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INTEGRATION OF ARCHERY WHITE-TAILED DEER (Odocoileus virginianus) HARVEST DATA INTO A SEX-AGE-KILL POPULATION MODEL

presented by

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Scott R. Winterstein
Major professor

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INTEGRATION OF ARCHERY WHITE-TAILED DEER (*Odocoileus virginianus*) HARVEST DATA INTO A SEX-AGE-KILL POPULATION MODEL

By

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ABSTRACT

INTEGRATION OF ARCHERY WHITE-TAILED DEER HARVEST DATA (*Odocoileus virginianus*) INTO A SEX-AGE-KILL POPULATION ESTIMATOR

By

Kimberly Marie Mattson Hansen

Archery hunting for white-tailed deer (*Odocoileus virginianus*) has gained popularity in Michigan over the past thirty years. Historically, few hunters participated in the archery hunting season, but Michigan has had a dramatic increase in archery license sales, hunter-days, and harvest since the 1960s. With an increasing proportion of the deer harvest coming from archery hunting season, harvest statistics were studied to determine if biological data from archery harvested deer should be included in a sex-age-kill (SAK) population model. It was determined that there were significant differences between firearm and archery harvest biological data. Firearm harvest biological data were incorporated both independently and combined with archery harvest biological data into the SAK model. Population estimates for years 1987-1996 for five geographic areas in Michigan were determined. Population estimates from the SAK model were plotted with annual deer-vehicle accident rates by year to detect trends. Results indicated that the SAK model appeared to be a reliable index of the size of the deer herd at various geographic scales. Variation among geographic areas appeared to be the result of density independent factors and regulation processes in each area. Further studies are needed to determine if the SAK model can be used as a reliable population estimator in Michigan.

DEDICATION

To Lily and Thore Mattson

Who encouraged each of their grandchildren
to go to school and get an education

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INTRODUCTION

Population Estimates

Managers have relied on various techniques, including nonharvest and harvest-based population estimators, to monitor local and regional white-tailed deer (*Odocoileus virginianus*) populations (McCullough 1979, Roseberry and Woolf 1991). Although data for nonharvest-based population models can be collected and evaluated directly by managers, harvest-based population models are dependent upon hunters for data collection. Changes in hunter participation, hunting regulations, hunter success rates and technology are only a few factors that would affect the quality of harvest-based data collected from hunters. Unless these changes are accounted for in harvest-based models, population estimates may be incorrectly determined. Therefore, reevaluation of harvest-based population models may be required if data begin to vary due to regulation or hunter-related changes.

There are a number of methods that can be employed to estimate the size of white-tailed deer populations. Three broad categories can be used to describe these methods: total population counts, population indices, and population estimators - which measure certain attributes of a population. Although total counts have been used in isolated areas, they are not reliable in large land areas and take many hours to perform (Hawn and Ryel 1969, McCullough 1979). Population indices provide information on relative abundance rather than absolute population numbers. Indices are important not only for general information about deer in a particular area, but also to assist in the validation of other population estimation techniques (Roseberry and Woolf 1991).

Validation generally comes from long-term monitoring of an index. Population estimators, however, ordinarily give absolute numbers rather than the relative results of indices. Furthermore, there are two general types of population indices and estimators, nonharvest-based and harvest-based.

Nonharvest-based population indices may incorporate data from spotlight surveys, track counts, summer deer observations, and deer-vehicle accidents. Relative densities of deer can be determined from spotlight surveys (Progulske and Duerre 1964). Counting the number of tracks on a known deer trail is an index of relative abundance (McCaffery 1976). This technique has been compared to other indices as well as to the sex-age-kill population estimator (McCaffery 1976, Mooty and Karns 1984). Summer deer herd observations are performed from July through September in Michigan (Langenau 1995). This index provides information on the numbers of bucks, does and fawns seen throughout Michigan. Deer population trends can also be determined by the number of deer-vehicle accidents in an area (Case 1978, McCaffery 1973). A positive relationship has been found between the number of deer-vehicle accidents and the estimated size of the deer population in Michigan and other areas (Case 1978, McCaffery 1973, MDNR unpublished data).

Nonharvest-based population estimators are also important. One of the primary population estimators used in Michigan is the deer pellet survey. Data are collected in the spring in the northern Lower and Upper Peninsulas of Michigan, but cannot be collected in southern Michigan due to habitat conditions (see Hill (1995) for a detailed study description). Pellet surveys are used to estimate the size of the previous fall's deer herd (Hill 1995), but can also be an index, giving relative densities of deer in particular habitats (Van Etten and Bennett 1965).

Most harvest-based population estimators have the same basic mechanism. There are usually three major parameters: harvest mortality, nonharvest mortality, and age structure data. These models estimate total population sizes, and some models may provide age class population estimates as well (Roseberry and Woolf 1991). The composition of the data collected depends on harvest regulations. For example, if the management goal is to protect young bucks, regulations are going to be different than in an area where a hunter may harvest any buck. Changes in regulations may affect the sex and age of deer harvested, and, hence, the data collected from harvested deer.

Archery Hunting Season Data

The most comprehensive information collected about the deer herd in Michigan is obtained from hunters through voluntary check stations and from mail surveys. Michigan has three annual fall hunting seasons. The split archery season extends from October 1 through November 14 and from December 1 to January 1 (MDNR 1996a). Firearm season is November 15-30, and muzzleloader season is held in December (MDNR 1996a). Biological data are obtained throughout the deer hunting seasons, with voluntary check stations open for the duration of all the seasons. In addition, highway check stations are open during a portion of the firearm hunting season. Information collected at check stations includes the sex and age of deer harvested and the hunting season and deer management unit in which each deer was harvested. Annual mail surveys are sent to a sample of hunters to obtain information regarding the sex of the deer harvested as well as the deer management unit and county in which hunting occurred (MDNR 1995).

Traditionally, the Michigan Department of Natural Resources (MDNR) has employed a harvest-based population estimator for setting deer harvest quotas in the fall hunting season. Models employing harvest-based population data have been developed for this purpose (Roseberry and Woolf 1991). Most of these models are based on firearm harvest data, as these data provide the most comprehensive historical base. In the early and mid twentieth century, archery hunting was not popular, so the number of deer harvested by this method was negligible. In recent years, however, archery hunting has gained popularity. This is demonstrated in the increasing numbers of deer harvested during the archery hunting season as shown in Figure 1 (Langenau et al. 1994).

With an increasing proportion of the deer harvest coming from archery hunting season, there is concern that data from these deer should be included in traditional harvest-based population models (Langenau et al. 1994). This is especially important when the types of data collected at check stations are considered. Biological data (henceforth, biodata) retrieved from deer harvested during the firearm season in Michigan have been used to determine sex ratios, fawn:doe ratios and total populations of white-tailed deer at various geographic scales (Moritz, MDNR, personal communication). It has yet to be determined if the inclusion of archery data will alter results that had been obtained exclusively from firearm harvest statistics in Michigan.

The MDNR has also been concerned in recent years about the effect of an increase in both archery license sales and the archery harvest on harvest-based population model estimates. Although firearm hunter numbers have remained relatively stable over the years, there has been a marked increase in the number of archery licenses sold (Winterstein et al. 1995). In 1981, less than 292,000 eligible bow hunting licenses

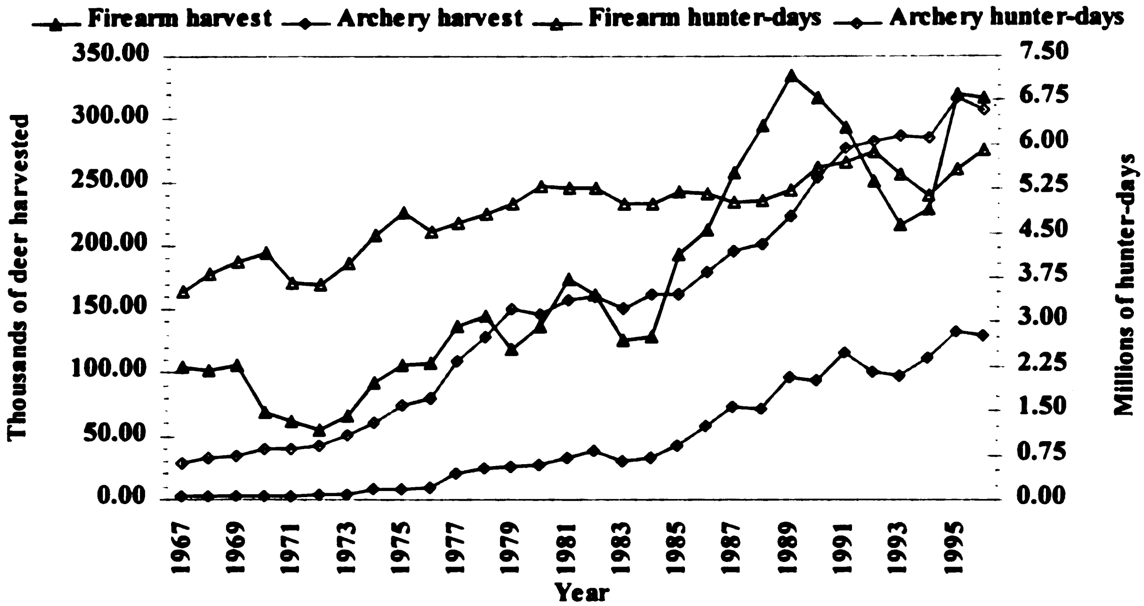


Figure 1. Statewide white-tailed deer harvest and hunter effort in Michigan (1967-1996).

were sold with a harvest of 33,320 deer; in contrast, 488,774 eligible bow hunting licenses were sold in 1995 with a harvest of 132,130 deer (Figure 1, MDNR 1980, MDNR 1996b). In addition to the normal archery hunting season license, eligible bow hunting licenses include those bow hunting licenses that are part of a package, such as the senior hunt license, which entitles the holder to hunt deer, small game, furbearing animals, and waterfowl. Because traditional harvest-based population estimates in Michigan have not included archery biodata, population estimates may not be an accurate representation of the size of the deer herd.

Further evidence that archery data may be an important component of estimating the size of the deer population in Michigan is reflected in harvest counts and the number of hunter-days during each deer hunting season. Harvest counts indicate that the proportion of archery kills was 27% of the total statewide deer harvest in 1992 (Langenau et al. 1994). This is an increase from the archery harvest in 1970, which was 10% of the combined (archery and firearm) statewide deer harvest (MDNR unpublished data). Recently, as much as 50% of the harvest has occurred during archery season in some areas (Langenau unpublished data). Hunter-days have shown a similar trend. Archery hunter-days statewide have almost doubled since 1980, whereas the number of firearm hunter-days have remained relatively stable (Figure 1, MDNR unpublished data).

All of these factors have contributed to a large increase in the number of deer harvested during the archery season. There are several concerns associated with this increase. First and foremost, managers need to determine how archery harvest data should be evaluated in terms of harvest-based population models. Once these data are evaluated, managers can determine if archery harvest is having a biological impact on the deer herd. Such a scenario would occur if the archery harvest is directly altering age and/or sex ratios. Biological impacts on the herd would then need to be considered during the regulation process. Results from studying the impacts of changing harvest statistics are also important when hunter relations and other sociological concerns are considered.

Population Model Analysis

The MDNR is studying the use of the sex-age-kill (SAK) method of population analysis as developed by Eberhardt (1960) and modified for use as a standard procedure in Wisconsin (Creed et al. 1984). The overall SAK method is actually a combination of kill-curves, as introduced by Eberhardt (1960), and sex and age ratios as discussed by Severinghaus and Maguire (1955). Creed et al. (1984) developed SAK further to assess the Wisconsin deer herd, using annual expansion factors when sample sizes were adequate and long-term averages when sample sizes were small. Since 1985, the Wisconsin method has also incorporated archery data into SAK analysis in an attempt to meet the assumptions of the model (WDNR unpublished data). This estimator is currently also being used in several other states (Moritz pers. comm.). Although the MDNR has relied on a derivative of this population estimator for years, its use has not been validated for the Michigan deer herd.

SAK is a retrospective population estimator, and does not consider over-winter loss (Creed et al. 1984). Being harvest-based, SAK relies on accurate biodata from the hunting seasons. The numbers of bucks, does and fawns harvested are used to determine the population size prior to the hunting seasons. This method works best when both bucks and antlerless deer are harvested, but an alternate source of data for sex and age compositions may be substituted in years or geographic areas with a bucks-only harvest (Creed et al. 1984). In Michigan, firearm harvest biodata are incorporated into the SAK model to determine deer harvest and population numbers each year. It is still unknown what effect the addition of archery harvest biodata may have on model results in Michigan.

Regulation changes and fluctuations in management goals may influence proper evaluation of the deer population. Any major change in regulations is reflected in the number and types of hunting permits available, and, therefore, in the harvest data collected at check stations. Although most regulation changes are minor, major changes can take place. One such example of changing management goals would be to limit the number of buck permits while allowing a very liberal number of antlerless permits, which is defined by some as the practice of quality deer management. Quality deer management (QDM) is defined as a strategy that promotes a healthy deer population through an appropriate antlerless harvest and a limited yearling buck harvest (Miller and Marchinton 1995). To understand the implications of these types of changes in management strategies, current archery harvest statistics must be evaluated to determine if sex and age compositions within the deer herd have changed without such revisions. This study attempted to aid in developing harvest regulations by giving the MDNR an evaluation of the impacts that an increasing archery harvest is having on the Michigan deer herd.

Due to the increasing percentages of archery hunters and harvest, archery harvest data may play a key role in obtaining accurate SAK population estimates. Considering the increasing number of archery hunters and the rising percentages of deer harvested during archery hunting season, data derived from the archery hunting season should be given closer examination. This study attempted to demonstrate the validity of a harvest-based population estimator by examining the importance of incorporating archery harvest data into the SAK population model.

STUDY OBJECTIVES

The primary objective of this study was to determine the validity of the sex-age-kill (SAK) model in estimating the size of the deer population of Michigan. The secondary objective was to determine if archery biodata should be incorporated into the SAK model. The assumptions of the SAK model were examined with respect to the primary objective. Data were analyzed on a statewide basis as well as by various geographic areas.

Objectives for this research were to:

1) Determine if current sample sizes of archery harvest data are large enough to permit population analysis at the district level.
2) Determine if biodata collected from the archery deer harvest are significantly different from biodata of firearm harvested deer.
3) Determine if voluntary check station sex and age composition data are comparable to that of mandatory check stations.
4) Test the assumptions of the SAK model to determine if the SAK model is a valid estimator for the population size of white-tailed deer in Michigan.
5) Determine if the inclusion of archery biodata into the SAK model significantly changes any of the following estimates: total population estimates, sex ratios, and/or fawn:doe ratios already expressed in the model.
6) Recommend procedures and guidelines for the use of the SAK population model.

METHODS

Sample Size

This study utilized harvest statistics and check station biodata furnished by the MDNR. More than forty years of firearm harvest data were available, compared to about twenty years of archery harvest data. Although the MDNR has been collecting archery hunting season data since the 1970s, sample sizes were small for antlerless deer until the 1980s. Antlerless deer biodata were not routinely collected in the Lower Peninsula until 1975 and not in the Upper Peninsula until 1978 (MDNR 1976, 1979). There were many areas closed to antlerless deer hunting within Michigan, and restricted permit availability in other areas (MDNR 1976, 1979). These factors, coupled with a small sample of archery biodata, prevented this study from utilizing the first several years of archery check station biodata.

To evaluate the check station biodata, harvest data were segregated by year, hunting season, sex of deer, and county of harvest. Buck and doe fawns were aggregated as one age class. All unknown age deer, which are deer with a recorded age of "A" or "AA" in the check station data, were removed from the study. These age categories are used by the MDNR to denote a 1.5 year old and older or a 2.5 years old and older deer, respectively, and are used when age cannot accurately be determined (MDNR unpublished data). One problem in using deer aged as an "A" or "AA" is that it is difficult to assess any discrepancies with their use. Since unknown age deer account for roughly 3-5% of the statewide deer check station data each year (MDNR unpublished data), deleting these age classes was not perceived to be a problem.

Adequate sample sizes (n_0) were determined for a 95% confidence level and a 0.10 degree of precision using the following equation:

$$n_0 = \frac{z^2 p(1-p)}{d^2}$$

where z is the $\alpha/2$ point of the normal distribution, p is the population proportion observed, and d is the desired degree of precision of the estimate (Thompson 1992:31-46). Adequate sample sizes could not be determined at county or district levels, so data had to be grouped into larger units.

Once adequate sample sizes were determined, county level data were grouped to obtain sample sizes that were statistically adequate, ecologically sound, and which provided study results that were useful to managers across the state. At the time this study was started, Michigan had 13 wildlife management districts. In 1998, the MDNR combined some of these districts to result in eight management units across the state (MDNR unpublished data). Five geographic groups were made from the thirteen wildlife management districts based on both district boundaries and ecological similarities (Figure 2). Ecological information was based on a hierarchical classification system as described by Albert (1995). Section level classifications were utilized throughout Michigan (Albert 1995). The resulting geographic groups were used for seasonal check station comparisons and for analyzing the SAK model.

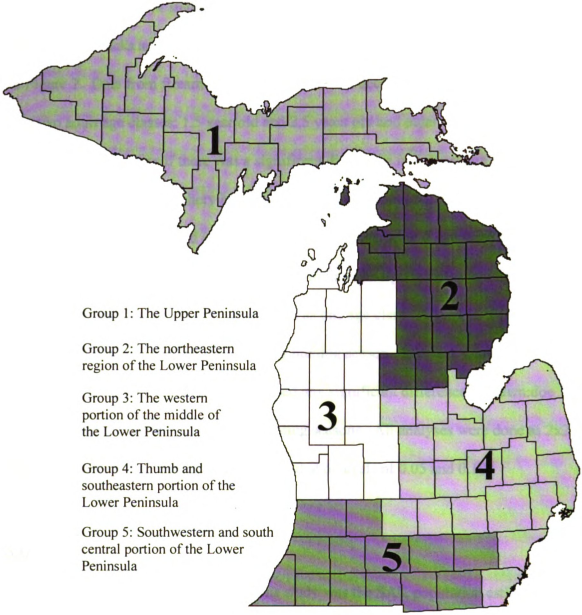


Figure 2. Geographic group delineation of Michigan. Groups are based on ecological similarities and 1996 MDNR Wildlife Division district boundaries. Numbers on the map correspond to the descriptions of each area on the left.

Seasonal Check Station Comparison

Voluntary check station biodata from 1987-1996 were utilized for this part of the study. Adult bucks and adult does were grouped into the five geographic groups shown in Figure 2. Data from firearm and archery harvested deer were aggregated by sex then into two adult age classes: 1.5 year old and 2.5 years old and older. Chi-square tests were performed to determine if there was a significant difference in harvest age structure between the firearm and archery hunting seasons. Data from adult bucks and adult does 1.5 year old and 2.5 years old and older were used to determine if age distributions in the harvest are independent of harvest methods. Similar Chi-square tests were done for fawns. Buck and doe fawns were aggregated as one age class. All fawns were evaluated against adult does 1.5 year old and older by hunting season. In effect, Chi-square analyses for this part of the study determined any significant differences in fawn:doe ratios between the archery and firearm hunting seasons. All analyses were done as 2x2 Chi-square tests with 1 degree of freedom and at α-levels of 0.05 and 0.10.

