a research study to assess the success of sterilization in controlling the growth of the deer population within the city limits of Highland Park.

The 12.5 $mi^2$ area of Highland Park was divided into 2 study areas, the control side (4 $mi^2$) west of Skokie Valley Rd. and treatment side (8.5 $mi^2$) east of Skokie Valley Rd. Using standard deer trapping protocol, 180 deer were captured between 2002 and 2004, and 67 females were surgically sterilized. Capture-related mortality was 6%. Over the course of the study, more treatment deer (27.6%) died than control deer (12.7%), with car collisions accounting for most of the deaths.

We found that sterilization can control the deer population in Highland Park at the goal population level of 5 deer per $mi^2$, if we can capture and sterilize an average of 32% of the female population per year. Our computer model suggests that the long-term maintenance of the population will require sterilizing an average of 6 does per year. Sterilizing more females will result in achieving the population goal more quickly. The model projections suggest that the population will continue to grow initially and peak at 3.7 years, until the effects of sterilization halt population growth. There after, the population will decline and hover around the target density after 9.5 years.

We evaluated the influence of sterilization on the behavior (home-range size and dispersal rates) of the sterilized and control deer. In general, deer used extremely small home ranges in this urban environment and there were no differences in either the home range sizes or dispersal rates of sterilized deer verses the control deer. Fawns used larger home ranges than adults, and home ranges were larger during the winter. Although the sample size is exceedingly small, we found that more treatment deer than control deer made exploratory movements out of their home range. There is also an initial indication that sterilized deer traveled farther and used larger home ranges than control deer.

With respect to the efficacy of surgical sterilization under field conditions, we found that tubal ligation, by ventral laparotomy, provides a safe, humane form of sterilization with low mortality in white-tailed deer. The ability to capture, chemically immobilize and perform surgery on wild deer, under field conditions was highly successful.

Although the initial start-up costs for the project were high due to the research aspects of the study i.e.(radio telemetry), we estimate that deer could be sterilized for a base cost of $750 per deer under a management, rather than research, regime. This includes $150 in drugs per deer, in addition to salary costs for a month of veterinarian's time.

** This report was prepared for the Highland Park City Council as a lay-person's summary of the technical information. Forthcoming later publication in scientific journals will offer a full analysis of the data.*

## Justification

The City of Highland Park has had a long history and intense interest in the management of its deer population. In November, 1992 the City of Highland Park Environmental Commission appointed a Deer Management Committee. The Committee surveyed the deer population, developed a resident survey, and conducted public meetings. In 1994, the city established a deer task force to explore issues related to efficient and publicly acceptable means of controlling the deer population. The task force surveyed residents, performed aerial surveys, produced an informational booklet, and established a state-of-the-art geographic information system to track deer incidents. Residents were deeply divided about the type of control (lethal or non-lethal) that they found acceptable to control the deer population. A deer reduction was implemented during the winter of 1995-1996 when 20 deer were translocated to Wildlife Prairie Park, in Peoria. Following the initial translocation, the Illinois Department of Natural Resources (IDNR) would not renew the City's permit to remove additional deer.

Following the decision of the IDNR to eliminate translocation as an option for deer management, the task force recommended that the city cull 20 deer per year using lethal means. They also recommended looking into non-lethal control measures. A referendum was held on culling deer and passed by a narrow margin. After the recommendation to cull, a lawsuit was filed against the city to prevent implementation. Citizens cited concerns about safety and anti-hunting sentiments as the primary reasons. The lawsuit was not successful and eight deer were removed via sharp shooting in 2001. One year later, in an effort to address the concerns raised in the lawsuit, the City Council approved a motion to support a research project to investigate the efficacy of surgical sterilization of female deer as an alternative means of regulating the deer population. The Illinois Department of Natural Resources approved the research. This is the first scientific study testing the long-term effects of sterilization as a management tool to control urban deer populations on a localized scale.

### History of the Deer Population in Highland Park

Based on aerial surveys, the deer population has varied from a high of 145 in 1994 to a low of 65 in 2000. Caskey (2001) has suggested that the counts in 2000 grossly underestimated the deer. Based on aerial surveys conducted by Highland Park from 1995-2002, we estimate an average population density ranging between 6 and 8 per $mi^2$ of total land area and 7 to 9 deer per $mi^2$ of available deer habitat. Highland Park has set a deer density goal of 5 deer per $mi^2$ (Caskey 1997). Between 1995 and 1997, an average of 25 deer were killed each year in vehicle collisions.

### History and Background of Surgical Sterilizations

Preliminary data on the efficacy of sterilization as a means of controlling deer at the population-level on the grounds of the Milwaukee County Zoo, suggested that this technique held promise for localized management of closed populations (Frank et al. 1993). Over a five-year period (1990 to 1995) 16 free-ranging white-tailed deer (8 males, 8 females) were surgically sterilized on the Milwaukee Zoo grounds. The number of deer regularly seen on zoo grounds dropped from a high of 12 in 1990 to 1 in 1993. Since 1995, no surgical procedures were performed and the number of female white-tailed deer on the zoo grounds remained constant at 1 or 2 per year until 1997.

Longevities of study animals ranged from 10 months to over 7 years. In 1997, the last study animal was killed by an automobile outside zoo grounds. The resident population was 0 from 1997 until 2005. During the spring of 2005, at least one doe and her fawn were seen on zoo grounds. No other methods of deer control have been employed in this study area. This preliminary work provides the first empirical foundation for this study. Despite numerous calls for research investigating the efficacy of surgical sterilization, no other previous studies have been completed (Hobbs et al. 2000). Cornell University (Merrill et al. 2005) and the community of Cayuga Heights, NY began a surgical sterilization study in 2002. The study was abandoned after one year of sterilizations. A one shot single-injection vaccine, SpayVac®, is being studied in both Ohio and New York.

The purpose of this research was to test the efficacy of surgical sterilizations as a means of regulating population growth of the white-tailed deer population in Highland Park, IL. We hypothesized that sterilizing 80-90% of breeding does would lead to a stable or declining population in a 4 year time period. Based on the results of initial model, we proposed an 80% sterilization rate to reduce the current deer density from $8/mi^2$ to $5/mi^2$, or a female population of $4/ mi^2$ to $2.5/ mi^2$, with the initial effects surfacing in 4 years.

**GOAL:** Investigate whether surgical sterilization of female deer can regulate a population of white-tailed deer within a 4-year period.

**OBJECTIVES:**

1) Assess the demographic impacts of sterilization on the population
2) Assess the behavioral impacts of sterilization
3) Assess the efficacy of surgical sterilization of female deer under field conditions
4) Evaluate the cost effectiveness of the sterilization effort.

**METHODS:**

**General Study Area** --Highland Park (HP) is a 12.5 $mi^2$ residential community bordering Lake Michigan, 26 miles north of Chicago, IL (Figure 1.). HP is bordered on the East by Lake Michigan, on the North by Highwood and Lake Forest, on the South by Northbrook and Glencoe, and on the West by Deerfield and Bannockburn. No major roadways provide barriers to deer movements from either the North or South. Green Bay Rd. and U.S. Hwy 41, Skokie Valley Rd., bordered by Union Pacific Railroad lines, divide HP longitudinally. Five east-west arteries cross HP laterally, connecting it with suburbs to the West. The habitat throughout this community is a mixture of mature, deciduous and coniferous forest, maintained yards, and golf course-like grasslands. Ornamental plantings and non-native grasses provide high quality browse and forage year- round for deer.

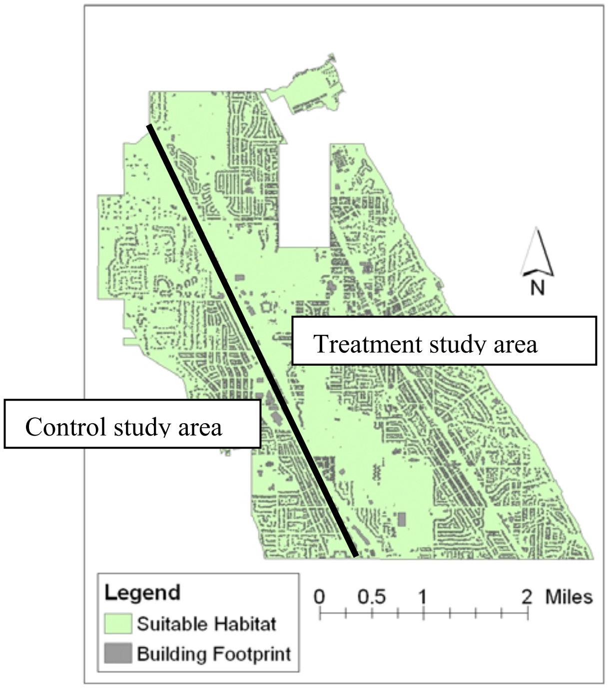


**Figure 1. Control and treatment study area for white-tailed deer sterilization study in Highland Park, Illinois; total area is 12.5 mi $^2$, available deer habitat, in green, is 11.08 mi$^2$, available deer habitat in control area is 3.36 mi$^2$, available deer habitat in treatment area is 7.72 mi$^2$.**

**Control Area** – We designated the control site as a 4 mi$^2$ area on the western border of HP, encompassing Sectors 1, 3, 6, and 9 (Figure 1.). U.S. 41, Skokie Valley Rd. is a major north-south road that provides a significant barrier to deer movements between the eastern and western Sectors of HP. Based on police reports and prior observations of residents, deer in these sectors may move freely between Deerfield, and Highland Park, crossing the Chicago River but not to the eastern side of HP. The amount of available deer habitat on the control area is 3.36 mi$^2$.

Sector 1 includes the Heller Nature Center and low-density residential zoning, including multi-acre homes. Sector 3 includes Highmoor Park (a 10 acre Illinois Nature preserve), Olson Park, Berkeley Prairie, Hybernia and the adjoining Prairie Wolf Slough wetlands, and the Deerfield High School Property. Residential zoning in this sector is a combination of low and medium densities. Habitat loss from the development of Painter's Lake and Emerald Woods contribute to the movement of deer in and out of this sector. Sector 6 includes Westridge Park. Sector 9 includes Red Oak Park and Woodridge Park, and is bordered by U.S. 41 on the East and Lake Cook Road and Northbrook Court Shopping Center on the South.

**Treatment Area**– We designated the treatment area as an 8.5 mi$^2$ area, east of U.S. 41, Skokie Valley Rd (Figure 1.). This includes Sectors 2, 4, 5, 7, 8, 10, and 11. Based on Police reports and prior observations of residents, the deer may move freely among these sectors, in and out of the HP community, but not between the designated control and treatment areas. The amount of deer habitat on the treatment area is 7.72 mi$^2$.

Sector 2 includes Sleepy Hollow and Centennial Park, as well as Old Elm Golf Course. This sector has had the largest number of individuals observed. Sector 4 contains the Highland Park Country Club and Exmoor Country Club. Sector 5 included Moraine Beach, Park Avenue Beach, and Central Park as well as a ravine system. Sector 7 includes 3 golf courses, while sector 8 includes 2 parks, Rosewood Beach and the highest concentration of ravine systems. It is likely that this sector contains a high number of deer that have not been detected by the aerial surveys. Sector 10 is bounded bythe Botanic Gardens on the east and includes the Northshore Sanitary District property and Northmoor Country Club. Few deer have been observed in this sector. Sector 11 contains many ravine corridors bordered by the Turnbullwoods Forest Preserve on the east and is believed to host a significant number of deer.

## Capture and Handling Methodology

**Capture locations** –Potential capture sites were selected in conjunction with the Highland Park Police Department based on the extensive records of sightings, collisions or complaints. Sites were selected in areas with the highest number of sightings of fawns and adults, as well as car collisions and complaints, and required the cooperation of the property owner. Capture sites were established on properties after written permission was obtained. Prior to the placement of traps, approximately 10-15 bait sites were established in each of the control and treatment study areas. Bait sites were established at least 2 weeks prior to initiation of any trapping to assess deer activity. Each site received 1-2 gallons of deer bait daily. Evidence of use, and direct observations of deer were recorded daily to aid in identifying the best trapping locations. A total of 18 trap locations were established: 9 on the control side and 9 on the treatment side. Several trap locations were moved or added in subsequent years to increase the success rate of captures.

**Capture techniques** – Deer were captured using Clover traps, baited withcorn, apples, and pears. Traps were operated and checked four times daily from January 2002 - April 2002, October 2002 – March 2003, and October 2003 – March2004. Traps were not operated when temperatures dropped below 15$^{o}$ F or when temperatures exceeded 65$^{o}$ F. Some deer were conditioned to a bait area and later captured using a dart gun (Dan-Inject "AC Model" CO2 rifle with a 13mm barrel to accommodate .50 caliber 6ml Pneudart radiotransmitter darts; Appendix B).

**Handling, Anesthesia and Surgical Procedures** – Deer were anesthetized at the capture site using injectable anesthetic agents, an accepted methodology in veterinary medicine and wildlife management (Appendix A). When appropriately sedated (ie, when animal is no longer struggling), the animal was blindfolded to decrease visual stimuli, given a physical exam, and vital signs (respiratory rate, heart rate and temperature) were monitored and recorded. All deer captured were marked with ear tags (yellow for females and orange for males). Radio collars with a battery life of 3 years were attached to all females. All females captured on the treatment side underwent surgical sterilization using tubal ligation (Appendix B). Sterilizations were performed in a mobile surgery unit provided by the City of Highland Park, as close as possible to the capture site. Post surgery, animals were given pain medication, ear tagged and fitted with a mortality sensing, 480 g radio transmitter with a battery life of 3 years (ATS, Model 2520). Deer were returned to the capture site, and the effects of the anesthesia were reversed using intravenous administration of specific reversal agents. Each animal was observed or relocated at regular intervals (every 2 hours, for 6 hours) post release. Total average handling time for sterilized deer was approximately 2.5-3 hrs.

**Animal Monitoring**—*Mortality*: On January 22, 2002 we began tracking surgically sterilized and control does using radio collars. We counted a doe as alive from the day it was radio collared, until the time of death, or the day it was no longer "on the air", or at the end of the field study on June 30, 2005. We counted the number of mortalities among collared does in the surgical and control groups in each year, and the total number of days in each year for which does in each group were alive and at least one year old. Does that died before age one, and does that died from project-related causes were eliminated from the analysis. We used a Mayfield analysis to determine mortality rates for surgical and control does during each year.

*Radio Telemetry*: Control and treatment deer were monitored using a variety of methods. Radio collared deer were relocated 1-2 times per week using triangulation to obtain sample sizes sufficient for the calculation of seasonal home ranges. Efforts were made to obtain a sample of 30-40 total relocations per deer and 15 per reproductive season.

***Spotlight Surveys*:** Spot light surveys were conducted once per month through November of 2004 to obtain an index of deer abundance. Standard driving routes were established in both the control and treatment areas. Surveys involved 2 observers using 100,000 candle-power spotlights out of both sides of a vehicle, driving at 5-10 mph. Surveys commenced at sun down on nights when weather conditions are conducive to good observations (e.g., no precipitation, < 5 mph winds).

***Aerial Surveys*:** The City of Highland Park and the Illinois DNR continued to conduct yearly aerial helicopter surveys, each winter, using techniques established in previous surveys.

***Deer/Vehicle Collision Rates and Dead Deer*:** The Highland Park Police Department recorded all dead deer found within the City limits during the time of the study. Tagged deer killed outside the study area are included if reported.

## Results and Analyses

### Objective 1: Assess the demographic impacts of sterilization on the population

Captures--A total of 180 individual deer were captured (101 females and 79 males; Table 1). Of these, 167 deer were trapped in the Clover traps, 305 times. Traps were open and set from January – April 2002, October 2002 – March 2003, and October 2003 - March 2004, for a total of 2,349 trap days and a 13% trap success. 12 does, and 1 buck were captured by darting over bait piles. 67 does were sterilized by tubal-ligation either through laparoscopy (n = 3) or laparotomy (n = 64).

