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AN EXAMINATION OF POPULATION-LEVEL QUALITY INDICES AS A MEASURE OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) HERD CONDITION IN MICHIGAN.

By

Sarah Laurel Panken

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ABSTRACT

AN EXAMINATION OF POPULATION-LEVEL QUALITY INDICES AS A MEASURE OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) HERD CONDITION IN MICHIGAN

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One of the best methods to examine the condition of white-tailed deer is to evaluate the physical growth of yearling deer. Antler development, consisting of average beam diameter and number of points, as well as lactation status were identified as measurable population-level quality indices for yearling deer in Michigan. The condition of the deer herd, as measured by these quality indices, was examined temporally and spatially both within and among 3 distinct regional study sites in Michigan. Each of the population-level quality indices increased along a north to south regional gradient, which suggested that deer in the southern part of Michigan were in relatively better condition than their counterparts in the more northern regions. This trend in deer herd condition may be attributed to winter severity, population density, and habitat quality differences among the 3 distinct regional study sites in Michigan. The temporal and spatial trends in each of these factors were evaluated both within and among the 3 distinct regional study sites, as was the relationship between these factors and yearling antler development. Multiple factors affected deer herd condition within each regional study site; in the northern part of the state weather gave way to a mixture of weather and density, and in the southern-most part of the state, density had the most influence on herd condition.

To Max.
I could not have done it without your love, support, and patience.

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GENERAL INTRODUCTION

Project Overview

The research discussed in this thesis was developed as part of a larger project that attempts to examine deer management using an ecosystem paradigm. This "umbrella" project is more holistic in nature than traditional approaches to deer management because it attempts to address the ecological, social, and biological aspects of deer management at a landscape level. To quantify the ecological aspect of deer management, habitat models, based on the physiography of the land and vegetation types, were used to predict the potential for deer habitat requirements in specified areas of the Michigan. To quantify the social aspect of deer management, surveys were conducted to understand how people in Michigan view deer and deer management. To quantify the biological aspect of deer management, the condition of the deer herd, as measured by quality indices, was examined in different regions of Michigan. Upon completion of the 3 different sections of the "umbrella" project, the ecological, social, and biological aspects will be incorporated into a landscape-based model to aid managers in developing statewide scientifically sound deer management strategies.

The overall objectives of the study are:

1) Assess whether a hierarchical ecological classification system effectively delimits land units exhibiting differing deer reproductive potential, expressed in the form of recruitment to fall hunting populations and measured in fawn-to-doe ratios in check station data.

2) Determine whether reproductive potential, as measured by fawn-to-doe ratios in check station data, can be used to estimate biological carrying capacity of ecological units.
3) Determine whether antler measurements from harvested bucks in check station data can be substituted for reproductive recruitment to determine biological carrying capacity, especially in areas where antlerless harvests are absent or limited.
4) Assess whether a habitat-based model of deer population estimation can be used to calculate population goals and compare with models based on reproductive potential.
5) Estimate cultural carrying capacity in study areas using primary stakeholder groups based on farming and hunting participation.
6) Integrate animal-based models, habitat-models, and cultural carrying capacity models into a statewide deer management strategy.

This thesis concentrates on the biological aspect of the landscape level approach to deer management in Michigan by looking at the differences in deer herd condition in the 3 main regions of the state and the underlying mechanisms that have the potential to influence herd condition. This thesis is divided into 3 sections:

Chapter 1: A Regional Comparison of White-Tailed Deer Herd Condition Indices in Michigan.

Chapter 2: An Examination of Underlying Mechanisms That May Influence White-Tailed Deer Herd Condition in Michigan.

Conclusions and Management Implications.

In Chapter 1, I used population-level quality indices to examine the temporal and spatial trends in the condition of the white-tailed deer herd in Michigan from 1987 through 2000. Chapter 2 addresses two main topics. First, I explored temporal and spatial trends in some of the underlying mechanisms that have the potential to influence the condition of white-tailed deer in Michigan. Second, I determined the relationship between those factors that may influence deer herd condition and male yearling antler measurements as indices of white-tailed deer herd quality. In the final section, I discuss overall conclusions and management implications based on the results from Chapters 1 and 2.

STUDY AREA

Michigan is divided into 3 distinct regions based on climate and physiography (Figure 1.1; Albert et al. 1986). These 3 regions were then further classified according to Albert et al. (1986) into smaller ecological regions (ecoregions) based on the homogeneity of the localized climate and physiography, and, to some degree, vegetation (Figure 1.2). We designated 3 study sites. Each site was located within a different region of Michigan (Region 1, Region 2, and Region 3) and consisted of several distinct ecoregions (Figure 1.3). These study sites were selected based on the heterogeneity of habitat, the existence of available information and the variation in deer numbers. In addition, these study sites were defined by political, not ecological, boundaries (i.e., counties) because the data used in this project were collected within political boundaries that serve as a convenient way to define an area unit for deer management.

Upper Peninsula (UP)

Region 1 (Figure 1.1) is the Upper Peninsula of Michigan. Northern hardwood forest ecosystems are common in this region, as are pine forest ecosystems. Soils are primarily loam and sandy textures. This region has little agriculture and the least amount of urban development of the 3 regions. The climate in Region 1 is the harshest of all of the regions in Michigan; winters tend to last longer and generally have more snowfall and colder temperatures. Total precipitation in this region is 800-900 mm and the annual average temperature is between 4 °C and 5 °C. Generally higher than the elevation in the other 2 regions, the elevation in Region 1varies from 184-604 m, but is predominately

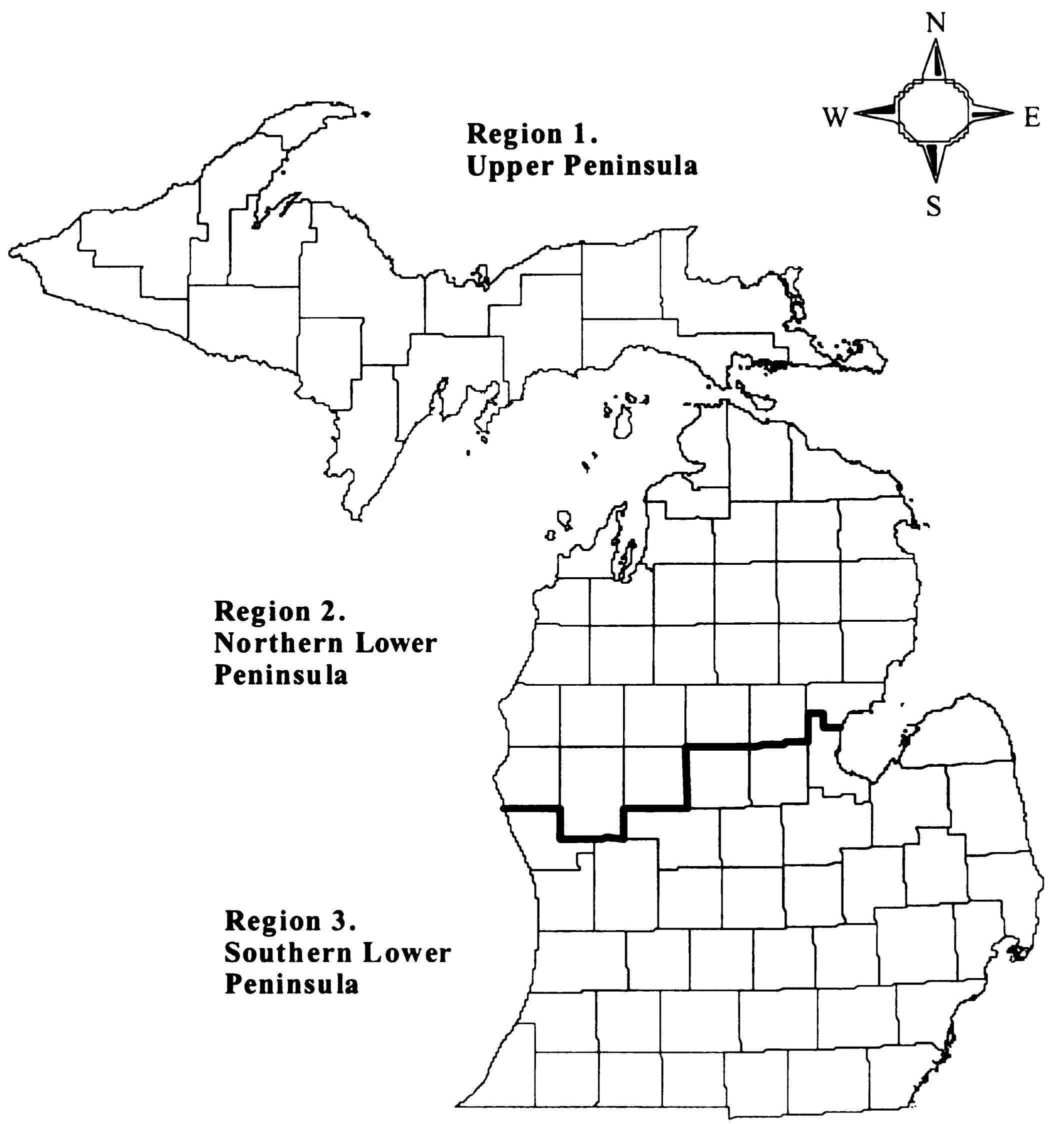

Figure 1.1. The three distinct regions of Michigan based on Albert et al. 1986 classification of ecological regions.

Figure 1.2. Ecological regions (ecoregions) of Michigan based on homogeneity of localized climate and physiography. Classified according to Albert et al. 1986.

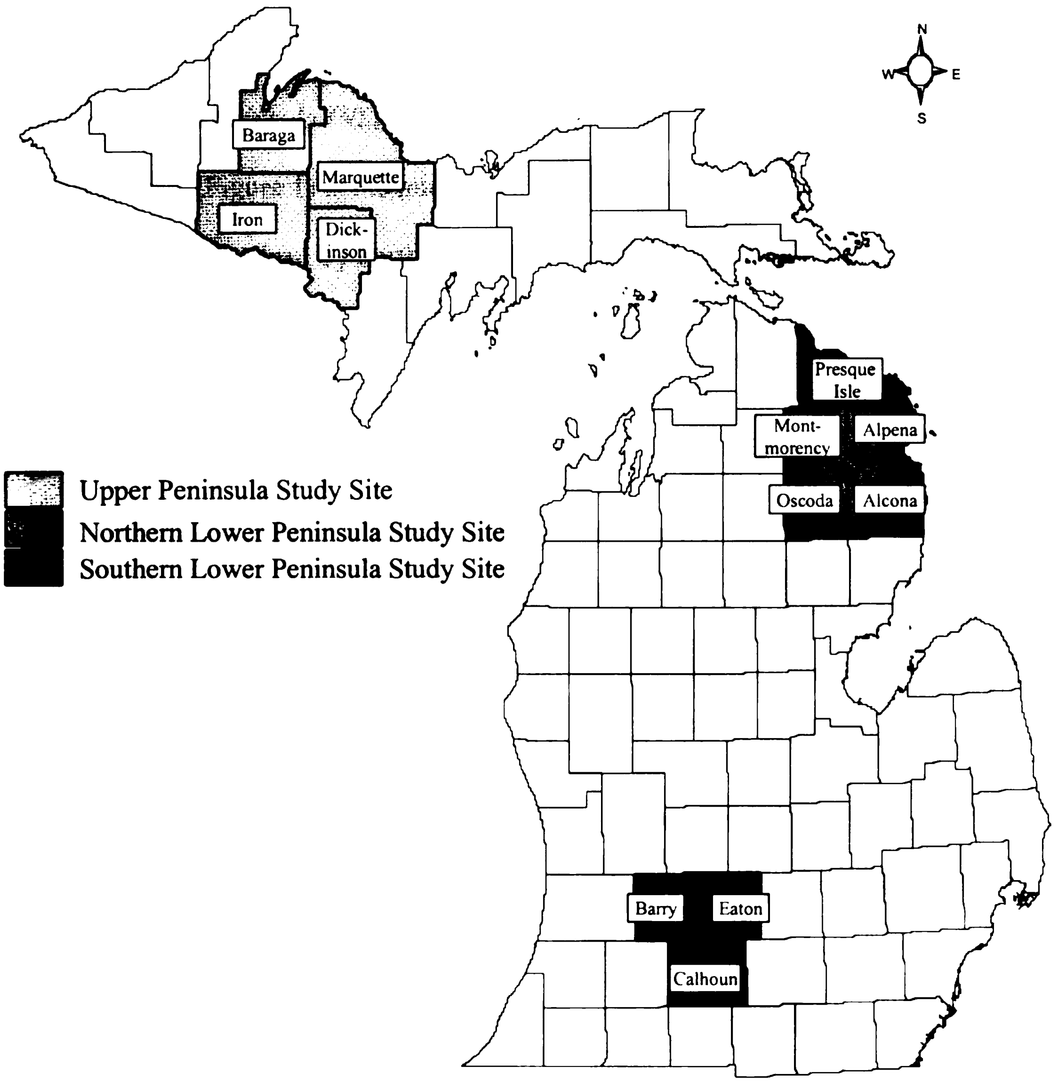

Figure 1.3. The three designated study sites. One site was located within each of the three ecological regions of Michigan and consisted of several counties.

between 366-518 m (Albert et al. 1986). Four counties, Baraga, Dickinson, Iron and Marquette, were selected within this region (Figure 1.3).

Northern Lower Peninsula (NLP)

Region 2 (Figure 1) is the mid-northern region of Michigan. The vegetation in this region is characterized by northern hardwood forest and pine forest ecosystems, and is not as diverse as Region 1. Oak-pine (*Quercus sp.-Pinus sp.*) forests are common in addition to pine forests that consist of white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), and northern white cedar (*Thuja occidentalis* L.).

The soils in Region 2 tend to be predominately sandy. Agriculture and urban development exist in this region but these land uses are not as prominent as in the southern-most region. Therefore, there has not been as much permanent alteration of the vegetation communities present. The climate for the NLP is more variable than the climate in the Southern Lower Peninsula; winters are cold and there is more snowfall. The total precipitation for Region 2 is about 770 mm and the annual average temperature is 6.2 °C. The highest elevations in the Lower Peninsula of Michigan, which range up to 526 m, occur in Region 2 (Albert et al. 1986). In addition, Bovine TB has recently been discovered in region 2. This, in part, was the impetus for the selection of specific counties within this region. Five counties, Alcona, Alpena, Montmorency, Oscoda, and Presque Isle, were selected (Figure 3).

Southern Lower Peninsula (SLP)

Region 3 (Figure 1) is the southern-most region of Michigan. The vegetation is characterized by hardwood forest ecosystems, such as beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), oak (*Quercus sp.*), and hickory forests (*Carya sp.*), that exist primarily on loam and clay soil textures. Although sandy soils are not as common in this region, there are some areas where this soil type exists. There is a high occurrence of agriculture and urban development that has greatly reduced the once diverse plant communities in this region. The climate for the southern region is more mild than in the more northern regions; fluctuations in temperature are less severe and typically there is less snowfall and a longer growing season (Michigan Weather Service 1974, Ozoga et al. 1994). Total annual precipitation for this region is approximately 9.4 mm and the annual average temperature is approximately 19 °C. This region is flatter when compared with the more northern regions. Elevations range between 178-390 m, but are predominately below 305 m (Albert et al. 1986). Three counties, Barry, Calhoun, and Eaton, were selected within this region (Figure 1.3).

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CHAPTER 1

A REGIONAL COMPARISON OF WHITE-TAILED DEER HERD CONDITION IN MICHIGAN

INTRODUCTION

In Michigan, traditional white-tailed deer (*Odocoileus virginianus*) management strategies manipulated the number of deer in an area. Unchecked harvest, as well as the alteration of habitat due to human activities, has historically influenced deer numbers. By the late 1800s, Michigan deer numbers were low because of unregulated market hunting, and the public called for hunting regulations. Early measures to restrict hunting were weak, and it was not until 1895 that legislation was passed to establish an official hunting season, a bag limit, and a required license to hunt deer (Langenau 1994). These restrictions on hunting, in addition to forest fire control and a subsequent increase in available deer browse, contributed to a slow population increase in the early 1900s. However, concern about slow growth of the deer herd led to further hunting restrictions in the early 1900s, such as reducing the number of days hunters could take deer as well as the bag limit. The "buck law" was passed in 1921, which allowed only one buck to be taken per hunter per year (Jenkins and Bartlett 1959).

