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POPULATION SIZE ESTIMATION AND QUALITY MANAGEMENT TECHNIQUES FOR A LOCAL POPULATION OF WHITE-TAILED DEER (ODOCOILEUS VIRGINIANUS)

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Mark Earl Moore

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Scott Winterstein
Major professor

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POPULATION SIZE ESTIMATION AND QUALITY MANAGEMENT TECHNIQUES FOR A LOCAL POPULATION OF WHITE-TAILED DEER (ODOCOILEUS VIRGINIANUS)

By

Mark Earl Moore

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ABSTRACT

POPULATION SIZE ESTIMATION AND QUALITY MANAGEMENT TECHNIQUES FOR A LOCAL POPULATION OF WHITE-TAILED DEER (ODOCOILEUS VIRGINIANUS)

By

Mark Earl Moore

Infrared triggered cameras and monitors were used to census white-tailed deer (*Odocoileus virginianus*) on South Fox Island, a 1,400 ha. island in Lake Michigan in Lelanau County, Michigan. Twenty-day censuses were conducted in September (pre-harvest) and the last two weeks of November and the first two weeks of December (post harvest) of 1993 and 1994. The population was estimated using: (1) pellet group surveys, (2) Lincoln-Peterson estimators utilizing camera and harvest data, (3) the ratio estimator of individually identifiable fork antlered bucks to spike bucks, bucks:does, and does:fawns from the camera data, and (4) the change-in-ratio of males to females in the pre- and post harvest camera censuses. A modified Lincoln-Peterson and the ratio estimator yielded the best estimates during the post harvest censuses when compared to population estimates derived from the harvest data. Infrared camera systems can be effectively used to monitor deer in their natural habitat.

ACKNOWLEDGEMENTS

This project could not have been successfully completed without the assistance of many people. I would like to express my appreciation to my major professor Dr. Scott R. Winterstein for all of his help, support, and professional wisdom that he so graciously bestowed upon me. I would also like to thank my committee members Dr. Rique Campa and Dr. James Sikarski, DVM. for their assistance in reviewing my manuscript. A special thanks to Dr. Harry Jacobson from Mississippi State University for his expert assistance, for reviewing my manuscript, and for the use of his drop-nets.

I extend my gratitude to David V. Johnson with Victor International and the Michigan Department of Natural Resources, Wildlife Division for funding and making this project possible. This project was partially supported by the Federal Aid in Wildlife Restoration Act under Pittman-Robertson project W-127-R. A special thanks to all Mirada Ranch employees who assisted me in the field and helped to make this project a success. I would like to extend my appreciation to Island Airways for safely transporting me and my supplies to and from the island.

South Fox Island proved to be a wonderful place and without the support of the hunters this project would not have been as successful. Thanks to all MDNR personnel who assisted with pellet group surveys each spring. I would like to extend my deepest gratitude to the faculty and staff at Michigan State University's, Department of Fisheries and Wildlife for allowing me to have this opportunity to further my education.

I thank my entire family for allowing me to have the opportunity to broaden my horizons and for their support through the many missed holidays and special events.

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INTRODUCTION

White-tailed deer (Odocoileus virginianus) are one of Michigan's most prized big game mammals. According to the U.S. Fish and Wildlife Service (1982), of all the managed wildlife species, none are as popular or more commonly hunted than the white-tailed deer. With an ever increasing number of archery and firearm deer hunters (Winterstein et al. 1995), the Michigan Department of Natural Resources (MDNR) will need more efficient and more accurate population estimators to manage the state's deer herd. Even though white-tailed deer have been studied extensively in Michigan, (Eberhart and Van Etten 1956, King 1970, Ozoga et. al. 1994, and Ryel 1971) researchers and managers contend that current population estimation techniques (e.g., pellet group counts) are time consuming and expensive to use. Additionally, it is questionable that they provide dependable population estimates.

The science of wildlife population estimation confuses many wildlife biologist, yet it dictates every action that they take. Wildlife population estimation began with simple mark-recapture models that Lincoln and Peterson devised in the early 1900's (Seber 1982). From the Lincoln-Peterson model, many complex models have since evolved (e.g., Chapman and Jolley-Seber) (Seber 1982).

Population indices are another way to look at populations since they are directly related to the true population (Ratti and Garton 1994). An index should follow the same trends as the true population over time. Population indices (e.g., pellet group counts and call counts) are used by many wildlife management agencies as a basis for management recommendations and decisions.

The MDNR has relied extensively on pellet group surveys (counts) (Eberhart and Van Etten 1956) to estimate white-tailed deer populations, even though it has come under extreme criticism over the past 40 years. According to Eberhart and Van Etten (1956), large errors in population estimates could result if: (1) not all pellet groups in the sample area are counted and (2) if old pellet groups are counted as new pellet groups. Van Etten and Bennett (1965) stated that population estimates from pellet group counts tend to be conservative. Fuller (1991) concluded that estimates by pellet group counts do not directly correlate to the true population size.

The MDNR currently uses pellet group surveys, deer-vehicle accidents, and spot-light surveys in the northern 2/3 of the state to obtain deer population trends. In the southern lower peninsula the MDNR has been using sex-age kill data, deer-vehicle accident data, and crop damage data to estimate population trends. Although the pellet group survey is one of the most expensive and labor intensive it has a long tradition of use as a population estimator by the MDNR.

OBJECTIVES

The main objective of the study was to compare and evaluate the usefulness of four techniques for population estimation of white-tailed deer on South Fox Island, Michigan. Estimators used were:

(1) Pellet group counts

(2) Mark-recapture estimator

(3) Ratio estimator

(4) Change-in-ratio estimator

The pellet group index was compared to each of three estimators (mark-recapture, ratio, and change-in-ratio) derived from photographic data collected by infrared camera systems.

A second objective of the study was to initiate and evaluate a quality white-tailed deer management program.

STUDY AREA AND HISTORY

South Fox Island offered a unique opportunity to study a closed population of white-tailed deer in their natural habitat. The study was conducted from August 1993, to December 1995. Benefits of using an island setting were that I could control the deer population by manipulating different harvest strategies and that I could control what types, of management activities, if any, were implemented.

South Fox Island is located in Leelanau County in Lake Michigan approximately 48-km due west of Charlevoix (Figure 1.). The island is approximately 8-km^2 in size with 18.5-km

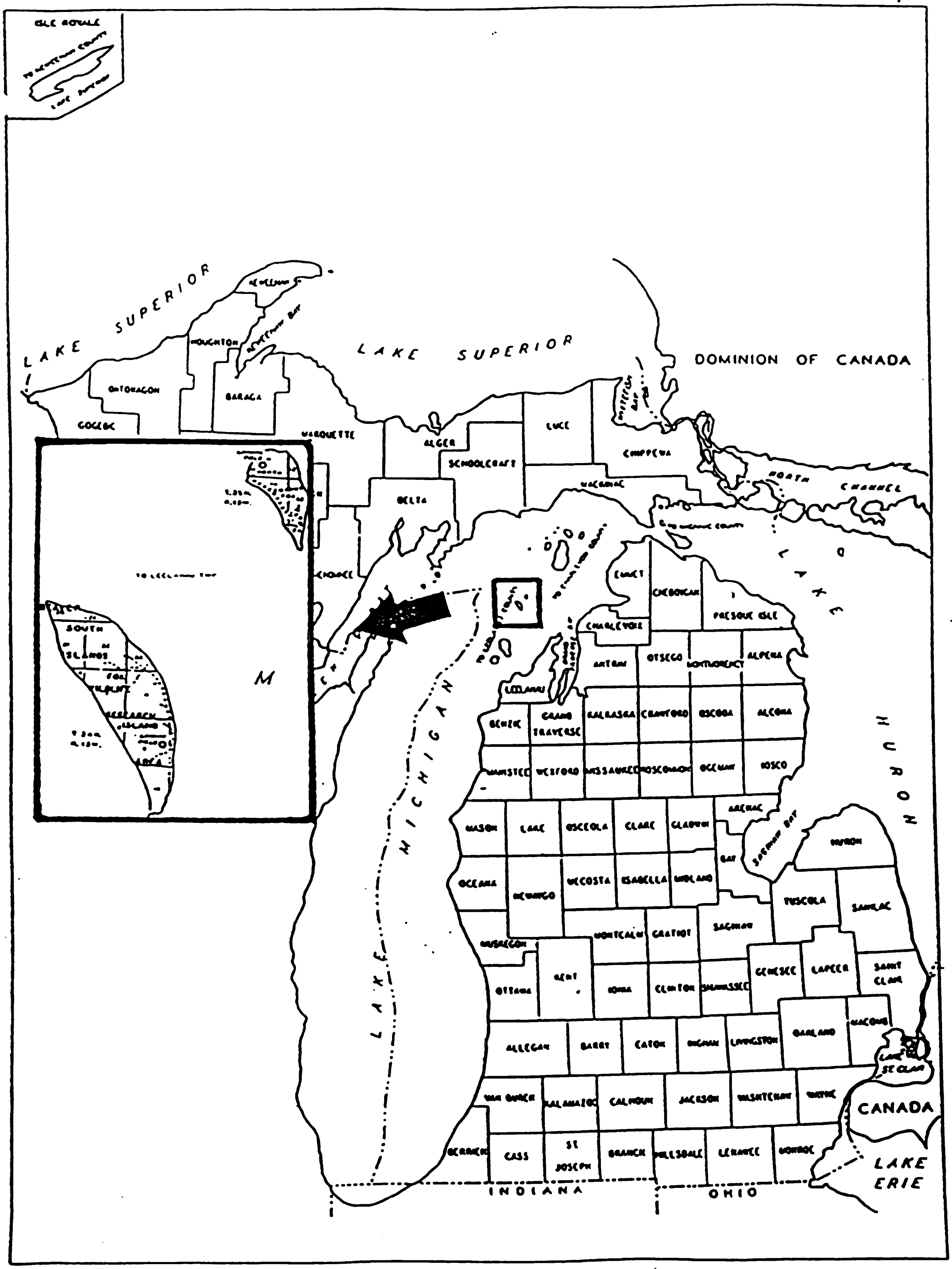

Figure 1. Location of South Fox Island, Leelanau County, MI.

of shoreline. It is mostly forested with a few open fields around old homesteads. The dominant trees are American beech (Fagus grandifolia), maple (Acer spp.), ash (Fraxinus spp.), northern white cedar (Thuja occidentalis), basswood (Tilia spp.), and shumard oak (Quercus shumardii). One stand of Eastern white pine (Pinus strobus L.) is known to exist on the island.

Soils are in the Deer Park-Dune land association and East Lake-Eastport-Lupton association (Weber 1973). Both tend to be moderate to well drained sandy loams. Average slopes range from 0 to 45%. There is one small pond (0.003 ha.) and a few smaller water holes on the island.

South Fox Island is divided into public and private holdings with the public lands interspersed in the private lands (Figure 2.). Because of difficult hunter access and trespass problems an agreement was developed by the MDNR in 1971, to render only the northern 1/3 (484.4 ha.) of the island as public land during deer season, but private land hunters were allowed to hunt this area. The line is depicted by the township line between T 34 N and T 35 N (Figure 3). The southern 2/3 (968.8 ha.) of the island was for private land hunting only. No hunting by public or private land hunters was permitted on the southern 46.5 ha. surrounding the light house and dune areas. This agreement allowed public hunters to have access to a solid block of land, and it also reduced trespass problems. The agreement only persists for the hunting season and was strictly for hunting

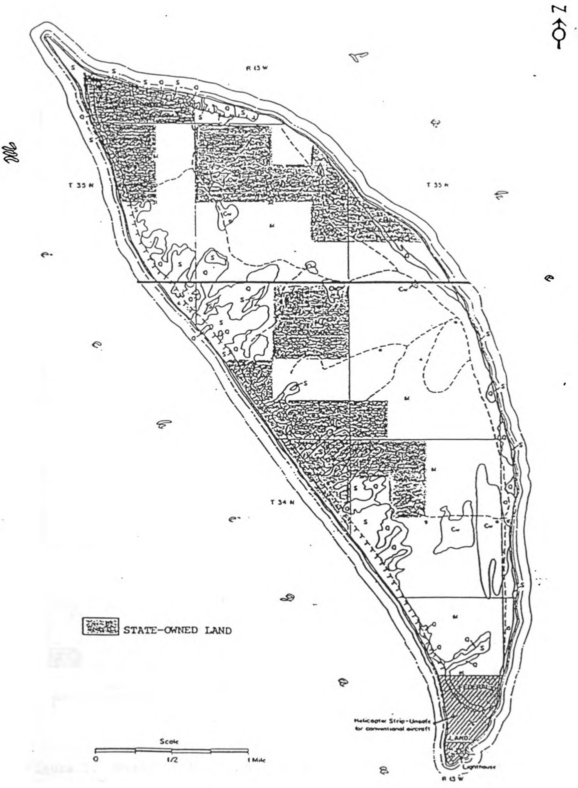

Figure 2. Distribution of public and private lands on South Fox Island, MI.