**Table 1. Captures of white-tailed deer in Highland Park, Illinois, 2002-2004.**

| | Females-control | Females-treatment | Total Males | Total Females | Total Deer |
|---|---|---|---|---|---|
| 2002 | 12 | 19 | 19 | 31 | 50 |

| | | | | | |
|---|---|---|---|---|---|
| 2003 | 13 | 27 | 28 | 40 | 68 |
| 2004 | 9 | 21 | 32 | 30 | 62 |
| Total | 34 | 67 | 79 | 101 | 180 |

Mortality-- Based on direct counts of mortality, 41% of the females died. Overall mortality directly attributable to the project is 11/181 (6.1%) individuals or 11/304 (3.6%) captures (Table 2). Causes of mortality included: vehicle or train collision, predation, poaching, culling by neighboring communities and other miscellaneous causes. A total of 33 of 66 (50%) treatment does, and 9 of 36 (25%) control does died throughout the course of the study. 36% of the marked males were known to have died.

Based on the Mayfield estimate of mortality, using the number of days the deer were monitored, the weighted mean annual mortality for sterilized does was 27%, and the weighted mean mortality for control does was 13%. Mortality rates of sterilized does were significantly higher than controls.

**Table 2. Rates and causes of death of white-tailed deer in Highland Park, Illinois, 2002-July 2005.**

| | # of Deaths | Total Males | Total Females | Tagged | Tagged Females | Tagged Males | Control | Trtmt | Total Auto Collision | Total Project Related | Total Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 40 | 13 | 15 | 20 | 10 | 10 | 4 | 6 | 24 | 8 | 8 |
| 2003 | 38 | 15 | 21 | 22 | 13 | 9 | 1 | 12 | 20 | 2 | 16 |
| 2004 | 51 | 22 | 24 | 18 | 11 | 7 | 3 | 8 | 20 | 1 | 30 |
| 2005 | 19 | 4 | 10 | 8 | 7 | 1 | 1 | 6 | 8 | 0 | 11 |
| Total | 148 | 54 | 70 | 68 | 41 | 27 | 9 | 32 | 72 | 11 | 65 |

**Radio-Telemetry** -- Radio telemetry was used to relocate does within 2-6 hr post recovery, then daily for the first 14 days. Throughout the remainder of the year, does were located a minimum of one time per week to obtain 40 to 50 relocations per deer, and a minimum of 8 relocations by season. All sightings by residents were recorded as additional data and anecdotal information about the deer's condition were noted. Reproductive seasons were designated as: rut (October 10 - December 31, gestation (January 1- April 13), parturition (April 14 -July 18) and pre-rut (July 19 - October 9).

Spot Light Surveys-- Spot light surveys were conducted monthly to assess trends in population. Due to the difficulty of observing deer among homes and in heavily vegetated landscapes, few deer were observed at any time of the year on either side of the study area. Spot light surveys were abandoned after 2 years, and we conclude that they will not provide enough data to use as an index to population trends.

Car Collisions-- The Highland Park Police Department maintained records of all deer mortalities within the city limits and of marked deer that moved out of the area. As one means of monitoring the deer population density, we determined the number of collisions in each of the study areas (Table 3.)

**Table 3. Number of white-tailed deer killed in Highland Park, by treatment area, from 2002- July 2005.**

| Year | # Killed – Control | # Killed – Treatment | # Killed Overall |
|---|---|---|---|
| 2002 | 14 | 21 | 35 |
| 2003 | 10 | 19 | 29 |
| 2004 | 21 | 16 | 37 |
| 2005 | 8 | 8 | 16 |
| Total | 53 | 64 | 117 |

Aerial Surveys-- Aerial surveys were conducted yearly, as a continuation of the monitoring effort begun in 1994. Surveys were conducted each winter when snow cover was abundant, and deer more easily observed. The aerial counts were conducted from a helicopter and counts were made by two observers. Over the course of the study, deer density for the entire HP area ranged from 12-16 deer per $mi^2$ of deer habitat, with some variation between the treatment and control areas (Table 4). Deer density ranged from 16 to 26 deer per $mi^2$ on the control side, and 6 to 10 per $mi^2$ on the treatment side. We corrected for observability, using a 60% observation rate, and the total amount of deer habitat in each of the study areas (3.36 control and 7.72 treatment) to calculate a density (Table 4).

**Table 4. Density of deer per $mi^2$ based on results of aerial surveys of white-tailed deer in Highland Park, IL 2002-2005. Estimated available deer habitat in each study area was 3.36 $mi^2$ in control area and 7.72 $mi^2$ in treatment area. A 60% observability rate was used to correct raw data; corrected data presented below.**

| Year | Number of Deer in Control Side (deer / $mi^2$ deer habitat) | Number of Deer in Treatment Side (deer / $mi^2$ deer habitat) | Number of Deer Overall (deer / $mi^2$ deer habitat ) |
|---|---|---|---|
| 2002 | 88 (26) | 50 (6) | 138 (12) |

| | | | |
|---|---|---|---|
| 2003 | 65 (19) | 72 (9) | 137 (12) |
| 2004 | 92 (27) | 88 (11) | 180 (16) |
| 2005 | 103 (31) | 57 (7) | 160 (14) |

Population Models-- We used a demographic stochasticity (random) model to predict the dynamics of an open population under management with time optimal surgical sterilization. A demographic stochasticity model tracks each individual animal in the modeled population. Mortality, recruitment (birth rate), and emigration (does leaving the area) affect each individual with a defined probability in each time step. The time optimal management algorithm predicts the number of does in each time step that should be sterilized to bring the population back to its managed equilibrium at the population goal level, in the shortest possible time.

We parameterized our model for mortality, recruitment, immigration, emigration (dispersal), and capture rate using data collected by Etter (2001) in DuPage County and data collected on the ground in Highland Park. Each parameter was allowed to vary as a logistic function of the parameter mean. We selected our recruitment parameter to obtain the most conservative estimate of the effect of sterilization on the population. Thus, our model underestimates the effects of sterilization on the population.

When developing any model, it is necessary to provide numbers for rates that may not be directly determined by the study in progress. These "assumptions" were taken from previous published reports. We assumed a recruitment rate of 0.54 does per adult female (Etter 2001). The adult mortality rate for fertile does was set at 0.13, and the adult mortality rate for sterile does was set at 0.27 (data from this study). We assumed a 0.06 dispersal rate for control deer and a 0.075 dispersal rate for treatment deer (this study), and we assumed that all dispersing does left the study area. Does immigrated with mean probability of 0.06 from an external population held constant at the population goal. Does were captured with a probability of 0.42 (this study). Up to the predicted time optimal number of fertile does were sterilized in each time step. We simulated an aerial population survey by "detecting" deer in the modeled population with a probability of 60%, and scaling the number of deer detected by a factor of $0.6^{-1}$ to estimate the population size for the purpose of management. The estimated population was used to calculate the time optimal sterilization rate in the next time step. This allowed us to introduce management error caused by the potentially inaccurate estimation of population size.

Our model assumes that recruitment and mortality are not density dependent near the population goal level, and that there is a one-to-one sex ratio in the unmanaged and managed populations. These assumptions are conservative, and if either assumption is violated we expect control to be more, rather than less effective. We also assumed that immigration and emigration were not density dependent (Skuldt 2005), and that there was no capture bias in the population. We assumed that managers could accurately estimate mean parameters of population dynamics, and we did not allow for adaptive management.

Results--Our model predicts that time optimal surgical sterilization can control the deer population in Highland Park at the goal level if we can capture an annual average of 32% of the female population. A conservative estimate of our achieved capture rate is 42%. Our parameterization of the model suggests that the long-term maintenance of the population will require sterilizing an average of 6.2 does per year. If recruitment in Highland Park is lower than the 0.54 estimate with which we parameterized the model, the average required sterilization will be lower than 6.2 does per year. If our parameters are correct, on average it should take 3.7 years for the population to peak before starting to decline, and it should take 9.5 years for the population to be fully controlled.

Our model projections suggest that in the early stages of a time optimal sterilization regime the managed population will continue to grow. The managed population will peak when a critical level of sterilization has been reached. Thereafter, the population will decline and hover around the target density of 5 deer per square mile (Figure 2).

To assess the quality of population control with time optimal surgical sterilization, we compared our model of time optimal sterilization to a model of population control with culling by lethal injection (Figure 3). Population control with lethal injection was modeled as described above, except that deer sterilized in the first model were removed immediately from the population in the lethal culling model. The modeling suggests that it will take longer to bring a large population under control with surgical sterilization than with lethal culling. Once the population has been brought to the goal level, the dynamics of a population controlled with sterilization will not be meaningfully different than those of a population controlled with lethal culling. Population management with sterilization will require a slightly greater capture effort than management with lethal culling (on the order of 7 days per year), but the number of does treated in each year after control is achieved will be fewer under sterilization than under lethal culling.

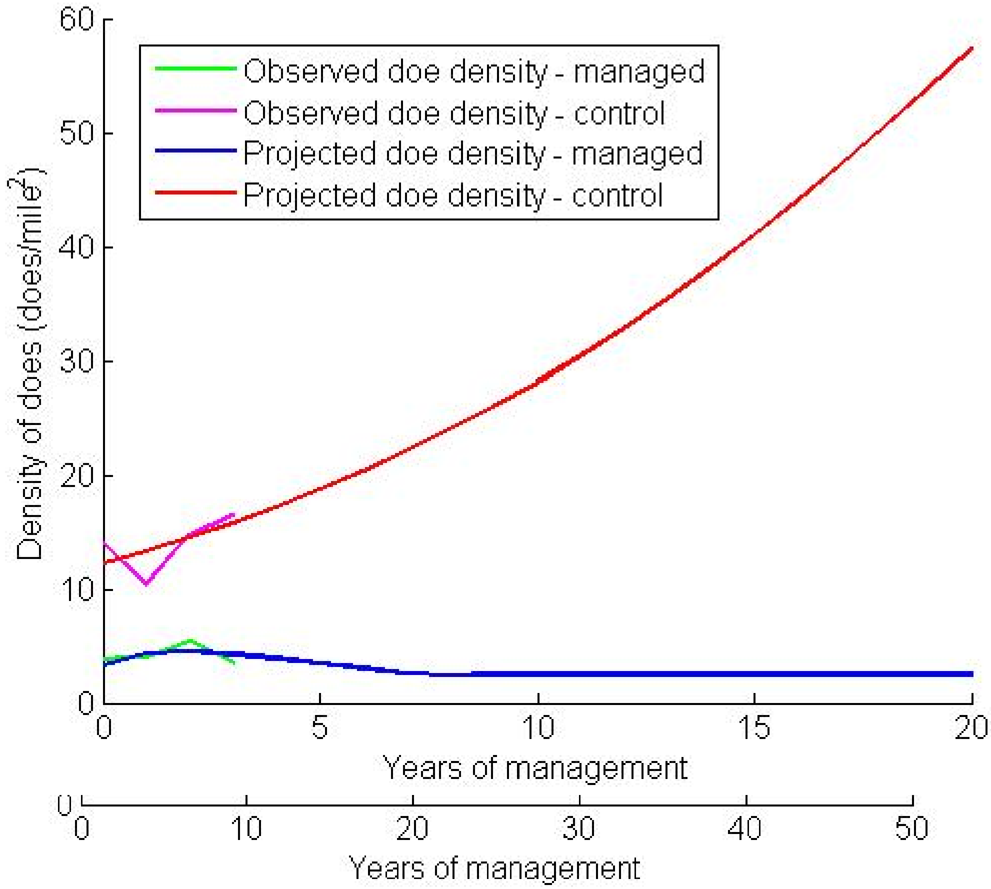


**Figure 2. Dynamics of deer population managed with time optimal sterilization and allowing for demographic stochasticity and environmental variance. The modeled population begins at 14.3 deer per mi$^2$, equal to the highest historical density estimated for Highland Park in corrected aerial surveys. In the first few years of management the population increases, and then rapidly decreases to the population goal level. Thereafter, the population fluctuates around the population goal.**

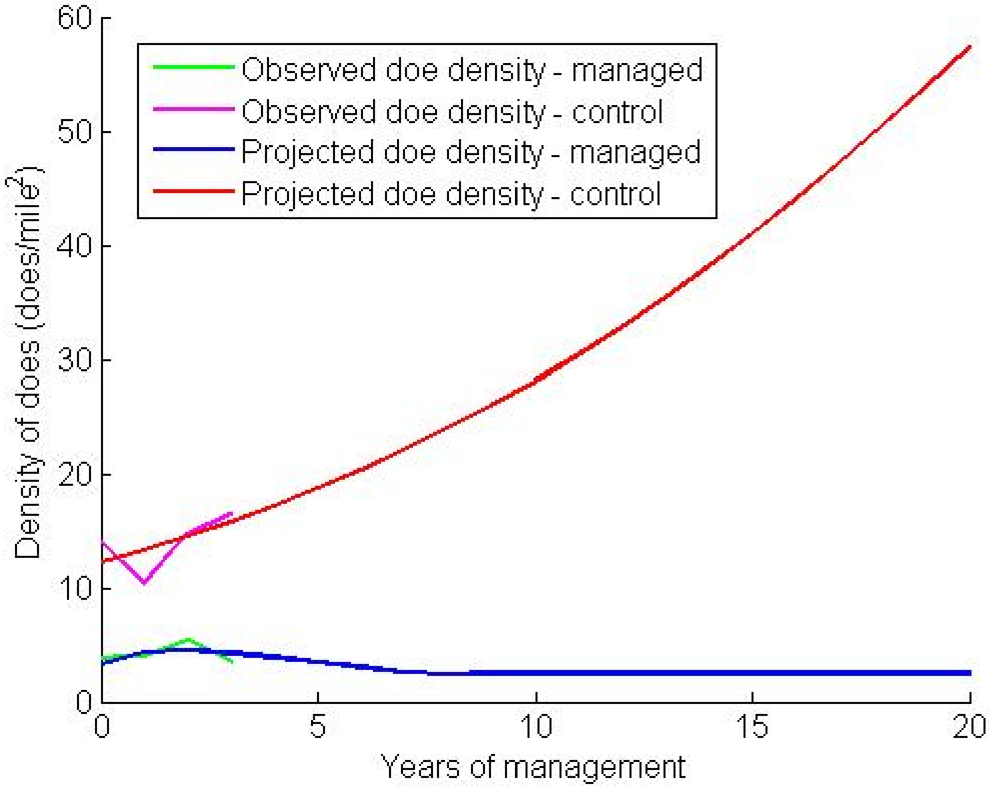


**Figure 3. Projected and observed doe densities in the deer sterilization treatment area of Highland Park, IL 2002-2022. Doe density in does per mi$^2$ was projected for the treatment area under management with time optimal sterilization (blue), and compared to projections for management with lethal culling (red). Observed doe density is overlaid on the projection.**

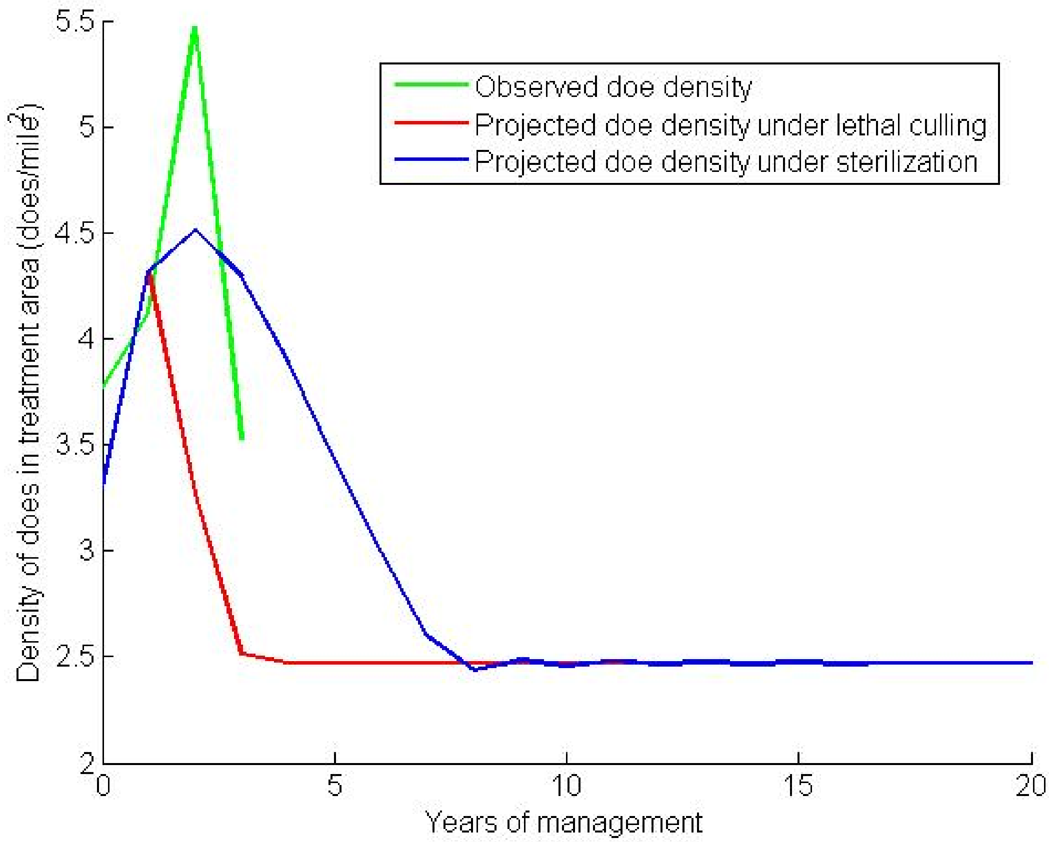


**Figure 4. Observed and projected population densities for control and managed deer populations. The magenta line shows the observed density of the control population while the red line shows the projected population density in the absence of natural or managed density dependence. The green line shows the observed density of the managed population. The blue line shows the projected population density under time optimal sterilization.**

**Objective 2: Assess the behavioral impacts of sterilization.**

**Telemetry and Home Range Analyses--** All telemetry data were entered into a spread sheet and sorted by deer identification number, year, and season. Seasonal files were created for each deer. Seasons were defined as gestation (Jan 1 – April 13), parturition (April 14 – July 18), pre-rut (July 19 – October 9), and rut (October 10 – December 31). Locations were estimated using Location of a Signal (LOAS), Version 3.02. A minimum of ten locations was required to calculate each seasonal home range. Home ranges were estimated using the 95% fixed kernel method in the animal movement extension for ArcView® GIS, Version 3.2. Home ranges were also estimated using the 50% fixed kernel method for parturition to identify fawning territories. Due to the small sample sizes of younger deer (yearlings), all does were grouped together by treatment to estimate home ranges. We accepted locations that consisted of azimuths obtained within 20 minutes from each other and resulted in positional errors $\leq 0.02$ $mi^2$.