About this time, the newly created State Department of Conservation, now the Michigan Department of Natural Resources (MDNR), began to promote scientific deer management. In 1928, the Game Division within the Department of Conservation was created, which encouraged specialized personnel to gather scientific data in an organized manner to use as the basis for management decision-making. This approach was intensified after the 1937 Pittman-Robertson Act was passed. Concurrently, the deer herd in Michigan rebounded to approximately 1 million deer and by 1930, winter starvation and over-browsing indicated that the herd had exceeded carrying capacity. Since this approach to deer management was not creating the desired results, the Department of Conservation decided to alter its approach to deer management and reduce deer numbers as well as improve long-term suitable habitat. Despite these efforts, the herd continued to grow, habitat was severely damaged, and hunters became concerned with low buck-to-doe ratios (Jenkins and Bartlett 1959).

In 1941, the Department of Conservation again allowed antlerless hunting in selected areas in an effort to control population growth. The antlerless regulations were experimental and in 1952, after what many described as a slaughter of antlerless deer, the Department initiated an area and quota system to regulate the harvest of antlerless deer. During this period of increased antlerless hunting, resources for deer became scarcer in the 1960s due to forest succession that produced mature forest and prevented the availability of browse. The result was another decrease in the Michigan deer herd. By the 1970s, managers refocused on improving deer habitat and in 1971, the Deer Range Improvement Program (DRIP) was established. This program allocated a certain portion of the revenue generated from hunting license sales to be used for land acquisition, as well as improving and maintaining deer habitat (Langenau 1994).

Deer habitat improvements were facilitated by more logging in northern Michigan and an increase in agriculture in southern Michigan. These changes in land-use coupled with mild winters and artificial feeding contributed to a 1989 peak in deer numbers. This led the MDNR to set a goal of 1.3 million deer in the fall herd and specified that 35% of the fall herd be antlered bucks. To advance this goal, an increased harvest of antlerless deer was encouraged by the MDNR. In addition, block permits were issued to allow landowners to harvest nuisance deer. The MDNR restated its commitment to this population goal in 1997 and has been initiating regulations to help reach this target population size since that time. Many managers and stakeholders, however, have questioned the scientific basis for this population goal. Therefore, there is a need to re-evaluate Michigan's population goal from a biological and social context (i.e., public attitudes toward deer in Michigan).

Traditionally, public attitudes about white-tailed deer focused on deer numbers. Deer were not only a food source but the skins could be traded for money or other goods. Therefore, in general, the public perception was that higher deer numbers were better. Currently, attitudes about deer in Michigan depend on which sector of the public you are dealing with. Overall, hunters still seem to be more concerned with deer numbers, whereas the general public appears to be more concerned with the condition of the herd. The public often uses the number of deer seen as roadkill and the number of deer-vehicle accidents to form their perception of deer over- or under-abundance. Many individuals attribute the perceived lack of deer as a direct result of over-harvest and are not aware of the underlying habitat factors that could also influence deer population dynamics (W. Moritz, MDNR, Wildlife Division, pers. commun.).

Public attitudes have influenced the current management strategy and facilitated the MDNR's shift in management focus from primarily managing for the size of the herd to managing for the quality of the herd. This shift in management focus is evident nationwide, as management objectives in several states have shifted from the promotion of herd growth to population stabilization or herd reduction (Foster et al. 1997).

The recent discovery of Bovine Tuberculosis (*Myobacterium bovis*) (TB) in northeastern Michigan has also served as an impetus for the MDNR to examine herd quality. Bovine TB is spread through aerosols and close contact of infected individuals is necessary to transmit the disease. Poor habitat along with high deer population densities have resulted in an unhealthy herd in which TB has been able to spread and become self-sustaining (Schmitt et al. 1997). In light of the emergence of this disease, and large population fluctuations, and habitat damage resulting from traditional deer management strategies (McCabe and McCabe 1997), the MDNR realized the need to develop an alternative management approach that would incorporate ecological as well as social and biological objectives.

The current approach is more holistic than traditional management practices. It is ecosystem-based and incorporates landscape-level planning into deer management instead of primarily manipulating deer numbers to achieve management goals. Ecosystem-based management emerged in the 1970s when managers began to acknowledge that to develop realistic management strategies, "living systems" should be regarded as complex and dynamic, varying at many spatial and temporal scales (Johnson and Agee 1988, Grumbine 1994). Implementation of ecosystem-based management requires a broad knowledge base that synthesizes the relationship among the structure and function of ecosystem processes and composition, species demographics, and the economic and social values of users of these ecosystems.

A hierarchical land classification can provide the framework for developing ecosystem-based deer management strategies by delineating areas of differing ecological potential at various spatial scales (Albert et al. 1986). Using these ecological units to minimize spatial variation of habitat potential, the biological and cultural carrying capacity can be estimated. Understanding these data allows the MDNR to establish deer management goals for ecologically and culturally homogenous areas that integrate biological and social significance.

There is an established relationship among the productivity and physical condition of deer and the quality of the habitat (Ford et al. 1997). Therefore, 1 way to achieve a more accurate estimate of the biological carrying capacity, is to consider herd quality, or health, because the physical condition of the deer herd can affect the maximum number of deer that can be supported at equilibrium (McCullough 1982). Nutritionally stressed deer are generally in poor physical condition and, thus, tend to experience low reproductive rates, low survival rates, and low recruitment (Huot 1988). However, before considering herd health in deer management efforts, managers need to have a definition of quality or condition of white-tailed deer (Rasmussen 1985). According to Hamilton et al. (1995) a quality deer herd is defined by deer that are in good physical condition and that are in balance with the existing habitat.

One of the best methods to measure the condition of deer is to evaluate the physical growth of deer (Severinghaus 1955, Cowan and Long 1962, McCullough 1982, Severinghaus and Moen 1983, Rasmussen 1985). Antler development, consisting of average beam diameter and number of points, lactation status and fall recruitment have been identified as measurable population-level quality indices (Hill et al. 1981, Cook and Winterstein 2000). These population-level quality indices can reflect the possible reproductive potential of the deer, which is important in defining an appropriate scale at which to measure the quality of the deer herd.

In addition to having a clear definition of herd quality, it is important to examine spatial and temporal patterns in herd quality. Studying temporal and spatial variability in herd condition may help isolate some of the underlying mechanisms (e.g., weather) that cause shifts in the biological carrying capacity of the deer population. Spatial and temporal trends may also be beneficial for examining how population-level quality indices correspond with certain ecological and social aspects of management. A complete definition of a high quality deer population, coupled with ecological and social considerations allows managers to develop sound management strategies as well as inform the public about how and why management decisions are made.

Objectives

This study will define indices of herd quality for white-tailed deer in Michigan by evaluating measurable characteristics over spatial and temporal scales to determine which are appropriate indicators of herd health. Specifically, the following objectives will be met:

1) Use experimental road survey methods to determine if adequate data can be obtained to determine fall recruitment, as measured by fawn-to-doe ratios;
2) Determine the appropriate landscape scale at which to examine differences in deer herd condition;
3) Assess whether population-level indices, such as antler measurements or lactation status, can be used to examine differences in deer herd condition;
4) Use population-level indices to explore temporal and spatial patterns in the condition of the deer population;

By meeting these objectives, this study will help the MDNR to develop an ecosystem-based management approach for white-tailed deer in Michigan and, if successful, will provide a framework for managing other species in a holistic manner.

METHODS

Data Sources

Biodata

Information on the biological characteristics of the deer herd is necessary to evaluate population quality indices and examine how they reflect the biological carrying capacity of white-tailed deer in different areas of the state. The MDNR provides this type of biophysical data, known as the biodata, which have been collected every year since 1951 from deer that hunters voluntarily bring into MDNR check stations each deer season. Currently, the MDNR maintains 4 highway check stations that are located along 3 major southbound highways and at the Mackinac Bridge. Other check stations are located at 75 field offices, state game areas, and recreation areas. These are dispersed throughout the state to minimize a bias in the spatial distribution of the data (Cook and Winterstein 2001).

The check stations are run by MDNR employees or trained volunteers. They collect information on the location (county, deer management unit, township and range coordinates, and private or public land), season (archery, firearm, muzzleloader, early firearm, late firearm) and composition (sex and age) of the kill. This is in addition to the information collected on physical condition which includes antler development of bucks (number of points, left and right beam diameter), lactation status of does, and preliminary TB status based on chest cavity observations (Cook and Winterstein 2001). Since 1987, these data have been compiled into a database in Statistics Package for the Social Sciences (SPSS). This study encompasses the data collected between 1987 and 2000.

Summer Driving Transects

The biodata provide information about biological characteristics that are potential quality indices, but other indices of herd condition needed to be examined. In addition to antler development and lactation, fall recruitment, as assessed by fawn-to-doe ratios, is a measure of deer reproductive potential (Ozoga et al. 1994). To gather information on fawn-to-doe ratios, an experimental protocol was developed to maximize the number of deer observed in different habitat settings.

Summer driving transects were first conducted in the summer of 2000 and based on the findings, were modified in the summer of 2001. In the summer of 2000, driving surveys were conducted by driving a fixed route (transect) each morning and evening for 3 consecutive days during July, August, and September in the SLP and the NLP. The summer driving transect in the UP, however, was conducted only in September due to logistical constraints. There were a total of 4 driving transects, 1 in the SLP, 2 in the NLP (designated NLP1 and NLP2) and 1 in the UP, each of which consisted of a different distance. To achieve complete driving route circuits, the starting point was alternated between a clockwise and counterclockwise direction each morning and evening. Each route in the SLP and NLP was driven a total of 6 times each month, 3 morning and 3 evening. The route in the UP, however, was driven 3 times, 1 morning and 2 evenings over a 2-day period. Two observers recorded the number of does, fawns and bucks observed at the specific mileage along the route, in addition to the side of the road (left, right or in), and the habitat type (woods, opening, row crop, pasture or development) where deer were observed (Figure 1.4).

Date: ____________ Region: SLP NLP1 NLP2 UP Survey Number: ______ Starting Time: ________

Observer(s): ____ Stopping Time: ________

Weather Comments: _______________________________________ Ending Mileage: ________

Direction & Option	Mileage	Doe	Fawn	*Buck*	Side of Road	Type of Habitat					Comments
						Woods	Opening	Row Crop	Pasture	Dvlpmt	

Figure 1.4. The data sheet used for the summer driving transects for both 2000 and 2001.

Beginning summer 2001, the July driving routes were eliminated so that survey efforts could be concentrated on the latter part of August and September, and in 1 case early October (NLP1), to maximize the number of deer observed. Additionally, the morning transects were eliminated because higher fawn-to-doe ratios and overall doe counts existed in the evening. In the summer of 2001, driving routes were conducted for 4 consecutive nights, alternating clockwise and counterclockwise directions, to achieve 3 complete circuits and maximize the number of does observed.

Sample Size

The data used for this project were historical in nature. Once the data were collected, there was not an opportunity to increase the amount of data; sample sizes were contingent on how many hunter-killed deer were checked each year. Therefore, preliminary analyses were conducted to determine where sufficient sample sizes existed so that statistical analyses could be performed. Minimum required sample sizes were calculated with the following equation:

$$n = (z^2_{\alpha/2}p(1-p))/E^2$$

Where n is the required sample size, $z_{\alpha/2}$ is the value on the standard normal curve that corresponds to $(1-\alpha)$ percent confidence, p is the proportion of interest, and E is the desired margin of error (Wackerly 1996). In areas where sample sizes were not sufficient to conduct statistical analyses, these data were used to guide the aggregation of the data, as well as the interpretation of the results.

Yearling Age-Class

When the project was initiated, population quality indices for all age classes of the deer harvested were to be examined. After exploring the literature and the biodata, it was determined that population quality indices from yearling deer were the best measure of overall herd condition. The exception, however, was fall recruitment because it was based on fawn-to-doe ratios from the summer driving routes, and it was impossible to determine the age of the deer observed beyond the category of fawn or adult. Thus, except for fall recruitment, the examination of the quality indices was focused on the yearling age class for 2 reasons. First, this age class had the largest sample sizes. Secondly, biological information collected from yearlings is more telling of the overall herd quality because males in this age class have the added burden of completing body growth while developing antlers (Ullrey 1983, Rasmussen 1985). Therefore, male yearlings are more likely to have larger antlers with more points and wider average beam diameter if they are in good condition. Similarly, female yearlings are more likely to produce fawns if they are in good condition.

Population Quality Indices

Fall Recruitment

Information obtained from the summer driving routes was used to examine differences in deer reproductive potential, expressed as fall recruitment, and measured by fawn-to-doe ratios. Based on the number of adult does and the number of fawns observed each time that a route was driven, a fawn-to-doe ratio was determined.

$$\text{Fawn:Doe Ratio} = \frac{\text{Number of Fawns Observed}}{\text{Number of Adult Does Observed}}$$

To detect differences in reproductive potential, fawn-to-doe ratios were compared qualitatively at the regional level. The total, average, and maximum deer count per region were calculated to examine the differences, as were the total, average, and maximum fawn-to-doe ratio for each region. This was partially due to extremely small sample sizes at smaller scales (i.e., county level). In addition, there was not enough information to conduct any sort of quantitative statistical analyses.

Lactation Status

Fawn-to-doe ratios are not the only possible way to estimate fall recruitment. Another method is to examine the lactation status of does. This is appropriate because, theoretically, the number of lactating does reflects the number of surviving fawns (Cook and Winterstein 2000). In the biodata, lactation status reflects whether or not there was milk present on a doe either when the deer was brought into the check station or when the deer was field dressed by the hunter. Does were classified as lactating or having milk (HM+), or as not lactating or not having milk (HM-). Lactation status is a biophysical index that has been collected only since 1993 and due to small sample sizes, these data were aggregated to the regional level, even though these data were originally collected at the county level. In addition, lactation status data are nominal-level data; they only define the presence or absence of lactation in female deer. Therefore, only basic statistical analyses such as descriptive statistics were employed.

Antler Measurements

Reproductive potential as measured by fawn-to-doe ratios is one possible method for estimating deer herd condition (Cook and Winterstein 2000). Another possible method is to evaluate antler measurements from harvested bucks that were recorded in check station data and determine whether these indices can be substituted for reproductive potential to determine the condition of deer. There were 2 types of antler measurements examined: average beam diameter and point count. The average beam diameter measurement was obtained when the right and left beam of a set of antlers were each measured to the nearest millimeter with calipers approximately 1 inch above the base of the skull and then averaged together. Point counts were obtained using the eastern point count system, in which all of the points were counted on both the right and left beam of a set of antlers. The antler measurement data are ratio-level data. Therefore, unlike the lactation data, statistical analyses were appropriate for these data.

For each of the 3 study sites, differences in yearling average beam diameter and point count were examined at a regional, county, and, for 1999 and 2000, township level to determine the appropriate spatial scale at which to work. Tests for normalcy were conducted and after the data were found to be normally distributed, analysis of variance (ANOVA) was conducted to test for differences at different spatial scales. It was established that even though there were statistically significant differences among both average beam diameter and point count at the township level, realistically the MDNR would not manage deer at this spatial scale. Therefore, the county level was determined to be the most appropriate spatial scale at which to examine differences in antler measurements.

Within Regions

Examining whether specific quality indices can be used to estimate the biological carrying capacity has limited usefulness. To truly understand what underlying mechanisms cause shifts in herd health, it is necessary to explore how the physical condition of deer changes temporally and spatially. Temporal trends give insight as to how the physical condition of the deer population has changed over time, whereas spatial trends give insight as to how the physical condition of the deer population changes over space.

Since it was not appropriate to conduct analyses at the county level, all analyses performed on the lactation data were conducted at the regional level. Within each region, the number of does lactating each year from 1993-2000 was compared to the total number of does checked for lactation in the same year to determine the percentage of does lactating and the ratio of does lactating (HM+) to does not lactating (HM-). These yearly percents were then plotted and compared to one another. Ranking and frequency methods were used because it was not appropriate to employ quantitative methods on the lactation data.

Unlike the lactation data, the analyses for average beam diameter and point count were conducted at the county level within each study site. Preliminary analyses were conducted to determine how the data were distributed. Frequency distributions were used to determine the range of the average beam diameter and points for yearling male deer on a yearly basis from 1987-2000. In addition, the mean average beam diameter and mean point count per county were calculated on a yearly basis from 1987-2000. After initial descriptive analyses, an ANOVA was conducted to examine whether there were statistical differences among counties for either average beam diameter per county or point count per county for each year from 1987-2000. Mean comparisons were then examined using a Tukey-Kramer multiple comparison test with an alpha level of 0.05.

Temporal trends in both average beam diameter and point count were spatially analyzed using a geographic information system (GIS; ArcView 3.2, Environmental Systems Research Institute). This showed the spatial variability in the physical condition of the deer herd, and allowed for an eventual overlay of the spatial distribution of quality indices with a landscape-level habitat potential model that was developed as another part of this project (A. Felix, unpublished data). This model minimized spatial variation using Albert's hierarchical land classification, and provided a framework to assess the biological carrying capacity within ecologically homogeneous areas.