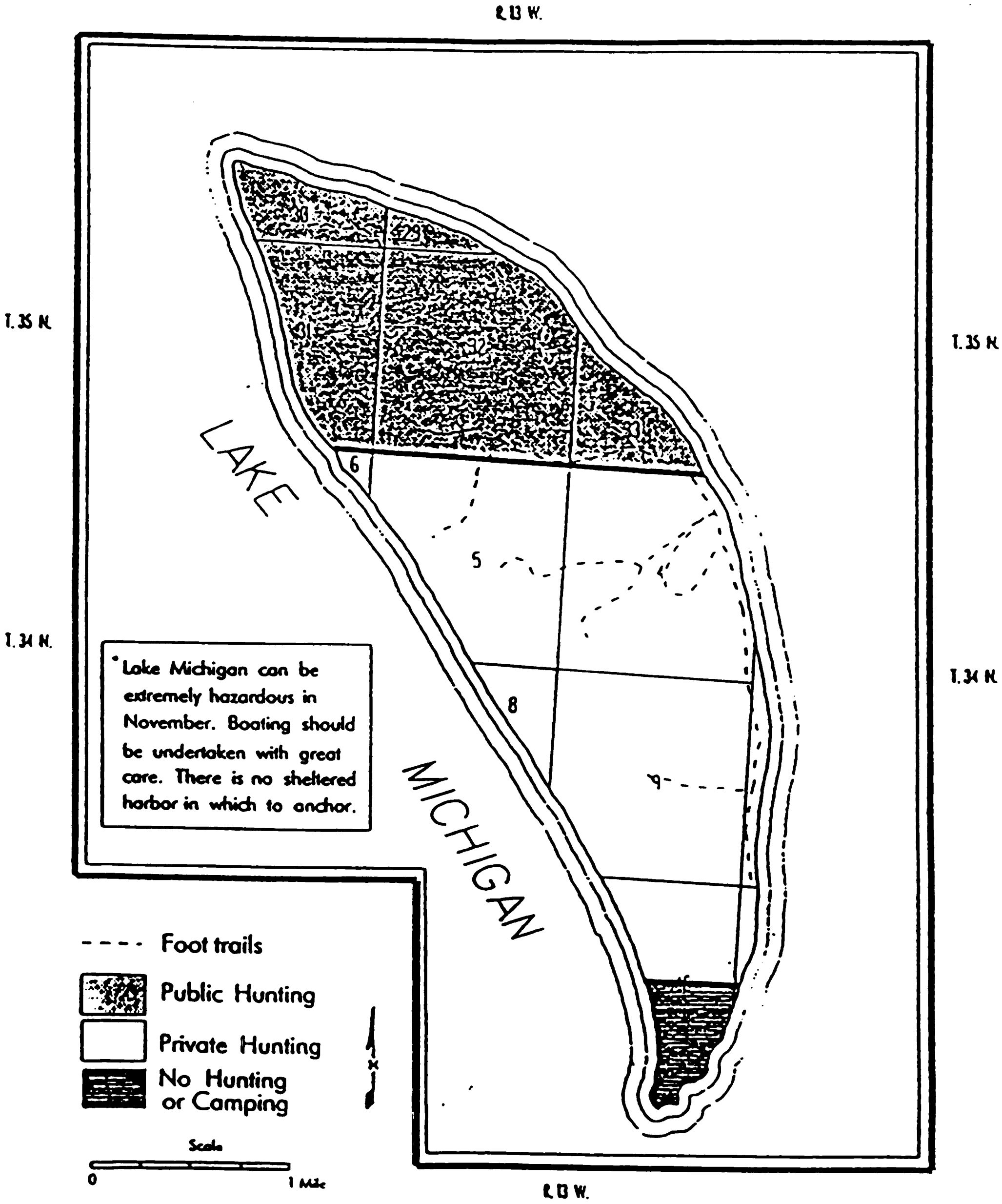

Figure 3. Distribution of public and private lands on South Fox Island, MI during white-tailed deer hunting season. Private land hunters can hunt on public lands.

rights.

Deer were first introduced to the island in 1915 by the MDNR (Hatt et al. 1948). The deer population grew to an estimated 40 individuals by 1925. In the ensuing years, the population dramatically decreased due to unrestricted harvests by island residents. While surveying the island's deer herd and habitat Bartlett (1945) noticed only one set of deer tracks on the northern end of the island.

White-tailed deer were reintroduced for a second time by the MDNR in 1962, with 17 deer released, six males and eleven females (Craker 1983). All deer originated from wild pen-raised Michigan stock and were of known age except for one buck (Harger and Cook 1972). According to Harger and Cook (1972), the deer that originally inhabited the island as a result of the 1915 release had been exterminated prior to the 1962 release.

The 1962 release followed a recent logging operation that allowed the deer to have an abundance of browse available the following spring. Bartlett (1945) noted a thick understory composed mostly of American yew (Taxus canadensis), dogwoods (Cornus spp.), Viburnum spp., and elders (Sambucus spp.) that was impenetrable in places. The first year after the release, two female fawns were known to have died (Craker 1983). The remaining 15 individuals populated South Fox Island.

Following the 1962 release, the deer herd exploded and by the late 1960's, the MDNR was trying to bring the herd under control. The MDNR was concerned that the deer would over-exploit the island, and severe winters would result in die-offs. South Fox Island is part of the Beaver Island Wildlife Research Area, and, consequently, the Department of Conservation (presently the MDNR) authorized an experimental hunt which allowed for more does to be harvested (Harger and Cook 1972). The experimental hunt allowed a hunter to kill three deer with one being a buck.

In the 1970's, the deer herd hit an all time high. Approximately 76 deer per square mile were estimated on the island in 1970, (Craker 1983). Over the next three years (1969-1971), 689 deer were killed. The MDNR decided the deer herd had been brought under control by the mid 1970's and that 100 deer would have to be harvested annually to keep the population under control. Following the population peak in the 1970's, many favorable browse species, such as American yew declined. King (1970) estimated that 25% of the American yew had been consumed and many of the Northern white cedars had moderate browse lines.

The MDNR had planned to do some timber cuttings to enhance the understory, but before any habitat improvements were conducted, the owner of the private lands died in a 1973 airplane crash on the island (Craker 1983) and the new owners were not interested in deer management. Although the private land owners lost interest in the deer on the island, deer harvests continued with some 3,848 deer being killed by public and private hunters over the past 29 years (Figure 4).

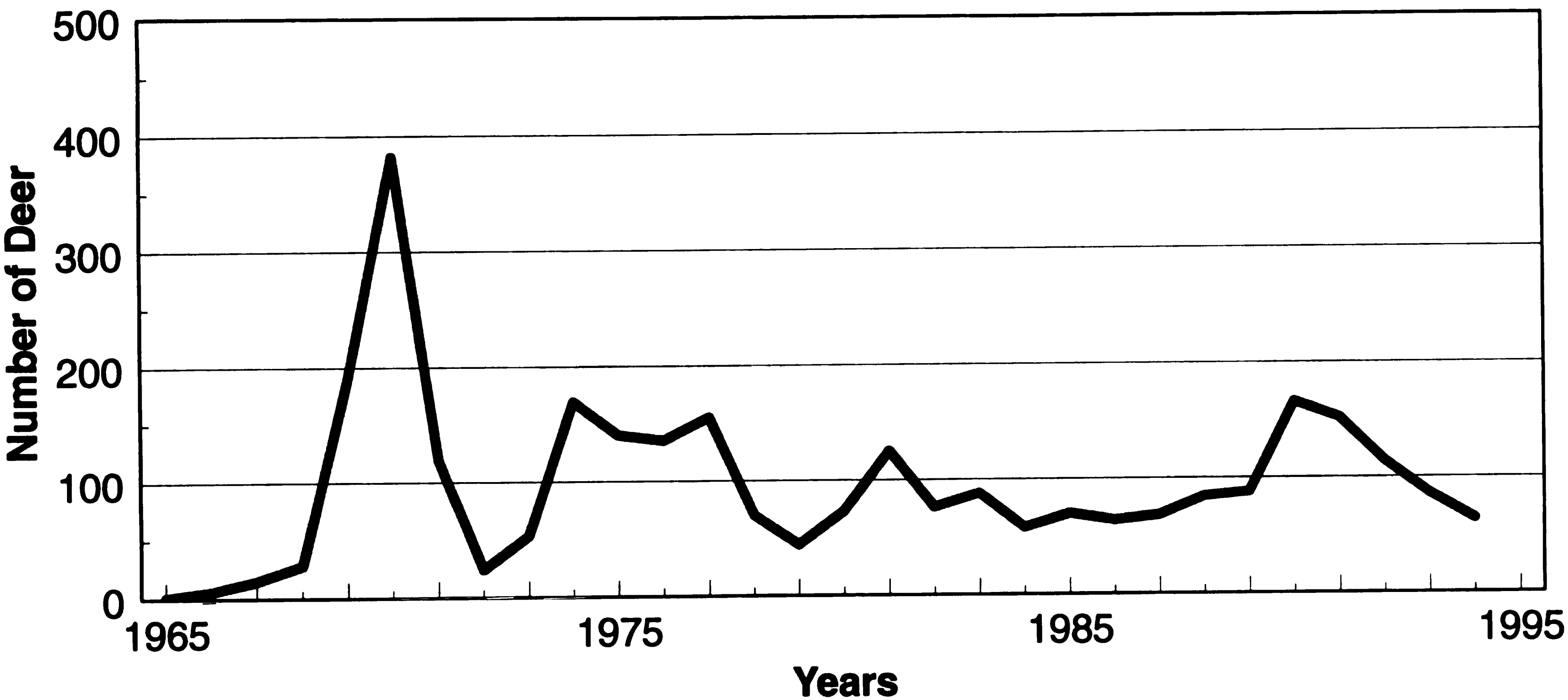

Figure 4. White-tailed deer harvested on South Fox Island, Michigan from 1965 to 1994, all numbers are approximate (Unpublished P.R. report, MDNR, Wildlife Division).

In 1988, the private lands were purchased by David V. Johnson. Mr. Johnson was reluctant to harvest any deer the first year but, with persuasion from employee's and the MDNR, deer harvest were continued. In 1992, the MDNR contacted Mr. Johnson about helping to fund a study on the island's deer herd. In 1993, this project was started in cooperation with Mr. Johnson and the MDNR.

CAPTURE METHODS

Deer were trapped using a modification of the drop-net technique described by Ramsey (1968) and clover traps described by Clover (1956). Whole shelled corn was used as the primary attractant along with minerals and apples. Each trapping location was baited prior to setting nets up to determine if any deer were attracted to the site. Before trapping began and after the nets were set-up, each station was baited for two to three days or longer depending on deer response. The delay gave deer time to become habituated to the nets and/or traps. Drop nets were utilized from early Fall, after the bucks had rubbed out of velvet, through December (Table 1). Clover traps were utilized the second year from early Fall through the winter months.