SAK Model

The population model used for this study was the SAK population estimator (Eberhardt 1960, 1969; Johnson 1994). This model uses biological data from harvested deer to estimate the population size prior to all hunting seasons. Future populations can be projected by following averages and trends. The data needed for the model are a nonharvest mortality rate, check station biodata, and information from post-hunting season mail surveys. Biodata used from the check stations include the numbers of bucks, does, and fawns brought to the stations as well as sex and age ratios from these deer. Model results include estimates of buck mortality, doe:buck ratios, and fawn:doe ratios prior to the hunting seasons, and the total number of deer in the previous fall population (Creed et al. 1984).

To use the SAK model as a population estimator, a major mortality source and a measure of age structure are needed. These criteria are conveniently obtained from harvest data. Each year, harvested deer are sexed and aged at voluntary check stations throughout Michigan. These biodata are then used as a representative sample of the deer harvested to estimate the population size prior to the hunting seasons. Only known age deer are used in this estimate due to a lack of age ratios for unknown age deer. To obtain a population estimate of the entire deer herd, bucks and antlerless deer need to be harvested and counted. Otherwise, for a bucks-only season, there are insufficient data to estimate doe and fawn numbers. In an area without an antlerless hunting season, summer herd observations, spotlight counts, or another index of sex and age ratios may be used (Creed et al. 1984).

In the SAK model, nonharvest mortality is used as a constant rate over the whole year. Nonharvest mortality includes density dependent and density independent factors such as scant summer food sources, illegal hunting and winter mortality. Winter severity varies throughout the state each year and may differentially affect age classes. However, a constant mortality rate is used for all sectors of the population in the SAK model, so any differences in mortality for fawns versus adults throughout the year is not directly reflected in this model (Creed et al. 1984). Nonharvest mortality, considered separate from harvest mortality, is called the lifetime recovery rate, r, and is presented as the percentage of deer living throughout the year (Creed et al. 1984). For example, if 15% of the population (fawns and adults) died of nonharvest mortality throughout the year, the lifetime recovery rate would be 85%.

The size of each sector of the population is extrapolated using the following methods. Mail surveys are sent to a random sample of deer hunters shortly after the hunting seasons have ended. Survey methods include a random or a systematic sample with a random start drawn from hunting license holders, and reminders are sent to nonrespondents (Research Triangle Institute 1966, MDNR 1995). This provides a response rate of approximately 90% each year. The returned surveys provide a representative sample of the total buck harvest across seasons (Hawn and Ryel 1969). This estimate is then used in the SAK model to calculate the buck population from the previous fall (before any harvesting had taken place). All other model variable data are taken directly from check station biodata.

Bucks

Methods used to calculate the number of bucks that were alive prior to the hunting seasons are shown below. The information needed for the first equation is collected at check stations. Fawns are dealt with separately from adults.

$$\text{Percentage of yearling bucks} = \frac{\#1.5 \text{ year old bucks}}{\text{Total known age adult bucks}}$$

For example, if there were 1,000 adult bucks of known age registered at the check stations, and 750 of them were aged as yearlings, then there would be a percentage of

0.75 yearling bucks in the harvest.

Total buck mortality includes both yearling and adult bucks, but not fawn bucks. To calculate the total adult buck mortality, the lifetime recovery rate, r, must be used to account for any natural mortality that may have occurred throughout the year. The r value is a total survival rate for the population; the product of r and the percentage of yearling bucks in the harvest is the estimated total adult buck mortality:

$$\text{Total adult buck mortality} = \text{percentage of yearling bucks} \times r$$

Therefore, if 90% of the deer population survives throughout the year, the r value is 0.90. Multiply this value by the percentage of yearling bucks from the previous example, 0.75. The estimated total adult buck mortality is, therefore, 0.675, which is the percentage of adult bucks that died from both nonharvest and harvest-based mortality factors.

Once the total buck mortality has been estimated, the adult buck population prior to the hunting seasons can be determined. This population is the adult buck population (1.5 year old and 2.5 years old and older) available on October 1 of the previous year, since the archery deer hunting season starts October 1. Information from the mail survey is used for this estimate:

$$\text{Total available bucks} = \frac{\text{Total buck harvest}}{\text{Total buck mortality}}$$

To continue the example, assume the mail survey returned a sample of 14,000 1.5

year old and 2.5 years old and older bucks harvested across all hunting seasons. Divide this number by the total buck mortality of 0.675, and the total adult buck population prior to the hunting seasons would be 20,741 deer.

Does and Fawns

In areas that have antlerless hunting seasons, check station biodata should be used to determine doe and fawn populations. If harvest data are not available, other data sources, such as summer deer observations or spotlight counts, can be utilized (Creed et al. 1984). These data would be used in a similar manner as that listed below for harvest data. Because some areas in Michigan have not continually been open to antlerless harvest, not all years will have adequate harvest data samples.

The percentage of yearling does in the population is determined in a similar manner to the percentage of yearling bucks:

$$\text{Percentage of yearling does} = \frac{\#1.5 \text{ year old does}}{\text{Total known age adult does}}$$

Assume 1,000 known age does were obtained from the check stations. If 450 of these were 1.5 year olds, the percentage of yearling does in the population is 0.45.

The percentage of does can be compared to the percentage of bucks to find the sex ratio in the population. This ratio is not affected by the lifetime recovery rate because it uses firearm check station data exclusively. Only yearling bucks and yearling does are used to find the sex ratio because it is assumed that harvest data reflects each age group proportionally to abundance in the population (Severinghaus and MacGuire 1955). See

Appendix A for a detailed derivation of this equation.

$$\text{Doe:buck} = \frac{\text{Percentage of yearling bucks in firearm biodata}}{\text{Percentage of yearling does in firearm biodata}}$$

The doe:buck ratio can be found using results from the previous calculations. There are 0.75 yearling bucks and 0.45 yearling does obtained at the check stations, yielding a doe:buck ratio of 1.67 adult does for each adult buck.

It is possible to estimate the numbers of does and fawns in the population for management areas that have sex and age composition data available. Information recorded at check stations is used to estimate the number of does and fawns, as well as the fawn:doe ratio. The number of adult does, including yearlings, is calculated using the doe:buck ratio, which determines the total doe population on the previous October 1.

$$\text{Total Available Does} = \text{Total available bucks} * \text{Doe:buck ratio}$$

In this example, the total available does is 20,741 total available bucks multiplied by the doe:buck ratio (1.67). This results in an estimate of 34,638 does in the population prior to the hunting seasons.

The fawn:doe ratio includes all fawns as well as yearling and 2.5 years old and older does. Data are collected at the check stations, and the calculation is the number of fawns divided by the number of adult does. The number of available fawns is calculated similarly to the numbers of available does and bucks.

Total number of fawns = # of adult does * fawn:doe ratio

The total fawn population would then be the 34,638 adult does multiplied by the fawn:doe ratio from the check stations, say 1.01, resulting in 34,984 fawns in the population prior to the hunting seasons.

The estimated total deer population before the beginning of the hunting seasons can now be calculated by summing the total numbers of bucks, does and fawns estimated above. In this example, the estimated total population would be the sum of 20,741 bucks, 34,638 does, and 34,984 fawns for a grand total of 90,363 deer.

SAK Model Assumptions

For the SAK model to be accurate, there are a number of assumptions that must be met (Eberhardt 1960, Creed et al. 1984). The assumptions are that: 1) the population is at a stable age distribution; 2) the sample sexed and aged at check stations is representative of the population; 3) fawn production is measured accurately; 4) nonharvest mortality is known; and 5) buck harvest pressure is uniform from year to year. Wisconsin, which has mandatory registration of harvested deer, also uses the assumption that 98% of the deer harvested are registered in that state (WDNR unpublished data). Since Michigan has voluntary check stations, the MDNR does not use this assumption.

Testing SAK Model Assumptions

Most of the SAK model assumptions were analyzed. First, a stable age distribution was tested by utilizing firearm and archery harvest biodata. A stable age distribution is defined as a distribution of constant proportions of individuals in each age class. It occurs in a population when age-dependent survival and productivity rates remain constant over a long period of time, resulting in a stabilization of each age class (Johnson 1994). To test this assumption, firearm and archery check station biodata were combined, then grouped by sex and separated into adult age classes for each of the five geographic groups in Figure 2. Percent yearlings from the combined seasons were tested for differences among years during a ten year period (1987-1996) to determine if a stable age distribution existed over the years.

Contingency tables were constructed to determine absolute differences in percent yearlings among the ten years. For individual geographic groups, the expected number of yearling and 2.5 years old and older deer were determined each year. Additionally, the percent yearlings from the combined seasons were plotted against each respective year for individual geographic groups to determine long-term trends within age classes. Regression analyses were done on these data to determine any significant deviations in the percent yearlings from the long-term mean among years. The regression analyses tested the assumption that the percent yearlings in the check station biodata each year represent random fluctuations around a long-term mean with a slope of zero.

The other SAK model assumptions were handled as follows. For the purposes of this study, estimates of fawn production in Michigan were considered accurate. No data were available to assess this assumption further. In determining nonharvest mortality for the SAK model, a constant value has traditionally been used over long periods of time (Creed et al. 1984). A value of 0.9 has been used for the Michigan deer herd, so this value was kept constant when determining model estimates. The assumption that buck harvest pressure is uniform from year to year was tested. This assumption also relies on the stability of year to year values for percent yearling bucks in the harvest data. The validity of this assumption was determined by evaluating the percent yearling bucks in the check station biodata, thus the results of the stable age distribution analyses were also utilized to test this assumption.

Intrastate and Interstate Comparisons

One of the SAK model assumptions is that the biodata are representative of the herd. It was determined that the best method of testing this assumption was to compare voluntary and mandatory check station biodata, since mandatory check stations are assumed to collect representative data about the herd. Check station biodata are collected on a voluntary basis in Michigan, so data were requested from surrounding states that had mandatory check stations. Data were requested from Wisconsin, Ohio, and Indiana. One of the overlying assumptions of this analysis was that the herds in each of these states had similar compositions. If this particular assumption was not met, then results may be erroneous due to the fact that equivalent populations were not being tested. To mitigate this, data from similar geographic areas in each state were requested.

The southern farmland region of Michigan has similar ecological features as Wisconsin's southern farmland region, Indiana and Ohio (Albert 1995). This made it *potentially* possible to compare the deer herds among these areas to determine if voluntary check station data are representative of the herd. Mandatory check station data are assumed by definition to be representative of the deer herd. Voluntary registration, on the other hand, checks a random, or assumed random, sample of deer from the population. Since one of the assumptions of the SAK model is that the harvest is representative of the herd, the initial intent was to compare voluntary check station biodata from Michigan to mandatory check station biodata from nearby states to determine if the voluntary check station biodata really do represent the herd.

There were too many assumptions and uncontrollable factors involved to be able to correctly interpret any results. There could be two reasons for this. First, the herds may have had different compositions. Each state's data could accurately reflect the composition of that state's deer herd, but the herd composition could be different between states. Secondly, data collection methods in Wisconsin may have been different from those in Michigan. For example, the major assumption of this analysis was that Michigan and the other states had herds with similar sex and age compositions. If this assumption was false, then the trends seen within the check station biodata may not be interpreted correctly. After examining the biodata from Michigan and Wisconsin, it was determined that the results of such an analysis were invalid. Therefore, this analysis did not progress, and no results are presented.

Mortality

The SAK model has three data sources that involve mortality: check station biodata, mail surveys, and nonharvest mortality. The MDNR collects harvest data annually from post-hunt mail surveys. These data include the hunting season in which a deer was harvested and the sex of the harvested deer. Total buck harvest data across hunting seasons from 1987-1996 were utilized for this study. Nonharvest mortality was not determined empirically. The MDNR has consistently used an r value of 0.90 in the

SAK model, which corresponds to an overall annual nonharvest mortality of 10% for the deer herd. This value was utilized and kept constant throughout the SAK model analysis.

SAK Model Analysis

All data for the SAK model variables were aggregated into the five geographic groups shown in Figure 2. These variables included the total buck harvest from mail surveys, as well as the percent yearling bucks, percent yearling does, and fawn:doe ratios from check station biodata. There were two models generated for each geographic group. One model used only firearm check station biodata, while the other model used combined firearm and archery check station biodata. Both models included total buck harvest estimates. SAK model results were calculated for each of the five geographic groups in each year (1987-1996).

In previous analyses, SAK had been shown to consistently underestimate deer populations, so comparison with a population index was intrinsic to this study (Mooty and Karns 1984). Deer-vehicle accidents have been a consistent and reliable source of population trends throughout Michigan and elsewhere (Case 1978, McCaffery 1973), and were used to compare general trends in the SAK model results. Deer-vehicle accident data were collected by the Michigan State Police and reported at a county level each year, so these data were aggregated into the same five geographic groups as the hunting seasons data (Figure 2). To account for any fluctuations in the number of miles traveled, deer vehicle accidents were standardized by the total number of million miles traveled within each geographic group. Total population estimates from the SAK model results were plotted with annual deer-vehicle accident rates by year (1987-1996).

SAK population estimates from the study were also compared to statewide deer population estimates. Deer herd population estimates were obtained from the MDNR (MDNR unpublished data). By summing all of the geographic group estimates together each year, it was possible to determine if the study results were reasonable absolute estimates of the statewide deer population. Any large differences between the geographic group sum and the statewide population estimates might indicate that the SAK model estimates were incorrect. Statewide deer-vehicle accident rates were plotted with seasonal SAK model results by year to compare trends.

RESULTS

Sample Sizes

Historical voluntary check station biodata were aggregated into the five geographic groups shown in Figure 2. These geographic groups were delineated based on ecological characteristics and management boundaries. Therefore, some geographic groups have larger sample sizes than others. Sample sizes were generally larger in the northeastern Lower Peninsula of Michigan (geographic group 2) than the rest of the state. Minimal sample sizes were determined for varying confidence levels following Thompson (1992). If 95% certainty is warranted with a 0.05 degree of precision, then minimum sample sizes should be 385 deer, for 95% confidence with a 0.10 degree of precision, minimum sample sizes should be 96 deer. All sample sizes within this study were determined with 95% confidence and a 0.10 degree of precision.

Adequate sample sizes were determined based on total sample size of each sex and age category (1.5 year old and 2.5 years old and older) by year within each geographic group. This made it possible to have adequate sample sizes for almost all geographic groups each year (Tables 1 and 2). Sample sizes dropped below the desired standards when data were further broken down by age class. Sample sizes from firearm hunting season were adequate, but archery biodata consistently had smaller sample sizes than did firearm biodata. For example, there were adequate sample sizes for firearm adult buck biodata in all geographic groups and all years, whereas archery adult buck biodata consistently had less than the desired sample sizes of bucks 2.5 years old and older (Table 1). The same trend was found in adult does, except that both age classes in the archery

Table 1. Firearm and archery hunting season check station biological data for yearling (1.5) and older (2.5+) white-tailed deer by sex, year, and geographic group.

a)

	Group 1									
	Firearm No. of Adult Bucks[a]		Archery No. of Adult Bucks		χ^2 [b]	Firearm No. of Adult Does		Archery No. of Adult Does		χ^2
Year	1.5	2.5+	1.5	2.5+		1.5	2.5+	1.5	2.5+	
1987	2281	944	104	16	14.362 **[c]	368	958	21	40	1.287
1988	2385	1177	107	22	14.511 **	136	310	28	37	4.122 **
1989	1726	877	125	30	13.624 **	117	241	40	49	4.704 **
1990	1845	1508	126	34	34.903 **	167	391	34	45	5.507 **
1991	1970	1284	109	51	3.684 *	156	388	57	71	12.031 **
1992	1503	1464	139	47	40.645 **	168	431	46	80	3.582 *
1993	1838	1690	158	52	42.651 **	74	178	53	102	1.042
1994	3984	2126	318	85	31.662 **	163	387	110	208	2.294
1995	2793	1573	301	72	42.418 **	405	917	117	147	18.658 **
1996	1009	1539	109	90	17.610 **	184	638	41	128	0.281

Table 1 (cont'd).

b)

	Group 2									
	Firearm No. of Adult Bucks[a]		Archery No. of Adult Bucks		χ^2 [b]	Firearm No. of Adult Does		Archery No. of Adult Does		χ^2
Year	1.5	2.5+	1.5	2.5+		1.5	2.5+	1.5	2.5+	
1987	3813	1524	417	68	47.276 **[c]	475	791	140	136	16.479 **
1988	3694	1741	391	86	40.273 **	516	967	162	132	42.882 **
1989	2208	881	387	79	27.487 **	254	479	137	166	10.179 **
1990	3495	1856	469	108	59.941 **	529	1092	165	158	39.937 **
1991	3101	1654	440	95	63.000 **	362	904	226	284	40.564 **
1992	2080	1206	339	93	38.671 **	367	781	171	225	16.307 **
1993	2137	1544	284	84	50.868 **	177	502	97	128	23.240 **
1994	3716	1969	472	138	35.696 **	111	279	136	225	7.207 **
1995	3780	1392	511	90	40.223 **	213	469	149	170	22.551 **
1996	3381	2038	467	121	66.820 **	467	1214	159	241	22.008 **

Table 1 (cont'd).

c)

	Group 3									
	Firearm No. of Adult Bucks[a]		Archery No. of Adult Bucks			Firearm No. of Adult Does		Archery No. of Adult Does		
Year	1.5	2.5+	1.5	2.5+	χ^2 [b]	1.5	2.5+	1.5	2.5+	χ^2
1987	2892	676	241	38	4.856 **[c]	274	515	61	93	1.341
1988	3032	886	280	41	16.817 **	487	898	64	97	1.324
1989	1934	586	262	46	10.945 **	468	803	64	79	3.448 *
1990	2483	961	265	57	15.538 **	550	1063	41	58	2.209
1991	2409	687	250	42	9.629 **	208	400	64	96	1.856
1992	1697	463	284	39	15.264 **	157	234	71	102	0.039
1993	1582	632	242	50	16.992 **	73	163	38	65	1.157
1994	2757	861	437	79	18.518 **	72	102	79	108	0.028
1995	2894	626	456	56	14.909 **	299	457	158	171	6.752 **
1996	2105	633	366	68	12.080 **	294	773	58	108	3.842 *

Table 1 (cont'd).