Among Regions

The long-term percent of lactating does from 1993 through 2000 was calculated for each of the 3 regions. This was accomplished by averaging the percent of does lactating over the 8 years that these data were available for this study, which resulted in 1 average value for each region. These long-term regional averages were then plotted on a line graph to examine trends among all 3 regions. Using the same method, the percent of does lactating was also compared among the 3 regions on a yearly basis from 1993-2000.

The long-term mean for both average beam diameter and point count from 1987 through 2000 for each of the 3 regions was also calculated. These overall means were calculated by averaging all of the values for each antler measurement over the 14 years of this study, which resulted in 1 average value for each antler measurement for each region. Regional averages were then compared by performing an ANOVA to determine if there were statistically significant differences in antler measurements among regions at an alpha level of 0.05. If an overall difference among regions was detected, mean comparisons were conducted using a Tukey-Kramer multiple comparison test at an alpha level of 0.05. In addition, yearly comparisons were conducted for both average beam diameter and point count for 1987-2000 among the 3 regions. This was accomplished by conducting an ANOVA and mean comparisons were again examined using a Tukey-Kramer multiple comparison test at an alpha level of 0.05.

Relationship Among Indices

Once qualitative and statistical differences in the quality indices were established at the appropriate spatial scale, and the quality indices were compared both within and among study sites, the potential relationships among the quality indices were examined. Scatter plots were used to investigate whether a relationship existed between lactation status and average beam diameter or point count.

The relationship between average beam diameter and point count, as well as the relationship between each of the antler measurements and lactation status was examined. Regression analyses were used to determine the relationship between point count and average beam diameter. Scatter plots were also used to examine if there was a correlation between average beam diameter or point count and lactation status of does.

RESULTS

Sample Sizes

UP

Of the 3 study sites, sample sizes of yearling deer in the UP study site were generally smaller than those in the NLP study site, but larger than those in the SLP study site. This trend was consistent for yearling males that had antler measurements taken, but not for yearling does that were checked for lactation. In the UP study site, the number of male yearlings for which an average beam diameter measurement was calculated ranged between 146 in 1997 and 1464 in 1994 (Table 1.1a). When the sample size was broken down by county, Marquette and Iron County had the largest overall number of male yearlings for which an average beam diameter measurement was calculated (n=3157 and n=2850, respectively) (Table 1.1a). Of the 4 counties, Baraga and Dickinson County had the least total number of male yearlings for which an average beam diameter measurement was calculated (n=2112 and n=1910, respectively) (Table 1.1a).

The number of male yearlings for which a point count was generated followed the same trend as the number of male yearlings for which an average beam diameter measurement was calculated. In the UP study site, the number of male yearlings for which a point count was generated ranged between 145 in 1997 and 1474 in 1994 (Table 1.1b). When the sample size was broken down by county, Marquette and Iron County had the largest overall number of male yearlings for which a point count was generated (n=3182 and n=2922, respectively) (Table 1.1b). Baraga and Dickinson County had the least overall number of male yearlings for which a point count was generated (n=2109 and n=1960, respectively) (Table 1.1b).

Table 1.1. Sample size of yearling deer in each county in the Upper Peninsula study site for (a) males that had an average beam diameter measured, (b) males that had number of points counted, and (c) females that were checked for lactation status.

(a) Average Beam Diameter

	BARAGA	DICKINSON	IRON	MARQUETTE	Total
1987	144	184	248	232	808
1988	160	205	247	239	851
1989	88	147	168	215	618
1990	106	161	171	227	665
1991	203	117	190	239	749
1992	145	69	89	174	477
1993	165	96	118	209	588
1994	329	269	382	484	1464
1995	240	131	276	297	944
1996	61	45	62	67	235
1997	17	26	51	52	146
1998	121	94	266	205	686
1999	157	160	316	247	880
2000	176	206	266	270	918
Total	2112	1910	2850	3157	10029

(b) Point Count

	BARAGA	DICKINSON	IRON	MARQUETTE	Total
1987	142	180	247	227	796
1988	157	212	257	241	867
1989	86	154	173	219	632
1990	108	178	193	236	715
1991	203	115	184	234	736
1992	145	76	101	181	503
1993	167	100	121	211	599
1994	327	271	392	484	1474
1995	241	136	282	309	968
1996	61	49	65	68	243
1997	17	26	50	52	145
1998	120	92	266	207	685
1999	157	159	315	240	871
2000	178	212	276	273	939
Total	2109	1960	2922	3182	10173

Table 1.1 (con't)

(c) Lactation

	BARAGA	DICKINSON	IRON	MARQUETTE	Total
1993	0	4	5	2	11
1994	2	5	9	7	23
1995	9	15	52	27	103
1996	3	14	8	10	35
1997	0	0	2	6	8
1998	0	7	2	1	10
1999	4	13	23	10	50
2000	6	27	43	19	95
Total	24	85	144	82	335

The number of yearling does that were checked for lactation followed a slightly different trend than for the number of male yearlings for which an average beam diameter or point count were calculated (Table 1.1c). In the UP study site, the number of yearling does checked for lactation ranged between 8 in 1997 and 103 in 1995 (Table 1.1c). When the sample size was broken down by county, Iron and Dickinson County had the largest overall number of yearling does checked for lactation (n=144 and n=85, respectively) (Table 1.1c). Marquette and Baraga County had the least overall number of yearling does that were checked for lactation (n=82 and n=24, respectively) (Table 1.1c).

NLP

Based upon the biodata, the largest sample sizes of yearling deer were located in the NLP study site. This included the sample size of yearling deer for each of the population-level quality indices: yearling average beam diameter, point count, and lactation status. In the NLP study site, the number of male yearlings for which an average beam diameter measurement was calculated ranged between 887 in 1992 and 2313 in 1998 (Table 1.2a). When the sample size was broken down by county, Alcona and Alpena County had the largest overall number of male yearlings for which an average beam diameter measurement was calculated (n=5337 and n=5294, respectively) (Table 1.2a). Oscoda County had slightly fewer male yearlings for which an average beam diameter measurement was calculated (n=4233) (Table 1.2a). Montmorency and Presque Isle County had the least overall number of male yearlings for which an average beam diameter measurement was calculated (n=3962 and n=3244, respectively) (Table 1.2a).

Table 1.2. Sample size of yearlings in each county of the Northern Lower Peninsula study site for (a) males that had average beam diameter measured, (b) males that had the number of points counted, and (c) females that were checked for lactation status.

(a) Average Beam Diameter

	ALCONA	ALPENA	MONTMORENCY	OSCODA	PRESQUE ISLE	Total
1987	438	422	318	377	246	1801
1988	353	352	294	290	252	1541
1989	184	239	180	228	165	996
1990	424	284	373	426	211	1718
1991	402	265	335	415	182	1599
1992	203	172	178	179	155	887
1993	189	262	160	141	161	913
1994	392	396	299	363	214	1664
1995	400	333	298	368	229	1628
1996	475	541	277	309	158	1760
1997	460	410	305	303	260	1738
1998	503	659	392	369	390	2313
1999	448	564	252	208	276	1748
2000	466	395	301	257	345	1764
Total	5337	5294	3962	4233	3244	22070

(b) Point Count

	ALCONA	ALPENA	MONTMORENCY	OSCODA	PRESQUE ISLE	Total
1987	430	418	313	367	244	1772
1988	361	366	321	297	255	1600
1989	185	238	187	229	165	1004
1990	427	280	380	438	213	1738
1991	399	256	335	415	180	1585
1992	222	174	179	181	156	912
1993	190	264	164	157	160	935
1994	384	385	303	358	216	1646
1995	415	334	306	372	232	1659
1996	536	589	300	311	167	1903
1997	461	414	312	304	266	1757
1998	560	659	407	395	407	2428
1999	508	564	300	251	294	1917
2000	460	397	302	259	351	1769
Total	5538	5338	4109	4334	3306	22625

Table 1.2 (Con't)

(c) Lactation

	ALCONA	ALPENA	MONTMORENCY	OSCODA	PRESQUE ISLE	Total
1993	16	24	15	13	13	81
1994	12	8	5	14	8	47
1995	18	23	13	19	18	91
1996	39	51	44	26	13	173
1997	55	43	47	48	15	208
1998	259	171	179	158	68	835
1999	108	154	97	112	82	553
2000	137	88	73	87	68	453
Total	644	562	473	477	285	2441

The number of male yearlings for which a point count was generated followed the same trend as the number of male yearling for which an average beam diameter measurement was calculated. In the NLP study site, the number of male yearlings for which a point count was generated ranged between 912 in 1992 and 2428 in 1998 (Table 1.2b). When the sample size was broken down by county, Alcona and Alpena County had the largest overall number of male yearlings for which a point count was generated (n=5538 and n=5538, respectively) (Table 1.2b). Oscoda County had slightly fewer male yearlings for which a point count was generated (n=4334) (Table 1.2b). Montmorency and Presque Isle County had the least overall number of male yearlings for which a point count was generated (n=4109 and n=3306, respectively) (Table 1.2b).

The number of yearling does that were checked for lactation also followed the same trend as the number of male yearlings for which an average beam diameter or point count were calculated (Table 1.2c). In the NLP study site, the number of yearling does checked for lactation ranged between 47 in 1994 and 835 in 1998 (Table 1.2c). When the sample size was broken down by county, Alcona and Alpena County had the largest overall number of yearling does checked for lactation (n=644 and n=562, respectively) (Table 1.2c). Oscoda County had slightly fewer yearling does checked for lactation (n=477) (Table 1.2c). Montmorency and Presque Isle County had the least overall number of yearling does that were checked for lactation (n=473 and n=285, respectively) (Table 1.2c).

SLP

In general, the SLP study site had the smallest sample sizes of yearling deer among the 3 study sites, with the exception of the number of yearling does that were checked for lactation, which was larger than the number of yearling does checked for lactation in the UP study site. Also, the yearly sample sizes were more consistent in this study site than the other 2 sites. In the SLP study site, the number of male yearlings for which an average beam diameter measurement was calculated ranged between 273 in 1987 and 394 in 1995 (Table 1.3a). When the sample size was broken down by county, Barry County had the largest overall number of male yearlings for which an average beam diameter measurement was calculated (n=3280), whereas Eaton County had the smallest (n=530) (Table 1.3a). In Calhoun County, the number of male yearling for which an average beam diameter measurement was calculated fell in between the number of male yearlings for the other 2 counties (n=530) (Table 1.3a).

The number of male yearlings for which a point count was generated followed the same trend as the number of male yearlings for which an average beam diameter measurement was calculated. In the SLP study site, the number of male yearlings for which a point count was generated ranged between 257 in 1991 and 387 in 1995 (Table 1.3b). When the sample size was broken down by county, Barry County had the largest overall number of male yearlings for which a point count was generated (n=3170), and Eaton County had the least overall number of male yearlings for which a point count was generated (n=514) (Table 1.3b). In Calhoun County, the number of male yearlings for which a point count was generated fell in between the number of male yearlings for the other 2 counties (n=656) (Table 1.3b).

Table 1.3. Sample size of yearling deer in each county in the Southern Lower Peninsula study site for (a) males that had an average beam diameter measured, (b) males that had the number of points counted, and (c) females that were checked for lactation status.

(a) Average Beam Diameter

	BARRY	CALHOUN	EATON	Total
1987	220	37	16	273
1988	215	43	30	288
1989	248	34	29	311
1990	230	53	25	308
1991	211	43	21	275
1992	223	39	17	279
1993	212	41	26	279
1994	261	48	82	391
1995	264	65	65	394
1996	264	42	43	349
1997	243	62	39	344
1998	241	56	36	333
1999	229	59	52	340
2000	219	55	49	323
Total	3280	677	530	4487

(b) Point Count

	BARRY	CALHOUN	EATON	Total
1987	210	35	16	261
1988	210	38	29	277
1989	238	34	26	298
1990	223	45	23	291
1991	195	41	21	257
1992	219	37	15	271
1993	203	37	25	265
1994	247	52	80	379
1995	259	64	64	387
1996	260	43	43	346
1997	236	61	38	335
1998	234	56	36	326
1999	224	59	49	332
2000	212	54	49	315
Total	3170	656	514	4340

Table 1.3 (Con't)

(c) Lactation

	BARRY	CALHOUN	EATON	Total
1993	22	13	2	37
1994	35	21	5	61
1995	26	19	6	51
1996	39	29	10	78
1997	64	41	12	117
1998	58	33	8	99
1999	46	15	7	68
2000	53	20	8	81
Total	343	191	58	592

The number of yearling does that were checked for lactation followed a slightly different trend than did the number of male yearlings for which an average beam diameter or point count were calculated (Table 1.3c). In the SLP study site, the number of yearling does checked for lactation ranged between 37 in 1987 and 117 in 1997 (Table 3c). When the sample size was broken down by county, Barry County had the largest overall number of yearling does checked for lactation (n=343) (Table 1.3c), whereas Eaton County had the least overall number of yearling does that were checked for lactation (n=58) (Table 1.3c). In Calhoun County, the number of yearling does checked for lactation fell in between the number of yearling does for the other 2 counties (n=191) (Table 1.3c).

Fall Recruitment

Throughout the 2000 summer, there were, in general, more deer observed during the evening transects than in the morning transects, regardless of which month the survey was conducted (Table 1.4). The average number of fawns observed in the morning ranged from 10 to 21, whereas the average number of fawns observed in the evening ranged from 12 to 57 (Table 1.4). Similarly, the average number of does observed in the morning ranged from 24 to 52, and the average number of does observed in the evening ranged from 26 to 108 (Table 1.4). Fawn-to-doe ratios, on the other hand, were not consistently higher in the evening. The average fawn-to-doe ratio in the UP site and NLP2 site was higher in the evening (0.70 and 0.65, respectively) than in the morning (0.59 and 0.45, respectively) (Table 1.4a&c). However, the average fawn-to-doe ratio in the NLP1 and SLP was higher in the morning (0.28 and 0.58, respectively) than in the evening (0.27 and 0.49 respectively) (Table 1.4b&d).

Table 1.4. Summer of 2000 total, average, and maximum fawn-to-doe ratio based on both morning and evening deer counts for each regional route in July, August, and September (b,c,d) and September only (a) .

(a) The Upper Peninsula

	Area	Month	Fawn Morning	Doe Morning	Ratio	Fawn Evening	Doe Evening	Ratio
	UP	September	17	29	0.59	57	81	0.70
Total			17	29	0.59	57	81	0.70
Average			17	29	0.59	57	81	0.70
Max			17	29	0.59	57	81	0.70

(b) The Northern Lower Peninsula Route #1

	Area	Month	Fawn Morning	Doe Morning	Ratio	Fawn Evening	Doe Evening	Ratio
	NLP1	July	17	64	0.27	15	120	0.13
		August	15	55	0.27	28	119	0.24
		September	11	37	0.30	38	85	0.45
Total			43	156	0.28	81	324	0.25
Average			14	52	0.28	27	108	0.27
Max			17	64	0.3	38	120	0.45

(c) The Northern Lower Peninsula Route #2

	Area	Month	Fawn Morning	Doe Morning	Ratio	Fawn Evening	Doe Evening	Ratio
	NLP2	July	9	28	0.32	11	49	0.22
		August	8	16	0.50	15	16	0.94
		September	14	27	0.52	11	14	0.79
Total			31	71	0.44	37	79	0.47
Average			10	24	0.45	12	26	0.65
Max			14	28	0.52	15	49	0.94

(d) The Southern Lower Peninsula

	Area	Month	Fawn Morning	Doe Morning	Ratio	Fawn Evening	Doe Evening	Ratio
	SLP	July	7	60	0.12	9	83	0.11
		August	29	35	0.83	36	46	0.78
		September	27	34	0.79	52	89	0.58
Total			63	129	0.49	97	218	0.44
Average			21	43	0.58	32	73	0.49
Max			29	60	0.83	52	89	0.58

Deer numbers and fawn-to-doe ratios also differed by month, except in the UP site where transects were only conducted in September (Table 1.5a). For the NLP1 site, deer numbers were highest in July and August (n=271 and n=273, respectively), with a slight decline in September (n=216) (Table 1.5b). In the NLP2 site, the highest deer numbers were observed in July (n=120) and there was a sharp decline in deer numbers for August and September (n=71 and n=76, respectively) (Table 1.5c). Deer numbers in the SLP were, conversely, lower in July and August (n=198 and n=194, respectively) than in September (n=252) (Table 1.5d). The number of does observed, for the most part, declined as the summer progressed, but the number of fawns observed tended to increase (Tables 1.4&1.5). This may explain why generally there were higher fawn-to-doe ratios in August and September than in July (Table 1.4). For the NLP1 site, the fawn-to-doe ratio steadily increased throughout the 3 months for both the morning and evening transects; morning fawn-to-doe ratios increased from 0.27 to 0.30 and evening fawn-to-doe ratios increased from 0.13 to 0.45 (Table 1.4b). The morning fawn-to-doe ratios for the NLP2 site increased from 0.32 in July to 0.52 in September and the evening fawn-to-doe ratios increased from 0.22 in July to 0.94 in August then declined slightly to 0.79 in September (Table 1.4c). The morning fawn-to-doe ratios in the SLP site increased from 0.12 in July to 0.83 in August then declined slightly to 0.79 in September (Table 1.4d). The evening fawn-to-doe ratios in the SLP site followed the same trend; fawn-to-doe ratios increased from 0.11 in July to 0.78 in August then declined to 0.58 in September (Table 1.4d).