Deer were anesthetized with Xyalazine hydrochloride (Rompum; 2.2 mg/kg of body weight) (Day et al. 1980) after they were captured to ensure the safety of the deer and the researchers. The anesthetized deer were removed from the nets and marked with color and number coded cattle ear tags (National Band and Tag Co. Newport, Ky) in one or both ears. A numbered metal clip tag was also placed in the ear to differentiate between sexes. Males were tagged in the upper top part of the right ear and females in the upper top part of the left ear.

After the deer had been marked, they were given injections of an antibiotic Liquamycin (LA-200; 8.8 mg/kg of body weight) and a reversal drug (Yobine; 0.1 mg/kg of body

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Table 1. Time table for South Fox Island's population size estimation research project.

Activity		Dates
		1993
Trapping		15 August - 1 October 26 November - 8 December
Camera set-up		24 September - 25 October 27 November - 20 December
Hunting Season	Archery Firearms	1 October - 28 October 30 October - 26 November
		1994
Trapping		1 January - 1 April 1 August - 10 December
Camera set-up		5 September - 30 September 24 November - 13 December
Hunting Season	Archery Firearms	1 October - 28 October 30 October - 26 November
Pellet Group Survey		9 May - 12 May
		1995
Pellet Group Survey		1 May - 5 May
Helicopter Survey		15 March (9:30-10:30 a.m.)

weight). The antibiotic was intended to help combat any infections due to trapping and/or handling related injuries. Each deer was monitored until it was able to walk away from the trapping site. All trapping, handling, and marking procedures were reviewed and approved by the All-University Committee on Animal use and Care (AUF Number: 01/94-029-01).

CAMERA STATIONS

Infrared camera triggered systems have been successfully used to monitor mule deer (Odocoileus hemionus), black bear (Ursus americanus), moose (Alces alces), turkey (Meleagris gallopavo), white-tailed deer, gray fox (Urocyon cinereoargenteus), grizzly bears (Ursus arctos), and wild pigs (Sus scrofa) (Kucera and Barrett 1993 and Kucera and Barrett 1995). Foster and Humphrey (1995) used Trailmaster® (Lenexa, KS) monitors and camera systems to monitor highway underpass use of Florida panthers (Felis concolor coryi) along a portion of Interstate 75 in southwestern Florida. The Trailmaster® systems provided a non-intrusive mechanism for studying wild animals in their natural habitat.

A study conducted in Mississippi by Jacobson et al. (In Press) employed the use of photographs taken by infrared camera systems at bait stations to estimate the population of a local white-tailed deer herd in a forested environment. Their study also provided an evaluation of three population estimators and determined if they could be economically and efficiently used to measure the size of a local white-tailed deer herd.

In the current study, Trailmaster® camera systems were used to take photographs of marked and unmarked deer at various camera stations locations. Camera stations consisted of mineral licks that were baited with whole shelled corn, salt, and minerals. Camera stations were monitored daily until a deer visitation pattern could be determined and then only every other day. Data were collected from the monitors when a roll of film (ISO 200, 36 exposure color print) had been exposed. Corn (approximately 3.5-kg) was replenished every other day as needed. Salt and minerals (approximately 2-kg) were initially put out at the onset of every camera census period (pre- and post-harvest).

The camera systems had two different configurations, a passive system and an active system. The passive system utilized passive infrared technology to detect the presence of animals based on body heat and motion (Figure 5). Movements of a warm-blooded animal passing through the area of sensitivity, were recorded and/or the animal's picture was taken. The active system employed a two component set-up with a transmitter and a receiver (Figure 6). An animal had to walk between the units and break the beam for the receiver to record an event and/or take the animal's picture.

The passive system's area of sensitivity is typically 20-m deep and spreads in an elliptical cone 150° wide and 4° high. The elliptical cone was reduced to 90° by placing electrical tape over portions of the front lens. The number

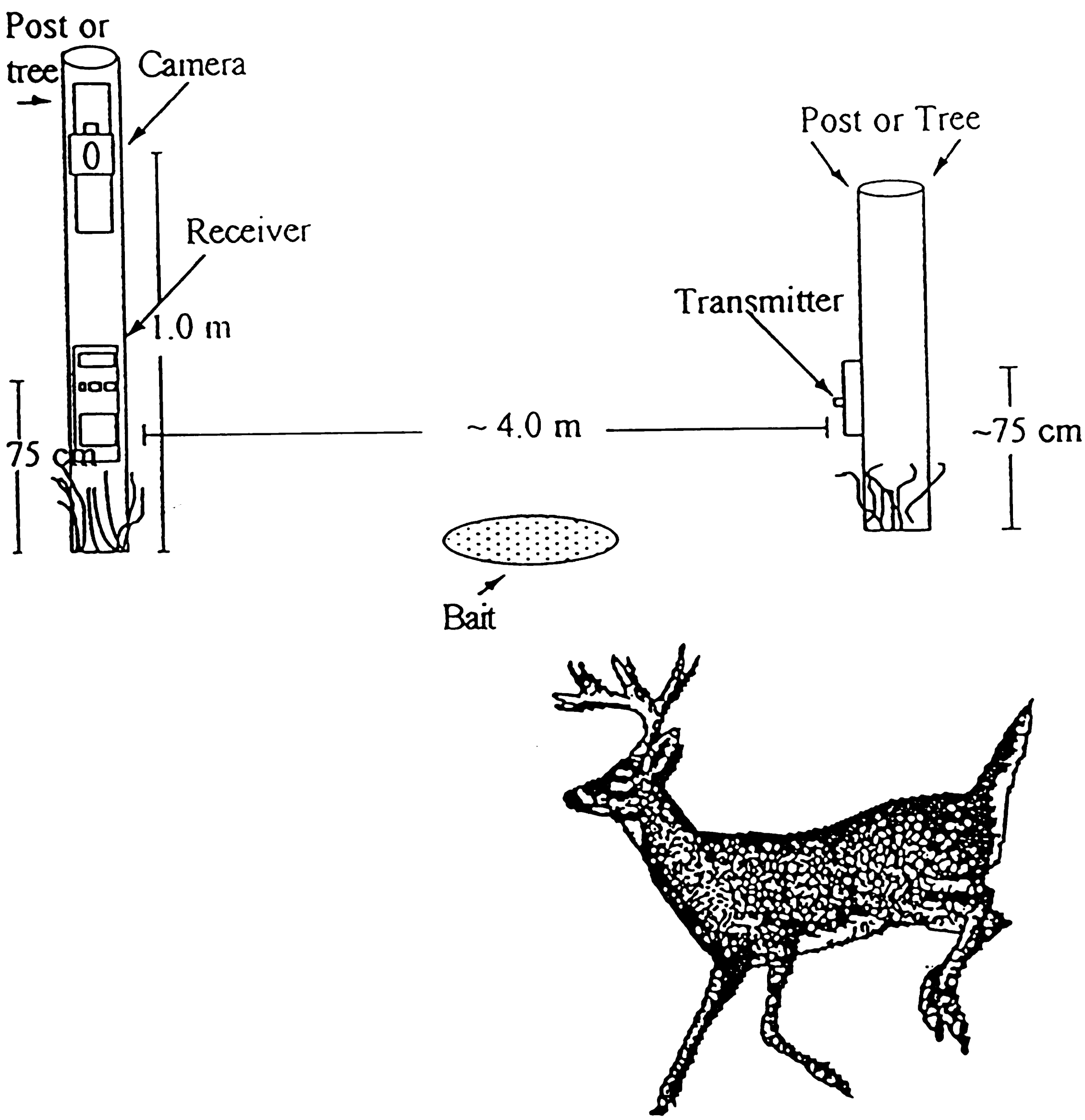


Figure 6. An active infrared receiver, transmitter, and camera set-up on South Fox Island, MI.

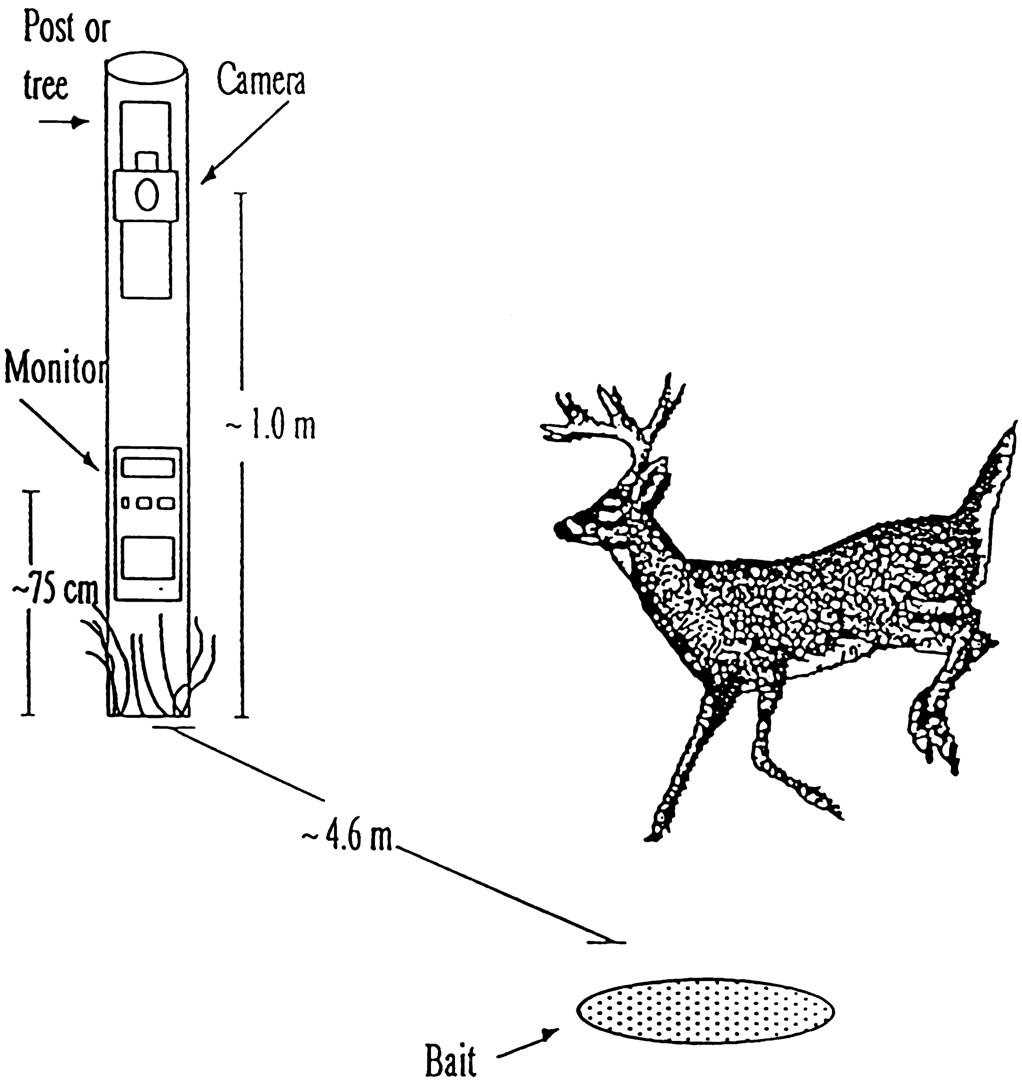


Figure 5. A passive infrared monitor and camera set-up on South Fox Island, MI.

of pulses (**P**) was set at 3-5; thus, three to five pulses had to be interrupted before the monitor recognized an event. Stations with low growing vegetation in the outer perimeter of the elliptical cone required a higher pulse setting than stations without any low growing vegetation due to adverse effects by wind. The pulse time (**Pt**) was set on three to four. The deer had to cover three to five pulses in a three to four second time period to be counted. The passive monitors were placed on posts 2-4 m from the bait at 60-76 cm above the ground.