d) Group 4

Year	Firearm No. of Adult Bucks[a] 1.5	2.5+	Archery No. of Adult Bucks 1.5	2.5+	χ^2 [b]	Firearm No. of Adult Does 1.5	2.5+	Archery No. of Adult Does 1.5	2.5+	χ^2
1987	1114	318	214	35	8.494 **[c]	122	142	36	48	0.289
1988	1255	322	251	38	8.290 **	235	293	51	40	4.156 **
1989	1247	369	293	69	2.443 *	312	357	56	63	0.007
1990	1016	313	293	51	12.223 **	245	283	59	46	3.362 *
1991	1046	373	267	55	11.995 **	183	251	67	78	0.723
1992	903	366	290	63	17.161 **	154	177	78	82	0.214
1993	931	427	287	73	17.194 **	130	159	71	64	2.137
1994	1671	525	425	80	15.366 **	215	279	83	85	1.753
1995	1485	461	398	89	6.527 **	178	276	76	99	0.935
1996	1416	415	541	118	6.524 **	225	406	88	117	3.491 *

Table 1 (cont'd).

e)

	Group 5									
	Firearm No. of Adult Bucks[a]		Archery No. of Adult Bucks		χ^2 [b]	Firearm No. of Adult Does		Archery No. of Adult Does		χ^2
Year	1.5	2.5+	1.5	2.5+		1.5	2.5+	1.5	2.5+	
1987	979	325	163	27	10.568 **[c]	276	298	46	13	19.115 **
1988	1071	275	164	21	8.597 **	320	289	22	21	0.031
1989	1124	356	206	34	11.515 **	302	288	38	25	1.902
1990	1114	335	237	31	17.996 **	262	260	33	24	1.220
1991	1062	335	227	48	5.540 **	224	289	55	41	6.049 **
1992	954	345	264	43	21.353 **	186	225	45	47	0.405
1993	898	407	271	64	19.012 **	220	270	68	63	2.043
1994	1384	591	395	85	28.879 **	289	360	88	80	3.310 *
1995	1302	595	380	86	30.396 **	339	440	86	98	0.627
1996	1407	480	432	87	17.003 **	421	604	74	93	0.620

a: Only known age deer from check station biodata were used in the analysis.

b: This is a test of age distributions in each harvest season being independent of harvest methods. Degrees of freedom=1.

c: *P<0.10, ** P<0.05

Table 2. Firearm and archery hunting season check station biological data for fawn (buck and doe) and adult doe (1.5+) white-tailed deer by sex, year, and geographic group.

a)

Group 1							
	Firearm Season			Archery Season			
Year	Fawns[a]	Adult Does	Fawn:Doe	Fawns	Adult Does	Fawn:Doe	χ^2 [b]
1987	1087	1326	0.82	43	61	0.70	0.552
1988	284	446	0.64	33	65	0.51	1.000
1989	393	358	1.10	45	89	0.51	15.989 **[c]
1990	344	558	0.62	50	79	0.63	0.019
1991	405	544	0.74	93	128	0.73	0.026
1992	426	599	0.71	65	126	0.52	3.791 *
1993	208	252	0.83	91	155	0.59	4.442 **
1994	389	550	0.71	194	318	0.61	1.724
1995	942	1322	0.71	104	264	0.39	23.547 **
1996	390	822	0.47	66	169	0.39	1.528

b)

Group 2							
	Firearm Season			Archery Season			
Year	Fawns[a]	Adult Does	Fawn:Doe	Fawns	Adult Does	Fawn:Doe	χ^2 [b]
1987	876	1266	0.69	299	276	1.08	22.771 **[c]
1988	1086	1483	0.73	241	294	0.82	1.392
1989	785	733	1.07	334	303	1.10	0.093
1990	1094	1621	0.67	317	323	0.98	18.132 **
1991	976	1266	0.77	446	510	0.87	2.642
1992	789	1148	0.69	300	396	0.76	1.186
1993	498	679	0.73	256	225	1.14	16.396 **
1994	239	390	0.61	304	361	0.84	7.905 **
1995	361	682	0.53	271	319	0.85	20.356 **
1996	759	1681	0.45	203	400	0.51	1.464

Table 2 (cont'd).

c)

Group 3							
	Firearm Season			Archery Season			
Year	Fawns[a]	Adult Does	Fawn:Doe	Fawns	Adult Does	Fawn:Doe	$\chi^{2\,b}$
1987	505	789	0.64	132	154	0.86	4.945 **c
1988	776	1385	0.56	130	161	0.81	8.456 **
1989	998	1271	0.79	120	143	0.84	0.258
1990	948	1613	0.59	122	99	1.23	28.431 **
1991	396	608	0.65	195	160	1.22	25.597 **
1992	215	391	0.55	111	173	0.64	1.083
1993	134	236	0.57	108	103	1.05	12.388 **
1994	142	174	0.82	161	187	0.86	0.118
1995	358	756	0.47	180	329	0.55	1.642
1996	458	1067	0.43	115	166	0.69	12.997 **

d)

Group 4							
	Firearm Season			Archery Season			
Year	Fawns[a]	Adult Does	Fawn:Doe	Fawns	Adult Does	Fawn:Doe	$\chi^{2\,b}$
1987	189	264	0.72	77	84	0.92	1.803
1988	396	528	0.75	100	91	1.10	5.783 **c
1989	514	669	0.77	145	119	1.22	11.460 **
1990	364	528	0.69	109	105	1.04	7.232 **
1991	296	434	0.68	125	145	0.86	2.672
1992	264	331	0.80	163	160	1.02	3.126 *
1993	238	289	0.82	117	135	0.87	0.110
1994	374	494	0.76	192	168	1.14	10.751 **
1995	322	454	0.71	165	175	0.94	4.757 **
1996	420	631	0.67	174	205	0.85	4.059 **

Table 2 (cont'd).

e)

	Group 5						
	Firearm Season			Archery Season			
Year	Fawns[a]	Adult Does	Fawn:Doe	Fawns	Adult Does	Fawn:Doe	χ^2 [b]
1987	563	574	0.98	68	59	1.15	0.741
1988	567	609	0.93	54	43	1.26	1.994
1989	560	590	0.95	83	63	1.32	3.445 *[c]
1990	493	522	0.94	73	57	1.28	2.651
1991	518	513	1.01	97	96	1.01	0.000
1992	406	411	0.99	117	92	1.27	2.632
1993	406	490	0.83	106	131	0.81	0.026
1994	530	649	0.82	132	168	0.79	0.088
1995	548	779	0.70	159	184	0.86	2.858 *
1996	823	1025	0.80	140	167	0.84	0.121

a: Only known age-deer from check station biodata were used in the analysis.

b: This is a test of the fawn:doe ratios in each harvest season being independent of harvest methods. Degrees of freedom=1

c: *P<0.10, ** P<0.05

season frequently had small sample sizes. The exception is for geographic group 2, in which all age classes for every year, except 1993, had adequate sample sizes. Fawn sample sizes mirrored those for adult does. Fawn biodata for geographic groups 2 and 3 had robust sample sizes in both seasons every year, while geographic groups 1 and 5 lacked sample size for the archery season (Table 2). Geographic group 4 fawn biodata had robust sample sizes every year for both seasons except 1987 and 1988.

Seasonal Check Station Comparisons

Biodata for each geographic group were tested for differences among age classes and hunting seasons. Analyses were for each geographic group for each of 10 years (1987-1996), and results were determined at α-levels of 0.05 and 0.10. Chi-square analyses for adult bucks generally rejected the null hypothesis of no difference among age classes between hunting seasons. Results were significant for all geographic groups for all years ($p \leq 0.05$), with the exception of geographic group 4, in which 1989 was significant only at an α-level of 0.10 (Table 1). In all significant tests, there were more yearling bucks harvested during archery season than expected when compared to firearm season. A nonsignificant result indicated that the same proportion of yearlings were harvested in both the archery and firearm seasons.

Adult does were tested under the same null hypothesis as the adult bucks. It was determined that there was a significant difference between firearm and archery check station biodata for several of the years within each geographic group tested (Table 1). In all significant tests, there were more yearling does harvested during archery season than expected when compared to firearm season. Chi-square results for geographic group 1 indicated significant differences in 1988 through 1991 and 1995, as well as 1992 ($p=0.05$ and 0.10, respectively). Geographic group 2 had significant Chi-square values ($p=0.05$) for all years, indicating that archery hunters consistently harvested younger deer than expected in this area when compared to firearm hunters. Results for geographic group 3 suggested significant differences in 1995 ($p=0.05$), and in both 1989 and 1996 ($p=0.10$). In the southernmost parts of Michigan, only a few years had significant differences between the firearm and archery biodata. Chi-square results indicated younger deer were harvested in 1989 ($p=0.05$), 1990 and 1996 ($p=0.10$) for geographic group 4, while geographic group 5 had significant results in 1987, 1991 ($p=0.05$ for both), and 1994 ($p=0.10$).

All buck and doe fawns were aggregated as a group against all adult does, and fawn:doe harvest ratios were tested. The null hypothesis was that check station biodata collected for the firearm and archery hunting seasons had the same fawn:doe ratios. Geographic groups 1, 2, and 3 had significant results ($p=0.05$) for about half of the years tested (Table 2). Results indicated that geographic group 4 had significantly different fawn:doe ratios in all years except 1987, 1991, and 1993. The fawn:doe ratios for geographic group 5 were significantly different in 1989 and 1995 ($p=0.05$). In all significant cases, there were more fawns harvested during archery hunting season than expected when compared to the firearm hunting season.

Stable Age Distribution

Maintaining a stable age distribution in the deer herd is one of the assumptions of the SAK model. This assumption was tested by combining firearm and archery check station biodata for all of the adult bucks and does by year (1987-1996). These data were then separated by sex and age class, and a bivariate distribution of yearlings versus all deer 2.5 years old and older was created. The percent yearlings for each geographic group (Figure 2) were then compared for differences over the ten year period (1987-1996).

Table 3 shows results of the Chi-square analysis. All geographic groups for both the yearling bucks and yearling does had different percent yearling age classes each year of the ten year period. Therefore, Chi-square results suggested that a stable age distribution did not exist throughout the ten year period for any geographic group of bucks or does ($p=0.05$).

Regression analyses were also performed on the percent yearlings to determine how the changes in percent yearlings deviated from a long-term mean over the ten year period. The null hypothesis tested for the slope equaling zero. Regression results indicated that geographic group 5 had a significant negative slope for both yearling bucks and yearling does (Table 4). Geographic groups 2 and 4 had significantly negative slopes for yearling does (Table 4). No other geographic groups were significant ($\alpha=0.05$) for either sex. The regression analyses suggested that, although Chi-square results indicated that the percent yearlings were different among all geographic groups and years, the differences did not have large effects on the long-term mean for each geographic group.

Table 3. Combined seasons (firearm and archery) check station biological data for yearling (1.5) and older (2.5+) white-tailed deer by sex, year, and geographic group.

a)

Group 1						
	No. of Adult Bucks[a]		χ^2 [b]	No. of Adult Does		χ^2
Year	1.5	2.5+		1.5	2.5+	
1987	2385	960		389	998	
1988	2492	1199		164	347	
1989	1851	907		157	290	
1990	1971	1542		201	436	
1991	2079	1335		213	459	
1992	1642	1511		214	511	
1993	1996	1742		127	280	
1994	4302	2211		273	595	
1995	3094	1645		522	1064	
1996	1118	1629		225	766	
			1072.14 **[c]			43.29 **

b)

Group 2						
	No. of Adult Bucks[a]		χ^2 [b]	No. of Adult Does		χ^2
Year	1.5	2.5+		1.5	2.5+	
1987	4230	1592		615	927	
1988	4085	1827		678	1099	
1989	2595	960		391	645	
1990	3964	1964		694	1250	
1991	3541	1749		588	1188	
1992	2419	1299		538	1006	
1993	2421	1628		274	630	
1994	4188	2107		247	504	
1995	4291	1482		362	639	
1996	3848	2159		626	1455	
			403.54 **[c]			63.55 **

Table 3 (cont'd).

c)

	Group 3					
	No. of Adult Bucks[a]			No. of Adult Does		
Year	1.5	2.5+	χ^2 [b]	1.5	2.5+	χ^2
1987	3133	714		335	608	
1988	3312	927		551	995	
1989	2196	632		532	882	
1990	2748	1018		591	1121	
1991	2659	729		272	496	
1992	1981	502		228	336	
1993	1824	682		111	228	
1994	3194	940		151	210	
1995	3350	682		457	628	
1996	2471	701		352	881	
			189.64 **[c]			62.60 **

d)

	Group 4					
	No. of Adult Bucks[a]			No. of Adult Does		
Year	1.5	2.5+	χ^2 [b]	1.5	2.5+	χ^2
1987	1328	353		158	190	
1988	1506	360		286	333	
1989	1540	438		368	420	
1990	1309	364		304	329	
1991	1313	428		250	329	
1992	1193	429		232	259	
1993	1218	500		201	223	
1994	2096	605		298	364	
1995	1883	550		254	375	
1996	1957	533		313	523	
			74.51 **[c]			30.15 **

Table 3 (cont'd).

e) Group 5

Year	No. of Adult Bucks[a] 1.5	2.5+	χ^2 [b]	No. of Adult Does 1.5	2.5+	χ^2
1987	1142	352		322	311	
1988	1235	296		342	310	
1989	1330	390		340	313	
1990	1351	366		295	284	
1991	1289	383		279	330	
1992	1218	388		231	272	
1993	1169	471		288	333	
1994	1779	676		377	440	
1995	1682	681		425	538	
1996	1839	567		495	697	
			90.49 **[c]			40.37 **

a: Only known age deer from check station biodata were used in the analysis.
b: Test of null hypothesis of no difference in percent yearlings among years. Degrees of freedom=9
c: *P<0.10, ** P<0.05

Table 4. Results of regression analysis (n=10) of the slope of the percent yearling bucks and does from 1987-1996 (see Figures 3 and 4).

Adult Bucks				
Geographic Group	**Slope**	**Y-intercept**	**F^a**	**P**
1	-0.0190	0.7049	4.788	0.060
2	-0.0058	0.7104	1.441	0.264
3	-0.0004	0.7790	0.001	0.980
4	-0.0032	0.7866	0.987	0.350
5	-0.0069	0.7955	6.308	0.036

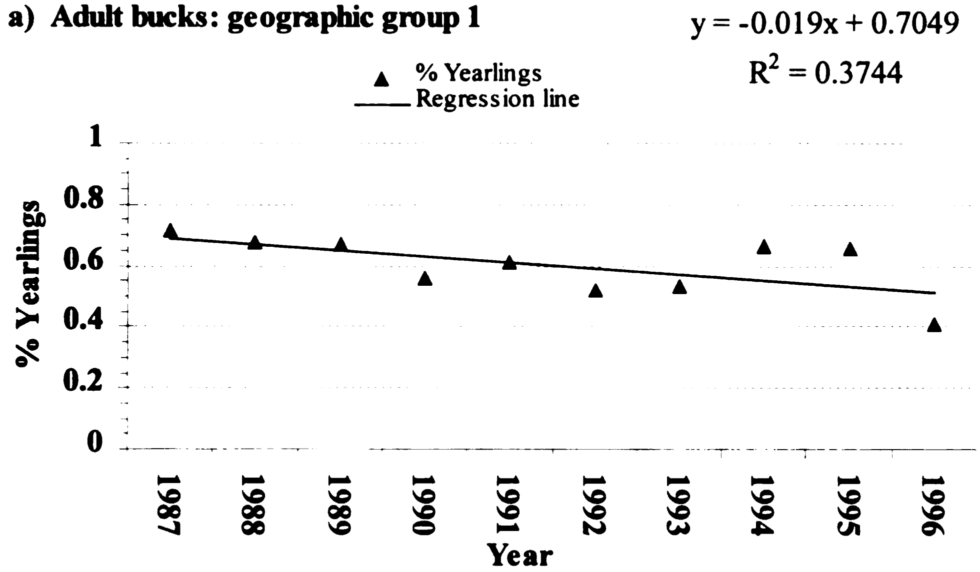
Adult Does				
Geographic Group	**Slope**	**Y-intercept**	**F^a**	**P**
1	-0.0039	0.3276	1.115	0.322
2	-0.0085	0.3958	12.938	0.007
3	0.0002	0.3633	0.002	0.969
4	-0.0072	0.4865	5.435	0.048
5	-0.0112	0.5381	42.557	< 0.001

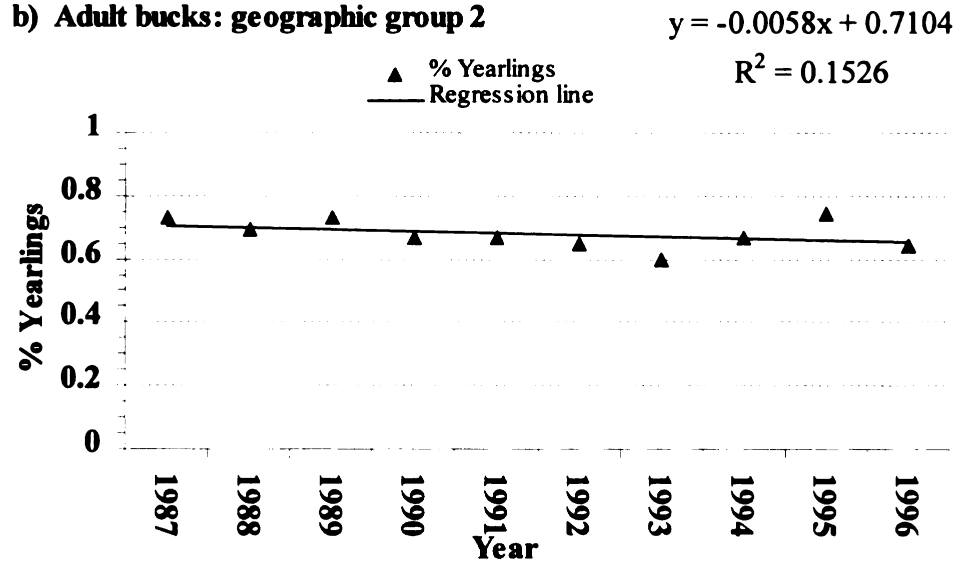
a: Test of null hypothesis that slope=0, with degrees of freedom 1,8.

Figures 3 and 4 display regression plots of the percent yearlings versus year by geographic group for bucks and does, respectively. As evidenced on these plots, the slopes were all close to zero, suggesting that there were no major changes in the proportion of yearlings over the ten year period. All of the slopes were slightly negative, except one positive slope for the percent yearling does (geographic group 3). A slope close to zero ($p>0.05$) suggested a stable age distribution in each respective geographic group (Table 4). If there had been a significant positive or negative slope ($p<0.05$), this would have indicated a growing or declining proportion of yearlings in the population over the ten year period. A significantly negative slope was determined for the percent yearling does in geographic group 5.