Multi-variant analyses were used to test for differences in home range size among treatment, age, and seasons by conducting pair-wise comparisons with Tukey-Kramer correction based on linear mixed effects models of natural log (ln)-transformed home range size with the unique identification number for each deer as the random effect. We added an "Affected/Unaffected" variable to aid in evaluating movement before and after sterilization that accounted for the lag time in the influence of sterilization on movements (starting during parturition the year after surgery).. This lag occurs because the sterilized does' movements were not affected until approximately one year from the sterilization date.

**Results--**

Home ranges for both the sterilized group of deer and the control deer were exceedingly small throughout the year (Table 4). In general, fawns used slightly larger home ranges than adults and treatment deer used slightly larger home ranges than control deer.

While the home ranges of experimental deer were larger throughout the year, on average, than the control deer, the difference was not significant (P=0.35; Appendix C). However, age of the deer and the season significantly affected home-range size. The home ranges of older deer were smaller than those of younger deer (P=0.03). Gestation home ranges were larger than home ranges during parturition (P=0.04), pre-rut (P<0.0001), and the rut (P=0.0003; Figures 5 and 6).

The second analysis focused on only the treatment deer during all seasons. This analysis compared the home-range size prior to the sterilization effects to home-range size post sterilization. Again, while the home ranges of the sterilized does were larger prior to the treatment impact, the difference was not significant (P=0.52). Neither age (P=0.15) nor season significantly affected home-range size of the sterilized deer, with the exception that gestational home ranges were significantly larger than pre-rut home ranges (P=0.04).

**Table 4. Home-range sizes of white-tailed deer captured on Highland Park, IL, 2002-2005 by treatment and control study areas.**

**Home Range Summary Table**

| Home Range Size (sq miles) | Treatment Deer | | | | | Control Deer | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | # of Deer | Sample Size | SD | Mean | Median | # of Deer | Sample Size | SD |
| All Seasons | 0.10 | 0.03 | 62 | 324 | 0.56 | 0.06 | 0.03 | 31 | 199 | 0.11 |
| Gestation | 0.08 | 0.04 | 59 | 117 | 0.12 | 0.06 | 0.04 | 31 | 76 | 0.08 |
| Parturition | 0.05 | 0.03 | 48 | 92 | 0.10 | 0.03 | 0.03 | 25 | 45 | 0.02 |
| Pre-Rut | 0.22 | 0.03 | 44 | 66 | 1.23 | 0.07 | 0.03 | 26 | 43 | 0.19 |
| Rut | 0.05 | 0.03 | 40 | | | 0.07 | 0.04 | 22 | 35 | 0.09 |

The last two analyses looked at home ranges during parturition only (Table 5: c and d.). The first used the 95% kernel home-range calculations and the second used the 50% home-range calculations. Both 95% and 50% kernel estimates were larger for experimental sterilized deer than control deer, but the difference was not significant ($P_{95\%}$=0.42, $P_{50\%}$=0.39). We would predict larger home ranges for the sterilized deer due to the lack of fawns. Age, however, was still significant in determining home-range size (P95%=0.004, P50%=0.008) with older does having smaller home ranges. For all of the analyses performed, small sample sizes were a concern. If samples sizes were larger, some of the initial trends may have been significant between the two sets of deer.

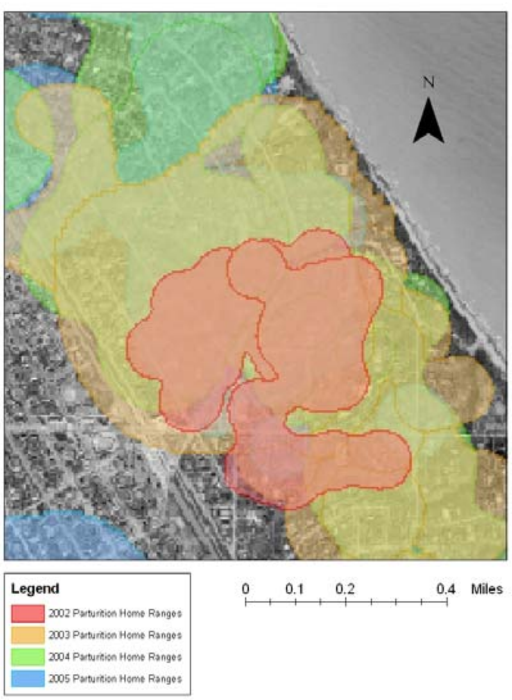


**Figure 5**. Map of home ranges of white-tailed deer in one social group during the fawning season on Highland Park, IL 2002-2005.

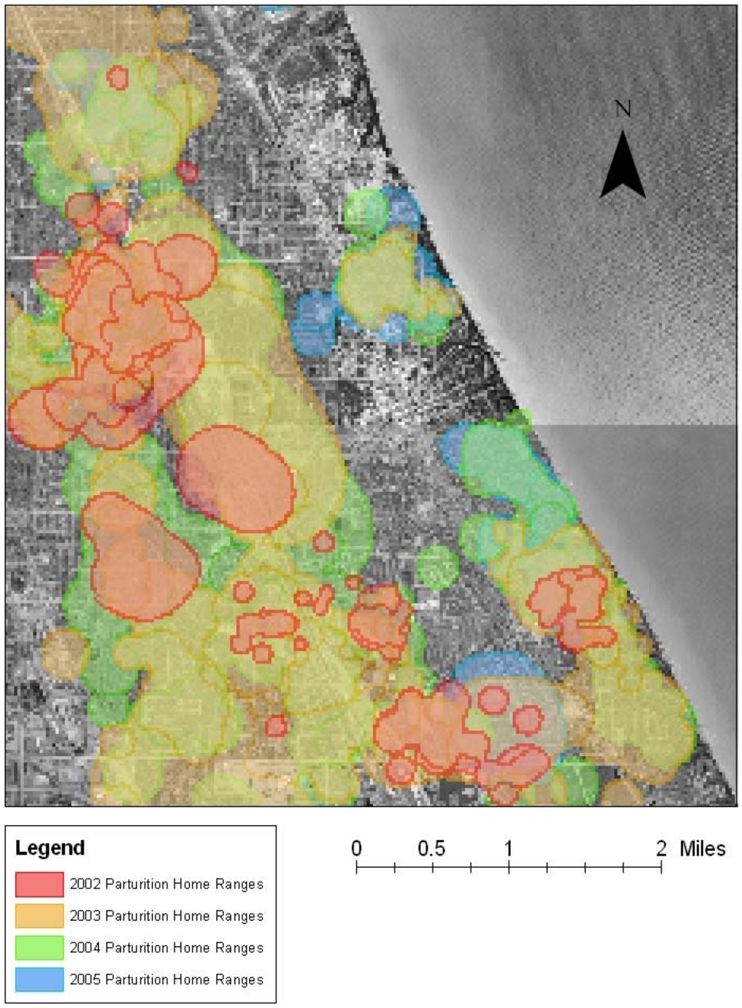


**Figure 6.** Home ranges of all females during the fawning season, during all years, in Highland Park, Illinois 2002-2005.

D**ispersal and Movements**-- A total of 5 of the 67 (7.5%) treatment and 2 of the 34 (6%) control deer dispersed. Overall, the dispersal rate was 7% (7 of 99 living deer). It appears that treatment deer dispersed farther away than control deer, however, small samples sizes precluded statistical testing of either dispersal rates or distances. A small number of treatment deer made exploratory movements, greater than 1.5 miles away from their home ranges, while no control deer made such movements. Although the sample size is exceedingly small, we found that more treatment deer (3) made exploratory movements out of their home range than control deer (0). These data suggest that sterilized deer may move more, travel longer distances and use larger home ranges than control deer. While these differences are not statistically significant, they are suggestive that activity levels may differ between the fertile and sterile deer.

Of interest, only 8% (5) of the deer crossed Rt. 41 at some point, and 2% (2) deer crossed Rt. 41 to relocate their home range. Several of the relocations were at the road edge, and may have actually been telemetry error, thus reducing the actual number of relocations across 41. These findings suggest that the deer populations east and west of Skokie Valley Road do not mix.

**Table 6. Long distance movements of treatment and control female white-tailed deer in Highland Park, IL 2002-2005.**

| | Dispersals | Ave Distance (miles) | Exploratory Mvmt | Ave Distance (miles) | Crossing Rt. 41 |
|---|---|---|---|---|---|
| Treatment | 5 | 2.48 | 3 | 2.59 | 11 |
| Control | 2 | 0.35 | 0 | 0 | 4 |
| Total | 7 | 1.87 | 3 | 2.59 | 15 |

**Objective 3**: **Assess the efficacy of surgical sterilization female deer under field conditions**

**Surgical methods**-- Surgical tubal ligation, leaving ovaries intact, was used for the sterilization of female deer. During this project the tubal-ligation procedure evolved through four variations of technique: a three-port elaparoscopy for simple tubal transection (n = 3), an open ventral laparotomy (abdominal incision)with tubal ligation and transection (n = 15), an open ventral laparotomy with tubal ligation and partial salpingectomy (removal of a portion of the tube) (n = 40), and an open ventral laparotomy with application of a mechanical oviductal occlusion clip (n=9); Hulka-Clemens®, Richard Wolf Medical Instruments Corp., Vernon Hills, Illinois 60061, USA; see Appendix A).

Results--Over three years, 67 females were sterilized by tubal ligation and/or transection. An initial procedure of laparoscopic tubal transection (n = 3) was abandoned after the first three animals in favor of ventral laparotomies (n = 64) in order to simplify procedures for this project. One mortality was directly attributable to a laparoscopic surgery, but no mortalities resulted from the laparotomies. The ventral laparotomy is a simple procedure that requires inexpensive equipment that iseasily obtained and processed. 69% of the treatment does were pregnant and carrying an average of 1.8 fetuses at the time of surgery. The surgery did not affect the does pregnancy because all surviving pregnant does were observed with live fawns in the spring. Laparotomy provided adequate patient safety based on survival data and was suitable for tubal ligations in late-term does. Moreover, the laparotomy technique is a simple surgery that can be transferred to any competent veterinarian.

Necessary personnel included a minimum of three persons for deer immobilization, and at least two (one of whom is the veterinarian) persons for anesthetic monitoring and surgery. The humane handling and care of the deer was an important aspect of this project to all involved. The project was reviewed and accepted by the Animal Care and Use Committee's at both the University of Wisconsin, Madison and the Milwaukee County Zoo.

In conclusion, tubal ligation by ventral laparotomy provides a safe, humane form of sterilization with low mortality in white-tailed deer. No treated deer were observed with fawns in the following years. All surviving surgical animals appeared healthy at the conclusion of the study.

**Evaluation of Field Surgical Procedures**--Capture and chemical immobilization in order to perform surgery on wild does in an urban environment was highly successful. The safety of the personnel working with the animals and the citizens of Highland Park was maintained throughout the period of the study. The availability of a mobile surgical unit was extremely advantageous to this project and allowed for the most efficient and humane handling of the deer. The technology required to capture, surgically sterilize and return does to their native environment is easily transferred if other communities choose to incorporate these techniques into their wildlife management programs.

**Objective 4: Evaluate the cost effectiveness of the sterilization effort**

The cost of the program was primarily funded by the City of Highland Park (Table 7.). Donations from residents of Highland Park were accepted and received. The University of Wisconsin Accounting System handled the funds for both the project and the research. The City of Highland Park also incurred direct costs for the project. The University of Wisconsin Foundation handled donations for the project.

As expected, the initial start-up costs for the project were high. Sterilizations were done for 3 of the 4 years, as planned, and project costs went down with each successive year. The cost of the research, radio-tracking individual deer and subsequent analysis, was substantial. The average cost per deer sterilization under this initial research-oriented project was over $1,000 with both veterinarian and Highland Park Police Department personnel time included. The direct cost for the veterinarian's work is approximately $750 per deer. This includes $150 in drugs per deer, in addition to salary costs for a month of a veterinarian's time. These costs, although intrinsic to this study, would be expected to vary in any future deer management program, depending on the trapping effort devoted to the work.

The Highland Park Police Department provided the personnel for trapping deer, assisting the veterinarians, and overall coordination of the sterilization portion of the program. This involved reallocating personnel time during the three years sterilizations were done. Close to 6,000 hours of personnel time was used over three years: 1,700 hours during the 2001-2002 season; 2,438 hours during the 2002-2003 season; and 1,811 hours during the 2003-2004 season. The information on costs and personnel hours relate only to this research project. An ongoing deer management program would be structured differently.

**Table 7. Yearly costs of the 2002-2005 Deer Sterilization Research in Highland Park, IL**

| Project Year | HP Budget | Donations | UW spent | HP spent Directly | Project Costs | Research Costs |
|---|---|---|---|---|---|---|
| 9/01-8/02 | $154,946 | $ 4,050 | $ 56,400.30 | $22,292.81 | $47,415.48 | $31,277.63 |
| 9/02-8/03 | $121,654 | $13,000 | $ 64,549.21 | $19,519.31 | $37,942.96 | $46,125.56 |
| 9/03-8/04 | $ 90,737 | $10,000 | $ 51,355.28 | $12,821.09 | $27,221.93 | 39,954.44 |
| 9/04-8/05 | $ 64,260 | $ 5,000 | $ 30,824.96 | $6,300.76 | $ 1,204.42 | $35,921.3 |
| Overhead | | | $ 70,384.68 | | | $70,384.68 |
| Fringe | | | $ 31,044.71 | | | $31,044.71 |
| Totals | $431,597 | $32,050 | $ 304,559.10 | $60,933.79 | $113,784.79 | $ 254,708.32 |

## Conclusions

We believe that surgical sterilization of female white-tailed deer is a viable means of regulating the growth of an urban deer population in Highland Park, Illinois. While we made a number of assumptions when determining the population model, in each case, we assumed the most conservative values for each parameter in order to under estimate the true effects. We recognize that random events on a yearly basis will affect the ability to accurately determine the number of deer to sterilize, and our ability to implement the management recommendations. Changes in dispersal rates and mortality rates will most likely change the "time to goal". Our modeling results are supported by models created by Merrill et al. 2005 and suggest that sterilization is feasible in closed, or nearly closed populations.