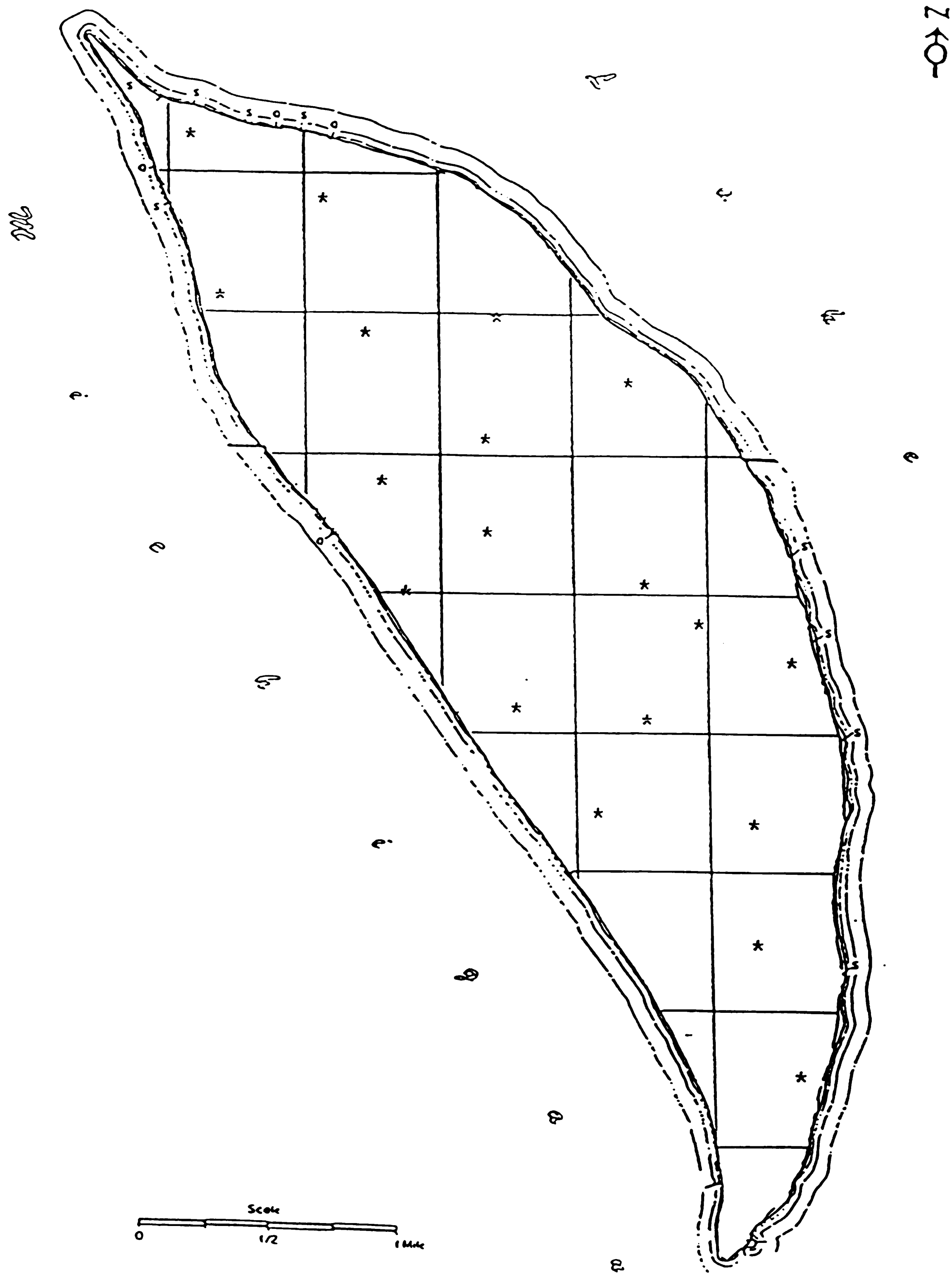
The active system's transmitter and receiver were set-up on posts two to four meters apart at 61-76 cm above the ground. Pulses were transmitted every 0.5 seconds. The animal had to break the beam for five pulses before an event was recorded by the receiver.

Olympus Infinity Twin® (Olympus Corp., Crossways Park, Woodbury, NY) cameras were modified to be triggered by an electrical pulse from Trailmaster® receivers. Cameras were equipped with a quartz clock that allowed the date and time to be displayed on each exposure. In addition, cameras were equipped with an automatic flash that could either be turned on all the time or just set to come on at low light levels. The cameras were attached to the receivers with an 8-m cable, allowing flexibility in the placement of the cameras in relation to the receiver.

Both systems were set up to collect data 24-hours a day. A five to seven minute camera delay was placed on both systems. The camera delay prevented cameras from taking photographs each time the infrared beam was broken after an initial photograph had been taken. The camera photographed the next event after the selected delay period, but event data continued to be collected and stored during the delay period.

Nineteen camera stations were systematically distributed over the entire island at various mineral licks and/or major deer trails giving a coverage of 1 camera/65-ha (Figure 7). Eight monitors were passive systems and eleven were active systems. Jacobson et al. (In Press) determined that approximately 20 camera stations were sufficient to photograph most of the island's deer population. They determined that 1 camera/65-ha accurately estimated the population of a local white-tailed deer herd in Mississippi.

The cameras collected data (pre-harvest census) from 24 September 1993 through 25 October 1993 and 5 September 1994 through 30 September 1994. To ensure their safety, camera stations were dismantled and removed during hunting season (1 October - 26 November). All stations started collecting data (post-harvest census) again after all the hunters left the island, 22 November 1993 and 24 November 1994, and ran until 8 December 1993 and 13 December 1994, respectively.



Figrue 7. Distribution of nineteen camera stations (*) on South Fox Island, MI. Each block represents approximately 65-ha.

HARVEST DATA

All deer harvested on South Fox Island were checked at one of two check stations. One check station was located on the public end of the island and served the public land hunters. The other check station was located on the private end and was utilized by private land hunters.

The following data were collected from all the harvested deer:

(1) weight
(2) age
(3) sex
(4) antler measurements
(5) lactation.

Weight was measured to the nearest five pounds. The lower jaw was removed from each deer using a jaw extractor (Marshall et al. 1964) and age determined by mandibular tooth wear and replacement (Larson and Taber 1980). All ages were recorded in half year increments (i.e. fawns are 0.5 years). Antler measurements followed MDNR antler measurement guidelines for all males (inside spread, main beam lengths, and circumference of main beams). Larger males (i.e. males 2.5 years old and older) were measured according to Boone and Crocket standards (Nessbit and Wright 1985) with the only deviation being that the antlers were not dried. For females, lactation was recorded as either milk present or not. Some female reproductive tracts were examined in the field to determine ovulation rates.

STATISTICAL APPLICATIONS

The primary focus of the study was to examine and compare different methodologies for estimating the size of a local deer population. The four population estimation techniques were:

(1) Pellet groups counts

(2) Mark-recapture estimator

(3) Ratio estimator

(4) Change-in-ratio estimator

The data collected from the photographs were used in the latter three estimators.

Pellet Group Counts

Pellet group counts (Eberhart 1957) were conducted each spring by the MDNR in association with Michigan State University (MSU) researchers according to MDNR standards. The population was estimated using he following equation:

$$\hat{N} = \frac{\overline{X_{pg}} * (plotsize)^{-1} * size\ of\ study\ area}{deposition\ period * defecation\ rate * number\ of\ plots} \qquad (1.1)$$

where:

$\hat{N}$ = *population estimate*

$\overline{X_{pg}}$ = *mean number of pellet groups per plot*

Assumptions of pellet group sampling are:

(1) the defecation rate is constant,

(2) all pellet groups are counted,

(3) the age of all pellet groups can be easily determined,

(4) a defecation period can be delineated (Ryel 1971).

Sixty-one transects 119 meters apart running east and west were established on the island in 1994. Ten lines were randomly picked and deleted from the survey. A random starting distance (i.e., where the first plot would be) was drawn because every line and every plot after that was systematically placed every 201 meters. Long rectangular plots (3.7-m x 22.1-m; 0.008-ha) were established at 45° to the right of the course line.

Fifty-two transects 137-m apart running east and west were established on the island in 1995. Twenty-four lines were randomly drawn with pellet courses running on these 24 lines. Plots were established along the course lines similar to the 1994 design.

Mark-recapture Estimator

The mark-recapture estimator followed the Lincoln-Peterson method (Pollock et al. 1990) to estimate the population size. The following formula was used to estimate the population:

(2.1) $$\hat{N} = \frac{n_1 n_2}{m_2}$$

where:

$\hat{N}$ = *population estimate*

n_1 = *number of marked animals*

n_2 = *number of animals that were photographed*

m_2 = *total number of marked animals that were photographed*

By using the pre-hunt photographs and hunter harvest data the size of the post-hunt herd was estimated. An estimate generated solely from post-hunt photographs was combined with the harvest data to check the pre-hunt estimate. Assumptions of the Lincoln-Peterson method are:

(1) the population is closed to immigration and emigration,

(2) all animals have equal probability of being captured in every sample,

(3) marks are not lost or over-looked (Pollock et al. 1990).

Hunter harvest data collected during the white-tailed deer hunting season were used to get a Lincoln-Peterson pre-harvest estimate of the population:

(2.2)
$$\hat{N} = \frac{n_1 n_2}{m_2}$$

where:

$\hat{N}$ = *estimated population,*

n_1 = *total number of marked animals,*

n_2 = *total number of animals that were harvested,*

m_2 = *total number of marked animals that were harvested,*

Two derivatives of the Lincoln-Peterson were used to compensate for some of the biases associated with antler and radio collar restrictions (see Chapter 2).

(2.3)
$$\hat{N}' = \frac{(M')\,(n')}{m'}$$

where

$\hat{N}'$ = *Population estimate except for radio collared individuals and males less than six points,*

M' = *All marked individuals except radio collared deer and males less than 6 points,*

n' = *Number of legally harvest deer except for bucks less than 6 points,*

m' = *Number of marked individuals harvested,*

and

(2.4) $$\hat{N}'' = \frac{(M'')\,(n'')}{m''}$$

where

$\hat{N}''$ = *Population estimate except for radio collared individuals,*

M'' = *All marked deer execpt radio collared ones,*

n'' = *Number of deer harvested,*

m'' = *Number of marked deer harvested.*

A Chapman estimator was used to estimate the population from hunter harvest data. The Chapman estimator is an unbiased estimator of the population (Lancia et. al. 1994).

(2.5) $$\hat{N}_c = \frac{(M + 1)\ (n + 1)}{(m + 1)} - 1$$

where

$\hat{N}_c$ = *Population estimate,*

M = *Total number of marked animals,*

n = *Total number of animals harvested,*

m = *Number of marked animals harvested.*

Two derivatives of the original Chapman were used to try to compensate for some of the biases associated with antler and radio collar restrictions (see Chapter 2).

$$\hat{N}'_c = \frac{(M' + 1)(n' + 1)}{(m' + 1)} - 1 \qquad (2.6)$$

where

$\hat{N}'_c$ = *Population estimate except for radio collared individuals and males less than six points,*

M' = *All marked individuals except radio collared individuals and males less than six points,*

n' = *Number of legally harvested deer except males less than 6 points,*

m' = *Number of marked animals harvested,*

and

$$\hat{N}''_c = \frac{(M'' + 1)(n'' + 1)}{(m'' + 1)} - 1 \qquad (2.7)$$

where

$\hat{N}''_c$ = *Population estimate except for radio collared individuals,*

M'' = *Marked individuals except radio collared individuals,*

n'' = *Number harvested,*

m'' = *Number of marked individuals harvested.*

Modified Lincoln-Peterson

A modified Lincoln-Peterson index utilizing photographic data was developed and utilized to obtain a population estimate from:

(1) The ratio of marked does to unmarked does in the photographs in relation to the total number of marked does,

$$h_d = \frac{a_d H_d}{A_d} \tag{2.8}$$

where

h_d = estimated number of individual unmarked does photographed,

a_d = number of marked individual does photographed,

A_d = total number of marked doe occurrences in photographs,

H_d = total number of unmarked doe occurrences in photographs,

and

$$R_d = \frac{h_d}{a_d} C_d + C_d \tag{2.9}$$

where

R_d = estimated total doe population,

C_d = total number of individually marked does.