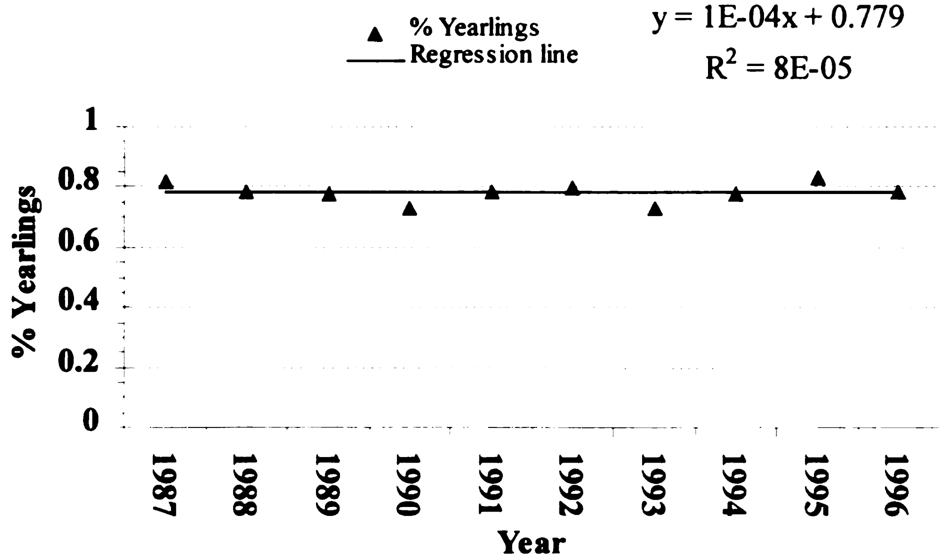
To determine the deviation of percent yearlings from the long-term mean within each geographic group, the long-term percent yearling mean was plotted with individual percent yearling values for each year (Figures 5 and 6). The largest deviation from a long-term mean was for bucks in geographic group 1, which had a 19% lower value in 1996 than the long-term mean (Figure 5b). The percent yearling bucks deviated from the mean by 11% in 1987 in geographic group 1, as well (Figure 5b). Deviations found in the yearling does were not as extreme. Geographic groups 1 and 3 both had individual percent yearling does that were 8% lower than each respective mean in 1996 (Figure 6a and c). These results may suggest which individual years are having the most effect on the rejection of a stable age distribution.

Figure 3. Regression analysis (n=10) of yearling white-tailed bucks by year. Equation is in the form y=mx+b.

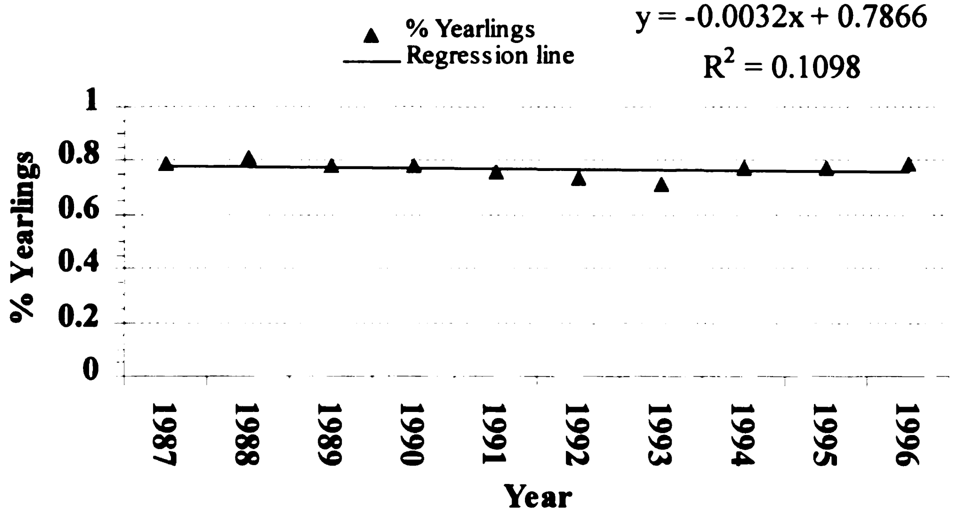




c) Adult bucks: geographic group 3



d) Adult bucks: geographic group 4



e) Adult bucks: geographic group 5

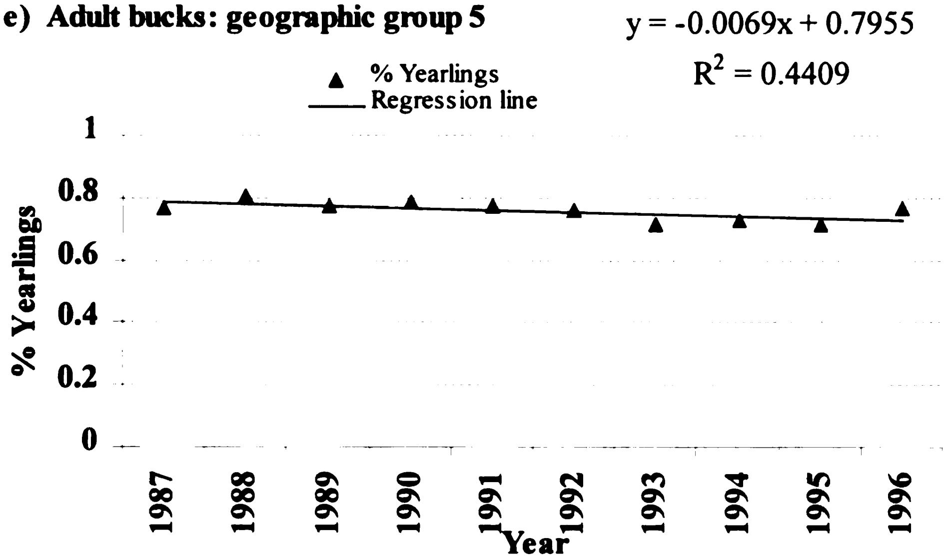
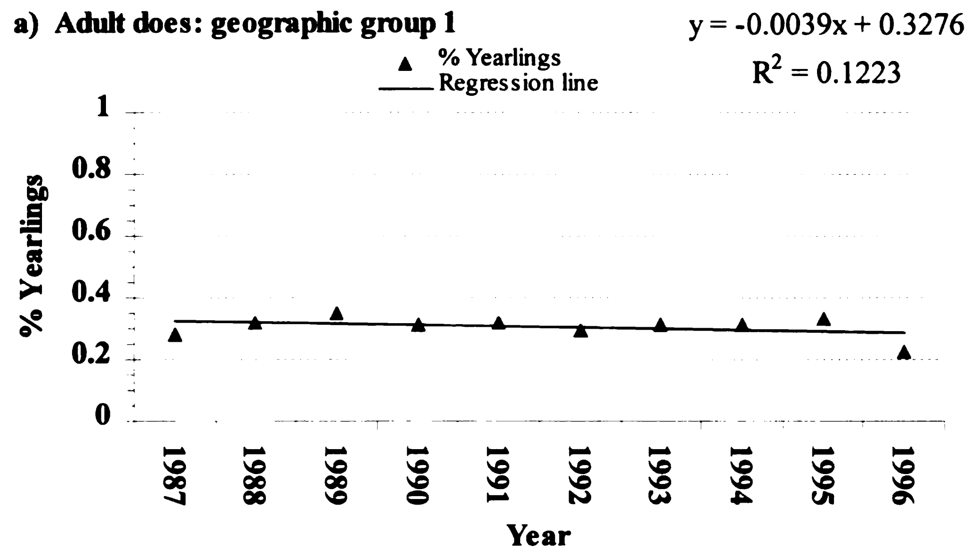
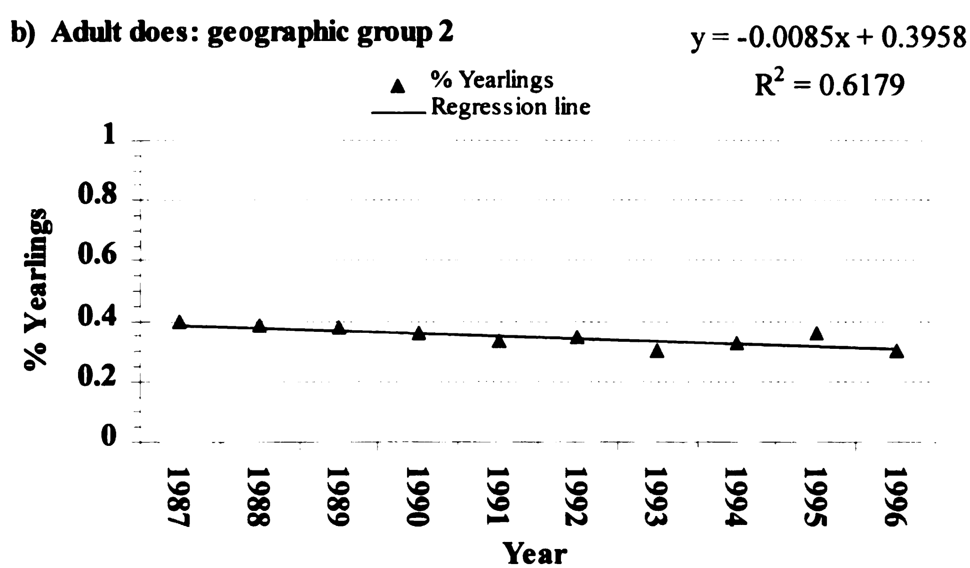
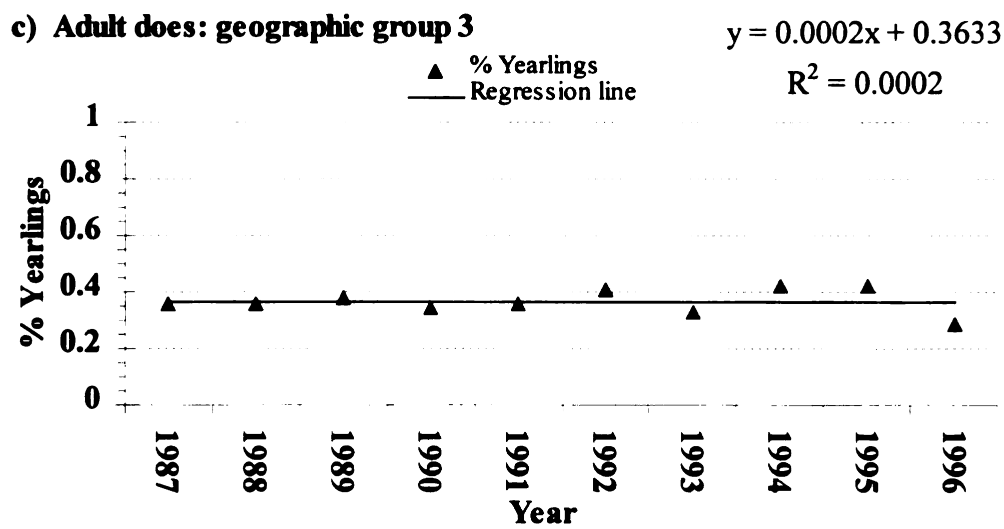
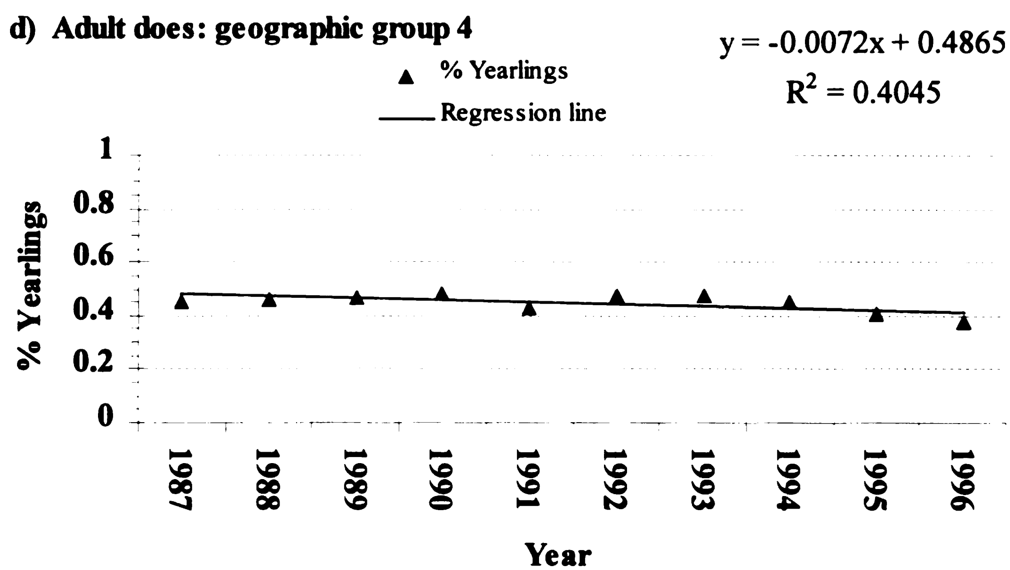


Figure 4. Regression analysis (n=10) of yearling white-tailed does by year. Equation is in the form y=mx+b.






c) Adult does: geographic group 3
y = 0.0002x + 0.3633
R^2 = 0.0002
% Yearlings
Regression line
% Yearlings
1
0.8
0.6
0.4
0.2
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year


d) Adult does: geographic group 4
y = -0.0072x + 0.4865
R^2 = 0.4045
% Yearlings
Regression line
% Yearlings
1
0.8
0.6
0.4
0.2
0
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year

e) **Adult does: geographic group 5**

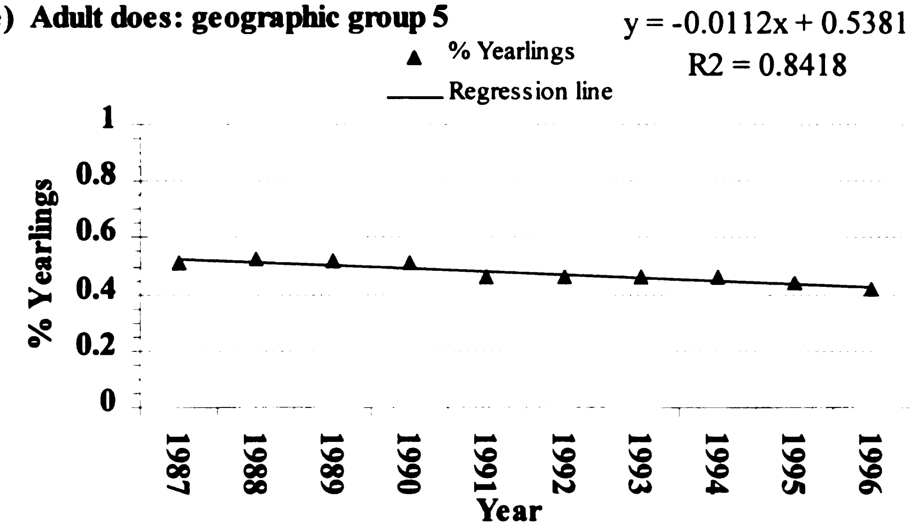
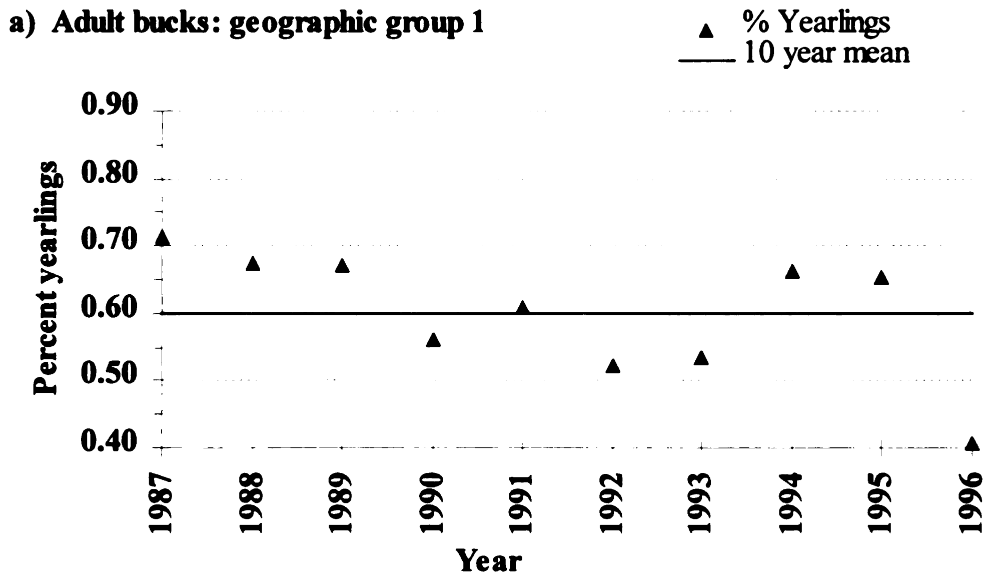
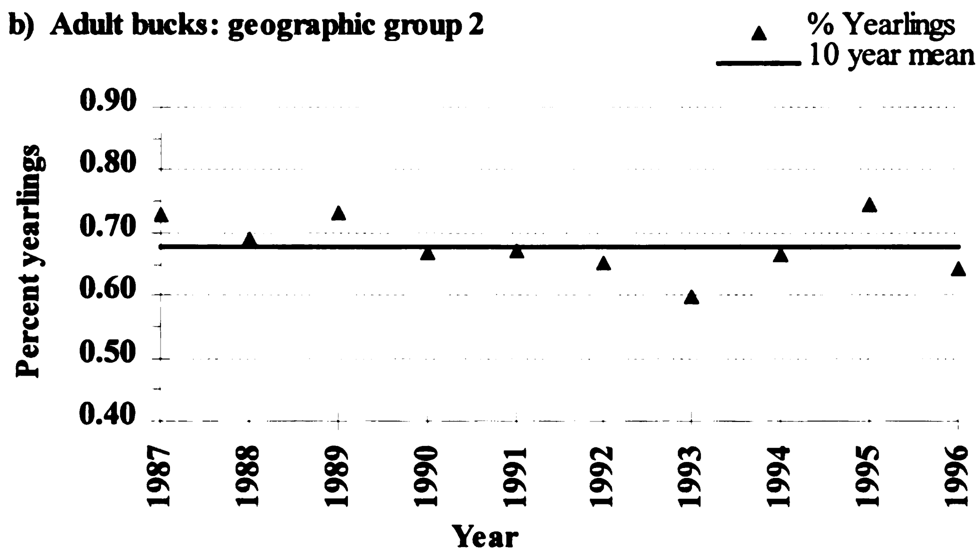
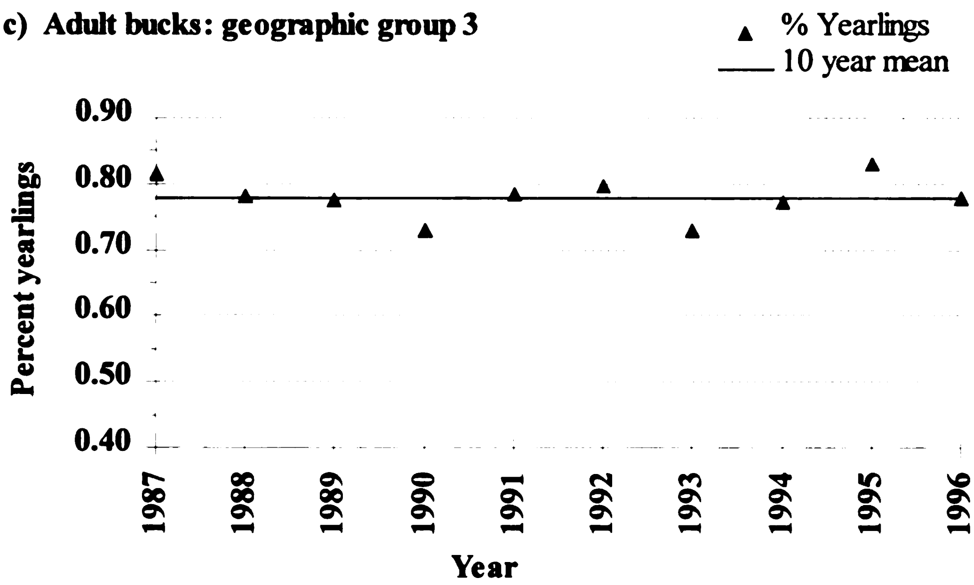


Figure 5. Percent yearling bucks by year and mean percent yearling bucks for the period 1987-1996.