Table 1.5. Total deer numbers observed based on the summer 2000 driving transect deer counts for each regional route in July, August, and September (b,c,d) and September only (a).

(a) The Upper Peninsula

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	UP	September	74	110	11	0	195
Total			74	110	11	0	**195**

(b) The Northern Lower Peninsula Route #1

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	NLP1	July	32	184	32	23	271
		August	43	174	36	20	273
		September	49	122	25	20	216
Total			124	480	93	63	**760**

(c) The Northern Lower Peninsula Route #2

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	NLP2	July	20	77	16	7	120
		August	23	32	4	12	71
		September	25	41	4	6	76
Total			68	150	24	25	**267**

(d) The Southern Lower Peninsula

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	SLP	July	16	143	21	18	198
		August	65	81	21	27	194
		September	79	123	21	29	252
Total			160	347	63	74	**644**

Of the deer observed along each transect, the majority were does, regardless of region, followed by the number of fawns, bucks, and unknown deer observed (Table 1.5). There were more deer observed in each category in the NLP1 site than in the other 3 sites (total n=760) (Table 1.5b). The number of deer observed in each category in the SLP site was slightly lower than in the NLP1 site (total n=644) (Table 1.5d), whereas the number of deer observed in each category in the NLP2 site was much lower than in the NLP1 site (total n=267) (Table 1.5c). The fewest deer in each category were observed in the UP site (total n=195) (Table 1.5a), this may be a reflection of the fact that deer were only observed during 1 month (September).

In the summer of 2001, deer numbers in the NLP1 site were highest in September (n=164), and declined in October (n=109) (Table 1.7b). In the NLP2 site, the highest deer numbers were observed in August (n=204) with a sharp decline in deer numbers for September (n=135) (Table 1.7c). Deer numbers in the SLP were also higher in August (n=121) than in September (n=90) (Table 1.7d). In addition, the number of does observed, for the most part, declined as the summer progressed, as did the number of fawns (Tables 1.6&1.7).

The fawn-to-doe ratios were not only more consistent but also higher in 2001 when compared to the fawn-to-doe ratios in the summer of 2000. There did not appear to be large differences in the fawn-to-doe ratios among months or among transect sites, although in general the fawn-to-doe ratios increased in September and October, with the exception of the NLP2 site (Table 1.6). The fawn-to-doe ratio in the NLP1 site increased from 1.06 in September to 1.23 in October (Table 1.6b), whereas the fawn-to-doe ratio in the NLP2 site decreased from 1.00 in August to 0.88 in September (Table 1.6c). Fawn-

Table 1.6. Summer of 2001 total, average, and maximum fawn-to-doe ratios based on evening deer counts only for each regional route in August and September (c,d), September and October (b) , and September only (a).

(a) The Upper Peninsula

	Area	Month	Fawn	Doe	Ratio
	UP	September	35	31	1.13
Total			35	31	1.13
Average			35	31	1.13
Max			35	31	1.13

(b) The Northern Lower Peninsula Route #1

	Area	Month	Fawn	Doe	Ratio
	NLP1	September	73	69	1.06
		October	53	43	1.23
Total			126	112	1.13
Average			63	56	1.15
Max			45	69	1.23

(c) The Northern Lower Peninsula Route #2

	Area	Month	Fawn	Doe	Ratio
	NLP2	August	83	83	1.00
		September	53	60	0.88
Total			136	143	0.95
Average			68	71.5	0.94
Max			83	83	1.00

(d) The Southern Lower Peninsula

	Area	Month	Fawn	Doe	Ratio
	SLP	August	45	59	0.76
		September	36	37	0.97
Total			81	96	0.84
Average			40.5	48	0.87
Max			45	59	0.97

Table 1.7. Total deer numbers observed based on the summer 2001 deer counts for each regional route in August and September (c,d), September and October (b), and September only (a).

(a) The Upper Peninsula

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	UP	September	35	31	17	32	115
Total			35	31	17	32	**115**

(b) The Northern Lower Peninsula Route #1

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	NLP1	September	73	69	18	4	164
		October	53	43	11	2	109
Total			126	112	29	6	**273**

(c) The Northern Lower Peninsula Route #2

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	NLP2	August	83	83	29	9	204
		September	53	60	17	5	135
Total			136	143	46	14	**339**

(d) The Southern Lower Peninsula

	Area	Month	Fawn	Doe	Buck	Unknown	Total
	SLP	August	45	59	11	6	121
		September	36	37	11	6	90
Total			81	96	22	12	**211**

to-doe ratios in the SLP site increased from 0.76 in August to 0.97 in September (Table 1.6d). The direction of change in the UP site was unknown because transects were conducted only in September (Table 1.6a).

The sex and age composition of deer observed along each transect were similar in 2000 and 2001. The majority were does, regardless of region, followed by the number fawns, bucks, and unknown deer observed (Table 1.7). There were, however, fewer unknown deer in 2001 when compared with 2000 (Tables 1.5&1.7). There were more deer observed in each category in the NLP2 site than in the other 3 sites (total n=339) (Table 1.7c). The number of deer observed in each category in the NLP1 site was lower than in the NLP2 site (total n=273) (Table 7b), whereas the number of deer observed in each category in the SLP site was slightly lower than in the NLP1 site (total n=211) (Table 1.7d). The fewest deer in each category were observed in the UP site (total n=115) (Table 1.7a), this may be a reflection of the fact that deer were only observed during 1 month (September).

Comparisons within Study Sites

UP

Of the total number of yearling does that were checked for lactation in the UP study site, the majority were not lactating (HM-) (Table 1.8). The percent of yearling does that were not lactating ranged between 81.8% and 100%, whereas the percent of yearling does that were lactating (HM+) ranged between 0% and 19.4% (Table 1.8). Overall, the number of does that were checked for lactation in the UP study site was relatively small (Figure 1.5). In fact in only 1 year (1995) did the number of yearling does

Table 1.8. The lactation status of yearling does harvested in the Upper Peninsula study site each year between 1993 and 2000, as well as the percent of yearling does lactating (HM+) and not lactating (HM-) each year.

Year	HM+	HM-	Total	%HM+	%HM-
1993	2	9	11	18.2	81.8
1994	3	20	23	13	87
1995	20	83	103	19.4	80.6
1996	5	30	35	14.3	85.7
1997	0	8	8	0	100
1998	0	10	10	0	100
1999	4	46	50	8	92
2000	10	85	95	10.5	89.5

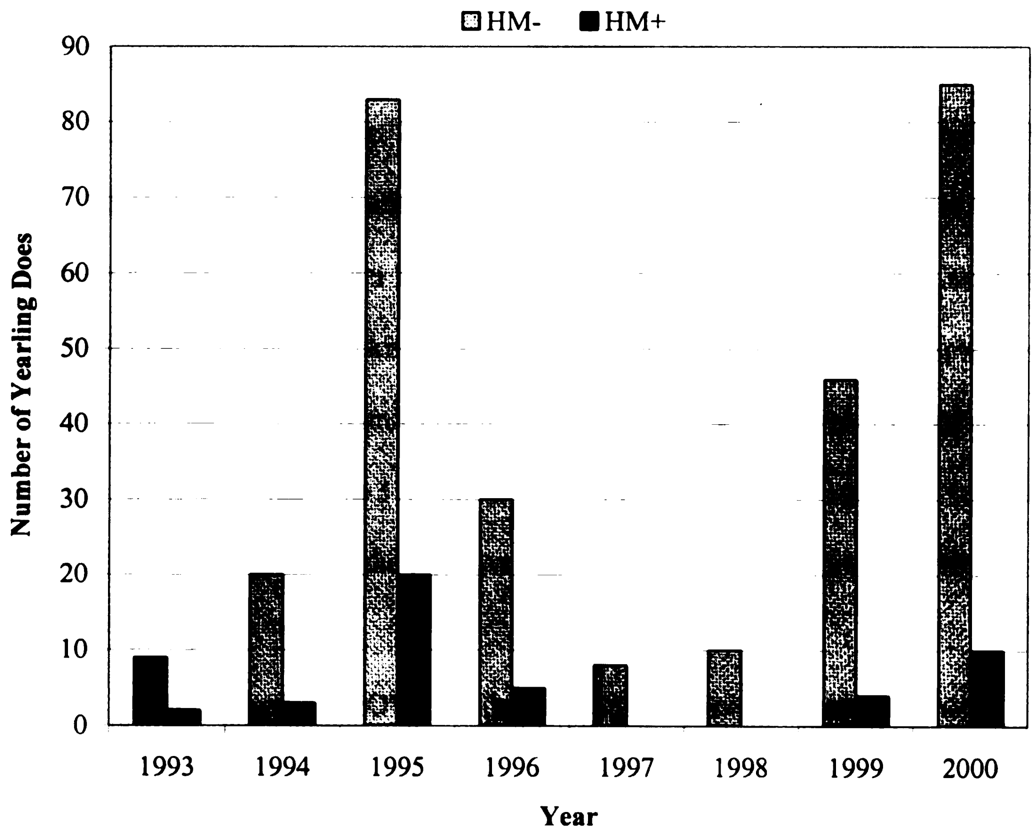

Figure 1.5. Lactation status of yearling does harvested in the Upper Peninsula study site for each year between 1993 and 2000.

checked for lactation exceed 100 (Table 1.8; Figure 1.5). Years (e.g., 2000) in which a relatively large number of does were checked for lactation in the UP study did not necessarily translate into a higher percent of lactation (Table 1.8; Figure 1.6). There were, however, years (e.g., 1993) in which small numbers of yearling does checked for lactation in the UP study site did translate into a higher percent of lactation (Table 1.8; Figure 1.6). In addition, there were several years in which, of the yearling does checked for lactation, there were no does lactating (e.g., 1997 and 1998) (Table 1.8; Figure 1.6).

In the UP study site, the overall mean average beam diameter for male yearlings across the 14 years of this study was 16.8mm and this index ranged between 16.1mm in 1995 and 17.5mm in 1987 for the 14 years of the study (Table 1.9). The mean average beam diameter for male yearlings in the UP study site peaked in 1987, 1991, and 1998; this index tended to oscillate around 17mm, but never fell below 16mm (Figure 1.7). The minimum average beam diameter for male yearlings was 6mm in Marquette County in 1994 and 1995 as well as in Dickinson County in 1989, although most of the low averages ranged between 8mm and 11mm (Table 1.10). The maximum average beam diameter for male yearlings was 31.5mm in Baraga County in 1992 and Iron County in 1987; however, the majority of the high averages ranged between 25mm and 29mm (Table 1.10).

The results from the ANOVA model run with male yearling average beam diameter indicated that the year variable was statistically significant ($F_{13, 9973} = 15.03$; $P < 0.0001$). Also, the results from the Tukey-Kramer multiple comparison test illustrated which years the male yearling average beam diameter was significantly different from

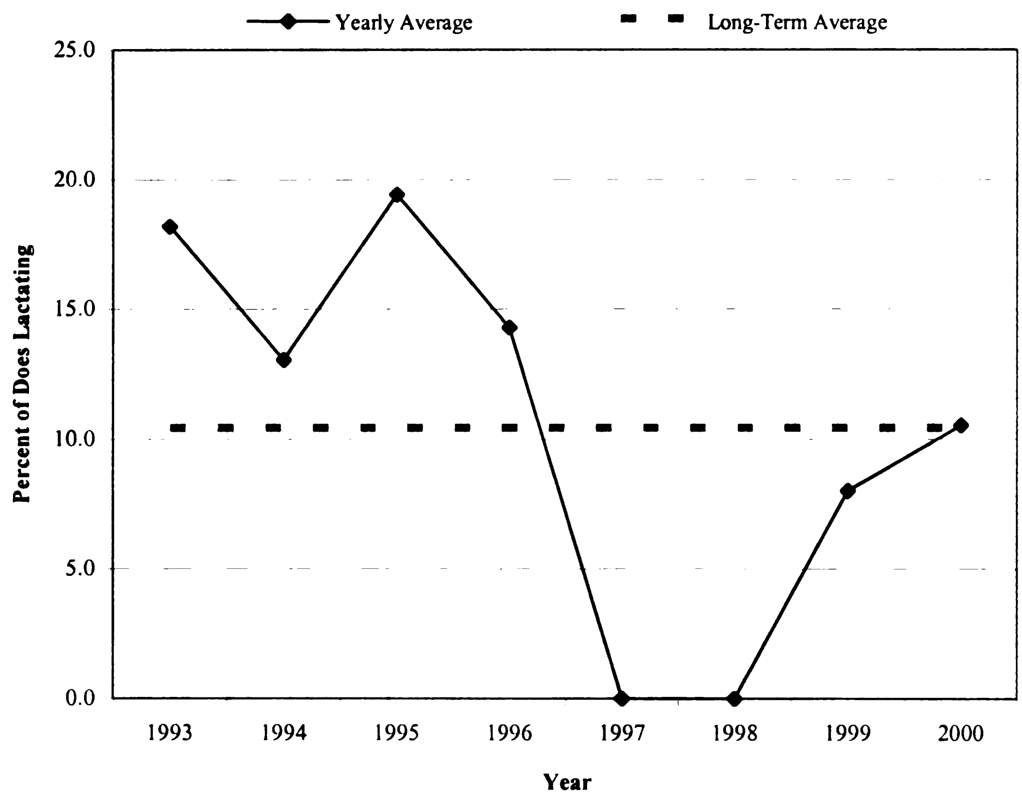

Figure 1.6. The percent of yearling does harvested in the Upper Peninsula study site that were lactating during each year between 1993 and 2000.

Table 1.9. The mean average beam diameter in mm for male yearlings harvested in each county in the Upper Peninsula study site for each year between 1987 and 2000 and the standard deviation, as well as the yearly averages for the entire study site and overall averages for each county.

Year	Baraga	Dickinson	Iron	Marquette	Yearly Average	StDev
1987	19.0	16.8	17.7	16.9	17.5	0.99
1988	17.4	16.4	17.1	16.6	16.8	0.46
1989	18.9	15.5	16.9	15.5	16.4	1.62
1990	18.1	16.1	16.8	16.2	16.6	0.90
1991	18.1	16.6	16.9	17.1	17.2	0.63
1992	18.2	15.1	16.7	16.9	17.0	1.26
1993	17.0	16.6	17.2	16.1	16.7	0.46
1994	16.5	16.6	17.0	16.2	16.5	0.31
1995	16.0	15.3	16.5	16.1	16.1	0.49
1996	18.0	14.7	15.7	15.9	16.2	1.36
1997	15.6	16.6	16.0	16.6	16.3	0.49
1998	18.1	16.9	17.1	17.3	17.3	0.54
1999	17.3	17.5	17.0	17.2	17.2	0.17
2000	17.8	16.8	16.4	17.2	17.0	0.63
Total	17.5	16.4	16.9	16.6	16.8	0.47

Table 1.10. The minimum and maximum average beam diameter in mm collected from male yearlings harvested in each county in the Upper Peninsula study site for each year between 1987 and 2000.