(2) The ratio of marked fawns to unmarked fawns in the photographs in relation to the total number of individually marked fawns,

(2.10)
$$h_f = \frac{a_f H_f}{A_f}$$

where

h_f = estimated number of individual unmarked fawns photographed,

a_f = number of marked individual fawns photographed,

A_f = total number of marked fawn occurrences in photographs,

H_f = total number of unmarked fawn occurrences in photographs,

and

(2.11)
$$R_f = \frac{h_f}{a_f} C_f + C_f$$

where

R_f = estimated total fawn population,

C_f = total number of individually marked fawns.

(3) The ratio of marked unbranched antler bucks to unmarked unbranched antlered bucks in the photographs in relation to the total number of

individual marked unbranched antlered bucks (spikes),

(2.12)
$$h_s = \frac{a_s H_s}{A_s}$$

where

h_s = estimated number of individual unmarked spikes photographed,

a_s = number of marked individual spikes photographed,

A_s = total number of marked spike occurrences in photographs,

H_s = total number of unmarked spike occurrences in photographs,

and

(2.13)
$$R_s = \frac{h_s}{a_s} C_s + C_s$$

where

R_s = estimated total spike population

C_s = total number of individual marked spikes.

(4) The ratio of marked branched antlered bucks to unmarked branched antlered bucks in the photographs in relation to individual marked branched antlered bucks,

(2.14) $$h_b = \frac{a_b H_b}{A_b}$$

where

h_b = estimated number of individual unmarked branched antlered bucks photographed,

a_b = number of individual marked branched antlered bucks photographed,

A_b = total number of marked branched antlered buck occurrences in photographs,

H_b = total number of unmarked branch antlered buck occurrences in photographs,

and

(2.15) $$R_b = \frac{h_b}{a_b} C_b + C_b$$

where

R_b = estimated total branched antlered buck population,

C_b = total number of individual marked branched antlered bucks.

A total population estimate was derived by summing all the individual component estimates:

(2.16) $$\hat{N} = R_d + R_f + R_s + R_b$$

where

$\hat{N}$ = *population estimate*

Ratio Estimator

The photographs were used to get an estimate of the total deer population. Individual bucks with branched antlers were identified by antler configuration. Any bucks with greater than or equal to one branched antler were considered branched antlered bucks (Jacobson et al. In Press). Ratio estimators were used to estimate the size of the deer herd by reconstructing the population from:

(1) The ratio of branched antlered bucks to unbranched antlered bucks (spikes),

(3.1) $$R_s = \frac{N_{sa}}{N_{fa}}$$

where

R_s = ratio of total deer occurrences in photographs that were spike-antlered,

N_{sa} = total number of deer occurrences in photographs that were spike-antlered,

N_{fa} = total number of deer occurrences in photographs that were branched antlered,

and

(3.2) $$E_b = (B * R_s) + B$$

where

E_b = estimated total buck population,

B = number of individually identified branched antlered bucks.

(2) The ratio of bucks to does,

(3.3) $$R_d = \frac{N_d}{N_b}$$

where

R_d = ratio of total adult deer occurrences in photographs that were does,

N_d = total number of adult deer occurrences in photographs that were does,

N_b = total number of adult deer occurrences in photographs that were bucks,

and

(3.4) $$E_d = E_b * R_d$$

where

E_d = estimated total doe population.

(3) The ratio of fawns to does,

(3.5) $$R_f = \frac{N_f}{N_d}$$

where

R_f = ratio of total antlerless deer occurrences in photographs that were fawns,

N_f = total number of antlerless deer occurrences in photographs that were fawns,

and

(3.6) $$E_f = E_d * R_f$$

where

E_f = estimated total fawn population.

A total population estimate was derived by summing all individual components:

(3.7) $$\hat{N} = E_b + E_d + E_f$$

where

$\hat{N}$ = *estimated population.*

Change-in-ratio Estimator

The change-in-ratio estimator required that the population be split into two mutually exclusive groups, x- and y-types (antlered vs. antlerless); that the number of individuals removed from the population be known; and that the number removed from one group be disproportional to their representation in the population (Lancia et al. 1994). The deer population was estimated by comparing the pre-hunt and post-hunt photographs. Assumptions associated with the change-in-ratio method are (Lancia et al. 1994):

(1) x- and y-types have equal probability of being sampled

(2) the population is closed except for harvest

(3) number of removals for both x- and y-types is known

(4) the proportion of x- or y-types in the harvest is different than in the population.

If the ratio of x- and y-types (x-type animals = males; y-type animals = females) changes due to removal a new (post-removal) proportion of x-type animals can be calculated by using the following equation (Lancia et al. 1994):

$$P_2 = \frac{X_1 - R_x}{N_1 - R} = \frac{P_1 N_1 - R_x}{N_1 - R} \tag{4.1}$$

where

R_x = the number of x-types removed (known),

R_y = the number of y-types removed (known),

$R = R_x + R_y$ = the total number of animals removed (known),

$P_1 = X_1/N_1$ = the proportion of x-type animals before the removal (where N_1 is the total population size before the removal),

$P_2 = X_2/N_2$ = the proportion of x-type animals after the removal (where N_2 is the total population size after the removal),

X_1 = the number of x-type animals in the initial (pre-removal) population,

Y_1 = the number of y-type animals in the initial (pre-removal) population.

By solving for N_1 an estimator of total population size before the removal can be calculated by using the following equation (Lancia et al. 1994):

(4.2)
$$\hat{N}_1 = \frac{(R_x - RP_2)}{(P_1 - P_2)}$$

where P_1 and P_2 are estimated from the photographs. The number of x-type animals in the population before removals can be estimated by (Lancia et al. 1994):

(4.3)
$$\hat{X}_1 = \hat{P}_1 \hat{N}_1$$

For other population parameter estimates, see Lancia et al. 1994.

RESULTS AND DISCUSSION

Photographic Data

Sixteen deer were trapped before and during the 1993 pre-harvest census period using drop nets (Table 2). In 1994, 32 deer were trapped using drop nets and 9 using clover traps. Of these 62 individuals, 9 were marked with radio transmitting collars (Lotek Engineering Inc, Newmarket, Ontario, Canada). All radio collars were equipped with mortality sensors set on 7 hour delays. Deer were randomly selected for marking with the radio collars, although each sex and age class (male:female and/or fawn:adult) was equally represented.

In 1993, 371 and 166 deer photos were taken during the pre- and post harvest census, respectively (Table 3). Of the 16 deer marked prior to the pre-harvest census, only 2 (12.5%) were photographed by the infrared camera monitors. During the post harvest census, 4 (26.6%) out of the 14 (2 deer were harvested during the hunting season) marked deer were photographed.

In 1994, 2,106 and 2,396 deer photos were taken during the pre- and post harvest census periods, respectively (Table 3). Of the 45 marked individuals prior to the pre-harvest census, 18 (40%) of the marked individuals were photographed. During the post-harvest census, 26 (56.5%) of the 46 (13 were marked after the pre-harvest period but 10 marked individuals were harvested during the hunting season) marked individuals were photographed.

Table 2. White-tailed deer tagged on South Fox Island, MI during 1993-1995.

Sex[a]	Age[b]	Date	Trapping Method	Radio Collar Frequency
Female	0.5	8/29/93	Drop-net	
Female	2.5	8/29/93	Drop-net	
Female	0.5	8/30/93	Drop-net	
Female	0.5	8/31/93	Drop-net	
Female	0.5	9/9/93	Drop-net	
Male	0.5	9/9/93	Drop-net	
Male	1.5	9/12/93	Drop-net	
Male	0.5	9/23/93	Drop-net	
Female	4.5	9/23/93	Drop-net	
Female	0.5	9/25/93	Drop-net	
Female	0.5	9/26/93	Drop-net	
Female	0.5	10/4/93	Drop-net	
Female	1.5	10/4/93	Drop-net	
Male	0.5	10/8/93	Drop-net	
Male	0.5	10/18/93	Drop-net	
*Female	6.5	10/18/93	Drop-net	
Female	0.5	2/9/94	Drop-net	
Female	Adult	2/9/94	Drop-net	
Female	Adult	3/9/94	Drop-net	
*Male	0.5	3/9/94	Drop-net	
*Male	0.5	3/9/94	Drop-net	
*Male	1.5	3/9/94	Drop-net	
*Female	Adult	3/9/94	Drop-net	
Male	0.5	4/1/94	Drop-net	
Female	2.5	4/1/94	Drop-net	
*Female	0.5	8/1/94	Drop-net	
*Male	0.5	8/1/94	Drop-net	
*Female	0.5	8/1/94	Drop-net	
Female	1.5	8/18/94	Drop-net	
Female	3.5	8/21/94	Drop-net	151.376
Female	Adult	8/22/94	Drop-net	151.347
Male	1.5	8/29/94	Drop-net	
Male	3.5	8/29/94	Drop-net	151.336
Female	0.5	8/31/94	Drop-net	
Female	0.5	8/31/94	Drop-net	
*Female	0.5	9/8/94	Drop-net	
Female	1.5	9/8/94	Drop-net	
Female	2.5	9/8/94	Drop-net	
*Male	4.5	9/9/94	Drop-net	
Male	1.5	9/16/94	Drop-net	151.356
*Male	3.5	9/19/94	Drop-net	
Male	0.5	9/2/94	Drop-net	151.317
*Female	5.5	9/26/94	Drop-net	
Male	0.5	9/26/94	Drop-net	
*Female	0.5	9/26/94	Drop-net	
Male	0.5	9/27/94	Clover	

Table 2 (cont'd).

Female	0.5	10/1/94	Drop-net	151.286
Male	0.5	10/1/94	Drop-net	
Female	5.5	10/1/94	Drop-net	
Female	0.5	10/5/94	Clover	151.326
Male	0.5	10/2/94	Clover	151.294
Male	0.5	10/7/94	Clover	
*Female	0.5	10/18/94	Clover	151.306
Female	Adult	11/29/94	Clover	
Male	0.5	12/1/94	Clover	
Male	0.5	12/6/94	Clover	
Female	0.5	12/10/94	Clover	
Female	0.5	2/1/95	Clover	
Male	2.5	2/2/95	Clover	
Male	0.5	2/18/95	Clover	
Female	Adult	2/18/95	Clover	
Female	Adult	3/8/95	Clover	

[a]* Deer that were either harvested or died of natural causes.
[b]Adult deer are any deer 1.5 years and older.

Table 3. Photographs of white-tailed deer on South Fox Island, MI during 1993 and 1994 pre- and post harvest camera census periods.

	Pre-Harvest		Post Harvest	
Sex	1993	1994	1993	1994
Does	136	1068	45	752
Fawns	213	763	99	1070
[a]Bucks	11	156	6	264
[b]Bucks	11	119	16	310
Total	371	2106	166	2396

[a]Bucks = Branch Antlered Bucks
[b]Bucks = Unbranched Antlered Bucks (spikes)

Harvest Data

Between 30 October 1993 and 26 November 1993 (white-tailed deer firearm hunting season on the island), 89 deer were harvested (14 adult bucks, 43 adult does, 13 buck fawns, and 16 doe fawns) (Table 4). During the 1994 white-tailed deer hunting season (30 October - 26 November), 64 deer were harvested (19 adult bucks, 27 adult does, 9 buck fawns, and 9 doe fawns) (Table 5). For complete 1993 and 1994 harvest results, see Appendix A.

Pellet Group

The 1994 and 1995 pellet group surveys were conducted during the second and first weeks of May, respectively. The defecation rate used in equation 1.1 for 1994 and 1995 was 13.37 pellet groups/day. The mean deposition period (number of days since leaf fall) used in equation 1.1 was 200 and 187 for 1994 and 1995, respectively. The 1994 and 1995 pellet group surveys estimated 156 and 100 individuals, respectively (Equation 1.1). The 1994 pellet survey should reflect the 1993 post-harvest population size and the 1995 survey the 1994 post-harvest population size. Lack of personnel in 1995 caused pellet courses to change, thus making it impossible to compare courses from 1994 to 1995 courses.