We have summarized our conclusions as follows:

1. Sterilization of female white-tailed deer, under urban conditions, with limited immigration, can effectively be used to regulate population growth.
2. Surgical sterilization has little effect on female behavior; however small sample sizes preclude definitive assessments of this. There is some indication that sterilized deer move more than fertile deer..
3. Sterilized deer die at a significantly higher rate than control deer.
4. Surgical sterilization using laparotomy can be used under field conditions to effectively sterilize white-tailed deer.
5. Sterilization of females, after start up costs, may be performed for approximately $750 per deer.

## Presentations and Papers

Throughout the course of the study, a total of 12 oral presentations were made to professional societies, University courses, or research groups. One technical paper has been submitted to the Journal of Zoo and Wildlife Medicine: Surgical technique for tubal ligation in white-tailed deer (Odocoileus virginianus)" (Appendix A). Three other technical papers are in preparation.

Mathews, N. E. March 2001. Deer Behavior: New paradigms for localized management. State Chapter of The Wildlife Society Annual Meeting. Eau Claire, WI.

Mathews, N. E., J. Paul-Murphy, E. S. Frank. 2001. Surgical sterilization of white-tailed deer for localized management in Highland Park, Illinois. Midwest Deer and Turkey Study Group, Mt. Horeb, WI.

Mathews, N. E. April 2001. Teaching the capstone class using realistic models in resource management. UW-Teaching Academy.

Mathews, N. E. October 2001. Deer Behavior: New paradigms for localized management. BIDS, UW-Madison.

Mathews, N. E. October 2001. Women in wildlife and Deer Behavior: New paradigms for localized management. U.W. Madison - WE 100.

Mathews, N. E. November 2001. Deer Behavior: New paradigms for localized management. U. W. Madison WE 375 - Behavioral Ecology.

Armstrong Rachel and Elizabeth Frank. 2002. A Trap-Neuter-Release Program for Urban White-tailed Deer. American Association of Zoo Veterinary Technicians - Milwaukee, WI, October 2002.

MacLean, R. A. Jr, D. V. M., E. S. Frank, M.A., J. Paul-Murphy, D.V.M, Dipl. ACZM, N. E. Mathews, Ph.D. 2002. Tubal ligation as a means of controlling a population of urban white-tailed deer: Preliminary results. 2002 Annual Proceedings of the American Association of Zoo Veterinarians.

Frank, E. S., N.E. Mathews, D. Grove, J. Paul-Murphy 2005. Program Update: Surgical Sterilization as a Means of Controlling the Growth of an Urban Deer Population. American Zoo and Aquarium Association Antelope Taxon Advisory Group Meeting. St. Louis, MO, June 2005.

Gilman. R. T, N. E. Mathews, E. S. Frank, and J. Paul-Murphy. 2005. Control of overabundant Odocoileus virginianus populations using density-dependent sterilization". Ecological Society of America Annual Meeting, Montreal, Canada, July 2005.

Joanne Paul-Murphy, DVM, Dipl. ACZM, [1*] Nancy E. Mathews, PhD,[2] Elizabeth S. Frank, MA, [3] Robert A. MacLean, Jr., DVM[2,4], Daniel M. Grove DVM[1], Robert T. Gilman[5.] Surgical Sterilization To Control An Urban Population Of White-Tailed Deer: Preliminary Results. 2005 Annual Proceedings American Association of Zoo Veterinarians. Omaha, NE, October 2005

Mathews, N. E. 2005. 66th Annual Midwest Fish and Wildlife Conference. Grand Rapids, MI, December 2005.

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Many field assistants helped with the radio telemetry work: 2003- Jennifer Biehl, Wade Ulrey, Rachel Armstrong; 2004- Luke DeGroot, Ian Hall, Farrah Fatemi; 2005- Mark Rosenthal, Vicki Blank. Wendy Sherman provided critical telemetry assistance from 2002-2004.

Sandra Driggett entered the field data into spreadsheet files. Nick Keuler and Veronique St. Louis from UW Madison assisted with statistical analyses.

Dr. MacLean also prepared the manuscript on surgical techniques for sterilization (Appendix A). We wish to thank Ms. Vicki Blank and Mr. R. Tucker Gilman for their incredible assistance during the summer of 2005 analyzing data, GIS work, and developing population models. Both contributed substantially to the preparation of this report.

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Finally, we thank the citizens of Highland Park, Illinois for their support for the project and access to their properties for trapping and telemetry.

## Literature Cited

Caskey, M. A. 1997. Summary of Deer Task Force Request for Council Action. November 1997. City of Highland Park, Department of Police.

Etter, D. R. 2001. Ecology and management of overabundant white-tailed deer from suburban Chicago, Illinois. Ph.D. Dissertation, University of Illinois at Urbana-Champaign. 106 pp.

Frank, E. S., and S. L. Sajdak. 1993. Sterilization as a method of controlling an urban white-tailed deer population, AAZPA Regional Proceedings 1993:485-490.

Hobbs, N. T., D. C. Bowden, D. L. Baker. 2000. Effects of fertility control on populations of ungulates: General, stage-structured models. Journal of Wildlife Management 64:473-491.

Long, E.S, D.R. Diefenbach, C.S. Rosenberry, B.D. Wallingford, and M.D. Grund. 2005. Forest cover influences dispersal distance of white-tailed deer. Journal of Mammalogy 86:623-629.

Merrill, J. A., E. G. Cooch, and P. D. Curtis. 2005. Time to reduction" factors influencing management efficacy in sterilizing overabundant white-tailed deer. Journal of Wildlife Management (IN PRESS).

Skuldt, L. H. 2005. Influence of landscape pattern, deer density and harvest intensity on behavior of white-tailed deer in southcentral Wisonsin. M.S. Thesis. University of Wisconsin – Madison.

## Appendix A: Paper submitted for publication to Journal of Zoo and Wildlife Medecine.

# TUBAL LIGATION IN WHITE-TAILED DEER
# SURGICAL TECHNIQUE FOR TUBAL LIGATION IN WHITE-

# TAILED DEER (<u>ODOCOILEUS VIRGINIANUS</u>)

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<u>Abstract:</u> Surgical tubal ligation was used for the sterilization of urban free-ranging white-tailed deer (<u>Odocoileus virginianus</u>) as part of a larger study investigating the influences of intact, sterile females on population and behavior. Over three years, 103 female and 78 male individual deer were captured in Highland Park, Illinois, and a subset of females were sterilized by tubal ligation and/or transection (n = 66). Deer were either trapped in clover traps (n = 54) and induced with an intramuscular injection of 2.5 mg/kg xylaxine and 2 - 3 mg/kg tiletamine/zolazepam or darted (n = 12) and induced similarly. Deer were intubated and maintained on isoflurane in oxygen. An initial procedure of laparoscopic tubal transection (n = 3) was abandoned after the first three animals in favor of ventral laparotomies (n = 63) in order to simplify procedures for this project. Laparotomy techniques included oviductal ligation and transection (n = 14), the application of an oviductal mechanical clip (n = 9), or ligation and partial salpingectomy (n = 40). One mortality (1 / 67, 1.5 %) was directly attributable to a laparoscopic surgery, but no mortalities resulted from the laparotomies. Tubal ligation by ventral laparotomy provides sterilization with low mortality in white-tailed deer.

<u>Key words:</u> capture, contraception, <u>Odocoileus virginianus</u>, population control, sterilization, surgery, white-tailed deer.

## INTRODUCTION

Overabundance of white-tailed deer (<u>Odocoileus</u> <u>virginianus</u>) in urban areas is a common management priority for urban wildlife managers and local governments.[3,37] Historically, several management techniques have been employed to control white-tailed deer population densities (e.g. sharp shooting, trap and relocate, hormone regulation, and immunocontraception).[26,37] Surgical sterilization of female deer is effective in preventing pregnancies, but has not been implemented in a free ranging population.[7,8,36] Surgical sterilization in the field would require not only refinements in technique and logistics, but also the political support of local government and state agencies.

Permanent sterilization of females may be an attractive management tool for certain municipalities because, although lethal culling is the most effective method of population density reduction, hunting is not acceptable in many urban settings. Trap and relocation programs are expensive, often result in a high post-relocation mortality, and include the risk of disease introcution to the relocation area..[11] Several hormonal agents have been evaluated; some with modest success, but concerns about effects on secondary consumers limits the use of hormone therapy.[1,4,8,9,20-24,30,38] Porcine Zona Pellucida (PZP) has been tested successfully in deer and free-ranging equids, as well as other species, however, the U.S. food and Drug Administration considers deer to be food animals and PZP to be an experimental drug, which limits its use.[5,6,12-18,27,31,35] Male-based contraception is thought to be ineffective for free-ranging white-tailed deer because it would require treatment of nearly all resident males, an effort which is not practical based on the dispersal behavior of bucks.[19] Computer modeling of permanent sterilization of the female deer in a population predicts a reduction in population density when the number of sterilized individuals exceeds 50% of the females.[2,10,32]

Surgery is currently the only proven means to obtain permanent sterilization in female deer. Tubal ligation of females provides effective sterilization while leaving the ovaries intact, presumably minimizing changes to behavior. In 2001, the Highland Park, Illinois, City Council approved a motion to investigate the efficacy of surgical sterilization of female deer as an alternative means of regulating the deer population. This paper reports the development and assessment of a sterilization technique suitable to be used to sterilize female deer under field conditions.

## MATERIALS AND METHODS

### General study area

Highland Park (HP) is a 32 km$^2$ residential community bordering Lake Michigan, 40 km north of Chicago, Illinois. The habitat throughout this community is a mixture of age classes of deciduous and coniferous forest, maintained yards, ravines, and golf course-like grasslands. Ornamental plantings and non-native grasses provide high quality browse and forage year-round for the deer. Aerial surveys of HP estimated a population density of 4 - 5 deer/km$^2$. Does captured east of Highway 41 (22 km$^2$, n = 67) served as treatment animals, and does captured west of Highway 41 (10 km$^2$, n = 34) served as controls.

### Capture and handling techniques

Sixty-six of 103 captured does were surgically neutered by tubal ligation. Of the remaining females, one received an ovariohysterectomy, 34 were sampled and tagged as described below without undergoing surgery, one was a trap mortality, and one was released untreated. All captured bucks (n = 78) were sampled similarly, but were not fitted with radio transmitters. Deer (n = 169 individuals) were captured using 10 - 12 Clover traps,[25] each baited with one kg of corn and four apples. Traps were operated and checked four times daily from January 2002 - April 2002, October 2002 - April 2003, and October 2003 - April 2004. Deer receiving surgery were handled by collapsing the trap netting around the deer and administering intramuscular (i.m.) anesthetic agents by hand syringe: 2.5 mg/kg xylazine HCl (X-ject E®, Burns Veterinary Supply, St. Paul, Minnesota 55104, USA) combined with 2 - 3 mg/kg tiletamine/zolazepam (Telazol®, Fort Dodge, Iowa 50501, USA) based on visually estimated body weight, and supplemented with 1mg/kg ketamine (Ketaset®, Fort Dodge, Iowa 50501, USA) i.m. or intravenously (i.v.) as needed. Anesthetized deer were blindfolded, after lubricating both eyes with ophthalmic ointment (Paralube®, Pharmaderm, Melville, New York 11747, USA), and removed from the trap. Vital signs were recorded and tags (Hasco Tag Company, Dayton, Kentucky 41074, USA) were placed in both ears, one metal (style 49) in left ear and one plastic (style 402) in each ear. All does were fitted with a neck collar with an attached 480 g radio transmitter with a mortality sensor and a battery life of 3 years (Model 2520, Advanced Telemetry Systems, Inc., 470 First Avenue North, Isanti, Minnesota 55040, USA). Blood samples were collected from the left cephalic vein, and either flank-muscle-punch or ear-punch 6 mm biopsies were harvested using aseptic technique for on-going disease and genetic monitoring. Deer were weighed with a spring scale (Hanson, Forestry Suppliers, Inc., Jackson, Mississippi 39202, USA) hanging from a tree or tripod, aged by tooth wear and molar eruption,[33] measured (chest girth and hock-toe length), and examined for ectoparasites. All does in the second season received ≥ 1 L Lactated Ringers Solution (LRS, Burns Veterinary Supply) i.v. as a bolus. Treatment does (n = 12) were also darted over a bait pile using a $CO_2$ rifle (Dan-Inject® "AC Model," Wildlife Pharmaceuticals, Inc. Fort Collins, Colorado 80521, USA) with a 13 mm barrel and explosive transmitter darts with a 3 ml capacity (Pneu-Dart, Inc, Williamsport, Pennsylvania 17701, USA). The darts were filled with 2 ml of a tiletamine/zolazepam/xylazine mixture (500 mg vial of Telazol reconstituted with 5 ml of 100 mg/ml xylazine). Darted deer were tracked after 5 min., using an ICOM IC R10 receiver and an H-style antenna (Advanced Telemetry Systems), and treated similarly to animals above.

Does receiving surgery were transported on a stretcher to either a nearby retired ambulance (n = 65) or to a nearby garage (n = 2), modified for clean surgical areas. Does were clipped (Oster A5®, McMinnville, Tennessee 37110, USA) from umbilicus to pubis for abdominal surgery and catheterized in the right cephalic vein using a 16 gauge 2.5 in. catheter (Abbocath, Abbott, Burns Veterinary Supply). LRS was infused i.v. at approximately 500 ml/hr. A pulse oximeter (V8200, Surgivet, Waukesha, Wisconsin 53188, USA) probe was placed on the tongue, a $CO_2$ airway sensor (Surgivet, Waukesha, Wisconsin 53188, USA) was placed inline, a remote temperature probe (indoor/outdoor thermometer, Menards, Madison, Wisconsin 53711, USA) was inserted into the rectum, and, in the second and third seasons, a noninvasive oscillometric blood pressure (BP) cuff (Memoprint®, Jorgensen laboratories, Inc., Loveland, Colorado 80538, USA) was placed distal to the left carpus. Anesthesia monitoring included respiration, heart rate (HR), $O_2$ saturation, end-tidal $CO_2$, rectal temperature, and BP (in the second and third seasons). Temperature was controlled using ice packs, snow, or alcohol during capture and induction and by an electric heating pad combined with a space blanket and ambient heated air during surgery. Atropine, 0.26 to 1.08 mg, (Atroject®, Burns Veterinary Supply) was administered i.v. when HR was less than 40 beats per minute after partial reversal of xylazine with yohimbine (Yobine®, Ben Venue Laboratories, Bedford, Ohio 44146, USA; approximately 0.05 mg/kg, i.v. PRN).

Does were intubated using a 9 mm (35 kg fawn) to a 12 mm (80 kg adult) inside diameter silicone endotracheal tube (Jorgensen Laboratories, Inc.). A rebreathing circuit (vaporstick Plus®, Surgivet, Waukesha, Wisconsin 53188, USA) was used with oxygen flow of 2 liters/minute and isoflurane vaporizer (V720101, Surgivet, Waukesha, Wisconsin 53188, USA) settings ranged from 0.25 – 1.5% isoflurane (Iso-Thesia, Vetus Animal Health, Burns Veterinary Supply). Most does were positioned in dorsal recumbency with the hips raised about 15 cm and their legs secured by rope (the first two does were placed in left lateral recumbency also with hips raised 15 cm for laparoscopy). A generic large baby diaper was secured to absorb urine, and the abdomen was surgically prepped three times using povidone iodine scrub (Burns Veterinary Supply) and alcohol. Each doe received 44,000 IU/kg penicillin G benzathine/procaine (Hanford's MFG Company/USVet, Syracuse, New York 13201, USA) subcutaneously (s.q.) and 0.05 to 0.2 mg/kg butorphanol i.m. (Torbugesic®, Fort Dodge). Additionally, 1g Cefazolin (generic, Burns Veterinary Supply) was administered slowly i.v. during the 2nd and 3rd seasons for added surgical infection prophylaxis.