	Baraga		Dickinson		Iron		Marquette	
	Min	Max	Min	Max	Min	Max	Min	Max
1987	12	26.5	9	25	8	31.5	9.5	26.5
1988	7.5	25	7	28	10	26	8	30
1989	10	37	6	23.5	10.5	25	7.5	24
1990	10	30.5	8.5	25	8.5	26	7	26
1991	12	26	10.5	25	10	25	9.5	27.5
1992	10	31.5	7.5	25	10	25	10	26
1993	9.5	26.5	9	25.5	11	26	9	24.5
1994	9	25	8.5	29.5	9.5	25.5	6	31
1995	9	25.5	7.5	28.5	8.5	24.5	6	27
1996	9.5	29	7.5	24.5	7	25	11	23
1997	11.5	21	8	22.5	10.5	24	11.5	27.5
1998	10	26.5	8.5	28	7	25	9	26
1999	11.5	29	10.5	27.5	9	26	10	25.5
2000	7.5	28	6	26	7	25	9.5	25.5

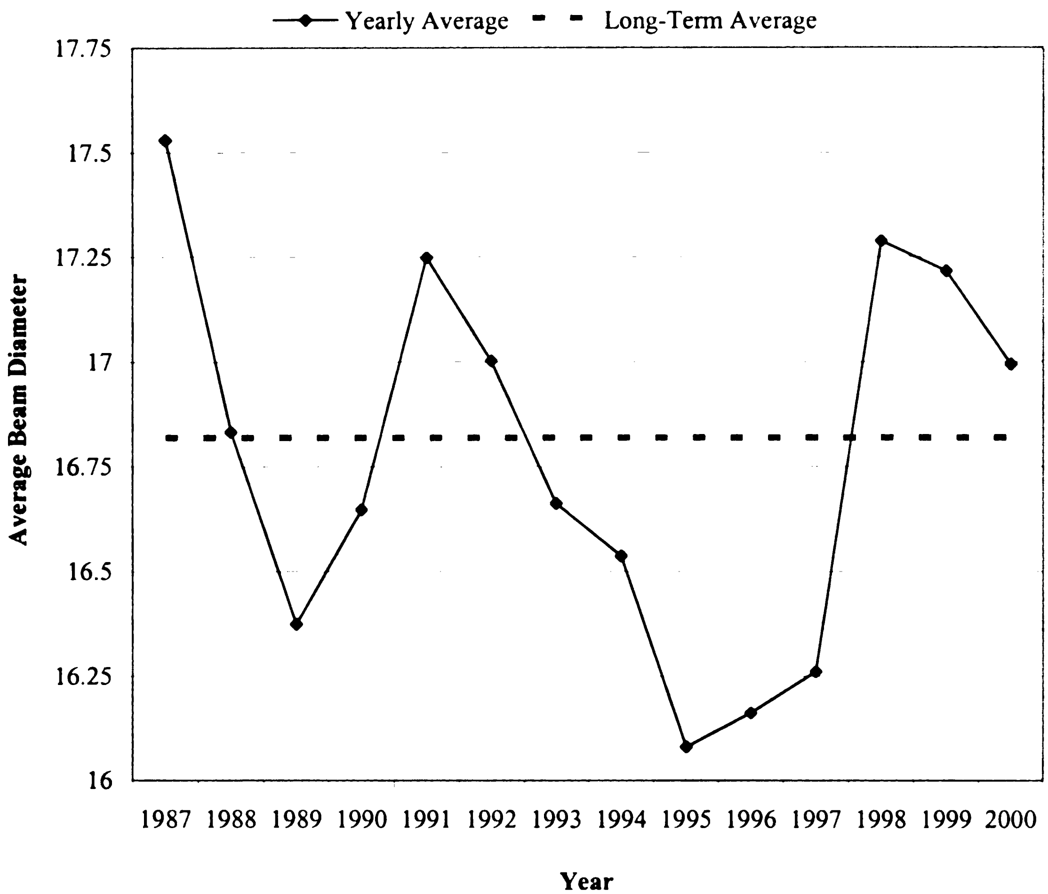

Figure 1.7. The temporal change in average beam diameter in mm for male yearlings harvested in the Upper Peninsula study site between 1987 and 2000.

one another (Table 1.11). The Tukey-Kramer multiple comparison test results showed that the male yearling average beam diameter in each of 1987 and 1995 was significantly different ($P \leq 0.05$) from the male yearling average beam diameter in most of the other years in the study (Table 1.11). Also, male yearling average beam diameter in each of 1998, 1999, and 2000 was significantly different ($P \leq 0.05$) from the male yearling average beam diameter in the middle years of the study as well as from each other (Table 1.11). There were additional years in which the male yearling average beam diameter was significantly different ($P \leq 0.05$) from one another, although there was not as much of a distinct pattern (Table 1.11).

When the mean average beam diameter was examined by county, male yearlings in Baraga and Iron County had the largest average beam diameter measurements in the UP study site ($\bar{x}$ = 17.5mm and $\bar{x}$ = 16.9mm, respectively) (Figure 1.8). Marquette and Dickinson County had the smallest average beam diameter measurements in the UP study site ($\bar{x}$ = 16.6mm and $\bar{x}$ = 16.4mm, respectively) (Figure 1.8). The results from the ANOVA model also indicated that the county variable was statistically significant ($F_{3, 9973} = 44.42$; $P < 0.0001$). According to the Tukey-Kramer multiple comparison test, the average beam diameter for male yearlings in Baraga County was significantly different ($P \leq 0.05$) from the average beam diameter in each of the other 3 counties (Table 1.12). In addition, the average beam diameter for male yearlings in Dickinson County was also significantly different ($P \leq 0.05$) from the average beam diameter in each of the other 3 counties (Table 1.12).

The overall point count for male yearlings in the UP study site was 3.086 and the average point count for male yearlings ranged between 2.88 in 1990 and 3.34 in 1998

Table 1.11. Mean pair-wise comparisons of average beam diameter for male yearlings harvested in the Upper Peninsula study site on a yearly basis. The x denotes a significant difference at an alpha level of 0.05.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1987														
1988	x													
1989	x													
1990	x													
1991														
1992	x													
1993	x													
1994	x				x									
1995	x	x	x	x	x	x	x	x						
1996	x	x			x									
1997	x													
1998			x				x	x	x	x	x			
1999								x	x	x	x			
2000	x							x	x	x				

Table 1.12. Mean pair-wise comparisons of average beam diameter for male yearlings harvested in the Upper Peninsula study site on a county basis. The x denotes a significant difference at an alpha level of 0.05.

	Baraga	Dickinson	Iron	Marquette
Baraga				
Dickinson	x			
Iron	x	x		
Marquette	x	x		

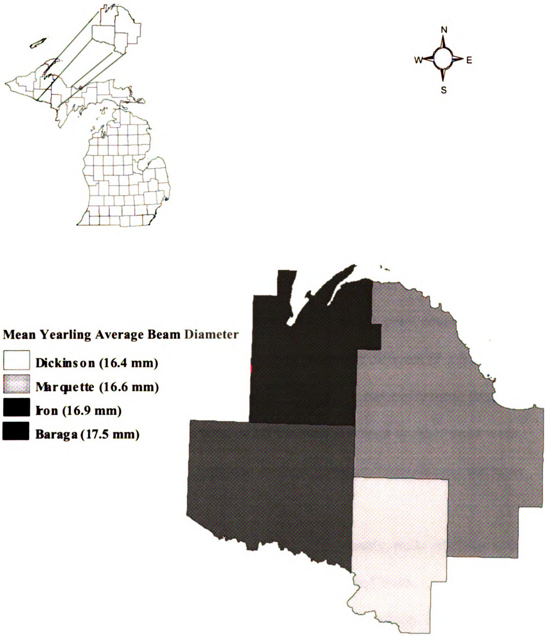

Figure 1.8. Mean yearling average beam diameter by county in the Upper Peninsula study site for 1987-2000.

(Table 1.13). The yearly average point count for male yearlings in the UP study site peaked in 1987, 1991, and 1998; this index oscillated around 3, but never fell below 2.8 (Figure 1.9). The minimum number of points for male yearlings in this study site was 2, which was consistent among years and counties (Table 1.14). The maximum number of points for male yearlings reached 20 in Marquette County in 1994; however, most of the maximum number of points ranged between 7 and 10 (Table 1.14).

The results of the ANOVA model run with the male yearling points indicated that the year variable was statistically significant ($F_{13, 10117} = 8.83$; $P < 0.0001$), and the results from the Tukey-Kramer multiple comparison test illustrated which years the male yearling point count was significantly different from one another (Table 1.15). According to the Tukey-Kramer multiple comparison test, the point count for male yearlings in each of 1987, 1998, and 1999 was significantly different ($P \leq 0.05$) from the point count for the majority of the other years in the study, especially those years between 1989 and 1996 (Table 1.15). The point count for male yearlings in other years were significantly different ($P \leq 0.05$) from one another; however, there was not a distinct pattern (Table 1.15).

When the average point count was examined by county, male yearlings with the most number of points were found in Baraga and Marquette County ($\bar{x} = 3.34$ and $\bar{x} = 3.08$, respectively) (Figure 1.10). On the other hand, male yearlings in Iron and Dickinson County had the fewest number of points ($\bar{x} = 3.01$ and $\bar{x} = 2.93$, respectively) (Figure 1.10). The results from the ANOVA model also indicated that the county variable was statistically significant ($F_{3, 10117} = 20.78$; $P < 0.0001$). The Tukey-Kramer multiple comparison test results showed that the point count for male yearlings in Baraga County

Table 1.13. The mean point count for male yearlings harvested in each county in the Upper Peninsula study site for each year between 1987 and 2000 and the standard deviation, as well as the yearly averages for the entire study site and overall averages for each county.

Year	Baraga	Dickinson	Iron	Marquette	Yearly Average	StDev
1987	4.14	2.85	3.25	3.24	3.32	0.55
1988	3.34	3.04	3.08	3.11	3.13	0.13
1989	3.36	2.69	3.01	2.89	2.94	0.28
1990	3.53	2.76	2.75	2.79	2.88	0.38
1991	3.70	2.86	2.88	3.24	3.22	0.40
1992	3.59	2.62	2.78	2.90	3.03	0.43
1993	3.18	3.04	2.97	3.03	3.06	0.09
1994	2.99	2.82	3.00	3.09	2.99	0.11
1995	3.08	2.71	2.78	2.94	2.90	0.16
1996	3.13	2.57	2.88	2.94	2.90	0.23
1997	2.47	3.27	2.90	3.15	3.01	0.35
1998	3.69	3.20	3.35	3.17	3.34	0.24
1999	3.17	3.40	3.26	3.39	3.30	0.11
2000	3.21	3.16	2.79	3.18	3.07	0.20
Total	3.34	2.93	3.01	3.08	3.09	0.18

Table 1.14. The minimum and maximum number of points counted on male yearlings harvested in each county in the Upper Peninsula study site for each year between 1987 and 2000.

	Baraga		Dickinson		Iron		Marquette	
	Min	Max	Min	Max	Min	Max	Min	Max
1987	2	9	2	8	2	9	2	8
1988	2	13	2	8	2	8	2	8
1989	2	8	2	7	2	8	2	8
1990	2	9	2	8	2	8	2	8
1991	2	8	2	7	2	8	2	8
1992	2	15	2	6	2	8	2	9
1993	2	9	2	8	2	7	2	8
1994	2	8	2	8	2	8	2	20
1995	2	8	2	8	2	8	2	8
1996	2	8	2	6	2	8	2	6
1997	2	5	2	6	2	8	2	8
1998	2	10	2	8	2	10	2	7
1999	2	11	2	8	2	8	2	8
2000	2	10	2	16	2	7	2	8

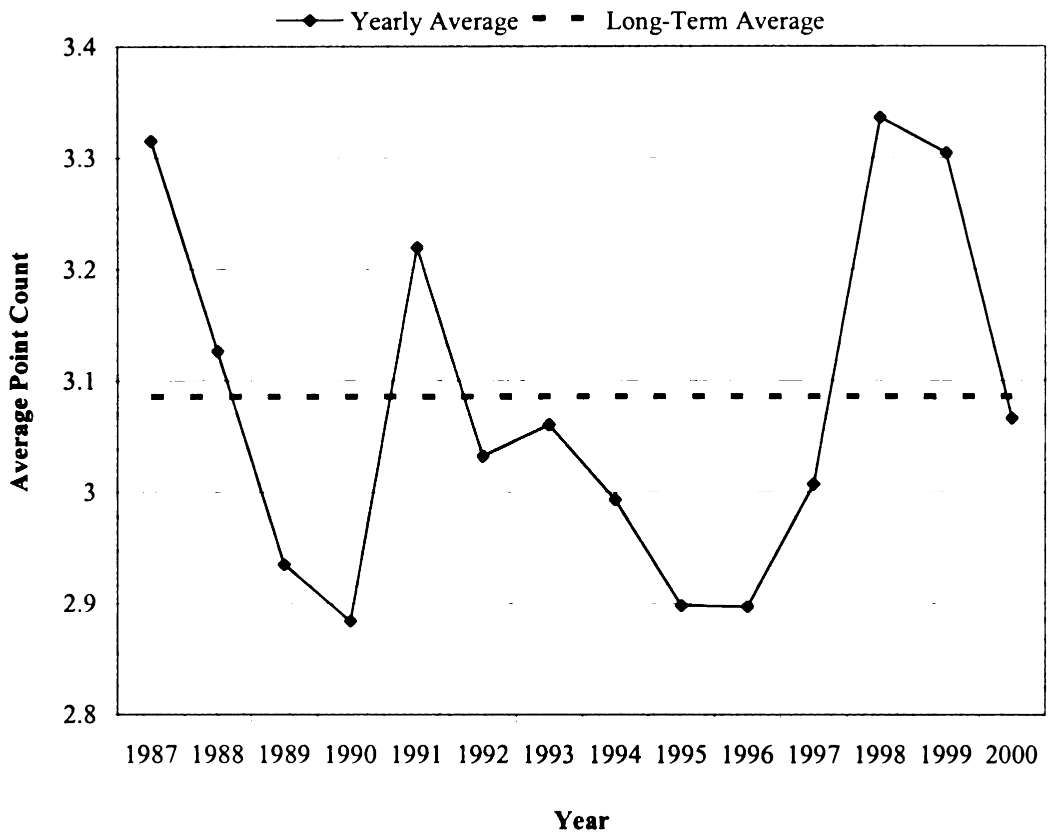

Figure 1.9. The temporal change in average point count for male yearlings harvested in the Upper Peninsula study site between 1987 and 2000.

Table 1.15. Mean pair-wise comparisons of average point count for male yearlings harvested in the Upper Peninsula study site on a yearly basis. The x denotes a significant difference at an alpha level of 0.05.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1987														
1988														
1989	x													
1990	x													
1991														
1992	x													
1993	x													
1994	x													
1995	x	x			x									
1996	x													
1997														
1998			x	x		x	x	x	x	x				
1999			x	x		x		x	x	x				
2000	x											x		

Table 1.16. Mean pair-wise comparisons of average point count for male yearlings harvested in the Upper Peninsula study site on a county basis. The x denotes a significant difference at an alpha level of 0.05.

	Baraga	Dickinson	Iron	Marquette
Baraga				
Dickinson	x			
Iron	x			
Marquette	x	x		

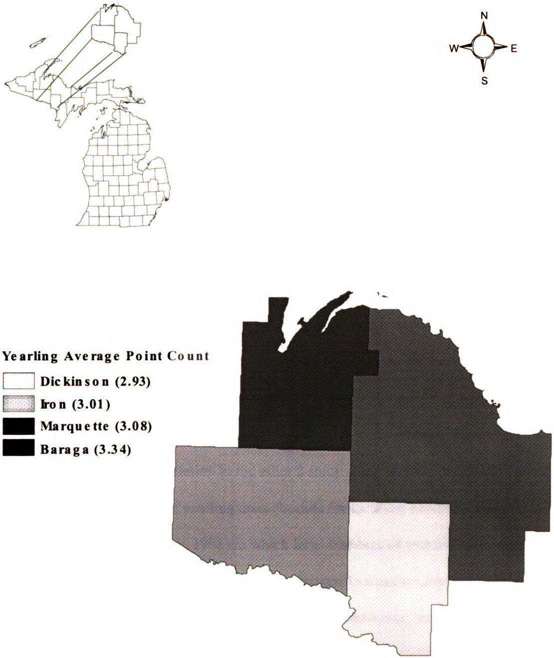

Figure 1.10. Yearling average point count by county in the Upper Peninsula study site for 1987-2000.

was significantly different ($P \leq 0.05$) from the point count in each of the other 3 counties (Table 16). In addition, the point count for male yearlings in Dickinson County was also significantly different ($P \leq 0.05$) from the male yearling point count in Marquette County (Table 16).

NLP

In each year that yearling does were checked for lactation in the NLP study site, there were more does that were not lactating (HM-) then were lactating (HM+) (Table 1.17). The percent of yearling does not lactating ranged between 83% and 93.8%, whereas the percent of yearling does lactating ranged between 6.2% and 17% (Table 1.17). However, the percent of yearling does that were or were not lactating was consistent among years (Table 1.17). In general, the number of does that were checked for lactation in the NLP study site was relatively large in comparison to the number of yearling does checked for lactation in the other 2 study sites. In fact, there were several years in which the number of yearling does checked for lactation exceeded 100 (Table 1.17; Figure 1.11). Years (e.g., 1998) in which large numbers of yearling does were checked for lactation in the NLP study did not necessarily translate into a higher percent of does lactating (Table 1.17; Figure 1.12). There were, however, years (e.g., 1994) in which small numbers of yearling does checked for lactation in the NLP study site did translate into a higher percent of lactation (Table 1.17; Figure 1.12).