Some problems encountered during the surveys were dense ground cover in 1994 and lack of personnel in 1995. The 1994 pellet group survey was conducted under extremely dense ground cover conditions. According to Neff (1968), pellet

Table 4. Age, gender, average dressed weight and number of antlered points, and total number of white-tailed deer harvested on South Fox Island, MI during the 1993 hunting season.

Age (years)	Bucks #	Bucks Average Wt.	Bucks Average # Pt's	Does #	Does Average Wt.
0.5	13	30.1 kg		16	24.8 kg
1.5	3	56.7 kg	4.0	9	40.3 kg
2.5	5	59.9 kg	7.8	4	42.5 kg
3.5	3	64.0 kg	7.3	9	44.6 kg
4.5	2	77.1 kg	9.0	9	45.9 kg
5.5	1	88.5 kg	8.0	5	44.9 kg
6.5				6	49.1 kg
7.5				1	52.2 kg
TOTAL=	27			59	

Age (years)	Bucks #	% of Bucks	Does #	% of Does	Total #	Total %
0.5	13	48	16	27	29	33.7
1.5	3	11	9	15	12	14.0
2.5	5	19	4	7	9	10.5
3.5	3	11	9	15	12	14.5
4.5	2	7	9	15	11	12.8
5.5	1	4	5	9	6	6.9
6.5			6	10	6	10.0
7.5			1	2	1	2.0
TOTAL=	27		59		89	

Table 5. Age, gender, average dressed weight and number of antlered points, and total number of white-tailed deer harvested on South Fox Island, MI during the 1994 hunting season[a].

AGE (Years)	BUCKS #	BUCKS Average Wt.	BUCKS Average # Pt's	DOES #	DOES Average Wt.
0.5	9	26.7 kg		9	22.9 kg
1.5	6	47.6 kg	5.8	7	40.2 kg
2.5	5	65.3 kg	7.8	7	44.0 kg
3.5	4	68.0 kg	6.5	1	43.1 kg
4.5	3	68.0 kg	7.7	5	47.6 kg
5.5				4	48.2 kg
6.5	1	81.6 kg	8.0	1	45.4 kg
7.5				2	46.5 kg
TOTAL =	28			36	

AGE (Years)	BUCKS #	BUCKS % of Bucks	DOES #	DOES % of Does	TOTAL #	TOTAL Total %
0.5	9	32	9	25	18	28
1.5	6	21	7	19	13	20
2.5	5	18	7	19	12	19
3.5	4	14	1	3	5	8
4.5	3	11	5	14	8	13
5.5			4	11	4	6
6.5	1	4	1	3	2	3
7.5			2	6	2	3
TOTAL =	28		36		64	

[a]Five adult deer (2-does and 3-bucks) were found dead on the island during and after hunting season and are not included in the above data.

group surveys conducted during dense ground cover conditions could augment errors associated with missed groups.

The 1995 pellet group survey was moved to the first week of May so it could be completed before dense ground cover became established. The 1995 pellet survey was conducted with minimal personnel with only half as many transect lines being completed. The personnel were not as skilled as the 1994 crew, and errors could have been made in aging pellet groups (i.e. calling new groups old and old groups new) (Neff 1968).

In a study conducted by Van Etten and Bennett (1965), two types of errors noticed were: (1) negative errors which tended to reduce the total count and (2) positive errors which tended to increase the total count. Van Etten and Bennett (1965) noted that negative errors, groups missed and new groups counted as old groups, were much more recurrent, making the resulting survey underestimate the true population.

Lincoln-Peterson

A Lincoln-Peterson estimate based on marked and unmarked individuals in the photographic data collected by the infrared camera system's proved to be positively biased (Lancia et. al. 1994) for both the 1993 and 1994 pre- and post harvest censuses. The 1993 pre- and post harvest population estimates were 2,597 and 664 individuals, respectively (Equation 2.1). The 1994 pre- and post harvest population estimates were 5,262.5 and 4,329.4 individuals, respectively (Equation 2.1). One explanation for over estimation could be that one or more of the model assumptions were violated. Recapture responses or behavioral responses in capture probabilities can result in population estimates that are either negatively biased due to trap happy animals or positively biased due to trap-shy animals (Lancia et. al. 1994). Refer to Appendix B for sample calculations.

A Lincoln-Peterson estimate based solely on hunter harvest data of marked and unmarked individuals estimated a 1994 pre-harvest population of 332.8 individuals (Equation 2.2). Two other Lincoln-Peterson estimates which tried to compensate for biases associated with antler and radio collared restrictions estimated a pre-harvest population of 254.2 individuals (Equation 2.3) (excludes all radio collared deer and marked bucks less than 6 points) and 281.6 individuals (Equation 2.4) (excluded radio collared individuals). A 1993 estimate was not calculated due to an inadequate sample size of marked individuals.

Some biases associated with hunter harvest data were attributable to having marked bucks with <6 antlered points and radio collared individuals because hunters were unable to harvest any of these bucks. We tried to correct for these biases by deleting marked individuals that fell into these two categories. We were unable to calculate the number of times that hunters passed on marked deer (those marked deer which did not fall into the above two categories).

Chapman Estimator

A Chapman estimate using the 1994 harvest data of marked and unmarked individuals calculated an estimated pre-harvest population at 312.2 individuals (Equation 2.5). Two additional Chapman estimates which were used to compensate for the biases associated with antler and radio collar restrictions estimated a pre-harvest population of 240.54 individuals (Equation 2.6) (excluded all radio collared deer and marked bucks <6 points) and 264.9 individuals (Equation 2.7) (excluded radio collared deer). A 1993 population estimate was not calculated due to a small sample size.

Modified Lincoln-Peterson

A simple Lincoln-Peterson mark recapture technique based solely on the total number marked individuals and the number of unmarked deer in the photographs simply did not produce reliable estimates. There was no way to account for marked and unmarked deer that showed up in the photographs more than once. A modified Lincoln-Peterson was developed that created a relationship between the ratio of the number of marked individuals and the number of times they appeared in the photographs and the number of times unmarked individuals showed up to get an estimate of the number of individual unmarked deer photographed.

A modified Lincoln-Peterson estimator based on marked and unmarked individuals photographed calculated a 1994 pre-harvest population estimate of 1696.54 individual deer

(Equations 2.8-2.16). The 1994 post harvest modified Lincoln-Peterson was more realistic with an estimated population of 198.76 individual deer (Equations 2.8-2.16) when compared to the straight Lincoln-Peterson. The post harvest population estimate was calculated as follows:

(1) The ratio of marked does to unmarked does in the photographs in relation to the total number of marked does,

(2.8)
$$h_s = \frac{(11)(555)}{197}$$
$$h_s = 30.99$$

and

(2.9)
$$R_d = \frac{30.99}{11}(21) + 21$$
$$R_d = 80.16$$

(2) The ratio of marked fawns to unmarked fawns in the photographs in relation to the total number of individually marked fawns.

(2.10)
$$h_f = \frac{(7)(893)}{177}$$
$$h_f = 35.32$$

and

(2.11)

$$R_f = \frac{35.32}{7}(15) + 15$$

$$R_f = 90.68$$

(3) The ratio of marked unbranched antler bucks to unmarked unbranched antlered bucks in the photographs in relation to the total number of individual marked unbranched antlered bucks,

(2.12)

$$h_s = \frac{(3)(155)}{155}$$

$$h_s = 3$$

and

(2.13)

$$R_s = \frac{3}{3}(3) + 3$$

$$R_s = 6$$

(4) The ratio of marked branch antlered bucks to unmarked branch antlered bucks in the photographs in relation to individual marked branch antlered bucks,

(2.14)

$$h_b = \frac{(5)(179)}{84}$$

$$h_b = 10.65$$

and

$$R_b = \frac{10.65}{5}(7) + 7 \qquad (2.15)$$

$$R_b = 21.92$$

A total population estimate was derived by summing all the individual component estimates:

$$\hat{N} = 80.16 + 90.68 + 6 + 21.92 \qquad (2.16)$$

$$\hat{N} = 198.76$$

Post harvest estimates were more reliable than the pre-harvest estimates. One of the major problems with this method is that the population must contain a minimum number of marked individuals and the number of marked individuals must be equally represented in each sex and age category (i.e. doe, buck, and fawns).

Ratio Estimator

The ratio method developed by Jacobson et al. (In Press) showed a 1993 pre-harvest estimated population of 246 individuals and a post harvest population of 122.5 individuals (Equations 3.1-3.7). The method also showed a 1994 pre-harvest estimated population of 364.5 individuals and a post harvest population of 209.02 individuals (Equations 3.1-3.7). The post harvest population estimate was calculated using the following equations:

(1) The ratio of branch antlered bucks to unbranched

antlered bucks (spikes),

(3.1)
$$R_s = \frac{310}{264}$$
$$R_s = 1.174$$

and

(3.2)
$$E_b = (23)(1.174) + 23$$
$$E_b = 50.00$$

(2) The ratio of bucks to does,

(3.3)
$$R_d = \frac{752}{574}$$
$$R_d = 1.312$$

and

(3.4)
$$E_d = (50.00)(1.312)$$
$$E_d = 65.63$$

(3) The ratio of fawns to does,

(3.5)
$$R_f = \frac{1070}{752}$$
$$R_f = 1.423$$

and

$$E_f = (65.63)(1.423) \quad (3.6)$$

$$E_f = 93.38$$

A total population estimate was derived by summing all individual components,

$$\hat{N} = 50.00 + 65.63 + 93.38 \quad (3.7)$$

$$\hat{N} = 209.02$$

Change-in-Ratio

The change-in-ratio method produced negative population estimates; thus, model failures. If a change in the proportion of x- to y-type animals (bucks to does, respectively) is small, the method is likely to produce excessively large or small population estimates or model failures (i.e., negative population estimates) (Lancia et. al. 1994).

Helicopter Survey

A helicopter survey was conducted by the MDNR on 15 March 1995, between 9:30-10:30 a.m. The helicopter flew at approximately 200 feet above the ground at 25-50 knots. There was an estimated 40% snow cover. Seventeen east-west transects were establish on a cover map of the island. The pilot started at the north end of the island and worked his way to the light house located on the southern end of the island. At this elevation, 1/8 to 1/4 mile strips were searched for deer. Eighty-one deer were counted and their locations plotted on a cover map. The MDNR estimated that they were only able to count 60 percent of the deer (B. Odum, MDNR, Wildlife Division, pers. comun). Correcting for animals they did not see, they estimated that there were 135 deer on the island. The 1995 helicopter survey should correspond with the 1994 post harvest population estimates.

Ideally, the survey should be done as late as possible, while still having 100% snow cover. On warm sunny days in late winter and/or early spring, deer are more likely to be out in the sun avoiding the colder conifers.

Economic Analysis

An economic analysis was conducted to compare the pellet group survey and camera systems. Pellet group surveys averaged approximately $4.82/ha on the island. It would have cost approximately $9.64/ha to conduct the same intensive survey on mainland Michigan (H. Hill, MDNR, Wildlife Division personal communication). Mainland costs exceeded island costs because with an island setting there are few travel expenses every day.

According to Jacobson et al. (In Press), the estimated cost of running a 14-day camera census at a density of 1-camera per 65-ha was $5.16/ha. The initial cost of the camera systems ($400-500) was depreciated over 5-years (life expectancy) and the average cost of each system was $1.29/ha/yr. Labor cost for running the camera systems will vary but our costs were approximately $.33/ha for 14-days. Corn cost for each station was $.14/ha. The total cost of conducting a 14-day camera census was approximately $6.92/ha. See Appendix C for a complete listing of expenses associated with camera systems.

Cost of running the camera systems on mainland should be similar, the only factors that may increase would be labor and/or transportation costs.

RECOMMENDATIONS AND CONCLUSIONS

A major problem encountered the first year of the study was that the deer had never been exposed to corn, essentially they did not know that it was a food source. Thus, the deer were reluctant to visit the trapping and/or camera locations. This resulted in low trapping success in 1993 and insufficient camera data for a Lincoln-Peterson estimate. The problem was overcome during the winter of 1993 by providing corn free choice all winter. The following years (1994 and 1995) I saw a dramatic increase in deer response at the camera stations (Table 3).