Necessary personnel included a minimum of three persons for deer immobilization, and at least two (one of whom is the veterinarian) persons for anesthetic monitoring and surgery. Gross necropsy examinations were conducted for fatalities, most of which included histopathology and brainstem sampling for Chronic Wasting Disease surveillance.

**Surgical procedures**

During this project the tubal ligation procedure evolved through four variations of technique: a three-port laparoscopy using simple tubal transection (n = 3), an open ventral laparotomy with tubal ligation and transection (n = 14), an open ventral laparotomy with tubal ligation and partial salpingectomy (n = 40),[28] and an open ventral laparotomy with application of a mechanical oviductal occlusion clip (Hulka-Clemens®, Richard Wolf Medical Instruments Corp., Vernon Hills, Illinois 60061, USA) (n = 9).

The laparoscopy was performed with a three-port laparoscopic technique using one 11 mm port for a 10 mm 0 (n = 2) or 30 degree (n = 1) laparoscope (attached to a video camera) and two 11 mm lateral ports with reducers for various 10 mm and 5 mm graspers, manipulators, and scissors. This technique was abandoned because of logistical challenges discussed below.

The ventral laparotomy approach used a 5 to 10 cm ventral midline skin and body wall incision cranial to the udder, avoiding injury to the bladder, which was frequently full. The incision was shifted cranially for gravid does. The right ovary and oviduct were exteriorized using two fingers to grasp the region of the uterine-tubal junction (UTJ). For fawns and some yearlings it was necessary to break down the cranial portion of the suspensory ligament. Minor bleeding occurred from ligament vessels. The ovary was examined, and the character of follicles and corpora lutea recorded.

Tubal ligation and simple transection was used in the 1st season. The isthmus of the oviduct was double ligated with 000 nylon suture (Ethilon™, Ethicon, Cornelia, Georgia 30531, USA) and transected. The failure rate of this technique was presumed to be higher than for more modern techniques, although a reported rate was not found during a review of the literature. During the 2nd and 3rd seasons, the isthmus was isolated with the index finger, and an avascular area of the mesosalpinx directly under the oviduct was perforated with a hemostat approximately 3cm proximal to the UTJ. The hemostat was opened to spread the mesosalpinx, thereby freeing approximately 1 cm of oviduct. The mesosalpinx opening was extended for approximately 3 cm, and the oviduct was ligated with 000 nylon suture at each free end. The intervening approximately 2 cm of oviduct was sharply excised. This technique, commonly referred to as the Parkland technique,[28] has a 2.5% failure rate in women.[34] For the mechanical oviductal occlusion, the oviductal clip was manually applied over each isthmus. This technique has a 3.7% failure rate in women.[29]

A three-layer closure was used for all open ventral laparotomy procedures, adding two or three near-far-far-near sutures of 1 polyglyconate monofilament suture (Monosorb®, Suturevet, Burns Veterinary Supply) in the linea alba for gravid does. The linea alba was closed using the above monofilament suture, and the subcutaneous tissues were closed with 00 polyglactin (Vicryl®, Ethicon, Cornelia, Georgia 30531, USA) suture, both in a simple continuous pattern. The skin was closed with 00 polyglactin suture in a continuous subcuticular pattern. Tissue glue (VetBond™, 3M, Burns Veterinary Supply) was used to aid apposition when necessary.

Postoperatively, deer were returned to the capture site and placed on a blanket. The torso and eyes were covered with part of the blanket, and 0.2 to 0.4 mg/kg yohimbine was administered i.v. to reverse the effects of the xylazine. The deer were extubated upon swallowing and observed until ambulatory. An additional 0.1 mg/kg of yohimbine was administered i.v. or i.m., if the deer remained recumbent for more than 30 min after the 1st dose and was unresponsive to noise or physical stimulation.

## Animal monitoring

Radio telemetry was used to relocate does within 2 to 6 hr post recovery, then daily for the first 14 days. Throughout the remainder of the year, does were located a minimum of one time per week to obtain 40 to 50 relocations per deer. All sightings by residents were recorded as additional data and anecdotal information about the deer's condition were noted.

## RESULTS

### Capture rates

Traps were open and set from 21 January – 19 April 2002, 14 October 2002 – 25 March 2003, and 6 October 2003 - 30 March 2004 for a total of 2,349 trap days. A total of 292 deer were trapped, representing a 12.4% success by trap day, and included 169 individual deer (91 females, 78 males) and 123 recaptured deer (59 individuals, 32 males averaging 2.5 recaptures and 27 females averaging 1.6 recaptures). Additionally, 12 does were captured by darting, bringing the total number of captured individual deer to 181. Sixty-six does were sterilized by tubal ligation either through laparoscopy (n = 3) or laparotomy (n = 63). One additional doe received an ovariohysterectomy (n = 1) to remove mummified fetuses, and one doe was released unmarked and untreated (n = 1). Approximately 8 man-hours/day were required for trap maintenance and inspection of the 12 traps.

### Mortality

As of 1 August 2004, 23 of 67 (34.3%) treatment does (including the ovariohysterectomy), 7 of 34 (20.6%) control does, 23 of 78 (29.5%) males, and one non-accessioned doe were known deceased. Overall mortality directly attributable to the project is 11/181 (6.1%) individuals or 11/304 (3.6%) captures. Four animals died in the trap before handling, one 7 yr doe and one 3.5 yr buck by asphyxiation, one 5 mo doe due to an atlantoaxial luxation, and one 4 yr buck of peracute capture myopathy. Two (2/25, 8.0%) control does, 6 yr and 5 mo, died 5 days and 2 days post-capture, respectively, with histologic evidence of subacute to acute capture myopathy. Two bucks, 7 mo and 2 yr, died during restraint with histologic evidence of asphyxiation and peracute capture myopathy, respectively. One 9 mo buck that died 5 days post capture is presumed to have died from capture myopathy, although there was no postmortem evidence. One 5 mo buck was euthanized 2 days post capture due to severe head trauma and had gross evidence of acute capture myopathy.

Mortality directly attributable to surgery was 1/67 (1.5%). One 2.5 yr doe died 3 days after laparoscopic surgery that was prolonged due to difficulties manipulating her uterus which was approximately 3 mo gravid with triplets. This surgery was converted to a left flank laparotomy for successful ligation of the oviducts, and the animal was observed standing and drinking the day prior to death. No gross evidence of disease was identified at post-mortem examination, and histopathology was not obtained for this animal.

Treatment doe mortalities not directly related to the project include 15 that were hit by vehicles, four culled by neighboring municipalities, one poached, and three of natural causes. None of these deer had evidence of capture myopathy or surgical complications on gross necropsy or histology. Control deer mortalities not directly related to the project include one culled by a neighboring municipality, two hit by vehicles, and one of unknown causes 15 mo post capture. Male mortalities not directly related to the project include 14 hit by cars and two culled by a neighboring municipality.

**Surgical statistics**

The three laparoscopy surgical procedure times, not including induction and recovery, were 1 hr 28 min, 3 hr 14 min, and 45 min. The data for tubal ligations by laparotomy is presented in Table 1. Between January and April, 36/52 (69%) of the treatment does were pregnant and carrying an average of 1.8 fetuses at the time of surgery. All surviving gravid does were observed with live fawns in the spring.

## DISCUSSION

Surgical sterilizations of 67 female white-tailed deer in Highland Park, Illinois were accomplished under field conditions during 2002 - 2004. Both laparoscopic and standard laparotomy techniques were used for tubal ligations.

While laparoscopy may have advantages for this surgery, such as small incisions and quick access to the oviducts, the three-port laparoscopic technique was abandoned after three surgeries because of its many disadvantages for this project. While practicing on cadavers, one operator could manage all three instruments, however, inside our mobile surgery unit, a sterile assistant was required to steady the camera. Moreover, the 2nd doe was estimated to be 90 days pregnant with triplets, making it difficult to manipulate the uterus adequately to access the oviducts and thus requiring a conversion to a right flank laparotomy to complete the sterilization. This animal was the only mortality directly related to surgery. Modifications to our laparoscopic technique may have improved its success, but none were tested. In addition to the technical challenges of laparoscopy, the length of the equipment required specialized containers and the use of a large commercial autoclave for sterilization. The equipment cost precluded purchasing multiple sets for this project, and thus allowed for only one sterile surgery every two days. We concluded that laparoscopy was inefficient and impractical given the resources available for this project.

The ventral laparotomy provided several advantages over the laparoscopy, including a considerable simplification of the procedure with inexpensive equipment that was easily obtained and processed. Additionally, there was no need for a sterile assistant. The laparotomy provided adequate patient safety based on survival data and was suitable for tubal ligations in late-term does. Moreover, the laparotomy technique is easily transferable to any competent veterinarian. One potential disadvantage to the laparotomy is the risk of catastrophic dehiscence, which, if publicly observed, could be politically disadvantageous. No complications were noted for any of the 64 laparotomy animals in this study.

Minilaparotomy techniques commonly used for tubal ligations in humans include the Pomeroy among others.[34] In this project the tubal ligation by laparotomy evolved from a simple ligation and transection using nonabsorbable suture in the 1st season to the Pomeroy excision in the 2nd and 3rd seasons largely due to concerns over the potential failure of the first technique. The Hulka-Clemens clips were used opportunistically on nine does. The clips were simple to use, did not require an expensive applicator, and application was faster than the Pomeroy excision. Most of the surgeries were performed in a retired ambulance at the site of trapping, which eliminated the need for transporting the anesthetized animal, thereby decreasing the procedure time and risk of anesthetic complications. The ambulance provided adequate shelter, a controlled temperature, and electricity for lighting and equipment. Two does, however, were transported in a van to a nearby facility for surgery and returned to the site of capture without complications.

This project was designed to investigate the long term effects of permanent female sterilization on deer behavior and abundance. Surgical tubal ligation is currently the only proven treatment that provides a long-term sterilization while preserving ovarian function. For reasons of project design and public scrutiny, the capture and surgical protocols implemented in this investigation were labor intensive and thorough. Sterilization by ventral laparotomy using standard anesthetic protocols and surgical techniques is a safe and effective method of performing tubal ligations in white-tailed deer.

Acknowledgements: The City of Highland Park, Illinois supported the project, with additional support form the Milwaukee County Zoological Society. We thank the Highland Park Police Department, especially former Chief Daniel Dahlberg, Sgt. George Pfutzenreuter, and his skilled deer crew, Ofc Mike Gilbert, CSO John Keil, Ofc Phil De Laurentis, CSO Mike Lichtwalt, Ofc Jonathan Lowman, CSO Eddie Mocogni, CSO Reyes Montemayor, CSO Jay Morris, CSO Kristin Tracey, and the many other officers who rose to the occasion whenever needed and always treated the animals with respect. Thank you, also, to Mike Bruno for building deer traps and maintaining our vehicles. Handling protocols were approved by the University of Wisconsin Animal Care and Use Committee, Research Animal Resources Center, permit # A-07-6900-A-1-49-3-10-01.

# Literature Cited


1. Bell, R. L., and T. J. Peterle. 1975. Hormone implants control reproduction in white-tailed deer. Wildl. Soc. Bull. 23:152-156.

2. Boone, J. L., and R. G. Wiegert. 1994. Modeling deer herd management: sterilization is a viable option. Ecol. Modeling 72:175-186.

3. Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. DuBow, and W. A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildl. Soc. Bull. 23:407-414.

4. DiNicola, A. J., D. J. Kesler, and R. K. Swihart. 1997. Dose determinationand efficacy of remotely delivered norgestomet implants on contraception of white-tailed deer. Zoo Biol. 16:31-37.

5. Fayrer-Hosken, R. A., D. Grobler, J. J. van Altena, H. J. Bertschinger, and J. F. Kirkpatrick. 2000. Immunocontraception of African elephants. Nature, London 407:149.

6. Fraker, M. A., R. G. Brown, G. E. Gaunt, J. A. Kerr, and B. Pohajdak. 2002. Long-lasting, single-dose immunocontraception of feral fallow deer in British Columbia. J. Wildl. Manage. 66:1141-1147.

7. Frank, E. S. and S. L. Sajdak. 1993. Sterilization as a method of controlling an urban white-tailed deer population. Am. Assoc. Zoo. Parks Aquar. Regional Conf Proc 1993:485-490.

8. Greer, K. R., W. W. Hawkins, Jr., and J. E. Catlin. 1968. Experimental studies of controlled reproduction in elk (wapiti). J. Wildl. Manage. 32:368-375.

9. Harder, J. D., and T. J. Peterle. 1974. Effects of diethylstilbesterol on reproductive performance in white-tailed deer. J. Wildl. Manage. 38:183-196.

10. Hobbs, N. T., D. C. Bowden, and D. L. Baker. 2000. Effects of fertility control on populations of ungulates: general, stage-structured models. J. Wildl. Manage. 64:473-491.

11. Jones, M. L., N. E. Mathews, and W. F. Porter. 1997. Influence of social organization on the dispersal and survival of translocated female white-tailed deer. Wildl. Soc. Bull. 25:272-277.

12. Kirkpatrick, J. F. 1993. Immunocontraception in zoo animals: vaccinating against pregnancy. Am. Assoc. Zoo. Parks Aquar. Regional Conf Proc. 1993: 290-292.

13. Kirkpatrick, J. F., P. P. Calle, P. Kalk, I. K. Liu, and J. W. Turner. 1996. Immunocontraception of Captive Exotic Species .II. Formosan Sika Deer (*Cervus nippon taiouanus*), Axis Deer (*Cervus axis*), Himalayan Tahr (*Hemitragus jemlahicus*), Roosevelt Elk (*Cervus elaphus roosevelti*), Reeves Muntjac (*Muntiacus reevesi*), and Sambar Deer (*Cervus unicolor*). J. Zoo Wildl. Med. 27:482-495.

14. Kirkpatrick, J. F., Fayrer-Hosken, R., Grabler, D., Raath, C., Bertschinger, H., Turner, J. W., and Liu, I. K. M. 1998. Immunocontraception Of Free-Ranging African Elephants

In Kruger National Park, South Africa. Am. Assoc. Zoo Vet. Am. Assoc. Wild. Vet Conf. Proc. 1998: 434.

15. Kirkpatrick, J. F. and J. W. Turner, Jr. 1997. Case studies in wildlife immunocontraception: wild and feral equids and white-tailed deer. Reprod. Fertil. and Dev. 9:105-110.

16. Kirkpatrick, J. F. and J. W. Turner, Jr. 1995. Urban deer fertility control: scientific, social, and political issues. Northeast Wildl. 52:103-116.

17. Kirkpatrick, J. F. and J. W. Turner, Jr. 1985. Chemical fertility control and wildlife management. BioScience 35:485-491.

18. Kirkpatrick, J. F. and J. W. Turner, Jr. 1991. Reversible contraception in nondomestic animals. J. Zoo Wildl. Med. 22:392-408.

19. Mathews, N. E. and W. F. Porter. 1993. Effects of social structure on genetic structure of white-tailed deer. J. Mamm. 73:4-7.

20. Matschke, G. H. 1980. Efficacy of steroid implants in preventing pregnancy in white-tailed deer. J. Wildl. Manage. 44:756-758.

21. Matschke, G. H. 1976. Non-efficacy of mechanical birth control devices for white-tailed deer. J. Wildl. Manage. 40:792-795.

22. Matschke, G. H. 1977. Antifertility action of two synthetic progestins in female white-tailed deer. J. Wildl. Manage. 41:194-196.

23. Matschke, G. H. 1977. Fertility control in white-tailed deer by steroid implants. J. Wildl. Manage. 41:731-735.

24. Matschke, G. H. 1977. Microencapsulated diethylstilbestrol as an oral contraceptive in white-tailed deer. J. Wildl. Manage. 41:87-91.

25. McCullough, D. R. 1975. Modification of the clover deer trap. California Fish and Game 61:242-244.

26. McShea, W. J., S. L. Monfort, S. Hakim, J. F. Kirkpatrick, I. K. M. Liu, J. W. Turner, Jr., L. Chassy, and L. Munson. 1997. Immunocontraceptive efficacy and the impact of contraception on the reproductive behaviors of white-tailed deer. J. Wildl. Manage. 60:23-34.

27. Miller, L. A., B. E. Johns, and G. J. Killian. 2000. Long-term effects of PZP immunization on reproduction in white-tailed deer. Vaccine 18:568-574.