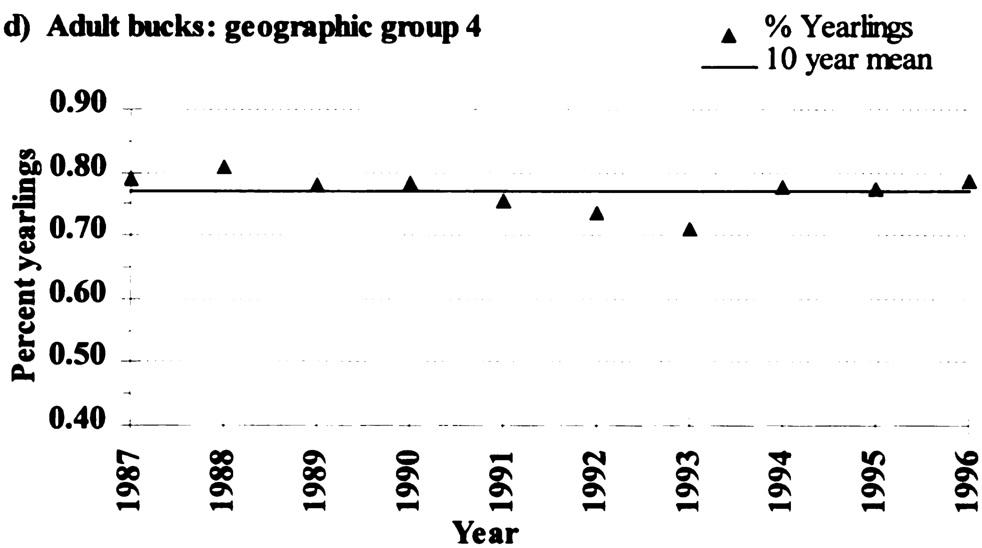




c) Adult bucks: geographic group 3



d) Adult bucks: geographic group 4



e) Adult bucks: geographic group 5

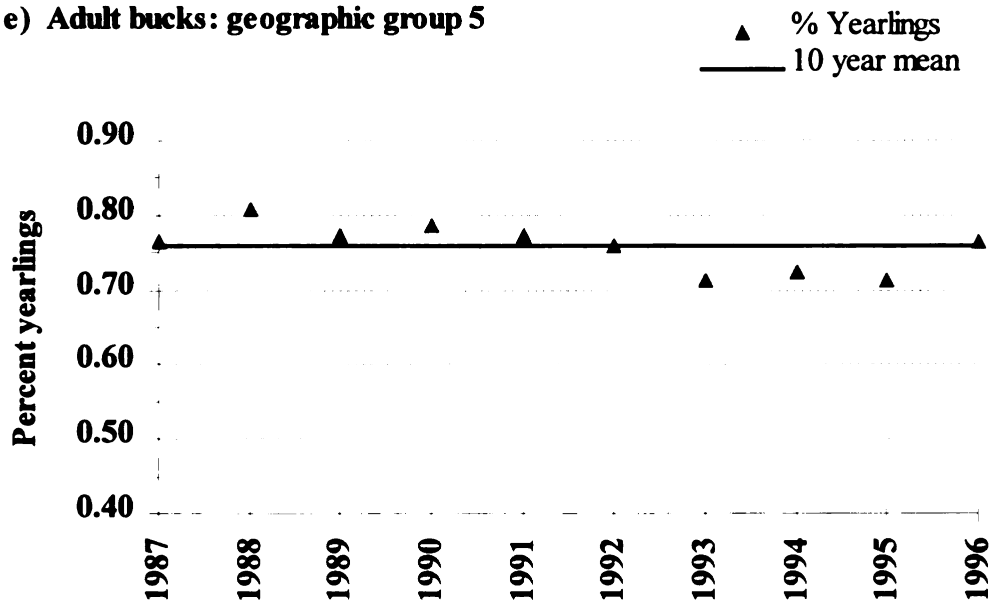
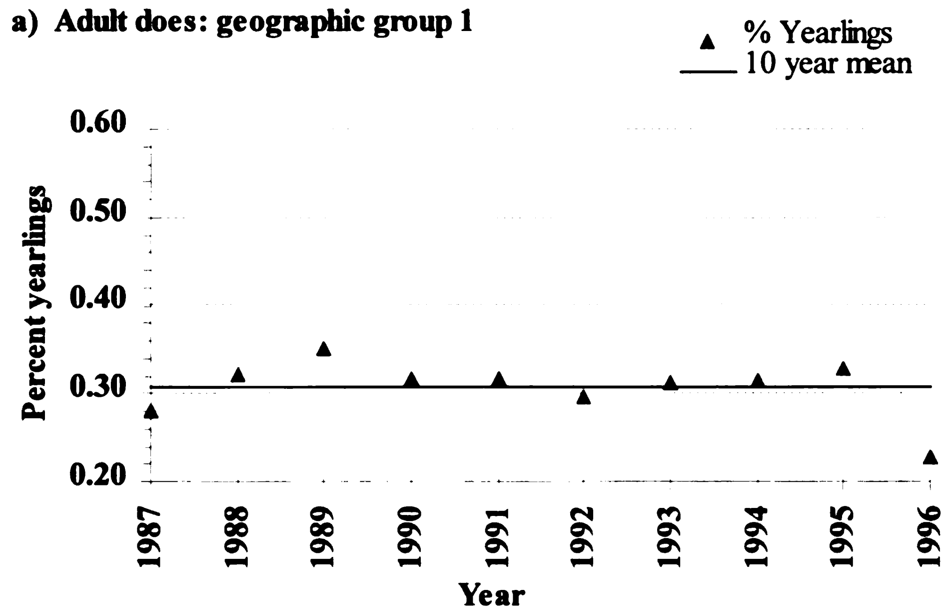
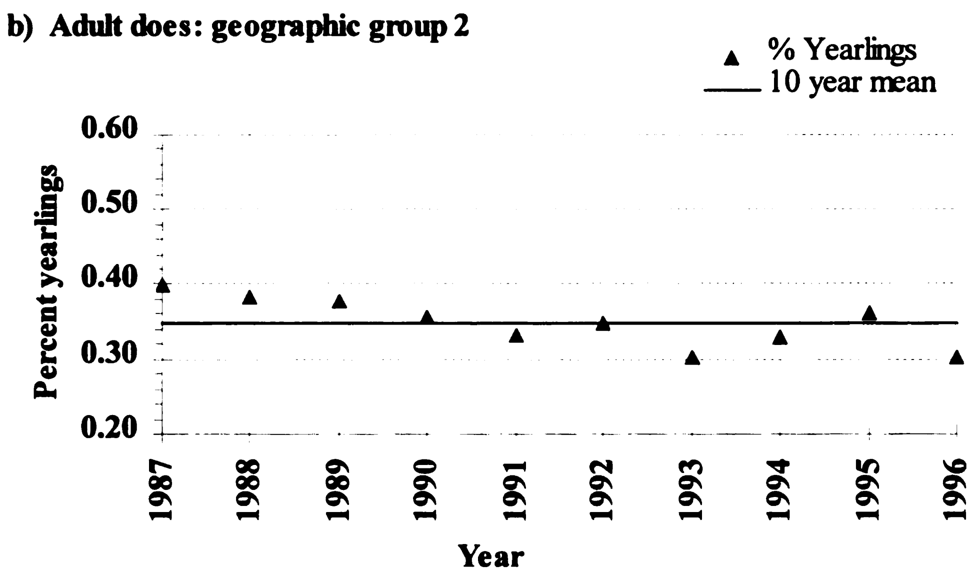
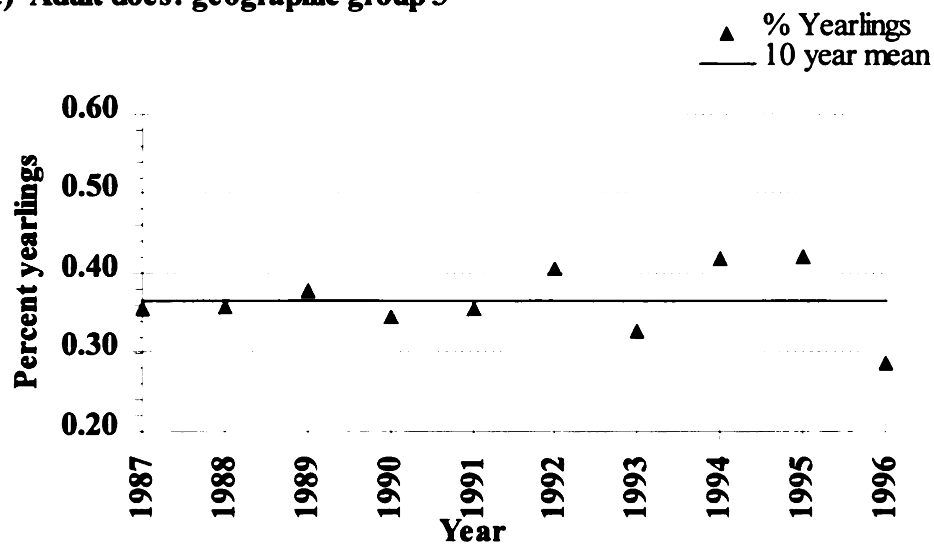


Figure 6. Percent yearling does by year and mean percent yearling does for the period 1987-1996.

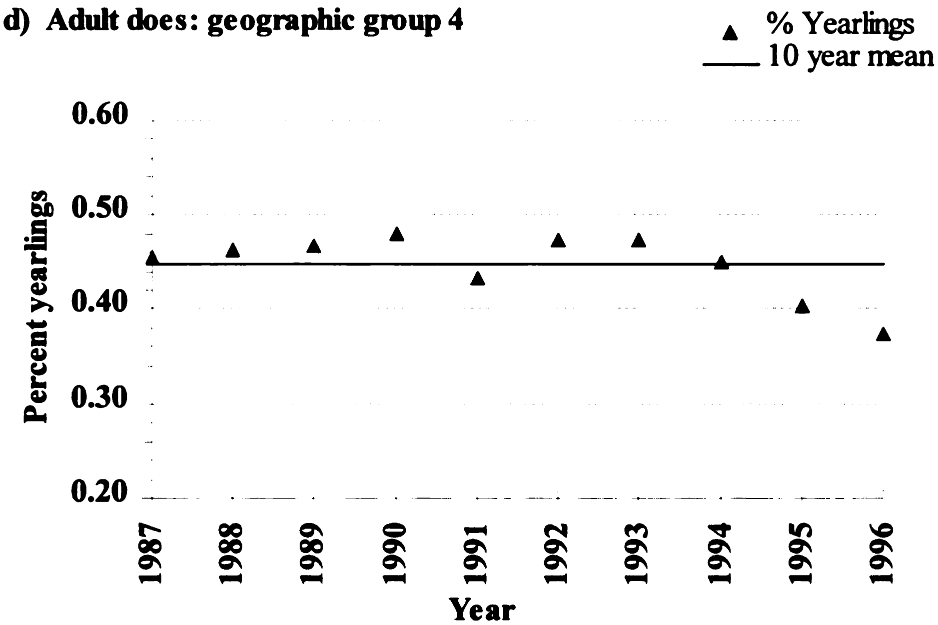




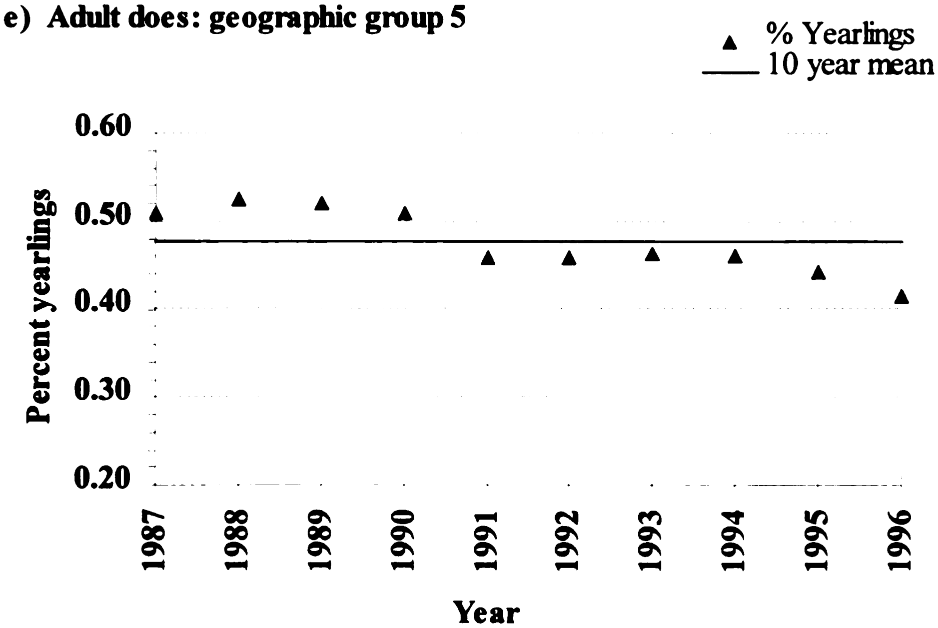
c) Adult does: geographic group 3



d) Adult does: geographic group 4



e) Adult does: geographic group 5



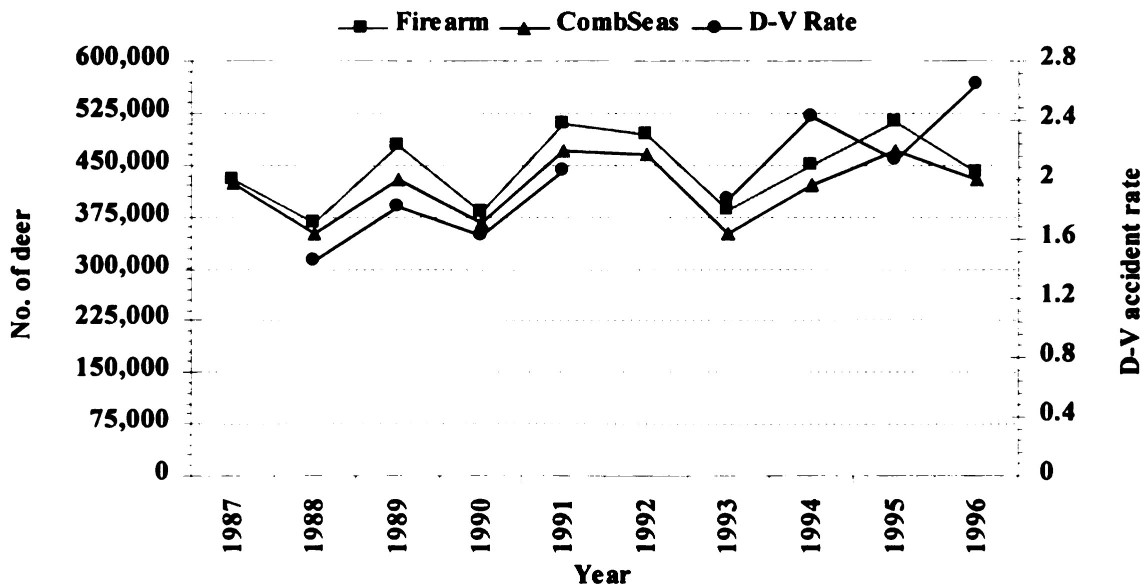
SAK Model Analysis

Population estimates were determined for each geographic group using the SAK model. The total buck harvest was calculated from a county level basis to fit the five geographic groups in Figure 2, and the percent yearling bucks and yearling does as well as the fawn:doe ratios were obtained from check station biodata. There were two models calculated for each geographic group, one with firearm biodata only, and the other using firearm and archery biodata combined. The traditional method of using only firearm biodata in the SAK model could, therefore, be compared to a model containing the archery harvest, and any effects that an increasing archery harvest may be having on model results could be determined. All models were done for years 1987-1996, and the total buck harvest was used in each model. The lifetime recovery rate was kept constant at 0.90. Deer-vehicle accident rate data were also aggregated into the five geographic groups (Figure 2). There were problems with two years of deer-vehicle accident data. First, no mileage data were available for 1987 and 1992; secondly, deer-vehicle accidents were collected in only parts of Michigan in 1992. Therefore, deer-vehicle accident data for these years were not represented on the plots.

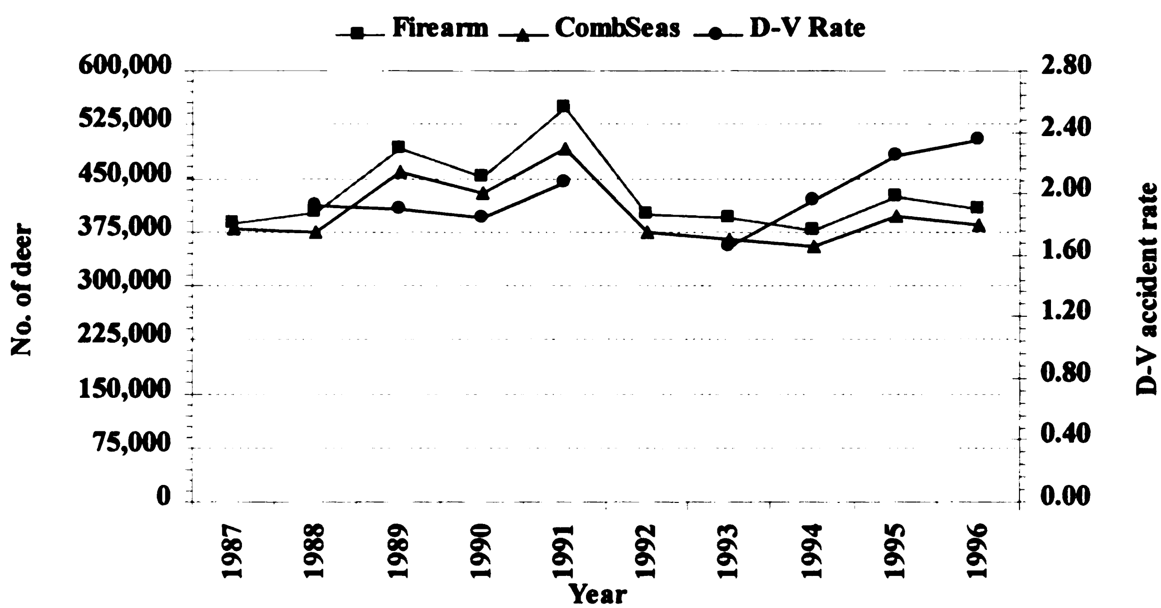
Population estimates from both the firearm and combined seasons SAK model results were plotted on the same graph, along with the deer-vehicle accident data (Figure 7). This was to detect any similarities between the trends in deer-vehicle accidents and SAK model results. Plots were constructed to determine if model results indicated the same trends as those of a reliable population index from a completely different database. In general, the results suggested that the trends were similar, but there were some

Figure 7. SAK model results using firearm and combined seasons (CombSeas) data (firearm and archery) and deer-vehicle accident (D-V Rate) trends plotted against time.