The ratio and the modified Lincoln-Peterson estimators produced reasonable estimates during the post harvest censuses (Table 6). Since I was able to check the pre-harvest and post harvest estimates by either subtracting or adding the number of harvested animals, I feel that the pre-harvest estimates of these two estimators over estimated the population. In doing so, I think that the post harvest estimates better represented the true population on the island. If nothing else, the general trend of these two estimators showed an increase in relative abundance of deer.

The pellet group survey was best when completed before ground vegetation became established (approximately the last two weeks of April). Some recommendations include having experienced individuals conduct the survey and keeping the same lines from year to year so that individual lines can be compared.

Table 6. Summary of white-tailed deer population estimates for 1993-1995 on South Fox Island, MI.

Estimator	Population Estimates		Equation #
	1993 (SE)	1994 (SE)	
[a]Pellet Group Count (MDNR)			
-Post Harvest	156	100	1.1
Lincoln-Peterson (photographic)			
-Pre-Harvest	2597	5262.5	2.1
-Post Harvest	664	4329.4	2.1
Lincoln-Peterson (harvest)			
-Pre-Harvest	NA	332.8 (96.7)	2.2
-Pre-Harvest excludes Radio collared individuals and marked bucks <6-pts.	NA	254.2 (73.6)	2.3
-Pre-Harvest excludes radio collared individuals.	NA	281.2 (81.8)	2.4
Chapman (harvest)			
-Pre-Harvest	NA	312.2 (73.3)	2.5
-Pre-Harvest excludes radio collared individuals and marked bucks <6-pts.	NA	239.5 (54.2)	2.6
-Pre-Harvest excludes radio collared individuals.	NA	264.9 (60.8)	2.7
Modified Lincoln-Peterson (photographic)			
-Pre-Harvest	NA	1696.54	2.8 - 2.16
-Post Harvest	NA	198.8	2.8 - 2.16
Ratio (photographic)			
-Pre-Harvest	246	364.5	3.1 - 3.7
-Post Harvest	122.5	209.4	3.1 - 3.7

Table 6 (cont'd).

[b]Helicopter (MDNR)			
-Post Harvest	NA	135	NA

[a]Pellet surveys were conducted in 1994 and 1995 but they correspond to the 1993 and 1994 post harvest estimates, respectively.
[b]Helicopter counts were conducted in the spring of 1995 but they correspond to the 1994 post harvest estimates.

Classical mark-recapture Lincoln-Peterson and Chapman estimators all require having marked individuals in the population. There was no set number of deer that needed to be marked in the population, however, the higher the percentage of deer marked the better the estimate. In the current study, only 20-25 percent of the population was marked. Higher percentage of marked animals would have provided greater confidence in population estimates (Table 6).

The modified Lincoln-Peterson did not work for the age and sex groups that had relatively few marked individuals (fawns). Ideally a greater number of marked individuals needed to be spread proportionally over each sex and age class (does, bucks and fawns).

The ratio method proved to be a reasonable estimator for the post harvest censuses. The post harvest censuses produced more reasonable results during 1993 and 1994 than many of the other estimators when compared to the harvest estimates (Table 6). One reason could have been that the deer were still stimulated from the hunt and were moving around more and thus were encountering more camera stations. Weather could have also play a role in that during the post harvest census snow was on the ground and food resources were becoming harder to locate.

More does than fawns were photographed in the pre-harvest census, and more fawns than does were photographed in the post harvest census. This could have been a result of the fact that fawns were starting to become more dependent on vegetation during the post harvest census and the corn may have served as an easily obtainable energy source for them at that critical time.

Of the two Trailmaster® monitoring systems (active infrared, TM1500; passive infrared, TM500), the active infrared system preformed the best during the study (1993-1994). With the TM1500, the area of sensitivity was restricted to the area between the transmitter and the receiver. The major problem with the TM500 was that the depth of the field (65-ft) could not be adjusted and low growing vegetation that became heated by the sun was able to activate the system when the wind was blowing.

A minor point to consider is that other animals such as red fox (Vulpes vulpes), coyote (Canis latrans), barred owl (Strix varia), Canada geese (Branta canadensis), blue jays (Cyanocitta cristata), and American crows (Corvus brachyrhynchos) are capable of activating the monitors. Crows use of corn was so bad in the pre-harvest censuses at some stations that corn was discontinued and salt was substituted.

Camera systems can be efficiently used to gather photographic data that can be utilized to generate a number of different estimators. The ratio estimation method seemed to have the least amount of bias associated with it, and also seemed the most practical method to use in other areas, such as on the mainland. The ratio method requires no marked individuals and has no hunter biases associated with it.

Mark recapture methods require marked individuals that must be in the population prior to the census. Thus, a lot of pre-census preparation must be completed before the census can start. By increasing the number of marked animals in the population the confidence intervals associated with Lincoln-Peterson estimates would be lower.

The pellet group survey required skilled personnel and is extremely time consuming. Defecation rates may change seasonally with diet and metabolism, defecation rates for penned deer on artificial diets may differ from wild deer, and they may also differ between species or within species in different habitats (Ryel 1971).

The camera systems could potentially prove to be very useful management tools for estimating populations of white-tailed deer on the mainland. The ratio estimation technique would be best suited for areas where marking individuals is not only impossible but impractical. The ratio technique requires less technically skilled personnel than pellet group surveys and is less time consuming. The optimal time for the camera systems to collect data would be after hunting season.

Chapter 2. Quality White-tailed Deer Management

A quality deer management program was started on South Fox Island by MSU researchers in conjunction with Dr. Harry A. Jacobson of Mississippi State University. Quality deer management can be defined as "the use of restraint in harvesting young bucks combined with adequate harvests of female deer to maintain a healthy population that is in balance with existing habitat conditions" (Quality Deer Management Association, undated). Quality deer management like trophy management stresses enriching nutrition, elevating the number of older bucks, and decreasing the number of does in the population (Ozoga et al. 1994).

Quality deer management varies from traditional management in that a larger percentage of bucks killed are in the 2.5 and older age classes. In the Southeastern U.S., quality deer management has a large following because most of the land is privately owned and many of the private individuals place self imposed restriction on their lands. The increased interest in quality deer management in the Southeast has led to the establishment of some public lands as quality deer management areas.

South Fox Island offered a unique opportunity to determine if quality deer management would be productive in Michigan for public and private lands. The objectives of quality deer management were tested by establishing a six point restriction on the antlered bucks harvested and a liberal doe harvest. Hunters were allowed to kill two does and one buck during the 1993 and 1994 hunting seasons. The "six point rule" stated that it was illegal to kill antlered bucks with less than six antlered points. The "six point rule" was put into law by MDNR Commission Order amendment number 5 and was published in the 1993-1994 and 1994-1995 Michigan Hunting and Trapping Guide. The "six point rule" was intended to eliminate bucks younger than 2.5 years old from being harvested.

During the 1993 and 1994 white-tailed deer hunting seasons, only five illegal bucks were killed on the island. Most of the hunters respected the "six point rule" and were willing to cooperate when I put a restriction on harvesting radio collared individuals. Two years was insufficient time to evaluate the effectiveness of quality deer management. However, the first two years have demonstrated that MI hunters will comply with restrictions (Appendix A).

In the first two years, hunters were very efficient at removing a vast majority of the deer >6-pionts. that are 1.5 to 2.5 years old (Tables 4-5). Because this included a number of 6-pt. yearlings additional restrictions (i.e. minimum inside antler spread of 11.0 inches) would be needed to protect this age class (1.5 year class) (Table 7).

Quality deer management is an achievable goal on any area in Michigan but the key is to have control of a large block of land. These large blocks could be deer management areas or state wide. Even today, some states in the Southeast have established state wide antler restrictions.

Table 7. Mean antler measurements (inches) of all bucks harvested on South Fox Island, MI during the 1993 and 1994 white-tailed deer hunting seasons.[a]

Age		Circumference		Tine Length		Inside
Years	#Points (SE)	Left (SE)	Right (SE)	Left (SE)	Right (SE)	Spread (SE)
1.5						
1993	5(0)	2.91(.04)	2.86(.10)	10.93(.89)	11.22(.98)	8.66(1.77)
1994	5.8(.91)	2.86(.17)	2.84(.17)	10.74(1.07)	10.65(.88)	9.46(.50)
2.5						
1993	7.8(.49)	3.37(.16)	3.45(.19)	16.02(.72)	16.04(.83)	12.97(.68)
1994	7.8(.48)	3.23(.07)	3.30(.12)	14.08(.49)	14.30(.69)	12.15(.57)
3.5						
1993	7.3(.33)	3.51(.22)	3.42).28)	15.94(.41)	15.88(.17)	13.48(.69)
1994	6.5(.65)	3.14(.11)	3.41(.12)	15.10(1.70)	14.82(1.03)	14.13(.44)
4.5						
1993	9(1)	4.70(.49)	4.48(.34)	21.27(.79)	20.37(1.28)	13.78(1.18)
1994	7.7(.88)	3.63(.12)	3.63(.19)	16.58(.46)	16.71(.79)	13.46(1.04)

[a]Antler meaurements are given in inches because any restrictions implemented for hunters would have to be in inches.

A major problem facing quality deer management in Michigan is that there is no clear understanding by the public as to what it really means. To some people it simply means quantity and to others it may mean seeing a lot of deer but at the same time also seeing quality deer (trophy deer). Until there is a clear understanding between the MDNR and the public as to what quality deer management means, it will be difficult to establish quality deer management areas on the mainland.

The MDNR could use quality deer management as a management tool in some of the heavily crop damaged areas. They have the standards established already with the block permits. Block permits are based the amount of crop damage a landowner has on his/her property in a given year. Block permits are restricted to antlerless deer only and may be used by any one that the landowner deems necessary.

Quality deer management could play a major role in better management of Michigan's deer resource through active management. Quality deer management if implemented and managed correctly would keep the deer population in balance with its environment.

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Appendix A

Hunter harvest data for 1993 and 1994 on public and private lands on South Fox Island, MI.

Table A1. Age, gender, average dressed weight and number of antlered points, and total number of white-tailed deer harvested on South Fox Island's public hunting area during the 1993 hunting season.

Age	Bucks			Does	
(years)	#	Average Wt.	Average # Pt's	#	Average Wt.
0.5	5	27.7 kg		4	22.7 kg
1.5				5	38.6 kg
2.5	1	63.5 kg	8	3	44.6 kg
3.5				2	47.6 kg
4.5	1	70.3 kg	10	3	44.6 kg
5.5				1	45.4 kg
6.5				2	45.4 kg
TOTAL=	7			20	

Age	Bucks		Does		Total	
(years)	#	% of Bucks	#	% of Does	#	Total %
0.5	5	72	4	20	9	33.4
1.5			5	25	5	18.5
2.5	1	14	3	15	4	14.8
3.5			2	10	2	7.4
4.5	1	14	3	15	4	14.8
5.5			1	5	1	3.7
6.5			2	10	2	7.4
TOTAL=	7		20		27	

Table A2. Age, gender, average dressed weight and number of antlered points, and total number of white-tailed deer harvested on South Fox Island's private hunting area during the 1993 hunting season.

Age	Bucks			Does	
(years)	#	Average Wt.	Average # Pt's	#	Average Wt.
0.5	8	28.5 kg		12	25.5 kg
1.5	3	56.7 kg	4.0	4	42.5 kg
2.5	4	58.9 kg	7.8	1	36.3 kg
3.5	3	64.3 kg	7.3	7	43.7 kg
4.5	1	83.9 kg	8.0	6	46.5 kg
5.5	1	88.5 kg	8.0	4	44.8 kg
6.5				4	51.0 kg
7.5				1	52.2 kg
TOTAL=	20			39	

Age	Bucks		Does		Total	
(years)	#	% of Bucks	#	% of Does	#	Total %
0.5	8	40	12	31	20	33.7
1.5	3	15	4	10	7	11.9
2.5	4	20	1	3	5	8.5
3.5	3	15	7	18	10	17.0
4.5	1	5	6	15	7	11.9
5.5	1	5	4	10	5	8.5
6.5			4	10	4	6.8
7.5			1	3	1	1.7
TOTAL=	20		39		59	

Table A3. Number of antlered points for each buck harvested by age class for private and public hunting areas on South Fox Island, MI during the 1993 white-tailed deer hunting season.