28. Pati, S. and V. Cullins. 2000. Female sterilization. Evidence. Obstet. and Gynec. Clin. North Am. 27:859-899.

29. Peterson, H. B., J. M. Xia, J. M. Hughes, L. S. Wilcoz, L. R. Tylor, and J. Trussell. 1996. The risk of pregnancy after tubal sterilization: findings from the U.S. Collaborative Review of Sterilization. Am. J. Obst. Gynec. 174:1161-1170.

30. Plotka, E. D. and U. S. Seal. 1989. Fertility control in female white-tailed deer. J. Wildl. Dis. 25:643-646.

31. Rudolph, B. A. and W. F. Porter. 2000. Evaluating immunocontraception for managing suburban white-tailed deer in Irondequoit, New York. J. Wildl. Manage. 64:463-473.

32. Seagle, S. W. and J. D. Close. 1996. Modeling white-tailed deer Odocoileus virginianus population control by contraception. Biol. Conserv. 76:87-91.

33. Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13:195-216.

34. Sklar, A. J. 2002. Tubal sterilization. Web address: http://www.emedicine.com/med/topic3313.htm. Accessed on 9-3-2003.

35. Turner, J. W., Jr., J. F. Kirkpatrick, and I. K. M. Liu. 1996. Effectiveness, reversibility, and serum antibody titers associated with immunocontraception in captive white-tailed deer. J. Wildl. Manage. 60:45-51.

36. Walock, S. C. 1997. Behavioral changes in a captive population of white-tailed deer after sterilization of does by tubal ligation. M.S. Dissertation. Mississippi State University, Mississippi State, MS.

37. Warren, R. J. 1997. The challenge of deer overabundance in the 21st century. Wildl. Soc. Bull. 25:213-214.

38. White, L. M., R. J. Warren, and R. A. Fayrer-Hosken. 1994. Levonorgestrel Implants as a Contraceptive in Captive White- Tailed Deer. J. Wildl. Dis. 30:241-246.

**Table 1.** Summary of anesthesia data from deer undergoing tubal ligations by laparotomy (n = 63).

| | Induction | | | Surgery | Anesthesia | Reversal | Reversal |
|---|---|---|---|---|---|---|---|
| | Telazol® (mg/kg) | Xylazine (mg/kg) | Ketamine[a] (mg/kg) | Duration (hr:min) | Duration (hr:min) | Yohimbine (mg/kg) | to Standing (hr:min) |
| Median | 2.7 | 2.7 | 2.6 | 1:02 | 2:33 | 0.4 | 0:27 |
| Min | 1.2 | 1.2 | 1.1 | 0:40 | 1:41 | 0.2 | 0:00 |
| Max | 4.7 | 5.0 | 6.0 | 1:47 | 4:38[b] | 0.8 | 1:55 |

[a] Ketamine is summarized only for those animals that required sedation in addition to the Telazol®/xylazine combination (n = 19).
[b] This animal was maintained sedated in the trap with 1.1 mg/kg xylazine, 5.7 mg/kg ketamine i.m. for 2:31 while awaiting surgery.

**APPENDIX B. Illinois Department of Natural Resources Scientific Permit-Application.**

Application Number:________

# ILLINOIS DEPARTMENT OF NATURAL RESOURCES
# SCIENTIFIC PERMIT-APPLICATION

**Personal Information**

Name of Applicants: Mathews, Nancy E. Birthdate: 3/9/58
Paul-Murphy, Joanne R. 4/20/54

Organization: Department of Wildlife Ecology and the School of Veterinary Medicine, University of Wisconsin-Madison

Mailing Address: 215 Russell Laboratory, 1630 Linden Dr. (DWE)
3152 Veterinary Medicine Building, 2015 Linden Dr. (SVM)

City: Madison State: WI Zipcode: 53706

Daytime Telephone Number: 608-263-6697 (NEM), 608-265-2608 (JPM)

Type of Permit Requested: **Research**, Salvage

Applicants's Qualifications (You may attach resume):

Qualifications Specific to the Project: Please see attached resumes.

Individuals Working Under Direction of Applicant:

| Name | Address | Birthdate |
|---|---|---|
| Robert A. MacLean, Jr. | 6208 Hammersly Rd., Madison, WI 53719 | 12/2/64 |
| Elizabeth S. Frank | 10001 W. Blue Mound Rd., Milwaukee, WI 53226 | 11/21/51 |

U.S. Fish and Wildlife Service Permits: none required

| Master Permittee | Permit Type | Permit Number |
|---|---|---|
| none required | | |

Description of Project (*You may attach project proposal*): Please see attached proposal

Title of Project: **An evaluation of surgical sterilization as a means of controlling an urban white-tailed deer population**

Duration of Project: November 2001- October 2005

Organization Sponsoring the Project: City of Highland Park

Funding Source: City of Highland Park

Description of monitoring, sampling or collecting Procedures:
Please see attached proposal

Specific flora, fauna or material to be monitored, sampled, or collected:

| Species, Family, Order | Type of Investigation | Number of Specimens |
|---|---|---|
| Odocoileus virginianus, Cervidae, Artiodactyla | population control | maximum of 110 |

Will the project involve species listed as state endangered or threatened? Yes / **No**

If the project involves endangered or threatened species, justify the need to employ these species: NA

Justification for collecting: Please see attached proposal

Disposition of collected or salvaged specimens: Animals that die incidentally to this research will be disposed of in accordance with the Illinois state guidelines and in accordance with Highland Park City procedures.

Location of Project

Address, General Location or County: This project will be headquartered at the Highland Park Police Department, 1677 Old Deerfield Rd, Highland Park, Illinois 60035. The research will take place within the 12.5 $mi^2$ boundary of the City of Highland Park, Lake County, Illinois.

I hereby certify that all statements made on the application are correct to the best or our knowledge.

Signature of Applicants:

Nancy E. Mathews, Ph.D. Date: 1/28/02

Joanne Paul-Murphy, D.V.M. Date: 1/28/02

Nancy E. Mathews, Ph.D.[1] and Joanne Paul-Murphy, D.V.M.[2]
With
Elizabeth S. Frank , M.A.[3] , and Robert A. MacLean, Jr., D.V.M.[4]
University of Wisconsin, Madison [1,2,4] and Milwaukee County Zoo[3]

## Introduction

**Justification**: Overabundance of white-tailed deer continues to challenge urban wildlife managers and local municipalities (Warren 1997). Municipalities have tried different management approaches to control white-tailed deer population densities (e.g. sharpshooting, trap and relocate, immunocontraceptives. While culling via lethal means is by far the most effective control technique, it is not an option in many urban settings due to logistical or political considerations. Trap and relocation programs are generally not cost effective and often there are difficulties in finding suitable sites to release the deer. Immunocontraception has more recently been hailed as a promising non-lethal management option for free-ranging populations. Porcine Zona Pellucida (PZP) has been tested extensively in white-tailed deer and free-ranging equids (Kirkpatrick 1985, 1991, 1995, 1996, Turner 1996, Rudolph et al. 2000). Female deer are darted at least twice in the first year and require annual boosters thereafter to maintain the effects of contraception. The largest studies, Fire Island National Seashore in New York and the campus of the National Institute of Standards and Technology in Maryland, have treated deer over six years. In both cases deer populations declined (ZooMontana 2000). Immunization against gonadotropin-releasing hormone (GnRH) was tested but does not appear to be reliable in preventing estrus (Becker 1999). While use of PZP continues to be explored, it is not a viable option for long-term population control over larger areas due to logistical difficulties and cost (Rudolf et al. 2000).

Other hormonal agents have been considered and tested in different formats, though none has lead to wide-spread acceptance for various reasons. Diethylstilbestrol (DES) proved successful when administered intramuscularly (Greer 1968, Harder 1974) or in silastic implants (Greer 1968, Bell 1975, Matschke 1977c) but was not well accepted in oral form (Harder 1974, Matschke 1977a). Melangestrol acetate (MGA) was also tried in an oral form but did not prevent or delay conception (Matschke 1977b). MGA implants prevented contraception for two years (Bell 1975, Plotka and Seal 1989) but did not provide for long-term contraception. The synthetic progestin, DRC-6246, also inhibited fertility for two breeding seasons (Matschke 1980). Levonorgestrel implants did not prevent pregnancies in captive white-tails (Plotka and Seal 1989, White 1994). More recent studies on Norgestomet implants show promise (DiNicola 1997). All hormonal agents need to be evaluated for their effect on secondary consumers.

In addition to immunocontraceptives and hormonal agents, several types of reversible and permanent contraceptives have been suggested and tried over the last thirty years with varying degrees of success. Mechanical devices proved unsuccessful in both white-tailed deer and elk. (Greer 1968, Matschke 1976). Chemical vasectomies performed on male white-tailed deer caused azoospermic ejaculates and were cost-effective (Bauman, pers. comm.). Yet, because virtually all bucks disperse, and residents essentially all must be treated for successful population control, male-based contraceptives is not a reasonable alternative for free-ranging white-tailed deer. Surgical sterilization of females is effective in preventing pregnancies but has not been tried at the population level (Greer 1968, Frank 1993, Walock 1997).

Recent field experimentation on the efficacy of sterilization as a means of controlling deer at the population-level on the grounds of the Milwaukee County Zoo, suggests that this technique holds promise (Frank et al. 1993). Over a five-year period (1990 to 1995) 16 free-ranging white-tailed deer (8 males, 8 females) were surgically sterilized. The number of deer regularly seen on zoo grounds dropped from a high of 12 in 1990 to 1 in 1993. Since 1995, no surgical procedures have been performed and the number of female white-tailed deer on the zoo grounds has remained constant at 1 or 2 per year. Longevities of study animals ranged from 10 months to over 7 years. No other methods of deer control have been employed in this study area. This preliminary work provides the only empirical foundation for this study. Despite numerous calls for research investigating the efficacy of surgical sterilization, no other previous studies have been completed (Hobbs et al. 2000).

Localized management of white-tailed deer, based on social behavior, has been a topic of research for nearly 20 years and generally revolved around lethal means of controlling deer in small areas. Previous studies have shown that as a result of female social behavior, it is possible to manage deer at a scale of under 1 square mile (Porter et al. 1991, Jones et al. 1997, McNulty et al. 1997). Numerous studies indicate that urban female deer use home ranges of under 190 acres (.3 $mi^2$). In fact, Etter (2001) indicates even smaller home ranges of does in Cook and DuPage County, IL. He reports that they ranged from 64 acres in summer to126 acres in winter (based on 95% minimum convex polygons). Females establish their home ranges overlapping and slightly extending the range of their mother (Mathews and Porter 1993), and tend to use traditional fawning areas each year. Females are highly philopatric (e.g., they stay in the same home range for life) and in this manner female deer form matrilines as a social group within a population.

Previous studies of urban deer indicate that dispersal of adult females ranges from 5-7% (Kilpatrick and Spohr 2000, Etter 2001 Given high levels of philopatry and low dispersal rates, it is reasonable to question whether population-level control may be applied at the level of a social group. It is quite possible that population level and localized regulation can be done at the level of a group, possibly reducing the overall number of animals required for treatment (or removal) to effect local results. This has been discussed and tested in previous research (Mathews 1989, Porter 1991, McNulty 1997). It has been further shown that immigrants rarely, if ever, succeed in joining a resident social group and do not succeed in becoming members of the breeding population (Jones et al. 1997). The lack of influx (immigration) into a social group lends veracity to the assumption of a closed population; a condition that would influence long term population control. No studies to date have explored the integration of non-lethal means of controlling deer populations with the existing knowledge of deer behavior as a means for controlling deer on a localized level.

**History of Deer Management in Highland Park**: The City of Highland Park has had a long history and intense interest in the management of its deer population. Since 1994 their Deer Task

Force has explored the issues related to efficient and publicly acceptable means of controlling their deer population. The Task Force has surveyed residents, performed aerial surveys, produced an informational booklet, and established a state-of-the-art geographic information system to track deer incidents. Residents are deeply divided about the type (lethal or non-lethal) of control they will accept of their deer population. Almost one year ago the Task force formulated recommendations on deer management for the City Council that included culling by lethal means, 20 deer per year. They also recommended looking into non-lethal control measures. One year later, November 2001, the City Council approved a motion to allow a research approach be taken to investigate the efficacy of surgical sterilization of female deer as an alternative means of regulating the deer population. This project reflects the culmination of the intentions of the residents and the first scientific approach to test sterilization as a management tool on a localized scale.

**Current Population Estimate**: Based on aerial surveys conducted by Highland Park from 1995-2001, we estimate an average population density ranging between 6 and 8 per $mi^2$ (Table 1 and 2; estimates are based on the assumption that the entire12.5 $mi^2$ is available habitat). Although aerial surveys taken at one point in time during the winter months are unlikely to reflect true, year-round abundance of deer, this is the only measure available from which to estimate the current deer population. We view it as highly likely that these numbers under estimate the deer population even after correcting for a range of detection. We derived the estimated density by correcting the results of the aerial survey for biases in observability in the helicopter counts. Many deer may be missed if they are under conifer canopy cover or in deep ravines. Standard corrections used throughout the Midwest for helicopter surveys range from 11% to 100%, depending on habitat type (Caughley 1974, Ludwig 1981, Floyd et al. 1979, Fuller 1990, Burgdorf 1991, Stoll 1991 et al., Beringer et al. 1998). In an urban setting, where there are well developed ravine systems, as well as open golf courses, we believe that the 60% detection rate most closely approximates the true error rate. We believe that this rate is conservative and will be modified when more measures of abundance are available. Further, Etter (2001) assumed a 66% detection rate in an area with less topographic relief. At this detection rate, the average winter deer population is 8 deer per $mi^2$. Additional means of estimating population are essential, however, to better refine this estimate. Further, based on recent urban deer research in DuPage County, we believe it is highly likely that the deer in Lake Forest show some seasonal movements. Etter (2001) found that up to 14% of does migrated 2.5 mi between summer and winter ranges. Thus, some animals may be leaving the area during the winter, and some animals may be migrating on to the area during the winter. It is important to note, however, that deer densities in DuPage county in Etter's study were an order of magnitude higher than those we believe to have in Highland Park. Some demographic parameters, including recruitment and dispersal, and perhaps migration, will be different in a less dense population.

Based on aerial surveys, the deer population has varied from a high of 145 in 1994 to a low of 65 in 2000. A deer reduction was implemented during the winter of 1995-1996 when 20 deer were translocated. Eight deer were removed via sharp shooting in 2001. Caskey (2001) has suggested that the counts in 2000 grossly underestimated the deer. Despite these fluctuations based on the aerial counts, it is most striking that the deer population has not shown significant increases during this time frame. Reductions in adjacent communities or a relatively high mortality rate, may partially account for the lack of population growth. Between 1995 and 1997 an average of 25 deer were killed each year in vehicle collisions. This may represent a significant portion of the population. In the absence of additional empirical demographic data, it is difficult to account for this seemingly anomalous pattern given the growth potential of the deer in adjacent communities. One possibility is that this population is at equilibrium (e.g., recruitment rate approximates mortality rate). Another is that predators may be significantly impacting fawn recruitment (e.g., coyotes) or additional adults are dying from other causes.

Highland Park has set a deer density goal of 5 deer/mi$^2$ over the entire 11 sectors (Caskey 1997). They have further specified density targets on a sector by sector basis. It is important to recognize that this figure was based on data from the uncorrected aerial surveys and is probably lower than their intention of the true target density. Again, assuming a detection rate of 60%, it is more likely that the true target density should be closer to 8 per sq mile. Consequently, it appears that the current population is very close to target densities. However, the City continues to have an unacceptable level of collision rates and complaints. We therefore believe that the target density should be set at 5/mi$^2$, slightly lower than current deer densities, for the purposes of this research. Should the findings of this research reveal new information causing us to rethink the current target, then the research target will be adjusted accordingly.

**Population Projections and Determination of Rates of Sterilization:** Using Etter's (2001) urban Chicago deer population model, we predicted the growth of the population over the next 5 years without sterilizations or reductions. Assuming similar demographic parameters to DuPage County, and a starting population of 108 animals, the population grew to over 1550 animals in 5 years. Given that the Highland Park deer population has not shown any sign of increase over the past 7 years, we must at this time conclude that the demographic parameters found in Etter's (2001) population are not similar to those in Highland Park. Thus, we choose not to use Etter's data for predicting population growth rates. Given that we do not know the demographic characteristics of this population, we shall adopt the population projection model proposed by Hobbs et al. (2000) that assumes a closed population at equilibrium, in order to estimate the number of does that need to be sterilized per year. While we can not assume that the Highland Park population is at equilibrium, we have no evidence to the contrary at this time.