In the NLP study site, the overall mean average beam diameter for male yearlings was 17.3mm and ranged between 16.7mm in 1997 and 18.036 mm in 2000 for the 14 years of the study (Table 1.18). The mean average beam diameter for male yearlings in

Table 1.17. The lactation status of yearling does harvested in the Northern Lower Peninsula study site each year between 1993 and 2000, as well as the percent of yearling does lactating (HM+) and not lactating (HM-) each year.

Year	HM+	HM-	Total	%HM+	%HM-
1993	5	76	81	6.2	93.8
1994	8	39	47	17	83
1995	14	80	91	15.4	84.6
1996	26	147	173	15	85
1997	22	186	208	10.6	89.4
1998	124	707	835	14.9	85.1
1999	57	496	553	10.3	89.7
2000	50	283	453	11	89

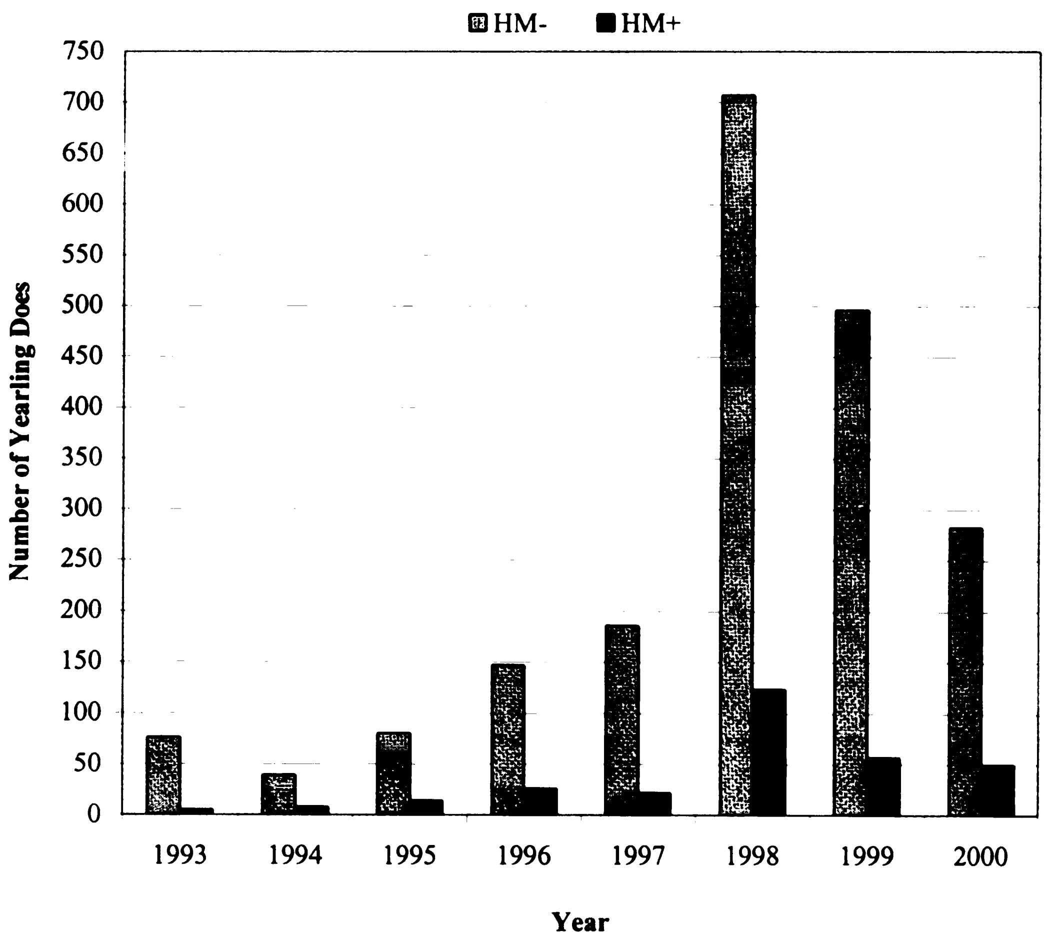

Figure 1.11. The lactation status of yearling does harvested in the Northern Lower Peninsula study site each year between 1993 and 2000.

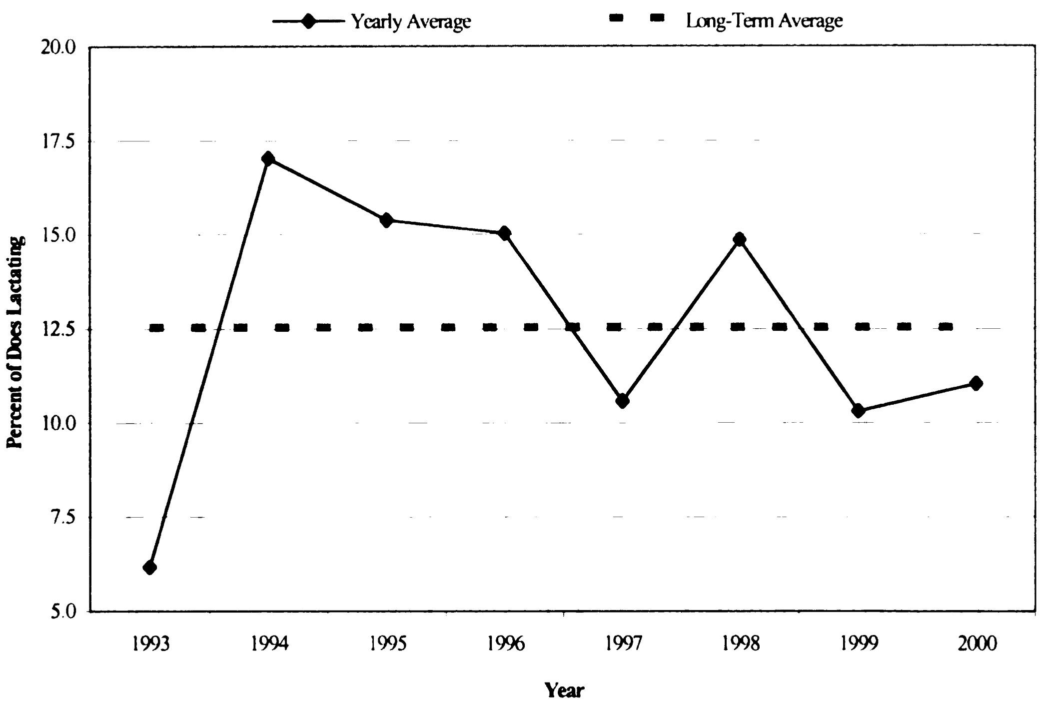

Figure 1.12. The percent of yearling does harvested in the Northern Lower Peninsula study site that were lactating during each year between 1993 and 2000.

Table 1.18. The mean average beam diameter in mm for male yearlings harvested in each county in the Northern Lower Peninsula study site for each year between 1987 and 2000 and the standard deviation, as well as the yearly averages for the entire study site and overall averages for each county.

Year	Alcona	Alpena	Montmorencey	Oscoda	Presque Isle	Yearly Average	StDev
1987	16.5	18.4	17.0	16.2	17.8	17.1	0.91
1988	16.8	18.4	16.9	16.6	17.4	17.2	0.72
1989	16.0	17.8	16.5	15.8	17.1	16.7	0.82
1990	17.5	18.2	17.6	17.2	17.0	17.5	0.45
1991	17.5	17.3	18.1	17.0	17.7	17.5	0.42
1992	16.8	18.0	16.5	16	17.4	16.9	0.78
1993	17.4	17.7	16.9	16.5	17.2	17.2	0.46
1994	17.6	18.0	16.8	16.8	17.4	17.4	0.52
1995	18.4	17.6	16.8	16.9	17.7	17.5	0.65
1996	17.0	17.5	16.8	16.3	17.6	17.1	0.54
1997	16.5	17.0	16.8	16.5	16.9	16.7	0.23
1998	17.0	18.7	17.5	16.4	18.6	17.8	1.00
1999	16.8	17.4	15.9	15.4	17.8	16.9	1.01
2000	18.2	18.3	17.3	17.8	18.4	18.0	0.45
Total	17.2	17.9	17.0	16.6	17.7	17.3	0.52

Table 1.19. The minimum and maximum average beam diameter in mm collected from male yearlings harvested in each county in the Northern Lower Peninsula study site for each year between 1987 and 2000.

	Alcona		Alpena		Montmorency		Oscoda		Presque Isle	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1987	6	26	8	28	9	27	7	27	10	29.5
1988	6.5	27	8.5	26	9.5	25.5	7	27.5	6.5	25
1989	7	25	8.5	26.5	8	28	8.5	29.5	10	24
1990	7.5	28.5	10.5	28.5	5	27.5	8	33	7.5	26.5
1991	7	35.5	8	27	11	33	6.5	29.5	10	26.5
1992	8	29.5	10	27.5	8	27	8	26.5	8	25
1993	7	28.5	9	25.5	10.5	29.5	9	26	8	25.5
1994	6.5	27.5	9	28	8.5	25	8	32	9.5	31
1995	8.5	31	8	33	10.5	28.5	9.5	28	8.5	29
1996	8.5	32	8.5	27	8.5	26	7.5	27	10.5	31.5
1997	8	28	9.5	24	9.5	25.5	8	29	9.5	26
1998	6.5	30	6	29	6	27	6.5	25.5	9.5	29
1999	6	31	6.5	32	6	29	6.5	24	7.5	28.5
2000	5	28.5	8.5	32	7	31	9	28	9	29

the NLP study site increased in 1990, 1995, 1998, and 2000. Although this index tended to oscillate around 17mm, it never fell below 16.5mm (Figure 1.13). The minimum average beam diameter for male yearlings was 5mm in Alcona County in 2000. Most of the minimum averages, however, ranged between 7mm and 10mm (Table 1.19). The maximum average beam diameter for male yearlings was 35.5mm in Alcona County in 1991; however, the majority of the high averages ranged between 25mm and 31mm (Table 1.19).

The results from the ANOVA model run with male yearling average beam diameter indicated that the year variable was statistically significant ($F_{13, 22000} = 22.14$; $P < 0.0001$). The results from the Tukey-Kramer multiple comparison test also illustrated which years the male yearling average beam diameter was significantly different from one another (Table 1.20). According to the Tukey-Kramer multiple comparison test, the average beam diameter for male yearlings in each of 1989, 1997, 1998, 1999, and 2000 was significantly different ($P \leq 0.05$) from the male yearling average beam diameter in the majority of the other years in the study (Table 1.20). In addition, the average beam diameter for male yearlings in other years was significantly different ($P \leq 0.05$) from one another (Table 1.20). The male yearling average beam diameter was significantly different ($P \leq 0.05$) between 1987 and 1988. This was also the case for the male yearling average beam diameter in 1992 and 1996 (Table 1.20).

When the mean average beam diameter was examined by county, male yearlings in Alpena and Presque Isle County had the largest average beam diameter measurements in the NLP study site ($\bar{x} = 17.9$mm and $\bar{x} = 17.7$mm, respectively) (Figure 1.14). Alcona, Montmorency, and Oscoda County had the smallest average beam diameter

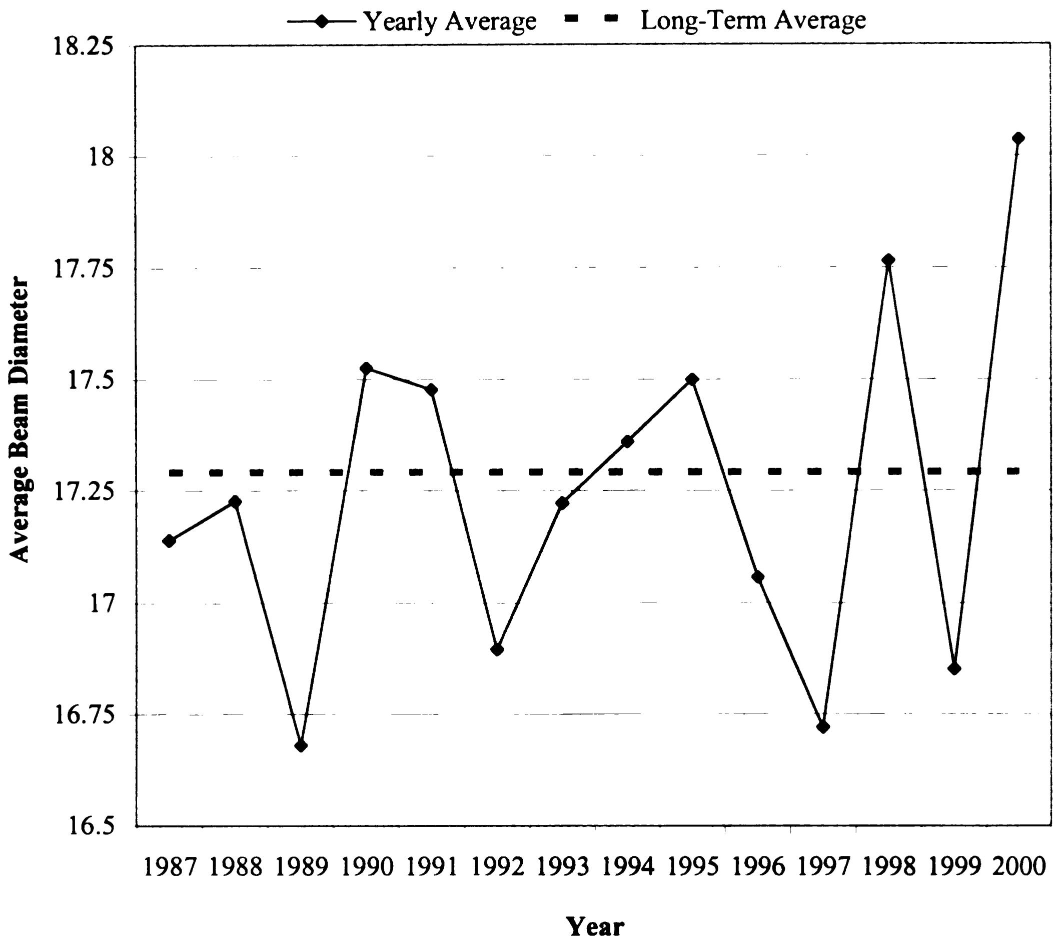

Figure 1.13. The temporal change in average beam diameter in mm for male yearlings harvested in the Northern Lower Peninsula study site between 1987 and 2000.

Table 1.20. Mean pair-wise comparisons of average beam diameter for male yearlings harvested in the Northern Lower Peninsula study site on a yearly basis. The x denotes a significant difference at an alpha level of 0.05.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1987														
1988														
1989	x	x												
1990			x											
1991			x											
1992				x	x									
1993														
1994			x											
1995			x			x								
1996				x	x				x					
1997	x	x		x	x			x	x					
1998	x	x	x			x	x			x	x			
1999	x	x		x	x		x	x	x			x		
2000	x	x	x	x		x	x	x	x	x	x		x	

Table 1.21. Mean pair-wise comparisons of average beam diameter for male yearlings harvested in the Northern Lower Peninsula study site on a county basis. The x denotes a significant difference at an alpha level of 0.05.

	Alcona	Alpena	Montmorency	Oscoda	Presque Isle
Alcona					
Alpena	x				
Montmorency		x			
Oscoda	x	x	x		
Presque Isle	x	x	x	x	

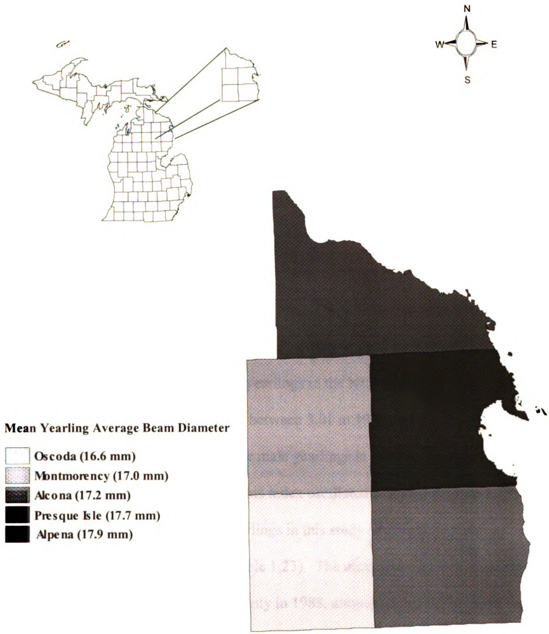

Figure 1.14. Mean yearling average beam diameter by county in the Northern Lower Peninsula study site for 1987-2000.

measurements in the NLP study site ($\bar{x}$ = 17.2mm, $\bar{x}$ = 17.0mm, $\bar{x}$ =16.6, respectively) (Figure 1.14). The results from the ANOVA model also indicated that the county variable was statistically significant ($F_{4, 22000}$ = 107.02; P < 0.0001). The Tukey-Kramer multiple comparison test results showed that the average beam diameter for male yearlings in Alpena, Oscoda, and Presque Isle County was significantly different (P ≤ 0.05) from the male yearling average beam diameter in each of the other 4 counties (Table 1.21). In addition, the average beam diameter for male yearlings in each of Alcona and Montmorency County was significantly different from the average beam diameter in 3 out of the other 4 counties, and the average beam diameter for male yearlings in those counties was not significantly different from each other (Table 1.21).