Age (years)	Private # of Points	Public # of Points
1.5	2,5,5	
2.5	6,8,8,9	8
3.5	7,7,8	
4.5	8	10
5.5	8	
TOTAL BUCKS =	12	2

Table A4. Public land hunters kill tag numbers and deer harvested on South Fox Island during the 1993 white-tailed deer hunting season.

TAG NUMBERS	DEER KILLED[a]
1. 93017 - 93019	
2. 93131 - 93133	D
3. 93107 - 93109	D D
4. 93113 - 93115	A D C
5. 93026 - 93028	
6. 93110 - 93112	D D
7. 93029 - 93031	
8. 93125 - 93127	A
9. 93134 - 93136	C C
10. 93119 - 93121	B D D
11. 93098 - 93100	D D
12. 93116 - 93118	B D C
13. 93032 - 93034	D D
14. 93038 - 93040	A D
15. 93035 - 93037	C D
16. 93014 - 93016	
17. 93020 - 93022	
18. 93023 - 93025	
19. 93011 - 39013	
20. 93095 - 93097	
21. 93104 - 93106	D
22. 93101 - 93103	
23. 93122 - 93124	
24. 93128 - 93130	A

[a]D = Adult Doe, C = Fawn Doe, B = Adult Buck, A = Fawn Buck

Table A5. Private land hunters kill tag numbers and deer harvested on South Fox Island during the 1993 white-tailed deer hunting season.

	TAG NUMBERS	DEER KILLED[a]
1.	93029 - 93211	
2.	93206 - 93208	
3.	93203 - 93205	
4.	93200 - 93202	
5.	93197 - 93199	D
6.	93194 - 93196	D
7.	93191 - 93193	A
8.	93188 - 93190	A
9.	93182 - 93184	A A B
10.	93179 - 93181	D B
11.	93173 - 93175	D C C
12.	93176 - 93178	D
13.	93170 - 93172	D
14.	93167 - 93169	D
15.	93164 - 93166	D
16.	93161 - 93163	D
17.	93158 - 93160	
18.	93155 - 93157	B
19.	93152 - 93154	
20.	93149 - 93151	D
21.	93146 - 93148	
22.	93143 - 93145	
23.	93140 - 93142	
24.	93092 - 93094	D A D
25.	93080 - 93082	B
26.	93089 - 93091	A D
27.	93086 - 93088	
28.	93137 - 93139	D D B
29.	93050 - 93052	
30.	93044 - 93046	

Table A5 (cont'd).

31.	93041 - 93043	D
32.	93047 - 93049	D C *B
33.	93065 - 93067	B
34.	93053 - 93055	C
35.	93056 - 93058	C
36.	93059 - 93061	
37.	93062 - 93064	
38.	93068 - 93070	
39.	93071 - 93073	C D
40.	93074 - 93076	D D C
41.	93077 - 93079	B
42.	93083 - 93085	C A
43.	93185 - 93187	D
44.	93212 - 93214	B
45.	93215 - 93217	
46.	93218 - 93220	B A
47.	93221 - 93223	D D
48.	93224 - 93226	D
49.	93227 - 93229	
50.	93230 - 93232	B
51.	93236 - 93238	D *B
52.	93243 - 93244	
53.	93239 - 93241	C C C
54.	93233 - 93235	C D D

[a]D = Adult Doe, C = Fawn Doe, B = Adult Buck, A = Fawn Buck, *B = illegal buck (less than 6 pts.)

Table A6. Age, gender, average dressed weight and number of antlered points, and total number of white-tailed deer harvested on the public hunting area for South Fox Island during the 1994 hunting season[a].

AGE (Years)	BUCKS #	BUCKS Average Wt.	BUCKS Average # Pt's	DOES #	DOES Average Wt.
0.5	4	30.1 kg		5	24.9 kg
1.5	2	39.2 kg	7.5	2	44.2 kg
2.5	2	68.0 kg	8.5	1	45.4 kg
3.5	2	69.2 kg	7.5	1	43.1 kg
4.5	1	58.9 kg	9.0	2	47.6 kg
5.5				2	52.2 kg
6.5	1	81.6 kg	8.0		
7.5				1	47.6 kg
TOTAL =	12				14

AGE (Years)	BUCKS #	BUCKS % of Bucks	DOES #	DOES % of Does	TOTAL #	TOTAL Total %
0.5	4	33	5	36	9	34
1.5	2	17	2	14	4	16
2.5	2	17	1	7	3	12
3.5	2	17	1	7	3	12
4.5	1	8	2	14	3	12
5.5			2	14	2	8
6.5	1	8			1	4
7.5			1	7	1	4
TOTAL =	12		14		26	

[a]Only 1 deer was taken during archery season, a 1 1/2 year old 6 point buck.

Table A7. Age, gender, average dressed weight and number of antlered points, and total number of white-tailed deer harvested on the private hunting area for South Fox Island, MI during the 1994 hunting season.

AGE	BUCKS			DOES	
(Years)	#	Average Wt.	Average # Pt's	#	Average Wt.
0.5	5	24.9 kg		4	20.4 kg
1.5	4	44.8 kg	5.0	5	38.6 kg
2.5	3	63.5 kg	7.3	6	43.9 kg
3.5	2	65.8 kg	5.5		
4.5	2	73.7 kg	7.0	3	47.6 kg
5.5				2	44.6 kg
6.5				1	45.4 kg
7.5				1	45.4 kg
TOTAL =	16			22	

AGE	BUCKS		DOES		TOTAL	
(Years)	#	% of Bucks	#	% of Does	#	Total %
0.5	5	29	4	18	9	23
1.5	4	29	5	23	9	26
2.5	3	18	6	27	9	23
3.5	2	12			2	5
4.5	2	12	3	14	5	13
5.5			2	9	2	5
6.5			1	5	1	3
7.5			1	5	1	3
TOTAL =	16		22		38	

Table A8. Number of antlered points for each buck harvested by age class for private and public hunting areas on South Fox Island, MI during the 1994 white-tailed deer hunting season.

AGE (Years)	PRIVATE # of Points	PUBLIC # of Points
1.5	6,6,6,2	6,9
2.5	8,8,6	8,9
3.5	5,6	7,8
4.5	6,8	9
5.5		
6.5		8
TOTAL BUCKS =	11	8

Table A9. Public land hunters kill tag numbers and deer harvested on South Fox Island, MI during the 1994 white-tailed deer hunting season.

	TAG NUMBERS	DEER KILLED[a]
1.	94393 - 94395	
2.	94595 - 94597	C,C
3.	94381 - 94383	
4.	94339 - 94341	
5.	94342 - 94344	
6.	94327 - 94329	
7.	94417 - 94419	B,D,A
8.	94384 - 94386	D,C
9.	94387 - 94389	
10.	94399, 94400, 94591	
11.	94321 - 94323	
12.	94592 - 94594	
13.	94372 - 94374	B
14.	94378 - 94380	
15.	94622 - 94624	C
16.	94614 - 94616	B,D
17.	94324 - 94326	
18.	94611 - 94613	
19.	94336 - 94338	
20.	94330 - 94332	
21.	94603 - 94605	
22.	94631 - 94633	
23.	94369 - 94371	
24.	94414 - 94416	B
25.	94411 - 94413	B
26.	94396 - 94398	B,D
27.	94375 - 94377	D
28.	94606 - 94608	D,A
29.	94348 - 94350	B
30.	94351 - 94353	A,D
31.	94345 - 94347	

Table A9 (cont'd).

32.	94333 - 94335	
33.	94617 - 94619	
34.	94360 - 94362	
35.	94401, 94402, 94420	C,A
36.	94628 - 94630	
37.	94354 - 94356	
38.	94598 - 94600	
39.	94357 - 94359	
40.	94390 - 94392	
41.	94363 - 94365	
42.	94366 - 94368	
43.	94625 - 94627	D
44.	94609, 94610, 94621	D,B
45.	94601, 94602, 94620	

[a]D = Adult Doe, C = Fawn Doe, B = Adult Buck, A = Fawn Buck

Table A10. Private land hunters kill tag numbers and deer harvested on South Fox Island, MI during the 1994 white-tailed deer hunting season.

	TAG NUMBERS	DEER KILLED[a]
	94180 - 94182	
	94049 - 94051	
	94082 - 94084	
	94070 - 94072	B
	94052 - 94054	D
	94186 - 94188	A
	94174 - 94176	
	94043 - 94045	D
	94103 - 94105	
	94010 - 94012	D,B
	94067 - 94069	B
	94159 - 94161	
	94058 - 94060	
	94001 - 94003	
	94097 - 94099	D,D
	94034 - 94036	B
	94031 - 94033	
	94028 - 94930	
	94016, 94017, 94021	A
	94040 - 94042	
	94085, 94089, 94090	C,D,B
	94294 - 94296	D,D
	94177 - 94179	
	94147 - 94149	
	94061 - 94063	D
27.	94055 - 94057	
28.	94291 - 94293	A,D
29.	94171 - 94173	C,D,B*
30.	94138 - 94140	
31.	94114 - 94116	
32.	94037 - 94039	

Table A10 (cont'd).

33.	94100 - 94102	C
34.	94120 - 94122	
35.	94117 - 94119	
36.	94094 - 94096	
37.	94086 - 94088	B*
38.	94004 - 94006	
39.	94076 - 94078	
40.	94046 - 94948	
41.	94165 - 94167	
42.	94123 - 94125	D
43.	94079 - 94081	B
44.	94132 - 94134	
45.	94126 - 94128	A,D
46.	94106 - 94108	
47.	94022 - 94024	B
48.	94025 - 94027	
49.	94168 - 94170	
50.	94162 - 94164	
51.	94156 - 94158	
52.	94073 - 94075	D
53.	94144 - 94146	D
54.	94183 - 94185	
55.	94013 - 94015	D
56.	94111 - 94113	
57.	94129 - 94131	
58.	94064 - 94066	D,C
59.	94153 - 94155	
60.	94150 - 94152	
61.	94091 - 94093	D,B
62.	94007 - 94009	

[a]A = fawn buck, C = fawn doe, D = adult doe, B = adult bucks, and B* = illegal bucks (less than 6-pts)

Appendix B

Sample calculations of equations listed in text.

Table B1. Numerical solutions for the 1994 post harvest population estimates from the Lincoln-Peterson and Chapman estimators based on photographic and hunter harvest data collected on South Fox Island, MI.

Equation 2.1

$$\hat{N} = \frac{47(2395)}{26} = 4329$$

Equation 2.2

$$\hat{N} = \frac{52(64)}{10} = 332.8$$

Equation 2.3

$$\hat{N}' = \frac{41(62)}{10} = 254.2$$

Equation 2.4

$$\hat{N}'' = \frac{44(64)}{10} = 281.6$$

Equation 2.5

$$\hat{N}_c = \frac{(52 + 1)\ (64 + 1)}{(10 + 1)} - 1 = 312.2$$

Equation 2.6

$$\hat{N}_c' = \frac{(41 + 1)\ (62 + 1)}{(10 + 1)} - 1 = 239.5$$

Equation 2.7

$$\hat{N}_c'' = \frac{(44 + 1)\ (64 + 1)}{(10 + 1)} - 1 = 264.9$$

Appendix C

Cost associated with operating infrared camera systems.

Table C1. An itemized list of all expenses associated with running infrared camera systems, all number are approximate.

Item	Number Needed	Cost
Camera Systems		$500
Passive	9	
Active	11	
"C" Batteries		$0.66/each
Passive	4/monitor	
Active	8/monitor	
Film		
35mm ISO 200, 36 exp.	80 rolls	$5.50/roll
Developing	80 rolls	$8.00/roll
Corn	1500 lbs	$6.00/50 lbs
Labor	2-3 weeks	$250/week
Total cost of running camera's for 14-days	=	$6.92/ha