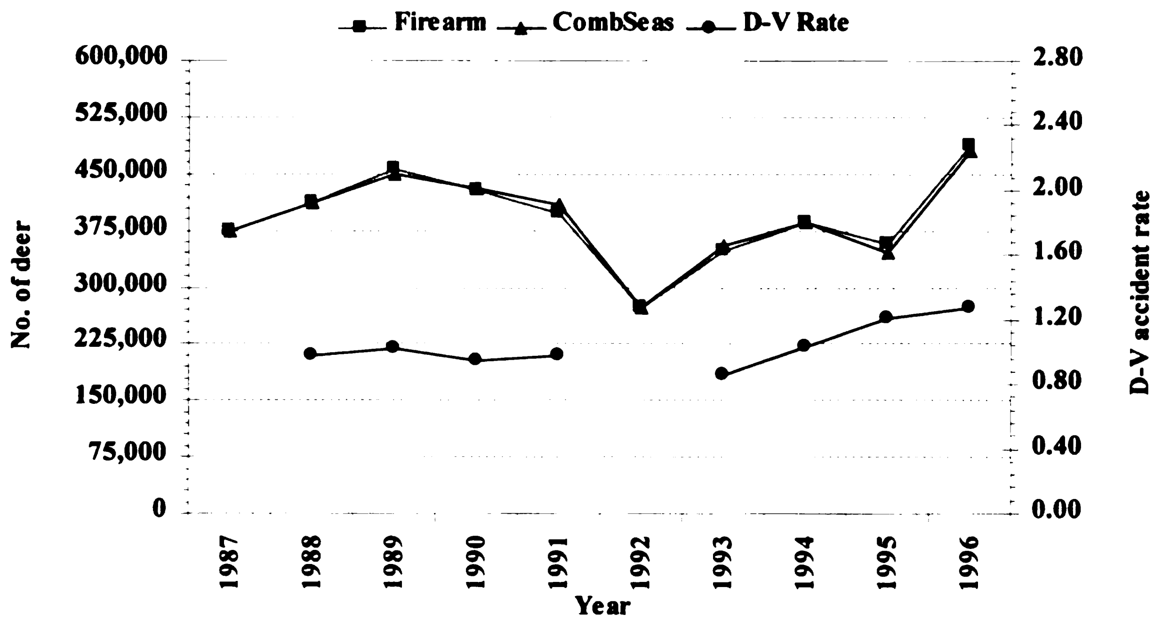
a) Geographic group 1



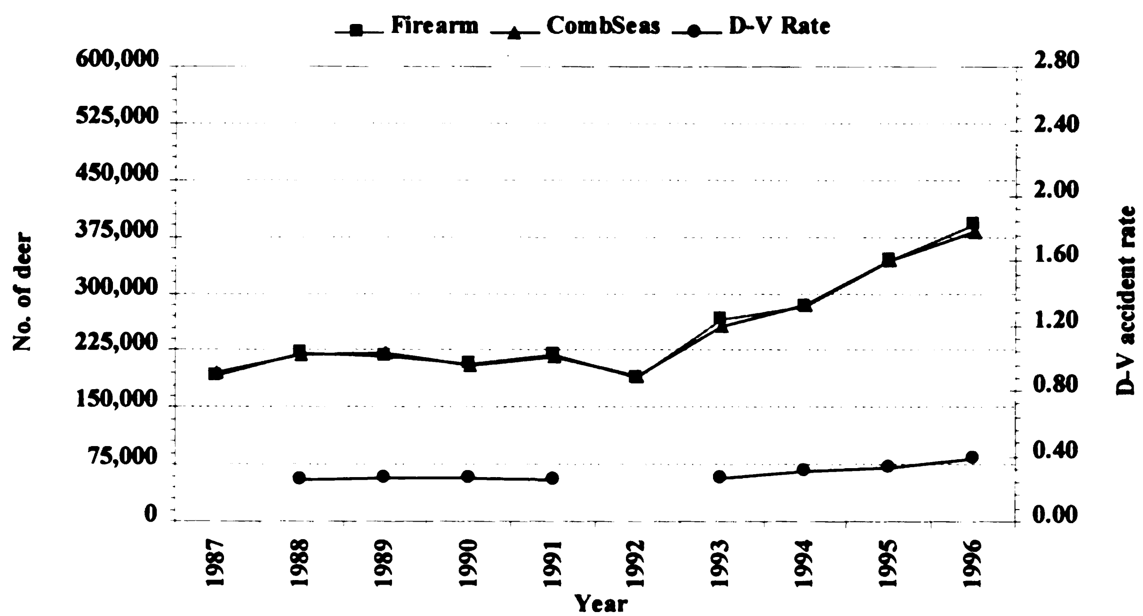
b) Geographic group 2



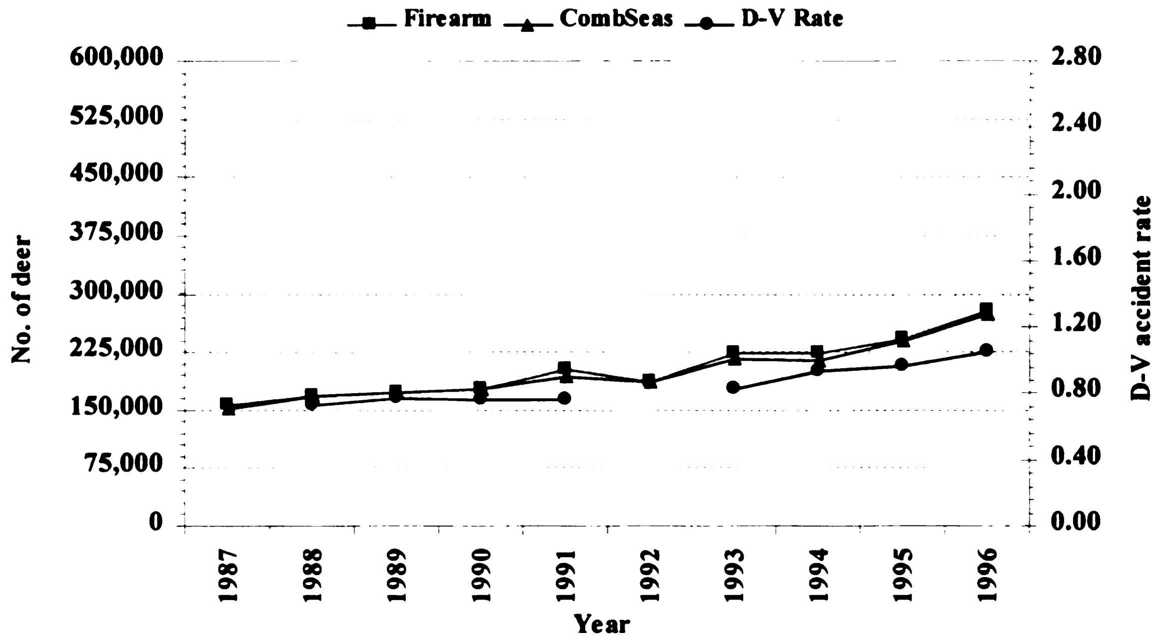
c) Geographic group 3



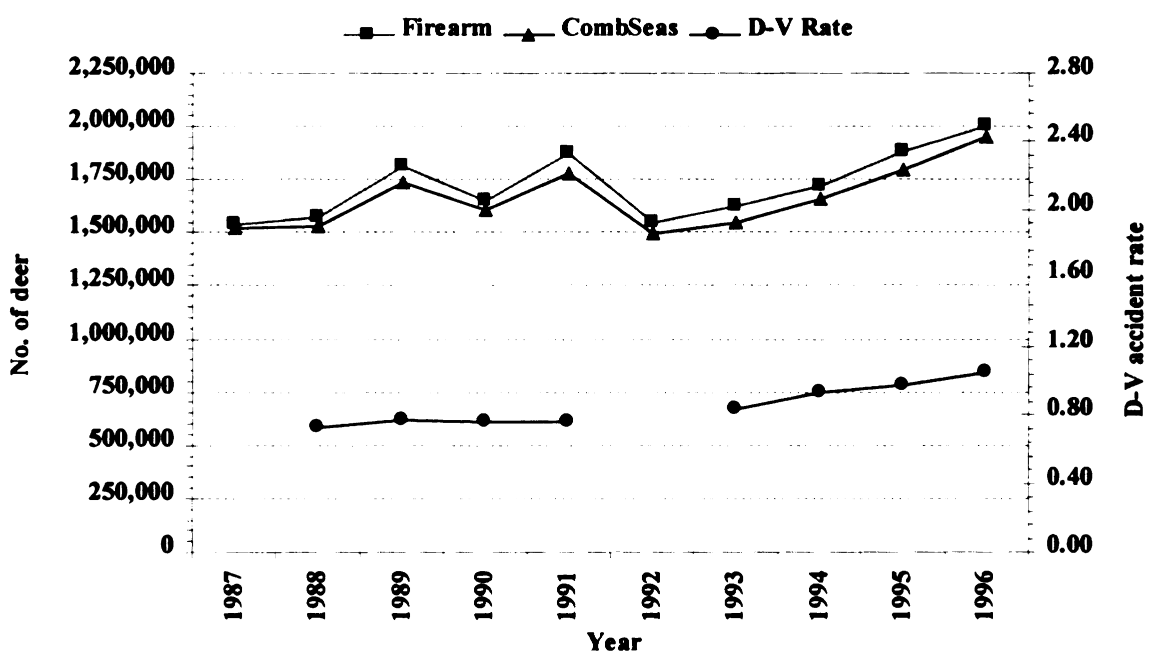
d) Geographic group 4



e) Geographic group 5



f) Statewide



deviations. There were also differences within the model results for firearm and combined seasons data. There were some results that suggested trends were moving in opposite directions.

Although the two hunting seasons results tracked each other fairly well in all geographic groups, there were certain years in which differences existed by as much as 12% between the two population estimates (see Appendix B). Charts corresponding to these analyses can be found in Figure 7. Individual geographic groups had slightly different results from each other due to the geographic area the data came from, density independent factors, and regulation processes in each area. Geographic group 1 showed some divergence between the two model estimates, particularly in years 1989 and 1995, with deviations of 11% and 9%, respectively (Figure 7a). There was consistency throughout the ten year period, however, in that population estimates based on firearm season data were always higher than population estimates based on the combined seasons. Although the population estimates in geographic group 1 tracked the deer-vehicle accident rates fairly well, in 1995 and 1996 the deer-vehicle accident rate rose while the population estimates from the SAK model declined.

There were a few disparities within the results for geographic group 2. Although the firearm and combined seasons SAK model results generally tracked each other, there was a 12% difference between the two in 1991 (Figure 7b). The other years in this geographic group had deviations between 2-8%. As for geographic group 1, the firearm season estimates were consistently higher than those for the combined seasons data. Deer-vehicle accidents had a deviation from SAK model results in years 1994-1996

(Figure 7b). The deer herd appeared to be stabilizing in these years according to the SAK model results, but the deer-vehicle accident data suggested that the herd had steadily increased over the last few years of the study period.

The results in Figure 7c for geographic group 3 showed almost identical population estimates for both SAK model results, with the largest difference between the two being 4% in 1995. Unlike geographic groups 1 and 2, in years with deviations, neither model consistently produced higher population estimates. Comparison of these outcomes to deer-vehicle accident rates for geographic group 3 generally indicated similar trends. There was a large discrepancy in 1995, in which deer-vehicle accidents continued an upward trend, but the combined seasons population estimates dropped from 384,724 in 1994 to 345,004 in 1995, then up to 480,791 in 1996 (Appendix B). This corresponds to a 10% drop in the deer herd estimates in 1995, then a 28% increase in 1996.

Population estimates based on firearm biodata and the combined seasons biodata in geographic group 4 were very similar. The largest deviation was 4% in 1993, but six of the ten years had deviations less than or equal to 1% (Figure 7d). This geographic group also appeared to track deer-vehicle accident trends (Figure 7d). There were minor discrepancies in 1990 and 1994, in which the deer-vehicle accident trend was opposite of the population estimates. Results of geographic group 5 were expected to be similar to those of group 4, since both geographic groups are located in southern Michigan. The firearm and combined seasons population estimates were very similar for both geographic groups, but firearm season estimates were consistently higher than those for the combined seasons in group 5 (Figure 7e). Deviations for this geographic group ranged from under

1% in 1988-90 and 1992 to 4.2% in 1987 (Figure 7e). The population estimates and deer-vehicle accident trends seemed to track for geographic group 5, although there were a few minor discrepancies. In 1989 through 1991, deer-vehicle accidents slightly decreased, whereas the population estimates increased slightly. The opposite was true for 1993 to 1994.

Statewide SAK model analysis were also done to compare statewide population estimates of the firearm and combined seasons SAK model results to estimated statewide population estimates for 1987-1996. Figure 7f shows SAK model results of the two data sets compared to deer-vehicle accidents. Firearm season population estimates were consistently higher than those for the combined seasons, deviating from 0.9% in 1987 to 5.2% in 1992 (Figure 7f). Both population estimates followed the same pattern. Model results and deer-vehicle accident rates indicated similar trends statewide. Both increased from 1993 through 1996, although deer-vehicle accidents were steady from 1989 to 1991, while SAK model population estimates indicated a slight decline in 1990. Comparisons of the statewide SAK model results to historical statewide SAK model population estimates showed a range of differences less than 1% in 1987 and 1993 to 15% in 1988 when compared to the firearm season biodata (Appendix B). Differences in population estimates ranged from 2% in 1987 to 17% in 1988 and 1995 when the combined seasons biodata were compared to statewide population projections (Appendix B). This indicated that the SAK model provided good population trends on a statewide scale.

DISCUSSION

This study was done to determine the role archery harvest statistics should have in a particular harvest-based population model. The SAK population model was developed as a population estimator for deer herds (Eberhardt 1960). Traditionally, firearm check station biodata have been used as data sources for population models because very little data were available from the archery and muzzleloader hunting seasons in Michigan. As the archery season increased in popularity and became a larger proportion of the total harvest, the question of how archery harvest biodata should be incorporated into the SAK model became pertinent.

One component in solving the problem of integrating archery harvest statistics into the SAK model is determining how the model is being used by managers. If the SAK model is used to provide an index, then the results of the study only need to demonstrate the same trends as that of other substantiated indices. For example, this study compared trends between the SAK model and deer-vehicle accidents. The data sets were from independent sources, so any similarities in the trends would demonstrate that SAK is a good index of population fluctuations. If, on the other hand, the SAK model is being used to provide population estimates, then SAK model results should have confidence intervals associated with them. This would involve determining variance estimators for the model itself. Although these confidence intervals would aid managers in determining the precision of the SAK model results, no variance estimators are currently available.

Sample Size

Having biodata in a usable format was important to this study, as was having an adequate sample size throughout the study areas. Although biodata were collected throughout the state each year at highway check stations and field offices, there were both years and geographic areas for which very little biodata were available. The amount of biodata available contributed to small sample sizes in the 1960s and 1970s, so more recent years were utilized for the study. Bow hunting started to become very popular in the 1980s, so more harvested deer from archery season were sexed and aged at highway check stations and field offices during this time. This led to an overall increase in sample sizes of check station biodata, with an increase in sample size from the archery hunting season starting in the mid 1980s. Because the increase in archery harvested deer coincided with an increase in the number of samples at the check stations, data before this time period were not as critical in determining the effects of the archery season on harvest statistics.

One of the objectives of this study was to analyze all data at the district level. This would have provided the district managers a complete analysis of each respective district. Since check station biodata were collected by county, data were aggregated at the county level into districts. Once the data were aggregated, however, sample sizes were very small for some of the districts. Therefore, larger geographic areas were needed to provide adequate sample sizes for the study. To obtain better sample sizes while keeping with the intent of providing information to district biologists, Albert's (1995) study on similar land types throughout the Great Lakes area was referenced. Information on similar soil and climatic conditions provided a framework for the five geographic regions shown in Figure 2.

The five geographic areas used in this study were constructed for two reasons. First and foremost, sample sizes from check station biodata were very small at a county level, and some of the district level data had small sample sizes, as well. The second factor involved in the formation of the geographic groups was the applicability of the study results to different areas of the state. Even though archery sample sizes were small in some geographic groups, these groups were maintained throughout the study. The analysis would not have been as useful to managers if larger geographic groups were used. Most of the total sample sizes in Tables 1 and 2 had adequate precision, but it was the delineation of samples into age classes (i.e. into 1.5 year old and 2.5 years old and older) that caused sample sizes to drop below the desired level of precision.

Obtaining robust sample sizes for all of the geographic areas was more complicated than it may appear. Tables 1 and 2 indicated that sample sizes for antlerless deer and archery hunting season data were the least represented. This may be due to hunting regulations or to the methods that have been used to collect biodata. For example, there is no firearm antlerless harvest in some counties, thus contributing to small sample sizes. The northern tier of counties in the Upper Peninsula did not have any or had small geographic areas open to firearm antlerless hunting throughout each year of the study. Although the availability of antlerless permits varied throughout the northern Lower Peninsula each year, Crawford and Roscommon counties either had no areas or very small geographic areas open to firearm antlerless hunting throughout the study period. Individual years were also variable. Most of the northern Lower Peninsula was closed to firearm antlerless hunting in 1994, with a scattering of permit availability in the northeastern and northwestern portions, respectively. All of these areas were open for firearm antlerless hunting in 1989, 1990, and 1996, except for parts of Crawford, Roscommon, and Kalkaska counties.