The overall point count for male yearlings in the NLP study site was 3.16 and the average point count for yearlings ranged between 3.01 in 1992 and 3.35 in 2000 (Table 1.22). The yearly average point count for male yearlings in the NLP study site increased in each of 1991, 1994, 1998, and 2000; this index oscillated around 3 (Figure 1.15). The minimum number of points for male yearlings in this study site was 2, which was consistent among years and counties (Table 1.23). The maximum number of points for male yearlings reached 23 in Alpena County in 1988, although most of the maximum number of points ranged between 8 and 10 (Table 1.23).

The results of the ANOVA model run with male yearling points indicated that the year variable was statistically significant ($F_{4, 22555}$ = 10.58; P < 0.0001). The results from the Tukey-Kramer multiple comparison test illustrated which years the male yearling point count was significantly different from one another (Table 1.24). According to the Tukey-Kramer multiple comparison test, the male yearling point count in 1994 and 2000

Table 1.22. The mean point count for male yearlings harvested in each county in the Northern Lower Peninsula study site for each year between 1987 and 2000 and the standard deviation, as well as yearly averages for the entire study site and overall averages for each county.

Year	Alcona	Alpena	Montmorencey	Oscoda	Presque Isle	Yearly Average	StDev
1987	3.02	3.34	3.06	2.74	3.28	3.08	0.24
1988	3.24	3.45	2.99	2.80	3.09	3.13	0.25
1989	3.03	3.48	2.88	2.66	3.05	3.03	0.30
1990	3.15	3.36	2.97	2.98	2.96	3.08	0.17
1991	3.49	3.27	3.34	2.99	3.19	3.26	0.19
1992	3.15	3.05	2.90	2.96	2.92	3.01	0.11
1993	3.28	3.27	3.02	2.85	3.05	3.12	0.18
1994	3.41	3.46	2.97	3.06	3.49	3.28	0.24
1995	3.49	3.45	2.83	2.90	3.31	3.20	0.31
1996	3.02	3.03	2.99	2.77	3.01	2.98	0.11
1997	2.96	3.17	3.05	2.95	3.13	3.05	0.10
1998	3.17	3.42	3.20	2.78	3.65	3.26	0.33
1999	3.18	3.35	2.65	2.62	3.45	3.12	0.39
2000	3.68	3.37	3.14	3.21	3.62	3.44	0.24
Total	3.24	3.32	3.01	2.88	3.29	3.16	0.19

Table 1.23. The minimum and maximum number of points counted on male yearlings harvested in each county in the Northern Lower Peninsula study site for each year between 1987 and 2000.

	Alcona		Alpena		Montmorency		Oscoda		Presque Isle	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1987	2	8	2	8	2	12	2	13	2	8
1988	2	12	2	23	2	20	2	10	2	8
1989	2	8	2	10	2	8	2	9	2	8
1990	2	8	2	10	2	9	2	13	2	9
1991	2	9	2	8	2	9	2	9	2	8
1992	2	8	2	9	2	6	2	8	2	8
1993	2	8	2	9	2	9	2	8	2	8
1994	2	9	2	19	2	8	2	9	2	10
1995	2	8	2	11	2	8	2	8	2	9
1996	2	9	2	9	2	13	2	7	2	8
1997	2	8	2	8	2	9	2	8	2	10
1998	2	10	2	11	2	9	2	13	2	13
1999	2	9	2	8	2	8	2	8	2	8
2000	2	9	2	10	2	9	2	9	2	8

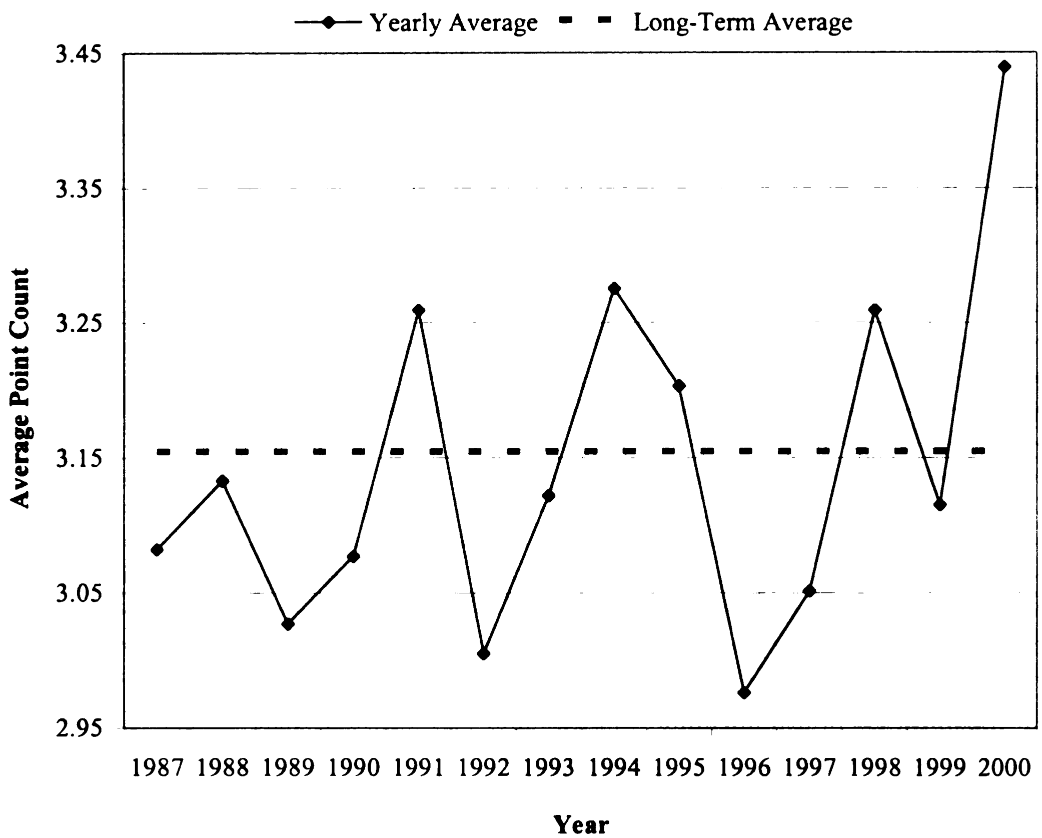

Figure 1.15. The temporal change in average point count for male yearlings harvested in the Northern Lower Peninsula study site between 1987 and 2000.

Table 1.24. Mean pair-wise comparisons of average point count for male yearlings harvested in the Northern Lower Peninsula study site on a yearly basis. The x denotes a significant difference at an alpha level of 0.05.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1987														
1988														
1989														
1990														
1991			x											
1992					x									
1993														
1994	x		x	x		x								
1995														
1996					x			x	x					
1997					x			x						
1998			x			x				x	x			
1999					x			x				x		
2000	x	x	x	x		x	x		x	x	x		x	

Table 1.25. Mean pair-wise comparisons of average point count for male yearlings harvested in the Northern Lower Peninsula study site on a county basis. The x denotes a significant difference at an alpha level of 0.05.

	Alcona	Alpena	Montmorency	Oscoda	Presque Isle
Alcona					
Alpena	x				
Montmorency	x	x			
Oscoda	x	x	x		
Presque Isle			x	x	

was significantly different ($P \leq 0.05$) from the male yearling point count in most of the other years in the study (Table 1.24). Male yearling point count was significantly different ($P \leq 0.05$) between 1991 and 1998 (Table 1.24). Furthermore, the male yearling point count in each of 1989, 1992, 1997, and 1999 was significantly different ($P \leq 0.05$) from the male yearling point count in each of the same years (Table 1.24). There were additional years in which the male yearling point count was significantly different ($P \leq 0.05$) from other years; however, there was not a distinct pattern (Table 1.24).

When the average point count was examined by county, male yearlings with the most points were found in Alpena and Presque Isle County ($\bar{x} = 3.32$ and $\bar{x} = 3.29$, respectively) (Figure 1.16). On the other hand, male yearlings in Alcona, Montmorency, and Oscoda County had the fewest number of points ($\bar{x} = 3.24$, $\bar{x} = 3.01$, and $\bar{x} = 2.88$, respectively) (Figure 1.16). The results from the ANOVA model also indicated that the county variable was statistically significant ($F_{4, 22555} = 61.72$; $P < 0.0001$). The results of the Tukey-Kramer multiple comparison test showed that the point count for male yearlings in Montmorency County was significantly different ($P \leq 0.05$) from the male yearling point count in each of the other 4 counties, as was the male yearling point count in Oscoda County (Table 1.25). In addition, the point count for male yearlings in Alcona County was also significantly ($P \leq 0.05$) from the point count for male yearlings in Alpena County (Table 1.25).

SLP

In each year that yearling does were checked for lactation in the SLP study site, there were more does that were not lactating (HM-) then were lactating (HM+) (Table

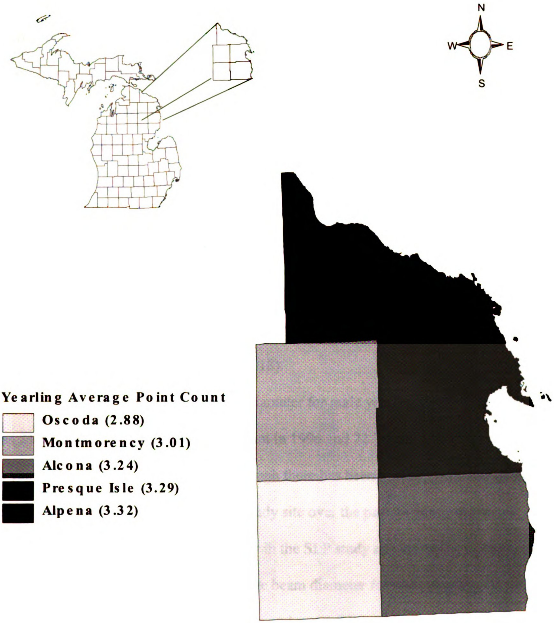

Figure 1.16. Yearling average point count by county in the Northern Lower Peninsula study site for 1987-2000.

1.26). The percent of yearling does not lactating ranged between 56.8% and 80.8%, whereas the percent of yearling does lactating ranged between 19.2% and 43.2% (Table 1.26). The percent of yearling does that were lactating in this study site was the highest out of the 3 study sites. Overall, the number of does that were checked for lactation in the SLP study site was relatively small, in fact there was only 1 year (1997) in which the number of yearling does checked for lactation exceeded 100 (Table 1.26; Figure 1.17). Years (e.g., 1997) in which large number of yearling does were checked for lactation in the SLP study did not necessarily translate into a higher percent of does lactating (Table 1.26; Figure 1.18). There were, however, years (e.g., 1993) in which small numbers of yearling does checked for lactation in the SLP study site did translate into a higher percent of lactation (Table 1.26; Figure 1.18).

The overall mean average beam diameter for male yearlings in the SLP study site was 21.91mm and ranged between 21.1mm in 1996 and 22.7 mm in 1989 for the entire 14 years of the study (Table 1.27). Although there has been a steady decrease in the male yearling average beam diameter in this study site over the past 14 years, the mean average beam diameter for male yearlings in the SLP study site increased in 1989, 1991, and 1995 (Figure 1.19). The mean average beam diameter for male yearlings in this study site tended to oscillate around 22mm and never fell below 21mm (Figure 1.19). The minimum average beam diameter for male yearlings was 6mm in Barry County in 1993. Most of the minimum average beam diameter measurements, however, ranged between 10mm and 15mm (Table 1.28). The maximum average beam diameter for male yearlings was 34mm in Barry County in 1990; however, the majority of the high averages ranged between 28mm and 33mm (Table 1.28).

Table 1.26. The lactation status of yearling does harvested in the Southern Lower Peninsula study site each year between 1993 and 2000, as well as the percent of yearling does lactating (HM+) and not lactating (HM-) each year.

Year	HM+	HM-	Total	%HM+	%HM-
1993	16	21	37	43.2	56.8
1994	17	44	61	27.9	72.1
1995	15	36	51	29.4	70.6
1996	15	63	78	19.2	80.8
1997	35	82	117	29.9	70.1
1998	26	73	99	26.3	73.7
1999	22	46	68	32.4	67.6
2000	17	64	81	21	79

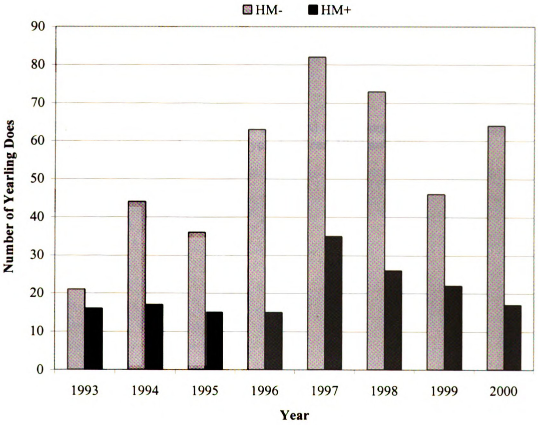

Figure 1.17. The lactation status of yearling does harvested in the Southern Lower Peninsula study site each year between 1993 and 2000.

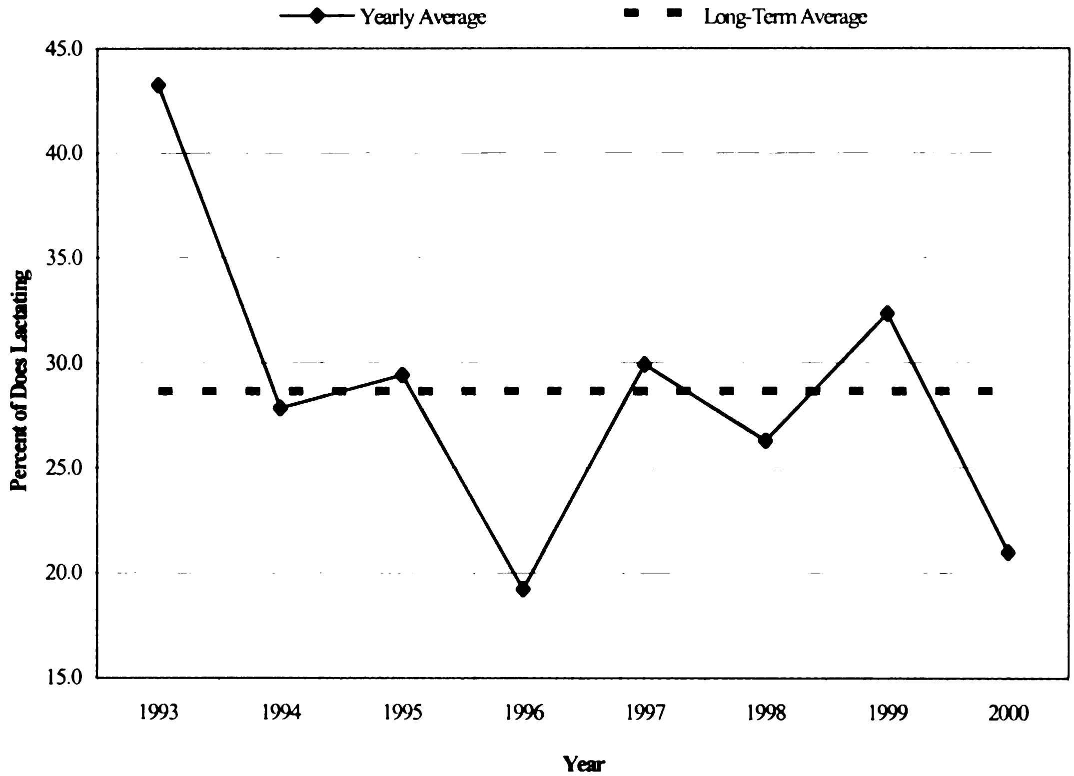

Figure 1.18. The percent of yearling does harvested in the Southern Lower Peninsula study site that were lactating during each year between 1993 and 2000.