Hobbs et al. (2000) present a stage-structured model to represent variation in the duration of the effect of fertility control agents. They conclude that more than 50% of the females will need to be maintained infertile to achieve meaningful population reductions even when fertility rates are low. Their models demonstrate that fertility control using long-lived or permanent sterilization can be more effective than culling in regulating deer numbers. Hobbs et al. (2000) and Boone and Wiegart (1994) caution that treating small, closed populations with irreversible agents increases the likelihood of population extinction relative to treatment by culling. Hobbs et al. (2000) indicate that approximately 10% of the population would need to be sterilized per year in order to achieve a 50% population-wide sterilization rate and a net reduction of the population. Hobbs et al. further show that when recruitment is .6 does/doe, and survival of adults is high (90%), then nearly 90% of the does must be rendered infertile to approach a target population density of less than 25 per sq mile. Swihart and DeNicola (1993), Boone and Wiegart (1994), Seagle and Close, 1996, and Nielsen et al. (1997) all found similar results.

If the model presented by Hobbs et al. (2000) is realistic, can we achieve either population stabilization or reduction given our current knowledge of population size in Highland Park? Etter (2001) indicates that recruitment rate varied between 0.39 and 0.54 for deer in DuPage County, while survivorship was approximately 93% year-round. Note that fetal rates (e.g., roughly equivalent to fecundity rate if all fetuses are born alive) collected from culled deer from adjacent communities (e.g., 1.12-2.0 fetuses per doe; M. Jones personal communication) are much higher than the recruitment rates reported by Etter (2001). However, recruitment (defined as the number of females surviving until breeding age) is generally much lower than fecundity rates. Thus, based on Hobbs et al. (2000) models, and adopting these rates from Etter (for lack of better data and which may over estimate recruitment), we estimate that we will need to sterilize 80-90% of does in the population. Assuming a 1:1 sex ratio, this equates to a maximum of 40-65 does during the course of the study. If sex ratios are skewed towards does, as Etter (2001; 60:40 does:bucks) and others have found in the Midwest, then we will need to sterilize more females. It is absolutely imperative that the population estimates, based on determinations of sex ratio, recruitment, survivorship, and dispersal be continually monitored. Our projections and population model will need to be revised as new information becomes available. Significant immigration, increases in recruitment or survival would lead to a slower rate of reduction of the population's growth rate. On the other hand, higher mortality, lower recruitment and little successful immigration would lead to negative growth rate and a deer population lower than target, if not to the elimination of all females from the population.

We propose to test the efficacy of surgical sterilizations as a means of regulating population growth of the white-tailed deer population in Highland Park, IL. We hypothesize that sterilizing 80-90% of breeding does will lead to a stable or declining population in a 4 year time period. We propose a sterilization rate to reduce the current deer density from $8/mi^2$ to $5/mi^2$, or a female population of $4/ mi^2$ to $2.5/ mi^2$ in this time frame.

**GOAL**: Investigate whether surgical sterilization of female deer can regulate a population of white-tailed deer within a 4 year period.

**Objectives:**

1) Assess the efficacy of surgical sterilization (e.g., laparoscopic tubal ligations) of adult and yearling female white-tailed deer as a means of limiting recruitment.

2) Assess the demographic impacts of sterilization at the levels of the population and social group (e.g., recruitment, survivorship).

3) Assess the behavioral impacts of sterilization at the levels of the population and social group (e.g., home ranges, movements and dispersal rates).

4) Evaluate the cost effectiveness of surgical sterilizations for use as a realistic population control technique in an urban area.

**Methods**

**General Study Area** --Highland Park (HP) is a 12.5 $mi^2$ (32.4 $km^2$) residential community bordering Lake Michigan, 26 miles north of Chicago, IL (Figure 1.). HP is bordered on the East by Lake Michigan, on the North by Highwood and Lake Forest, on the South by Northbrook and Glencoe, and on the West by Deerfield and Bannockburn. No major roadways provide barriers to deer movements from either the North or South. Greenbay Rd. and U.S. 41, Skokie Valley Rd., bordered by Union Pacific Railroad lines, subsect the community longitudinally. Five east-west arteries cross the community laterally, connecting it with suburbs to the West. The habitat throughout this community is a mixture of mature, deciduous and coniferous forest, maintained yards, and golf course-like grasslands. Ornamental plantings and non-native grasses provide high quality browse and forage year round for the deer.

**Control Area** – U.S. 41, Skokie Valley Rd. is a major north-south road that we believe provides a significant barrier to deer movements between the eastern and western Sectors of HP. We have chosen a control site to the West of U.S. that includes Sectors 1, 3, 6, 9, an approximately 4 $mi^2$ area on the western border of HP. Based on police reports and prior observations of residents, deer in these sectors are believed to move freely between Deerfield, and Highland Park, crossing the Chicago River. Collectively, 35 deer were observed among these Sectors in the 2001 aerial survey.

Sector 1 includes the Heller Nature Center and low density residential zoning, including multi-acre homes. Sector 3 includes Highmoore Park (a 10 acre Illinois Nature preserved), Olson Park, Berkeley Prairie, Hybernia and the adjoining Prairie Wold Slough wetlands, and the Deerfield High School Property. Residential zoning in this sector is a combination of low and medium densities. Habitat loss from the development of Painter's Lake and Emerald Woods contribute to the movement of deer in and out of this sector. Sector 6 includes Westridge Park. Sector 9 includes Red Oak Park and Woodridge Park, and has is bordered by U.S. 41 on the East and Lake Cook and Northbrook Court Shopping Center on the South.

**Treatment Area**– The treatment area is comprised of approximately 8.5 $mi^2$ east of U.S. 41, Skokie Valley Rd. This includes Sectors 2, 4, 5, 7, 8, 10, 11. Thirty one deer were sighted among these sectors in the 2001 aerial survey, roughly equivalent to the number observed in the control area. Based on Police reports and prior observations of residents, we believe that the deer move freely among these sectors, in and out of the HP community, but not between the designated control and treatment areas.

Sector 2 includes Sleepy Hollow and Centennial Park, as well as Old Elm Golf Course. This sector has had the largest number of individuals observed. Sector 4 contains the Highland Park Country Club and Exmoor Country Club. Sector 5 included Moraine Beach, Park Avenue Beach, and Central Park as well as a ravine system. Sector 7 includes 3 golf courses, while sector 8 includes 2 parks, Rosewood Beach and the highest concentration of ravine systems. It is likely that this sector contains a high number of deer that have not been detected by the aerial surveys. Sector 10 contains the Botanic Gardens, the Northshore Sanitary District property and Northmoore Country Club. Few deer have been observed in this sector. Sector 11 contains many ravine corridors, the Turnbullwoods Forest Preserve and is believed to host a significant deer number of deer.

**Capture and Handling Methodology**

**Capture locations** – Potential capture sites will be selected in conjunction with the Highland Park Police Department based on the extensive records of sightings, collisions or complaints. Sites will be selected in areas with the highest number of sightings of fawns and adults, as well as car collisions and complaints. Capture sites will be established only with the prior written permission of the land owner. Prior to the placement of traps in the field, approximately 10-15 bait sites will be established in each of the control and treatment study areas. Bait sites will be established at least 2 weeks prior to initiation of any trapping to assess deer activity. A commercial deer feed will be used, and 10 gallons of feed placed on each site daily. Evidence of use, and direct observations of deer will be recorded daily to aid in identifying the best trapping locations. Trapping locations may be changed throughout the trapping season based on deer activity patterns.

**Capture techniques** -- Deer will be captured using Clover traps (McCullough 1975), baited with commercial deer feed, as the primary means of capture. Deer will be removed from the traps using the standard approach of collapsing the soft-sided net trap around the deer, blindfolding, anesthetizing and removing the deer. Based on the success of this approach, other means such as Stephenson box traps or darting with transmitter darts will be considered. If Stephenson traps are used, deer will be removed again in the conventional manner of using a handling net over the trap entrance, coaxing the deer into the net, blindfolding and anesthetizing. If darting is used, deer will be darted only at designated bait sites free from hazards and not in close proximity to residential dwellings. The dart gun (Dan-Inject "AC Model" CO2 rifle with a 13mm barrel to accommodate .50 caliber 6ml Pneudart radiotransmitter darts) will use transmitter darts for more efficient recovery of the deer. Darting will be done by the veterinarian who is highly skilled with the use of darting equipment. The possibility exists that some does will be trap-shy. In these cases every effort will be made to capture the deer using darting.

Clover traps were selected as the primary means due to the high rate of success when used by the Highland Park Police Department in previous years and because of safety concerns for the residents. Clover traps have the lowest potential to accidentally harm both people and deer. Darting may be used in the case of targeted deer that do not come in to the Clover traps. The final selection of techniques will be based on human safety (e.g., to the residents of HP) and minimizing deer injuries or capture myopathy.

Trapping efforts will be proportional between the control and treatment areas (based on size of the study area) in an effort to standardize trap-effort. A minimum of 5-15 traps will be operated, simultaneously, throughout the trapping season per study area (November through March of each year). Trapping will continue each season with the goal of maximizing captures of the number of females up to the maximum number to be treated based on the population estimates. Traps will be operated during the nights and pinned open during the days following the removal of any captures. Trapping will continue on a 7 day per week basis during the peak of the capture season (December - January). Traps will not be operated when temperatures drop below $15^0$ F. In the event that we do not trap our target number of does, we may choose to operate traps during the summer, post parturition. We may be more likely to capture animals by darting during the warmer months. No animals will be handled when temperatures exceed $85^0$F. Does will not be captured during the time they are lactating and fawns are dependent. Captures would not resume until such time as fawns are mostly weaned (e.g., between late June and mid-August)

**Handling, Anesthesia and Surgical Procedures** -- Deer will be anesthetized at the capture site using accepted methodology in veterinary medicine andwildlife management (Warren 1997). Captured animals will be immediately blindfolded and sedated via an intramuscular injection of a combination of xylazine hydrochloride (4mg/kg) and ketamine hydrochloride (4mg/kg), or Telazol® (4.4mg/kg) and xylazine hydrochloride (2.2mg/kg). The exact combination will be determined after several trials to determine which best sedates the animals in general. It is understood that individuals may respond differently to the standard doses of anesthesia, thus doses may also be varied depending on the responses observed. This adaptive approach is standard practice especially when sedating animals during the winter months when animals may or may not be nutritionally deprived. When appropriately sedated (e.g., when animal is no longer struggling), the animal will be given a physical exam, and vital signs (respiratory rate, heart rate and temperature) will be recorded. Butorphanol (0.2mg/kg IM) will be administered to deer for preemptive pain control every 2 hours. Procaine penicillin G (22,000 u/kg IM) will be administered once to does for infection prophylaxis. On the treatment site, only does older than 9 months will be retained for treatment, all bucks and fawns less than 9 months old will be ear tagged and released on site. On the control site, all captured animals will be ear tagged and only adult does older than 9 months will be radio collared. The established withdrawal times for each of these drugs is as follows: Xylazine - 7 days, Penicillin G - 16 to 30 days, Ketamine - 7 days, Telazol - 30, Yohimbine - 7, and butorphanol - 30 days.

Deer will be transported from the trap site in a prone position in a handling crate or gurney, to a heated and cooled ambulance for aseptic surgery. Ketamine will be administered during transport as needed to maintain a light plane of anesthesia. Prior to surgery, each deer will be weighed, measured (chest girth and hind foot length), and examined for ectoparasites. Age will be determined using standard tooth wear and replacement patterns (Severinghaus 1949). A venous blood sample and a muscle tissue sample will be taken during surgery from laparoscopic incision site. Ectoparasites (e.g., ticks) will be collected and examined at a later date for the presence of the Lyme Disease spirochete (Borellia burgdorferi). While health monitoring is not a specified goal of this study, we believe that it is prudent to screen at a later date for tick titers (Lyme, ehrlichias), Leptospirosis, Epizootic Hemorrhagic Disease, Bluetongue, and Brucellosis using the blood samples collected from this study. Assessing the health of the population may become important to understanding the factors limiting population growth.

Treatment animals will be intubated and maintained on 100% oxygen and Isoflurane vapor at 2% or to effect. Sterile instruments will be used for each deer to prevent cross contamination with harmful bacteria. Laparoscopic tubal ligation will be performed by the field veterinarian (RSM). Corpora luteae will be counted if possible during surgery to estimate maximum natality rate. The number of fetuses observed per female will be recorded and will provide the most reliable estimate of natality. Gravid females will be allowed to carry fetuses to term. Previous research demonstrates that tubal ligation, during early to late stages of gestation, does not affect the ability of a large mammal to carry a fetus to term (Frank and Sajdak 1993). All procedures used will conform to standards set by University of Wisconsin's Research Animal Resources Center, Animal Use and Care Protocol (Appendix A).

Post surgery, animals will be ear tagged and fitted with a 480 g radio transmitter with a battery life of at least 3 years (ATS, Model 2520; Appendix B). Each collar will be fitted with approximately 1.5 inches of space (e.g., two finger widths) between the (neck just below the ear line) and collar. This amount of spacing has traditionally allowed for normal growth in older fawns and yearlings (Mathews 1989). Ear tags will include 1 Monel metal tag (to be attached to the anterior portion of left ear) and 2 plastic cattle tags (individually numbered, color coded by sex and attached to the posterior edge of both ears). Plastic tags will be clearly labeled "Experimental Animal - Do Not Consume".

Deer will be returned to the capture site, using the same handling procedures as previously described. Anesthesia will be reversed with Yohimbine (0.26mg/kg IV) or Tolazoline (3mg/kg IV). While there currently exists no reversal agent for Ketamine HCl, the effects of this drug generally wear off relatively quickly, though in some animals effects can linger. Deer will only be released when capable of standing and when they demonstrate appropriate alertness (e.g., vigilant enough to show a fear response). Researchers will stay in attendance to maintain the deer in a prone or left, lateral position until the effects wear off. Animals will be covered in wool blankets if the temperature is below 20$^{o}$ F. Each animal will be observed or relocated at regular intervals (every 2 hours, for 6 hours) post release. Total handling time will be approximately 2.5-3 hrs per deer.

Each radio collar is fitted with a mortality sensor (set at a 4 hour delay) to indicate potentially incapacitated or dead deer. If a deer has sustained more than minor injuries that are not treatable with a single intervention, the veterinarian will determine whether euthanasia is warranted according to the expectations of a reasonable quality of life, using the following criteria: inability to ambulate, weight loss > 10% (assessed only after re-capture), signs of serious infection or debilitation. If euthanasia is deemed necessary, a commercial solution (pentobartital-based) will be used at 1cc/5kg IV(or other appropriate dose). If the deer is not restrained at the time of the decision to euthanize, we will attempt to recapture through darting. At the end of the study period, no attempt will be made to remove radio collars or ear tags. Causes of death for all deer found dead will be determined based on circumstantial evidence.

**Animal Monitoring**-- *Radio telemetry*: Control and treatment deer will be monitored using a variety of methods throughout the study. For treatment animals, movements will be monitored via radio telemetry every 2 hours post release for the first 6 hours. Thereafter, these deer will be relocated twice daily for 2 weeks, with a visual attempt for the first 7 days and then a minimum of once weekly for the remainder of the study. Control deer will be relocated a minimum of 1-2 times per week to obtain sample sizes comparable to the treatment deer. Efforts will be made to obtain a sample of 30-40 relocations per deer per reproductive season (pre-fawning: February - April; fawning: May-July; pre- breeding: August -October; Breeding: November-January). Determination of social groups will be made using trapping, telemetry and observational data.

*Spotlight Surveys*: Spot light surveys will be conducted once per month throughout the duration of the study to obtain an index of deer abundance. Standard driving routes will be established in both the control and treatment areas. Surveys will involve 2 observers using 100,000 candle power spotlights out of both sides of a vehicle, driving at 5-10 mph. Surveys will commence approximately 2 hours past sun down on nights when weather conditions are conducive to good observations (e.g., no precipitation, < 5 mph winds).