Data collection methods may also contribute to small sample sizes. Location and operation hours of field offices and highway check stations should be evaluated. Highway check stations are only open during portions of the firearm season. Therefore, the majority of the archery biodata collected is from hunters checking harvested deer at field offices. This data collection method may not encourage hunters to have archery harvested deer checked. Not only are field offices closed on weekends, but they may not be located near main roads so that archery hunters can conveniently have harvested deer checked. Increasing the sample size of archery harvested deer may require opening highway check stations during archery season or to have field offices open on weekends. If trends in archery harvest continue to increase, the MDNR may want to consider these options.

Some problems with sample sizes were found in specific geographic areas. In at least one instance, a single county contributed more samples than the surrounding counties, thus possibly driving the results for the whole area. In the Upper Peninsula (geographic group 1), Menominee county had a high deer density and antlerless harvest was permitted during the firearm hunting season, whereas most of the Upper Peninsula had not had a consistent antlerless harvest for the years of this study (1987-1996). Additionally, there were few deer checked throughout the rest of the Upper Peninsula in relation to Menominee county. For example, no firearm harvested adult does were checked from Alger, Baraga, Keewanau, Luce, and Schoolcraft counties in 1992.

Menominee county, on the other hand, contributed 70 of 168 and 155 of 432 yearling and 2.5 years old and older does, respectively, to the firearm check station biodata in 1992.

There were similar findings for the other nine years of the study. Therefore, Menominee county contributed the majority of samples from this geographic group, and this should be considered when the results of this study are reported. One solution to obtaining sex and age data for a larger portion of the Upper Peninsula may be to open a highway check station near the Mackinac bridge. Theoretically, this would give hunters who live in the Lower Peninsula, but who hunt in the Upper Peninsula, an opportunity to have harvested deer checked at a convenient location. This would contribute to larger sample sizes with broader geographic ranges being represented.

Another area of the state that had small sample sizes was the southernmost two tiers of counties. In this area, individual counties had few deer checked each year. This occurred even though hunting was popular, the deer population was healthy, and there had continually been firearm antlerless permits available. One reason for small sample sizes in these counties may be due to landowners hunting on their own land. Hunters do not have to travel as far to go hunting in this area, and may be less likely to bring a harvested deer to a field office for aging. There are also no highway check stations in the area. Weekend hours at field stations and deer check stations on county roads may aid in increasing sample sizes.

Archery hunting season biodata had small sample sizes each year, even when the geographic groups were considered. The only exception to this was in the northeastern part of the Lower Peninsula (geographic group 2), in which sample sizes were robust at the geographic group level. If managers want to have an adequate number of deer checked on a county or management unit level, an effort must be made to increase sample sizes. If managers could be satisfied with a 10% degree of precision with 95% confidence, then a sample of approximately 100 known age deer from each county or wildlife management unit would be needed. If a 5% degree of precision is required, then at least 385 deer would need to be checked. These sample size estimates are for each season. Therefore, 100 bucks and 100 does and 100 fawns would be required for each hunting season in order to have adequate sample sizes for analysis within 95% confidence. If adequate sample sizes are not met, then data need to be aggregated into larger geographic groups. As long as the data are used correctly, having adequate sample sizes ensures that test results will be reliable.

Seasonal Check Station Comparisons

Biodata used for this study were collected over many years by MDNR staff and volunteers. These data are the major source of statewide deer herd information that is used for long-term population trends and estimates. As the archery hunting season increased in popularity over the years, there was concern that different age ratios of deer were being harvested in each hunting season. The problem was to determine how, if at all, the archery season was affecting deer herd statistics. Therefore, when changes in the archery hunting season statistics were observed, an initial study was done in 1993 to investigate how these changes were affecting hunter success, deer herd composition, and to investigate whether hunting regulations should be changed due to the changing harvest statistics (Langenau et al. 1994). The current study is a continuation of the one in 1993, emphasizing how archery harvest statistics should be incorporated into a SAK harvest-based population model.

Archery harvest has continually increased in Michigan since the 1960s. Archery biodata have been collected as long as hunters have employed this method, thus giving the MDNR an opportunity to track changes among the hunting seasons through time. Differences in sex and age ratios between firearm and archery hunting seasons were the first questions this study addressed because the SAK model is harvest-based. To determine how archery harvest data should be incorporated into the SAK model, it was necessary to determine (1) if archery harvest biodata are significantly different than firearm harvest biodata, and (2) if the inclusion of archery harvest biodata into the SAK model altered population trends.

Results of this study suggested that archery hunters checked a different age ratio of deer at the check stations when compared to firearm hunters for some geographic groups for some years. Therefore, archery hunters either harvested a different age composition of deer than firearm hunters, or archery hunters were selective in which deer were brought to the check stations. There was no indication of hunter selection in the check station biodata. Hunters have been receiving patches for bringing harvested deer to check stations since 1972, so this has mitigated any sex or age biases in the data (MDNR unpublished data). If the assumption of check station biodata adequately representing the herd was true, then the archery harvest may have affected local herd sex and age compositions. Since this assumption could not be tested, no definitive conclusions could be made.

More younger adult bucks were harvested during the archery hunting season than expected in all years of this study. The same was true for adult does in about half of the results. It was also found that the fawn:doe ratio was larger in the archery season than expected for approximately half of the study results. These results were similar to those reported by Langenau and Aho (1983) regarding the impact of firearm and archery hunting on deer populations. In their study, Langenau and Aho (1983) found that the proportion of fawns and adult does harvested during archery season was larger than the same respective age class during the firearm season in the Midwest in 1980. Specific reports for Michigan stated that the percent of yearling bucks was higher in the archery season than during the firearm season, as were the percent of adult does (Langenau and Aho 1983).

It has been reported that archery harvest pressure can have an impact on firearm hunter success in enclosed areas (Langenau and Aho 1983), but no studies were found that determined this at county or regional levels. Deer behavior has also been documented to vary among different sex and age classes (Nixon et al. 1994, Beier and McCullough 1990), but no studies were found to link these differences to harvest sex and age biodata. More studies are needed to determine whether biological factors, equipment bias, or hunter bias are causes for differences in harvest sex and age compositions occurring between the hunting seasons.

Biological differences have been analyzed by Coe et al. (1980). Their study focused on the vulnerability of solitary and grouped white-tailed deer, but found no conclusive results on sex and age ratios. For example, they determined that day-to-day changes in harvest sex and age ratios suggested which sex and age class of deer were more vulnerable, thus being dependent on the hunting methods employed. The study did not differentiate between hunting techniques (Coe et al. 1980). Comparing the inconclusive results of Coe et al. (1980) to the differences suggested in this study does not lead to any apparent conclusions. Additional studies are needed to determine if differences in sex and age ratios of harvested deer between firearm and archery hunting seasons are due to biological or hunter-related factors.

Although no studies could be found to directly relate the comparison between firearm and archery hunting seasons, studies have determined that equipment and experience are factors in archery hunting success rates. Gladfelter et al. (1983) found that the use of a compound bow gave archery hunters a 1.40 greater chance of harvesting white-tailed deer than the use of traditional archery equipment. Their study also determined that previous archery hunting experience increased success rates, but that the number of days hunted did not have a direct relationship with success rates (Gladfelter et al. 1983).

Ditchkoff et al. (1996) found comparable results to Gladfelter et al. (1983) when success rates between compound bow use and traditional bow use were compared. Ditchkoff et al. (1996) also determined that although total harvest and the numbers of bucks and does harvested were greater during compound bow hunts, deer population estimates and fawn:doe ratios did not change with equipment type. Although the current study also found no differences in deer population trends between firearm and combined seasons SAK model results, it was suggested that there were different sex and age ratios between the seasons. This may be due to the comparison of firearm and archery equipment instead of the comparison of various types of similar equipment such as the other studies had done.

SAK Model Assumptions

Meeting the assumptions of any model is an important step in having reliable results. This study assessed some of the SAK model assumptions, and determined if the deer herd in Michigan, or at least the data collected for the herd, adheres to these model assumptions. One assumption, that of the harvest being representative of the herd, was addressed in the interstate comparison part of this study. Another assumption, that fawn productivity is measured accurately, was assumed to be correct and, therefore, not tested.

The assumption of a stable age distribution in the SAK model was tested by comparing the percent yearlings in the biodata over a ten year period (1987-1996). In those geographic groups with significantly different percent yearlings, there was not a stable age distribution over the ten year period. There were differences in percent yearling bucks and percent yearling does among years in geographic groups 1 and 2. Deer from these geographic groups live in an area that typically has harsh winters, and there is probably a density independent factor involved. Therefore, even though the overall percent yearlings changed in these areas, it may not be due to the proportion of deer harvested during the archery season. Severe winters may in fact be determining the age distributions. For example, if the same proportion of fawns were recruited each year over a ten year period and there was a heavy over winter fawn loss in years 3 and 7, then the percent yearlings in the combined harvest would be different in years 4 and 8 without any influence from the harvest.

Chi-square analyses resulted in the rejection of a stable age distribution for all geographic groups. McCullough (1979) also found that the deer herd in the George Reserve did not have a stable age distribution when it was tested with a goodness of fitness test. McCullough (1979) determined that bucks more closely approximated a stable age distribution than did does. Regression analyses found that one out of five geographic groups for percent yearling bucks had slopes significantly different than zero. Two out of five geographic groups had significant slopes for percent yearling does. This suggested that bucks had a slightly higher proclivity for a stable age distribution than did does, which concurs with the results of McCullough's (1979) study.

Percent yearling deviations from long-term percent yearling means indicated that fluctuations were random. By studying how large the deviations were from each respective mean, it was determined if the long-term mean should be used to meet the assumption of a stable age distribution. If the individual percent yearling values are close to the long-term mean, then the assumption of a stable age distribution may be met by using these instead of the long-term mean. Conversely, the long-term mean may meet the assumption of a stable age distribution because it demonstrates the trend within the population over a number of years. This may be especially important in areas where density independent factors, such as weather, have a major impact on the deer herd.

Regression analyses were done to determine if the slope for percent yearlings was significantly different than zero among years. These results indicated that although the percent yearlings fluctuated between years, the slope was not significantly different from zero in many of the geographic groups (Figures 3 and 4). Therefore, there were random fluctuations around each long-term mean. This suggested that the assumption of a stable age distribution may have been met in those geographic groups. To be sure that the fluctuations in individual percent yearling deviations were not affecting population estimates, the SAK model was used as an index rather than as a population estimator.

Therefore, population trends were emphasized instead of any absolute population estimates.

One assumption tested was that the buck harvest pressure is uniform from year to year. This was tested by the same techniques that were used in determining if there was a stable age distribution for bucks. According to Burgoyne (1981), the percent yearling bucks in harvest check station biodata is an expression of the mortality or exploitation rate, in which the proportion of deer in the youngest age class is approximately equal to the annual mortality rate. Therefore, the percent yearling bucks is actually used for two purposes within the SAK model. It is not only a measure of the age structure of the herd, but it is also a measure of buck exploitation. The same analysis answers both questions.

Since the Chi-square tests rejected the hypothesis of a stable age distribution, the assumption of a uniform buck harvest was also rejected. However, results indicated that there were only random deviations around the long-term mean for each geographic group. These deviations can be accounted for in three ways - either by differential vulnerability of the age class each year, by a missing cohort that is reflected in later years, or by sampling error for those geographic groups with slopes of zero in regression analyses. Secondary factors, such as weather on opening day and throughout the hunting seasons, standing corn crops, food availability for deer, and hunter distributions may all be factors affecting the buck harvest pressure.

Results suggested that harvest pressure on bucks was not uniform from year to year. This may indicate a change in mortality or exploitation each year, but does not reflect any changes in recruitment (Burgoyne 1981). If the assumption of a uniform buck harvest is violated, the total buck mortality and the number of bucks predicted will have reciprocal outcomes in the SAK model. For example, if the percent yearling bucks decreased significantly from year 1 to year 2, then the total buck mortality in the SAK model would decrease while the number of predicted bucks in the population would increase. The same holds true if the scenario is reversed, and similar results will occur if there is no stable age distribution in the percent yearling bucks. Therefore, if the buck harvest pressure is not uniform from year to year, it will affect the total population estimates of the SAK model.

SAK Model Analysis

The SAK model was developed at a time when deer herds were smaller, and does were protected so that herds could expand. The model, therefore, relies heavily on buck harvest and the percent yearling bucks as data for the SAK model variables. If the percentage of yearling bucks in the check station biodata begins to change, this will affect model predictions. Having multiple hunting seasons with varying proportions of the herd being harvested in each season may also alter the sex and age ratios used in the model if combined seasons data are not used.

One of the advantages of using the SAK model is its versatility in regards to model parameters. Accurate sex and age ratio data are required as model parameters, but these data can be obtained from either observational indices or harvest data (Creed et al. 1984). The SAK model can incorporate any form of reliable sex and age ratio data in place of check station biodata. This may be convenient in areas where no or very little antlerless firearm hunting is allowed. Since the Michigan archery license is either-sex, samples should always be available from checked deer during the archery season. The only other data source that could be utilized for these parameters in Michigan comes from annual statewide summer herd observations. Summer herd observations have been recorded in Michigan since the 1930s (MDNR unpublished data), and were considered an alternative source of sex and age composition data for the SAK model at the beginning of this study. Once preliminary analyses were done, however, it was found that this data set could not be used.

Assessment of summer herd observations determined that the data were not reliable, and could not be substituted into the SAK model. The major reason for this was a lack of standardization in data collection methods. In some parts of the state, collection methods were rigorously followed, and the data were collected in a scientific fashion each year, while in other areas summer herd observations were not done to any standards. Sex and age ratios obtained from such data sources were unreliable, so no substitution for harvest data was done when model parameters were analyzed.

Other studies have also found that herd observations vary across time and habitat. Downing et al. (1977) found that even with strict methodology, fawns were observed less often than does in the late summer and early fall, and adult bucks and does had different observation rates except in August and November. Another study compared behavior of radio-collared deer to systematic dawn and evening counts (McCullough et al. 1994). The authors found three major sources of error in herd composition counts: differences in habitat use, in deer activity, and in deer behavior in relation to the observer. Standardization of both the methods used and the routes taken controlled some of the errors associated with herd composition counts (McCullough et al. 1994). If summer herd observation data are going to be utilized in the future as a resource for the SAK model in Michigan, then data collection methods should be standardized across the state, and perhaps training courses should be implemented for teaching proper techniques.

The only other data source needed for the SAK model is the number of bucks harvested in a season or the total buck harvest across all seasons. These estimates were obtained in Michigan by utilizing mail survey data. Total buck harvest estimates were used in this study instead of season-specific harvest data because total buck harvest estimates include all legally harvested deer. Both applications of the SAK model, therefore, utilized yearly total buck harvest estimates.

The lifetime recovery rate was set at 0.90 throughout all of the geographic group SAK model analyses. This enabled the analysis to truly test for differences in model results when each type of seasonal biodata was considered. The nonharvest mortality rate probably differs by geographic area across Michigan, although there have not been extensive studies to determine the actual rates. Survival and mortality rates from localized studies, however, may aid in determining nonharvest mortality at larger scales. Sitar (1996) determined survival rates for yearling and adult deer in Presque Isle, Montmorency, and Alpena counties of Michigan. Nonharvest survival rates for yearlings in 1994 and 1995 were 0.761 and 0.791, respectively, and were 0.581 in 1994 and 0.572 in 1995 for adult deer (Sitar 1996). A study done in the eastern Upper Peninsula determined annual survival rates of 0.88 for yearling does, 0.29 for yearling bucks, and adult survival of 0.77 and 0.23 for does and bucks, respectively (Van Deelen 1995).

Another data source for determining nonharvest mortality may be winter severity indices (WSI) that are recorded each year at stations throughout the state. Some of the measurements included in this index are ambient temperature, snow depth, air chill, and snow pack yield (Verme 1968). Measurements are recorded weekly across Michigan, and the severity of the winter is assessed. This index may serve as a measure of density independent mortality and, therefore, be used as a factor in determining annual nonharvest mortality rates. These data should be evaluated to determine if WSI values correlate with other population indices or dead deer surveys.

Deer-vehicle accidents were compared to the SAK model results. Jahn (1959) concluded that deer-vehicle accidents did not correlate with harvest trends; however, his study did not account for variable proportions of antlerless deer in the harvest. McCaffery (1973) determined that deer-vehicle accidents correlated with buck harvest in a mandatory registration setting. Case (1978) found that the annual numbers of road-killed animals were correlated with other population indices. Deer-vehicle accidents have also been found to correlate with the firearm buck harvest in Michigan (MDNR unpublished data), thus the accident rate is considered a reliable population index.

Different factors affected SAK model results for each of the geographic groups. Group 1 had similar trends between the firearm and combined seasons population estimates, but these did not match deer-vehicle accident trends throughout the ten year study period. There are many reasons why the SAK population estimates may have differed from deer-vehicle accident trends, among them were variable weather in the Upper Peninsula, small sample sizes, or the number of antlerless permits available each year. Variable weather is a density independent factor, hence the lifetime recovery rate would need to be changed to incorporate nonharvest mortality that might occur due to weather conditions. Small or clumped sample sizes may also affect trends in SAK model analysis. Both factors would increase the error in population estimates. Since geographic group 1 is a compilation of the entire Upper Peninsula, it is also difficult to determine if data from a small proportion of the geographic group is having a larger impact on population estimates than the area as a whole.

Population estimates for geographic group 2 showed general agreement between population estimates from the two seasonal data sets, but deer-vehicle accidents differed from these estimates in 1993-1996. Regression results from the stable age distribution analysis for this geographic group suggested that although the overall slope for yearling bucks was not significantly different from zero, yearling does had a highly significant negative slope ($p<0.01$). It appeared from the regression data that the herd was not increasing, and it cannot be determined from available data why the deer-vehicle accident trends and the SAK model results were so different for these years.

Geographic group 3 had similar trends between SAK model predictions and deer-vehicle accidents from 1987-1993. In 1994, the deer-vehicle accident rate had an upward trend, whereas the population estimates showed a decrease in 1995 then an increase in 1996. The drop in 1995 may have been affected by the availability of antlerless permits. If the number of antlerless permits available to and used by hunters changed dramatically between 1994 and 1995, then the SAK model would indicate changes in the percent yearling does and fawn:doe ratios within the check station biodata. For example, the fawn:doe ratio for geographic group 3 increased from 55% to 82% between 1993 and 1994 (firearm season data), then dropped to 47% and 42% in 1995 and 1996, respectively. These ratios were compounded by the percent yearling does in the harvest, which stayed relatively stable until 1996, when it dropped from about 40% to 28% in the firearm season data. These numerical changes in model parameters may have been the cause of the large fluctuations in the model predictions, especially since the doe component reflects recruitment into the herd (Burgoyne 1981).

Comparison of the firearm and combined seasons population estimates in geographic groups 4 and 5 indicated that the two SAK model predictions produced similar trends. This suggested that, in these areas, it may not matter if archery season data are included in SAK model calculations. This may change, though, if the archery harvest becomes a larger proportion of the total harvest. The overall results for either of these geographic groups were not unexpected, since there had been a consistent effort to harvest antlerless deer in these areas throughout the years of this study. Hence, there have continually been antlerless deer data from these areas to use in the SAK model. This was due to the availability of firearm antlerless hunting permits each year. Additionally, severe weather was not a common threat to the deer herd in this part of the state, so the annual harvest accounted for the majority of the mortality each year. Therefore, density independent factors would not need to be considered in nonharvest mortality rates for geographic groups 4 and 5.