*Observations*: Residents of Highland Park will be provided with record sheets on a monthly basis to record sightings of deer. Data to be collected will include: date, time, location (by sector), nearest intersection, total number of deer, number of deer by sex, number of fawns, number of marked animals. Record sheets will be returned to the Highland Park Police Department on a monthly basis.

*Mark-Recapture*: Annual trapping will provide a limited means of assessing deer abundance. We will use standard capture-recapture methodology (e.g., Peterson estimate based on proportion of marked to unmarked animals) for estimates.

*Aerial Surveys*: The City of Highland Park will continue to conduct their yearly aerial helicopter surveys using their previous methodology.

*Deer/Vehicle collision rates and Dead Deer*: Deer - vehicle collision rates often provide an effective index to population density. Rates will continue to be monitored and calibrated against other measures of abundance. Reproductive tracts will be collected from does that are recovered from car collisions to gain an additional measure of natality. The number of fetuses and corpora lutea will be recorded to augment the data collected from the live animals.

**Analyses and Evaluation**

Objective 1 <u>Success of Tubal Ligations</u>: The success of this objective will be evaluated based on observations and recapture of treated does. Evidence of pregnancy (presence of fetus, enlarged teats), observation of fawns or changes in home range patterns during fawning season (e.g., classic reduction of home range to less than 1 ha during late May and early June) will serve as the only means of evaluating the success of the tubal ligation post treatment on a per animal basis.

Objective 2 <u>Impacts on behavior</u>: Home range sizes of individual does will be assessed using radio telemetry data and program SEAS (J. Cary unpublished program, UW-Madison). Home ranges of social groups will be determined from the collective home ranges of all of its members. Attempts will be made to acquire a minimum of 40 relocations per season (pre-breeding, fawning, breeding, post breeding) for each deer. Minimum convex polygons (50% and 75%) and adaptive kernal estimates will be calculated and compared between the control and treatment group. The size and degree of fidelity of each individual deer's home range and each social group will be compared between the control and treatment group using the procedures of McNulty et al. (1997). Dispersal rates of resident females will be compared and evaluated for change during the duration of the study using t-tests and/or ANOVA.

Objective 3 <u>Population density and Demographic Characteristics</u>: The relative abundance of deer in the control area and treatment area will be determined using capture-recapture methodology. Based on these estimates, the relative abundance will be compared using ANOVA, blocked by year. Estimates of herd composition (e.g., sex ratio, age distribution, emmigration) will be made using data from all survey sources (trapping and observations). Annual recruitment will be estimated based on doe:fawn observations and capture data. Analysis of reproductive tracks from animals killed by car collisions may provide additional measures of natality but none of recruitment. Annual mortality rates will be determined using the staggered-entry design (Pollock et al. 1989).

Population projections will be made using the Chicago-area-specific model developed by Etter (2001) and modified to account for sterilizations. This modified model, or another deemed suitable, will be used to derive estimates of the number does that should be sterilized to meet

HP's goal of 5 deer/mi2. This goal will be re-evaluated in light of more accurate population estimates acquired through this study. No attempts will be made to empirically determine the survival and dispersal of males. These parameters will be estimated using data from other urban studies (Etter 2001) for the purposes of population projection models.

Objective 4 Efficacy of surgical sterilizations for population control: Using population models adapted from Hobbs et al. (2000) and Etter (2001), and empirical data we collect during the course of this study, we will evaluate the efficacy of surgical sterilizations, under the conditions we experienced, as a population-level management tool. We will also include a cost analysis using an approach similar to Rudolph et al. (2000).

## Reporting

Quarterly reports will be made to the IDNR and HP City Council. These reports shall include a brief summary and interpretation of the data. Yearly reports will include preliminary analyses of data, including population estimates and an evaluation of the preliminary estimates of the number of does to be treated in order to meet population goals. Revisions of these target goals will be made at the end of each year.

## Humane Care and Animal Use Issues

Every attempt will be made in this research to minimize the number of animals treated, and the physical pain inflicted upon them. Strict guidelines are set forth buy the Research Animal Resources Center (RARC) at the University of Wisconsin, Madison. The final ACUC permit was issued in December 2001, with a protocol code of A0104931001. The researchers deem that the goals of this research cannot be met through alternative means or through the use of alternative, non-invasive procedures.

## Assumptions and Limitations of Research Design

We recognize that a number of limitations exist that will restrict the generalization of the results of this research to other urban or suburban areas. First, the logistical investment inherent in the design and purpose of this research, precludes the use of replicates in our study areas. The potential for auto correlation within our results clearly exists. For these reasons, we define the population that we are impacting as those deer within the political boundaries of HP proper. We choose individual deer as our primary study unit. Our results may or may not apply to other urban deer populations because of variations in deer density, behavior, and demographic characteristics (e.g., recruitment, survival, mortality, and dispersal rates). Finally, we are aware that the most efficient means of immediately reducing a deer population are through the exclusive use of lethal control. Our approach assumes that lethal means are not an option and we make no generalizations about the long term efficacy of either approach. This has yet to be investigated in a comparative manner.

## Literature Cited

Bauman, K. L. 1994. Chemical vasectomies of male white-tailed deer at Tyson Research Center. pers. comm.

Becker, S. E., W. J. Enright, and L. S. Katz. 1999. Active immunization against gonadotropin-releasing hormone in female white-tailed deer. Zoo Biology 18: 385-396.

Bell, R. L. and T. J. Peterle. 1975. Hormone implants control reproduction in white-tailed deer. Wildlife Society Bulletin 3: 152-156.

Beringer, J., L. P. Hansen, and O. Sexton. 1998. Detection rates of white-tailed deer with a helicopter over snow. Wildlife Society Bulletin 26:24-28.

Boone, J. L., R. G., Wiegert. 1994. Modeling deer herd management: sterilization is a viable option. Ecological Modeling 72:175-186.

Burgdorf, S. J. 1991. White-tailed deer (Odocoileus virginianus)population estimation from aerial and spotlighting censuses in Indiana. M.S. Thesis, Purdue University, West Lafayette, IN. 53 pp.

Caskey, M. A. 1997. Summary of Deer Task Force Request for Council Action. November 1997. City of Highland Park, Department of Police.

Caskey, M. A. 2001. 2001 Deer population permit proposal/application. January 22, 2001. City of Highland Park, Department of Police. 10 pp.

Caughley, G. 1974. Bias in aerial survey. Journal of Wildlife Management 38:921-933.

DiNicola, A. J., D. J. Kesler, and R. K. Swihart. 1997. Dose determination and efficacy of remotely delivered norgestomet implants on contraception of white-tailed deer. Zoo Biology 16:31-37.

Etter, D. R. 2001. Ecology and management of overabundant white-tailed deer from suburban Chicago, Illinois. Ph.D. Dissertation, University of Illinois at Urbana-Champaign. 106 pp.

Floyd, T. L., L.D. Mech, M. Nelson. 1979. An improved method of censusing deer in deciduous-coniferous forests. Journal of Wildlife Management. 43:258-261.

Frank, E. S., and S. L. Sajdak. 1993. Sterilization as a method of controlling an urban white-tailed deer population, AAZPA Regional Proceedings 1993:485-490.

Fuller, T. L. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs. 110:1-37.

Greer, K. R., W. W. Hawkins, Jr., and J. E. Catlin. 1968. Experimental studies of controlled reproduction in elk (wapiti). Journal of Wildlife Management 32(2): 368-375.

Harder, J. D. and T. J. Peterle. 1974. Effects of diethylstilbestrol on reproductive performance in white-tailed deer. Journal of Wildlife Management 38: 183-196.

Hobbs, N. T., D. C. Bowden, D. L. Baker. 2000. Effects of fertility control on populations of ungulates: General, stage-structured models. Journal of Wildlife Management 64:473-491.

Jones, M.L., N. E. Mathews, and W. F. Porter. 1997. Influence of social organization on the dispersal and survival of translocated female white-tailed deer. Wildlife Society Bulletin 25:272-277.

Kilpatrick, H. J. and S. M. Spohr. 2000. Movements of white-tailed deer in a suburban landscape: a management perspective. Wildlife Society Bulletin 28: 1038-1045.

Kirkpatrick, J. F. and J. W. Turner, Jr. 1985. Chemical fertility control and wildlife management. Bioscience 35:485-491.

Kirkpatrick, J. F. and J. W. Turner, Jr. 1991. Reversible fertility control in nondomestic animals. Journal of Zoo and Wildlife Medicine. 22(4):392-408.

Kirkpatrick, J. F. and J. W. Turner, Jr. 1995. Urban deer fertility control: scientific, social and political issues. Northeast Wildlife 52: 103-116.

Kirkpatrick, J. F., J. W. Turner, Jr., and I. K. M. Liu. 1996. Effectiveness, reversibility, and serum antibody titers associated with immunocontraception in captive white-tailed deer. Journal of Wildlife Management 60: 45-51.

Kirkpatrick, J. F. and J. W. Turner, Jr. 1997. Urban deer fertility control: the seven stages of grief. Wildlife Society Bulletin. 25:515-519.

Kirkpatrick, J. F., J. W. Turner, Jr., I. K. M. Liu, R. A. Fayrer-Hosken, and A. T. Rutberg. 1997. Case studies in wildlife immunocontraception: wild and feral equids and white-tailed deer. Reproductive Fertility and Development 9:105-110.

Ludwig, J. 1981. Proportion of deer seen in aerial counts. Minnesota Wildlife Resources Quarterly 41:11-19.

Mathews, N. E. 1989. Social structure, genetic structure and anti-predator behavior of white-tailed deer in the central Adirondacks. Ph.D. dissertation. State University of New York, College of Environmental Science and Forestry. Syracuse, New York. 181 p.

Mathews, N. E., and W. F. Porter. 1993. Effects of social structure on genetic structure of white-tailed deer. Journal of Mammalogy 73:4-7.

Matschke, G. H. 1976. Non-efficacy of mechanical birth control devices for white-tailed deer. Journal of Wildlife Management 40: 792-795.

Matschke, G. H. 1977a. Microencapsulated Diethylstilbestrol as an Oral Contraceptive in White-tailed deer. Journal of Wildlife Management 41: 87-91.

Matschke, G. H. 1977b. Antifertility action of two synthetic progestins in female white-tailed deer. Journal of Wildlife Management 41: 194-196.

Matschke, G. H. 1977c. Fertility control in white-tailed deer by steroid implants. Journal of Wildlife Management 41: 731-735.

Matschke, G. H. 1980. Efficacy of steroid implants in preventing pregnancy in white-tailed deer. Journal of Wildlife Management 44: 756-758.

McCullough, D. R. 1975. Modification of the clover deer trap. California Fish and Game Journal 61:242-244.

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

McShea, W. J., S. L. Monfort, S. Hakim, J. F. Kirkpatrick, I. K. M. Liu, J. W. Turner, Jr., L. Chassy, and L. Munson. 1997. Immunocontraceptive efficacy and the impact of contraception on the reproductive behaviors of white-tailed deer. Journal of Wildlife Management. 60:23-34.

Nielsen, C. K., W. F. Porter, and H. B. Underwood. 1997. An adaptive management approach to controlling suburban deer. Wildlife Society Bulletin 25:470-477.

Plotka, E. D. and U. S. Seal. 1989. Fertility control in female white-tailed deer. Journal of Wildlife Diseases 25: 643-646.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

Porter, W. F., N. E. Mathews, H. B. Underwood, W. R. Sage, and D. F. Behrend. 1991. Gas molecule theory and management of white-tailed deer. Environmental Management 15:809-814.

Rudolph, B., W. F. Porter, H. B. Underwood. 2000. Evaluating immunocontraception for managing suburban white-tailed deer in Irondequoit, New York. Journal of Wildlife Management 64:463-473.

Seagle, S. W. and J. D. Close. 1996. Modeling white-tailed deer (*Odocoileus virginianus*) population control by contraception. Biological Conservation 76:87-91.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management. 13:195-216.

Stoll, R.J.,, Jr., W. McClain, J.C. Clem, and T. Plageman. 1991. Accuracy of helicopter counts of white-tailed deer in western Ohio farmland. Wildlife Society Bulletin 19:309-314.

Swihart, R. K. , and A. J. DeNicola. 1993. Modeling the impacts of contraception on populations of white-tailed deer. Pages 151-163 *in* Urban deer: a manageable resource? Proceedings of the1993 Symposium of the North Central Section, The Wildlife Society, St. Louis, Missouri, USA.

Turner, J.W., Jr., J. F. Kirkpatrick, and I. K. M. Liu. 1996. Effectiveness, reversibility and serum antibody titers associated with immunocontraception in captive white-tailed deer. Journal of Wildlife Management 60: 45-51.

Walock, S. C. 1997. Behavioral changes in a captive population of white-tailed deer after sterilization of does by tubal ligation. MS Thesis. Mississippi State University.

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

White, L. M., R. J. Warren, and R. A. Fayrer-Hosken. 1994. Levonorgestrel implants as a contraception in captive white-tailed deer. Journal of Wildlife Diseases 30(2): 241-246.

ZooMontana. 2000. Wildlife fertility control: fact & fancy. Billings, MT: ZooMontana.

Table 1. Results of helicopter surveys of white-tailed deer in Highland Park, IL, 1994-2001.

| | | Corrected Counts by Detection Rate | | | |
|---|---|---|---|---|---|
| Year | # Observed | 50% | 60% | 70% | 80% |
| 1994 | 87 | 174 | 145 | 124 | 108 |
| 1995 | 65 | 130 | 108 | 93 | 81 |
| 1997 | 67 | 134 | 112 | 96 | 84 |
| 2000 | 39 | 78 | 65 | 56 | 49 |
| 2001 | 65 | 130 | 108 | 93 | 81 |

| Mean | 65 | 129 | 108 | 92 | 81 |
|---|---|---|---|---|---|

Table 2. Density estimates of white-tailed deer based on corrected aerial surveys in the $12.5^2$ mi Highland Park, IL, 1994-2001.

| | | Density estimates per mi$^2$ based on different correction rates | | | |
|---|---|---|---|---|---|
| Year | Uncorrected | 50% | 60% | 70% | 80% |
| 1994 | 6.9 | 13.9 | 11.6 | 9.8 | 8.6 |
| 1995 | 5.2 | 10.4 | 8.6 | 7.4 | 6.5 |
| 1997 | 5.4 | 10.7 | 8.9 | 7.7 | 6.7 |
| 2000 | 3.1 | 6.2 | 5.2 | 4.5 | 3.9 |
| 2001 | 5.2 | 10.4 | 8.6 | 7.4 | 6.5 |
| Mean | 5.2 | 10.3 | 8.6 | 7.4 | 6.4 |

**Appendix C. Results of regression analyses to test for differences among seasonal home ranges between the home ranges sizes of treatment and control deer on Highland Park, IL 2002-2005 (Statistically significant results in yellow).**

C1. All deer, using 95% kernel estimates.

| | P values |
|---|---|
| Affected/Unaffected | 0.3489 |
| Age | 0.0309 |
| Season | <0.0001 |
| Pre-rut vs. Gest | <0.0001 |
| Pre-rut vs. Part | 0.2754 |
| Pre-rut vs. Rut | 1.0000 |

| | |
|---|---|
| Gest vs. Part | 0.0419 |
| Gest vs. Rut | 0.0003 |
| Part vs. Rut | 0.3447 |

C2. Treatment deer, using 95% kernel estimates.

| | P values |
|---|---|
| Affected/Unaffected | 0.5239 |
| Age | 0.1482 |
| Season | 0.0368 |
| Fawn vs. Gest | 0.0397 |
| Fawn vs. Part | 0.3435 |
| Fawn vs. Rut | 0.9642 |
| Gest vs. Part | 0.7393 |
| Gest vs. Rut | 0.2325 |
| Part vs. Rut | 0.7746 |

C3. All deer, using 95% kernel estimates during parturition season.

| | P values |
|---|---|
| Affected/Unaffected | 0.4217 |
| Age | 0.0039 |

C4.. All deer, using 50% kernel estimates during parturition season.

| | P values |
|---|---|
| Affected/Unaffected | 0.3871 |
| Age | 0.0079 |