The extent of the influence of the lifetime recovery rate on the SAK model is unknown. MDNR biologists have consistently used a lifetime recovery rate (r) of 0.90 statewide, but this value may need to fluctuate as density-independent factors become more important in determining herd survival. It must be noted, however, that changing the lifetime recovery rate is reflected in the SAK model by a similar, but opposite, multiplication factor. For example, if the SAK model is computed by keeping all parameters constant with $r = 0.90$ and the population is calculated as 215,144 deer, then a 10% decrease of r to 0.81 increases the population estimate by 11% to 239,049 (data are from geographic group 5 in year 1993). Since the lifetime recovery rate does not affect the SAK model predictions except by a multiplication factor, then the actual value of the lifetime recovery rate can be varied as long as the SAK model is merely used as an index for trend analysis. This only applies if the lifetime recovery rate remains constant among years.

The SAK model was found to be a reliable population index when compared to deer-vehicle accidents. The addition of archery harvest statistics was determined to change the absolute SAK model estimates in most of the geographic groups, but differences between firearm and combined seasons model predictions did not alter overall trends. Density independent factors in geographic groups 1 and 2 may have contributed to differences between the two SAK model estimate trends, as well as to differences between SAK model predictions and deer-vehicle accident trends for these groups. In the southern portion of Michigan, the addition of archery harvest statistics did not affect trends in SAK model results. If archery harvest statistics continue to increase, incorporation of these statistics into the SAK model will be imperative for both trend analysis and absolute population estimation.

MANAGEMENT IMPLICATIONS

The size of the geographic area used for management purposes depends on the sample size of harvest data available and on the effort required to collect an adequate number of samples. As the size of a management unit decreases, it will take more effort to collect the minimum required sample size for that area. Since each area managed will need approximately 100 each of adult bucks, adult does and fawns for 95% confidence with a 0.10 degree of precision, this needs to be factored into management schemes. Now that the 13 management districts that were in existence at the beginning of this study have been reconfigured into 8 management units, it should be easier for managers to obtain the minimum required sample size for each unit because most of the units are larger than the original districts. Samples should be collected throughout the entire management unit, however, to ensure that they are representative of the entire unit.

The SAK population model can be a good resource for managing white-tailed deer populations. This study showed that the SAK model is a reliable index for deer in several geographic areas of Michigan, but further studies will need to determine if SAK is also a reliable population estimator. Although an absolute population estimate can be determined from the analyses done in this study, it is impossible to decide how accurate or precise the estimate is. To properly use the SAK model, confidence intervals are needed for the estimate. There are no known studies that have used confidence intervals with the SAK model, so further analyses would be required to obtain them. Such a study involves computer simulation of a deer population, and would require variance estimates on all of the model parameters as well as the total population estimate.

Differences in sex and age ratios between the firearm and archery hunting seasons may be affecting local deer herds, although this could not be determined directly from this study. One of this study's objectives was to determine if harvest statistics have changed without major regulation changes in the hunting seasons. Hunter success rates are approximately equal between the firearm and archery seasons, but those hunters who utilize both seasons have a much higher success rate than season-specific hunters (Langenau et al. 1994). Regulation changes to control these success rates may alter the sex and age composition of deer harvested. The current study may serve as a comparison to future studies to determine how regulation changes affect harvest statistics.

For example, one alternative is to start practicing quality deer management (QDM) statewide. One of the main issues associated with QDM is how the harvest data will be affected. If a traditional management scheme of a controlled antlerless harvest and a liberal buck harvest was switched to an unlimited antlerless harvest and a controlled buck harvest, the sex and age composition of check station data should change to reflect these differences. If these data were then used as input into the SAK model as the model currently stands, there would be erroneous and invalid results. The assumptions of the model, namely that the data are representative of the herd and that buck harvest pressure is uniform from year to year, would be violated. In effect, if bucks become limited in the harvest via regulation changes, they will effectively assume the role that antlerless deer now have in the SAK model. This would require the SAK model to be inverted by using the antlerless component in the current role that the buck component has occupied. Therefore, any regulation changes should be studied to determine potential effects on the SAK model. One potential problem that would need to be studied is that bucks reflect exploitation and does reflect recruitment (Burgoyne 1981). The assumptions of the SAK model would need to be reevaluated based on any major regulation change.

An accurate measure of nonharvest mortality is required if the SAK model is to be used as a population estimator, but this parameter is not so important for trend purposes. The lifetime recovery rate is a measure of nonharvest mortality throughout the year. If the equations involved in the SAK model are looked at piecemeal, it is seen that changes in the lifetime recovery rate affect model predictions by a reciprocal amount of change. Therefore, proper measures of nonharvest mortality are required so that model estimates are accurate. Estimates of nonharvest mortality, especially mortality resulting from density independent factors, vary throughout Michigan. Severe weather affects deer in the Upper Peninsula much more readily than deer in the rest of the state. A whole fawn crop could be lost during one winter in the Upper Peninsula, and if this is not accounted for in the lifetime recovery rate, then the changes in harvested percent yearlings will reflect incorrect population estimates.

A study that would determine nonharvest mortality rates throughout Michigan is recommended, especially in the Upper Peninsula. This geographic area has different climatic patterns on the eastern and western ends (Albert 1995), so a nonharvest mortality study would have to determine results for both geographic areas. After determining nonharvest mortality rates for years with both mild and severe winters, a more accurate lifetime recovery rate in the SAK model could be determined. One data source that is already collected and could be applied to a nonharvest-based study at both local and statewide scales is the winter severity index (WSI). Studies are needed to determine if WSI can be correlated with substantiated population indices throughout Michigan. This would also improve deer management in general, giving concrete nonharvest mortality data to managers in areas for which there is no extensive data at this time. Although this will aid managers in the use of the SAK model, it is not the only model parameter that is affecting SAK estimates.

One of the inconsistencies in the SAK model involves antlerless deer harvest statistics. In areas where firearm antlerless harvest is not permitted, a different source of herd composition data may be useful. Summer herd observations are a measure of sex and age ratios that are independent of harvest statistics. Theoretically, this index should have the capacity to be a substitute for check station biodata in the SAK model. The index falls short, though, due to data collection methods used throughout Michigan. Poor experimental design equals poor data, and this study found that because summer herd observations are not standardized across the state, it was impossible to utilize the data. Also, problems with observing animals, especially bucks, may bias results. A reliable alternative data source would provide reasonable sex and age ratios for the SAK model in areas with little or no antlerless harvest.

The last assumption of the SAK model that should be examined further is that the harvest biodata represent the herd. Although there was no indication that this was not true within the confines of this study, testing the assumption will enable managers to decide if voluntary check stations are adequate. Such a study would answer the question of whether voluntary check station biodata are biased in regards to particular sex or age classes. Attempts to answer this question failed in this study. If such a study is attempted in the future, it should be investigated within the geographic boundaries of Michigan, and herd composition should be known beforehand. By keeping the study within Michigan, factors that may cause the study to be invalid, such as different herd compositions and different regulations, can be mitigated. Results of such a study would determine if the MDNR should continue to use voluntary check stations or switch to mandatory check stations to obtain representative samples of the deer herd.

LITERATURE CITED

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Albert, D. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. North Central Forest Experiment Station. General Technical Report NC-178.

Beier, P. and D.R. McCullough. 1990. Factors influencing white-tailed deer activity patterns and habitat use. Wildl. Monogr. 109, 1-51.

Burgoyne, G.E. 1981. Observations on a heavily exploited deer population. Pages 403-412 *in* C.W. Fowler, ed. Dynamics of Large Mammal Populations. John Wiley and Sons, Inc.

Case, R.M. 1978. Interstate highway road-killed animals: A data source for biologists. Wildl. Soc. Bull. 6(1):8-13.

Coe, R.J., R.L. Downing, and B.S. McGinnes. 1980. Sex and age bias in hunter-killed white-tailed deer. J Wildl. Manage. 44(1):245-249.

Creed, W.A., F. Haberland, B.E. Kohn, K.R. McCaffery. 1984. Harvest management: The Wisconsin experience. Pages 243-260 *in* L.K. Halls, ed. White-tailed Deer: Ecology and Management. Wildlife Management Institute.

Ditchkoff, S.S., E.R. Welch, R.L. Lochmiller, R.E. Masters, W.C. Dinkines, and W.R. Starry. 1996. Deer harvest characteristics during compound and traditional archery hunts. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies:50:391-396.

Downing, R.L., E.D. Michael, and R.J. Poux. 1977. Accuracy of sex and age ratio counts of white-tailed deer. J Wildl. Manage. 41(4):709-714.

Eberhardt, L. 1960. Estimation of vital characteristics of Michigan deer herds. MI Dept. of Conservation Game Division Report No. 2282.

Eberhardt, L.L. 1969. Population analysis. Pages 457-495 *in* R.B. Giles, ed. Wildlife Management Techniques. 3rd ed. The Wildlife Society, Bethesda, Md.

Gladfelter, H.L., J.M. Kienzler, and K.J. Koehler. 1983. Effects of compound bow use on deer hunter success and crippling rates in Iowa. Wildl. Soc. Bull. 11(1):7-12.

Hawn, L.J. and L.A. Ryel. 1969. Michigan deer harvest estimates: sample versus a complete count. J Wildl. Manage. 33(4):871-880.

Hill, H.R. 1995. The 1995 deer pellet group surveys. MDNR-WD Report No. 3232.

Jahn, L.R. 1959. Highway mortality as an index of deer population change. J. Wildl. Manage. 23(2):187-197.

Johnson, D.H. 1994. Population analysis. Pages 419-444 *in* T.A. Bookhout, ed. Research and Management Techniques for Wildlife and Habitats. Fifth ed. The Wildlife Society, Bethesda, Md.

Langenau, E. and R.W. Aho. 1983. Relative impact of firearms and archery hunting on deer populations. Proceedings from the Midwest Bowhunting Conference. LaCrosse, WI.

Langenau, E., S.R. Winterstein, and W.E. Moritz. 1994. Allocating deer hunting opportunities to Michigan hunters. MDNR-WD Report No. 3208.

Langenau, E. 1995. 1995 Deer herd observations. Michigan Department of Natural Resources (MDNR) unpublished report.

McCaffery, K.R. 1973. Road-kills show trends in Wisconsin deer populations. J Wildl, Manage. 37(2):212-216.

McCaffery, K.R. 1976. Deer trail counts as an index to populations and habitat use. J Wildl. Manage. 40(2):308-316.

McCullough, D.R. 1979. The George Reserve Deer Herd. Univ. of Michigan Press. John Wiley and Sons, Inc. 271 pages.

McCullough, D.R., F.W. Weckerly, P.I. Garcia, and R.R. Evett. 1994. Sources of inaccuracy in black-tailed deer herd composition counts. J Wildl. Manage. 58(2):319-329.

Michigan Department of Natural Resources (MDNR). 1976. Deer checking stations data – 1975. Surveys and Statistical Services Report No. 151.

Michigan Department of Natural Resources (MDNR). 1979. Deer checking stations data – 1978. Surveys and Statistical Services Report No. 179.

Michigan Department of Natural Resources (MDNR). 1980. 1980 Michigan deer seasons. MDNR-WD Report No. 2900.

Michigan Department of Natural Resources (MDNR). 1995. Federal aid to wildlife restoration job performance reports (Vol. 4). W-127-R-13.

Michigan Department of Natural Resources (MDNR). 1996a. Michigan hunting and trapping guide.

Michigan Department of Natural Resources (MDNR). 1996b. Expectations of 1996 Deer hunting season. Unpublished report.

Miller, K.V. and R.L. Marchinton. 1995. Quality whitetails: The how and why of quality deer management. Stackpole Books. Mechanicsburg, PA.

Mooty, J.J. and P.D. Karns. 1984. The relationship between white-tailed deer track counts and pellet-group surveys. J Wildl. Manage. 48(1):275-279.

Nixon, C.M., L.P. Hansen, P.A. Brewer, J.E. Chelsvig, J.B. Sullivan, T.L. Esker, R. Koerkenmeier, D.R. Etter, J. Cline, J.A. Thomas. 1994. Behavior, dispersal, and survival of male white-tailed deer in Illinois. Illinois Natural History Survey Biological Notes 139. 30 pp.

Progulske, D.R. and D.C. Duerre. 1964. Factors influencing spotlighting counts of deer. J Wildl. Manage. 28(1):27-34.

Research Triangle Institute. 1966. Review of procedures for estimating deer population and deer kill in Michigan. Statistics Research Division. Final Report Project No. SN-272.

Roseberry, J.L. and A. Woolf. 1991. A comparative evaluation of techniques for analyzing white-tailed deer harvest data. Wildl. Monogr. 117, 1-59.

Severinghaus, C.W. and H.F. Maguire. 1955. Use of age composition data for determining sex ratios among adult deer. NY Fish and Game J. 2(2):242-246.

Sitar, K.L. 1996. Seasonal movements of habitat use patterns. M.S. Thesis from Michigan State University, East Lansing, MI. 130pp.

Thompson, S.K. 1992. Sampling. John Wiley and Sons, Inc. 343 pages.

Van Deelen, T.R. 1995. Seasonal migrations and mortality of white-tailed deer in Michigan's Upper Peninsula. Ph.D. Michigan State University, East Lansing, MI. 158 pp.

Van Etten, R.C. and C.L. Bennett. 1965. Some sources of error in using pellet-group counts for censusing deer. J Wildl. Manage. 29(4):723-729.

Verme, L.J. 1968. An index of winter weather severity for northern Michigan deer. J Wildl. Manage. 32(3):566-574.

Winterstein, S.R., H. Campa, K. F. Millenbah. 1995. Status and potential of Michigan natural resources: Wildlife. MAES and MSU Special Report 75.

APPENDICES

APPENDIX A

Derivation of a doe:buck ratio for the SAK population model.

Determination of a percent yearling doe:buck ratio for SAK model analysis is summarized below. It is derived from Severinghaus and Macguire (1955). This procedure works whether or not the sample sizes are equal. Assume that there are equal numbers of yearling bucks and does in the population before hunting has occurred. The following variables are used:

b: number of yearling bucks in population

d: number of yearling does in population

B: total number of adult bucks in population (including yearling bucks)

D: total number of adult does in population (including yearling does)

Now, assume that b=d in the general population. The sex ratio between bucks and does in the population can be calculated as:

$$\frac{b/B}{d/D} = \frac{b}{B} * \frac{D}{d} \qquad (1)$$

which gives D/B, the ratio of does to bucks in the total adult population. This is equivalent to

$$D:B = \frac{\text{Percentage of yearling bucks}}{\text{Percentage of yearling does}} \qquad (2)$$

because

$$\% \text{ yearlings bucks} = b/B$$

and

$$\% \text{ yearling does} = d/D.$$

Therefore, the D:B ratio can be stated as in (2).

APPENDIX B

Table 5. Deer-vehicle accident data and SAK model results for years 1987-1996.

a)

Group 1				
			Total Deer	
Year	**Deer-Vehicle Accidents**	**Million Miles of Travel**	**Firearm**	**Combined**
1987	3,935		427,459	422,205
1988	4,069	2,780	367,424	349,687
1989	5,409	2,967	477,658	429,454
1990	4,963	3,059	381,917	365,683
1991	6,419	3,112	509,091	469,600
1992			493,361	464,477
1993	5,747	3,080	385,279	351,945
1994	7,381	3,059	449,195	420,535
1995	8,553	3,490	512,138	470,649
1996	8,162	3,093	439,308	428,506

b)

Group 2				
			Total Deer	
Year	**Deer-Vehicle Accidents**	**Million Miles of Travel**	**Firearm**	**Combined**
1987	6,333		387,248	379,717
1988	7,025	3,662	401,551	375,119
1989	7,422	3,904	491,133	458,242
1990	7,486	4,078	451,317	428,721
1991	7,950	3,841	547,972	491,660
1992			399,928	375,045
1993	6,353	3,827	395,448	364,809
1994	7,594	3,888	377,147	353,324
1995	8,384	3,735	424,180	396,519
1996	9,102	3,876	407,759	383,540

Table 5 (cont'd).

c)

		Group 3		
	Deer-Vehicle	Million Miles	Total Deer	
Year	Accidents	of Travel	Firearm	Combined
1987	9,182		374,057	373,300
1988	10,191	10,355	412,026	412,054
1989	10,963	10,697	457,318	449,579
1990	10,327	10,950	427,557	429,986
1991	10,827	11,013	398,794	409,128
1992			272,724	274,010
1993	10,217	11,828	348,890	356,450
1994	12,313	12,006	385,368	384,724
1995	14,325	11,811	358,618	345,044
1996	15,418	12,133	486,294	480,791

d)

		Group 4		
	Deer-Vehicle	Million Miles	Total Deer	
Year	Accidents	of Travel	Firearm	Combined
1987	10,881		189,603	195,418
1988	12,105	47,958	221,851	219,677
1989	12,742	48,978	215,931	221,402
1990	12,829	49,464	206,814	205,449
1991	12,540	50,103	218,400	217,596
1992			189,390	191,098
1993	13,758	52,797	266,639	255,690
1994	16,071	52,439	281,798	284,856
1995	17,332	52,795	342,707	343,662
1996	20,281	54,006	390,060	382,006

Table 5 (cont'd).

e) **Group 5**

Year	Deer-Vehicle Accidents	Million Miles of Travel	Total Deer Firearm	Total Deer Combined
1987	8,596		157,393	151,103
1988	9,478	12,971	167,791	168,816
1989	10,248	13,340	172,646	171,983
1990	10,340	13,655	177,995	177,221
1991	10,497	13,851	201,420	193,459
1992			186,612	186,807
1993	11,757	14,157	222,764	215,144
1994	13,219	14,191	221,947	213,743
1995	13,899	14,351	240,784	239,118
1996	15,259	14,560	277,171	273,842

f) **Statewide**

Year	Deer-Vehicle Accidents	Million Miles of Travel	Total Deer Firearm	Total Deer Combined	Statewide Population
1987	38,927		1,535,759	1,521,743	1,547,000
1988	42,868	77,726	1,570,643	1,525,353	1,841,000
1989	46,784	79,886	1,814,687	1,730,661	2,000,000
1990	45,945	81,206	1,645,600	1,607,060	1,700,000
1991	48,233	81,920	1,875,677	1,781,443	1,675,000
1992			1,542,015	1,491,436	1,588,000
1993	47,832	85,689	1,619,021	1,544,038	1,630,000
1994	56,578	85,583	1,715,456	1,657,182	1,760,000
1995	62,493	86,182	1,878,426	1,794,992	2,171,000
1996	68,222	87,668	2,000,592	1,948,685	2,026,000