Table 1.27. The mean average beam diameter in mm for male yearlings harvested in each county in the Southern Lower Peninsula study site for each year between 1987 and 2000 and the standard deviation, as well as the yearly averages for the entire study site and overall averages for each county.

Year	Barry	Calhoun	Eaton	Yearly Average	StDev
1987	22.1	22.9	23.1	22.3	0.53
1988	22.8	21.7	23.1	22.6	0.74
1989	22.6	23.3	22.4	22.7	0.47
1990	22.4	20.9	22.9	22.2	1.04
1991	22.6	22.5	22.5	22.6	0.01
1992	22.1	21.6	22.6	22.0	0.54
1993	21.5	21.9	23.4	21.7	1.03
1994	21.4	20.7	22.5	21.5	0.90
1995	22.3	21.8	23.0	22.3	0.61
1996	21.1	20.7	21.7	21.1	0.53
1997	21.2	21.7	22.8	21.5	0.80
1998	21.8	21.5	21.4	21.7	0.20
1999	21.2	21.6	21.2	21.3	0.22
2000	21.3	21.2	22.9	21.5	0.99
Total	21.9	21.6	22.5	21.9	0.43

Table 1.28. The minimum and maximum average beam diameter in mm collected from male yearlings harvested in each county in the Southern Lower Peninsula study site for each year between 1987 and 2000.

	Barry		Calhoun		Eaton	
	Min	Max	Min	Max	Min	Max
1987	12.5	32.5	17.5	30	20.5	26
1988	15	30.5	10	28.5	15.5	31.5
1989	10	33	15.5	32.5	11	29.5
1990	14.5	34	14	29	15.5	30.5
1991	14	32.5	18	28.5	18	28
1992	11.5	30.5	13	30	17	27
1993	6	33.5	15.5	26.5	13	35.5
1994	12.5	29	14.5	26	15.5	30
1995	15	30.5	12	30.5	10.5	30.5
1996	9.5	29.5	12.5	29.5	14.5	28
1997	12	36.5	13.5	28.5	12.5	33.5
1998	13	31	14.5	30.5	13.5	31.5
1999	12	30.5	15	29.5	15	32
2000	8.5	28.5	13.5	28	15.5	30

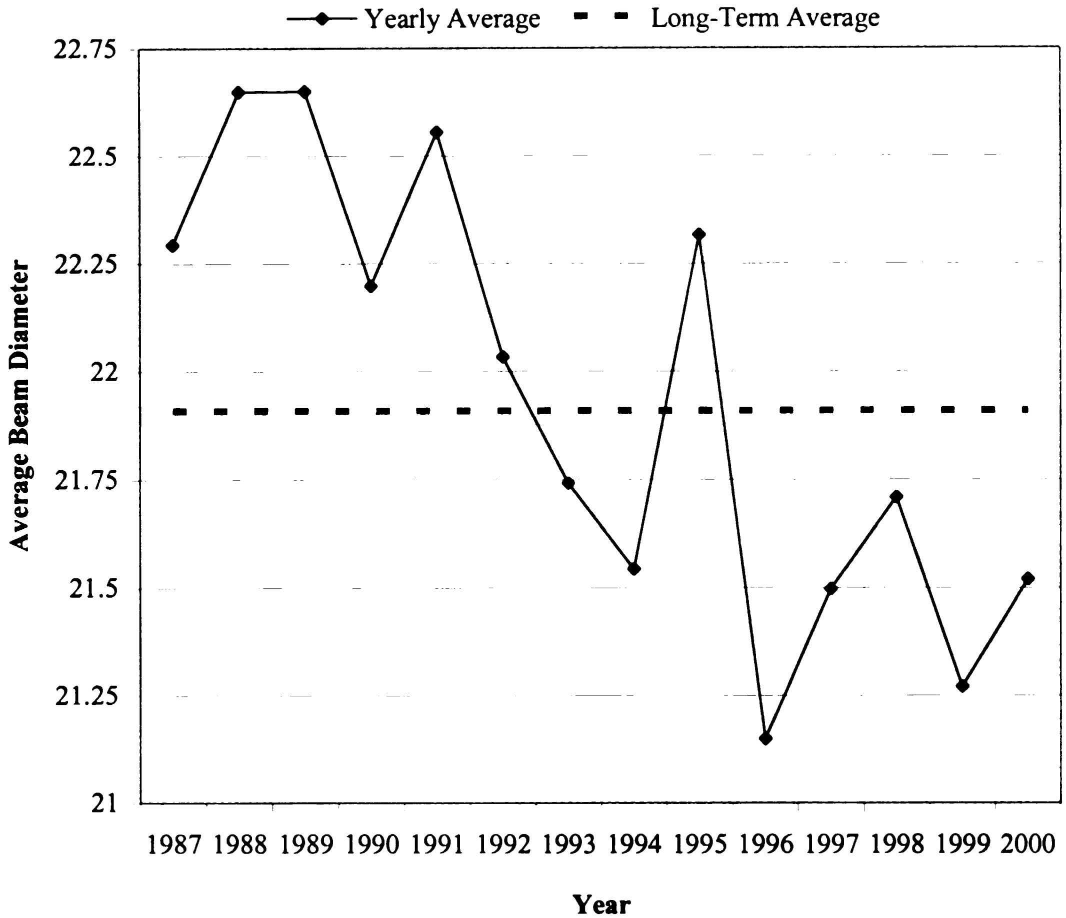

Figure 1.19. The temporal change in average beam diameter in mm for male yearlings harvested in the Southern Lower Peninsula study site between 1987 and 2000.

The results from the ANOVA model run with male yearling average beam diameter indicated that the year variable was statistically significant ($F_{2, 4445} = 4.18$; $P < 0.0001$) in the SLP study site. The results from the Tukey-Kramer multiple comparison test also showed which years the male yearling average beam diameter was significantly different from one another (Table 1.29). The Tukey-Kramer multiple comparison test results showed that the male yearling average beam diameter in 1996 and 1999 was significantly different ($P \leq 0.05$) from the male yearling average beam diameter in the early years of the study (Table 1.29). The male yearling average beam diameter in 1989 was also significantly different ($P \leq 0.05$) from the male yearling average beam diameter in 1994 (Table 1.29).

When the mean average beam diameter was examined by county, male yearlings in Eaton County had the largest average beam diameter measurements in the SLP study site ($\bar{x} = 22.5$mm), whereas male yearlings in Calhoun County had the smallest ($\bar{x} = 21.6$mm) (Figure 1.20). The mean average beam diameter for male yearlings in Barry County fell in between the mean average beam diameter for male yearlings in the other 2 counties ($\bar{x} = 21.9$mm) (Figure 1.20). The results from the ANOVA model also indicated that the county variable was statistically significant ($F_{13, 4445} = 10.01$; $P < 0.0001$). The results of the Tukey-Kramer multiple comparison test showed that the average beam diameter for male yearlings in Eaton County was significantly different ($P \leq 0.05$) from the average beam diameter in each of the other 2 counties (Table 1.30). The overall average point count for male yearlings in the SLP study site was 5.38 and the average point count for male yearlings ranged between 5.08 in 1996 and 5.81 in 1991 (Table 1.31). Although the average point count for male yearlings in the SLP study

Table 1.29. Mean pair-wise comparisons of average beam diameter for male yearlings harvested in the Southern Lower Peninsula study site on a yearly basis. The x denotes a significant difference at an alpha level of 0.05.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1987														
1988														
1989														
1990														
1991														
1992														
1993														
1994			x											
1995														
1996	x	x	x		x				x					
1997														
1998														
1999	x	x	x						x					
2000														

Table 1.30. Mean pair-wise comparisons of average beam diameter for male yearlings harvested in the Southern Lower Peninsula study site on a county basis. The x denotes a significant difference at an alpha level of 0.05.

	Barry	Calhoun	Eaton
Barry			
Calhoun			
Eaton	x	x	

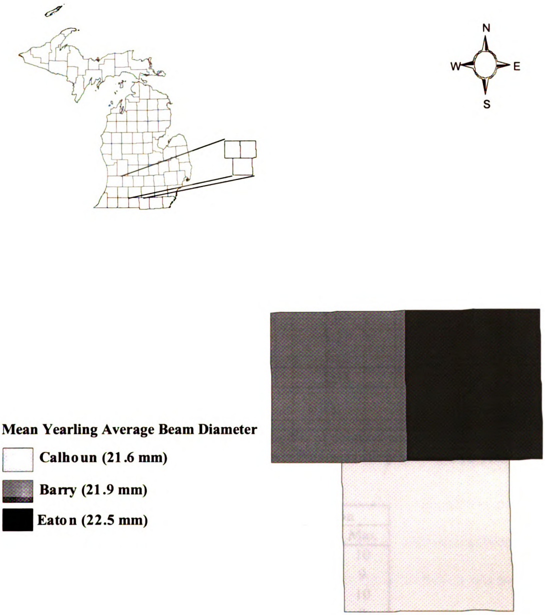

Figure 1.20. Mean yearling average beam diameter by county in the Southern Lower Peninsula study site for 1987-2000.

Table 1.31. The mean point count for male yearlings harvested in each county in the Southern Lower Peninsula study site for each year between 1987 and 2000 and the standard deviation, as well as yearly averages for the entire study site and overall averages for each county.

Year	Barry	Calhoun	Eaton	Yearly Average	StDev
1987	5.54	5.94	6.44	5.65	0.45
1988	5.50	6.05	5.62	5.59	0.29
1989	5.66	5.94	5.96	5.72	0.17
1990	5.53	5.67	5.74	5.57	0.10
1991	5.68	6.15	6.33	5.81	0.34
1992	5.27	5.14	6.47	5.32	0.73
1993	5.16	5.95	6.12	5.36	0.51
1994	5.11	5.19	5.19	5.14	0.05
1995	5.61	5.94	5.75	5.69	0.16
1996	5.03	5.26	5.23	5.08	0.13
1997	4.88	5.93	5.42	5.13	0.53
1998	5.02	5.18	5.42	5.09	0.20
1999	5.20	5.46	5.39	5.27	0.13
2000	5.01	4.74	6.04	5.12	0.69
Total	5.29	5.58	5.65	5.38	0.19

Table 1.32. The minimum and maximum number of points counted on male yearlings harvested in each county in the Southern Lower Peninsula study site for each year between 1987 and 2000.

	Barry		Calhoun		Eaton	
	Min	Max	Min	Max	Min	Max
1987	2	10	2	9	2	10
1988	2	9	2	9	2	9
1989	2	13	2	10	3	10
1990	2	10	2	12	2	9
1991	2	10	2	10	2	10
1992	2	19	2	10	3	11
1993	2	9	2	10	2	10
1994	2	10	2	10	2	10
1995	2	10	2	10	2	10
1996	2	10	2	10	2	9
1997	2	10	2	10	2	9
1998	2	8	2	8	2	10
1999	2	10	2	10	2	9
2000	2	11	2	8	2	10

site has been steadily decreasing over the past 14 years, the yearly average point count for male yearlings increased sharply in 1991 and 1995 (Figure 1.21). In addition, the yearly average point count for male yearlings in this study site oscillated around 5.4, but never fell below 5.0 (Figure 1.21). The minimum number of points for male yearlings in this study site was 2, which was consistent among most years and counties even though there were a few years in Eaton county in which the minimum number of points was 3 (Table 1.32). The maximum number of points for male yearlings reached 19 in Barry County in 1992, although most of the maximum number of points ranged between 8 and 10 (Table 1.32).

The results of the ANOVA model run with male yearling points indicated that the year variable was statistically significant ($F_{13, 4298} = 3.84$; $P < 0.0001$), and the results from the Tukey-Kramer multiple comparison test illustrated which years the male yearling point count was significantly different from one another (Table 1.33). According to the Tukey-Kramer multiple comparison test, the point count for male yearlings in 1991 was significantly different ($P \leq 0.05$) from the point count for male yearlings in each of 1994, 1996, 1998, and 2000 (Table 1.33). In addition, the point count for male yearlings in other years was significantly different ($P \leq 0.05$) from one another (Table 1.33).

When the average point count was examined by county, male yearlings with the most points were found in Eaton County ($\bar{x} = 5.65$) (Figure 1.22). On the other hand, male yearlings in Barry County had the fewest amount of points ($\bar{x} = 5.29$) (Figure 1.22). The average point count for male yearlings in Calhoun County fell in between the average point count for male yearlings in the other 2 counties ($\bar{x} = 5.58$) (Figure 1.22).

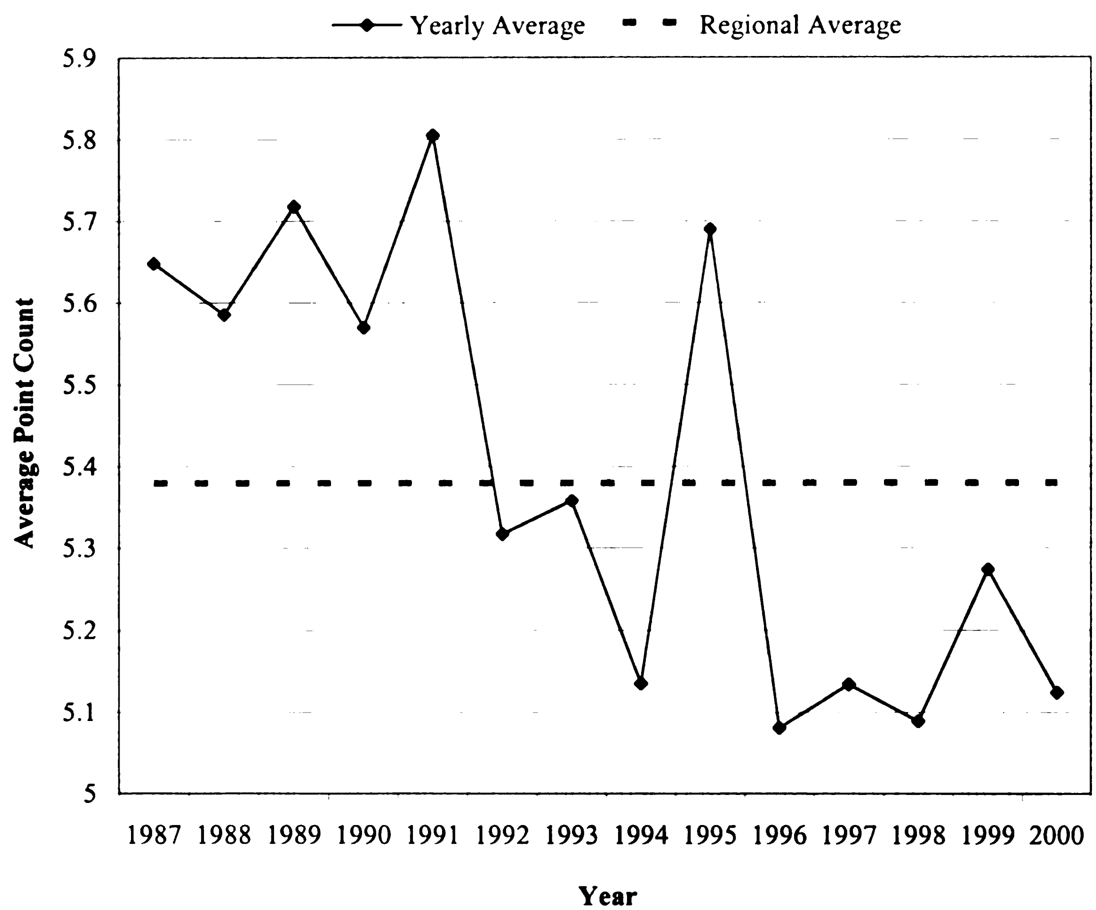

Figure 1.21. The temporal change in average point count for male yearlings harvested in the Southern Lower Peninsula study site between 1987 and 2000.

Table 1.33. Mean pair-wise comparisons of average point count for male yearlings harvested in the Southern Lower Peninsula study site on a yearly basis. The x denotes a significant difference at an alpha level of 0.05.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1987														
1988														
1989														
1990														
1991														
1992														
1993														
1994	x				x									
1995								x						
1996					x									
1997														
1998					x									
1999														
2000					x									

Table 1.34. Mean pair-wise comparisons of average point count for male yearlings harvested in the Southern Lower Peninsula study site on a county basis. The x denotes a significant difference at an alpha level of 0.05.

	Barry	Calhoun	Eaton
Barry			
Calhoun	x		
Eaton	x		

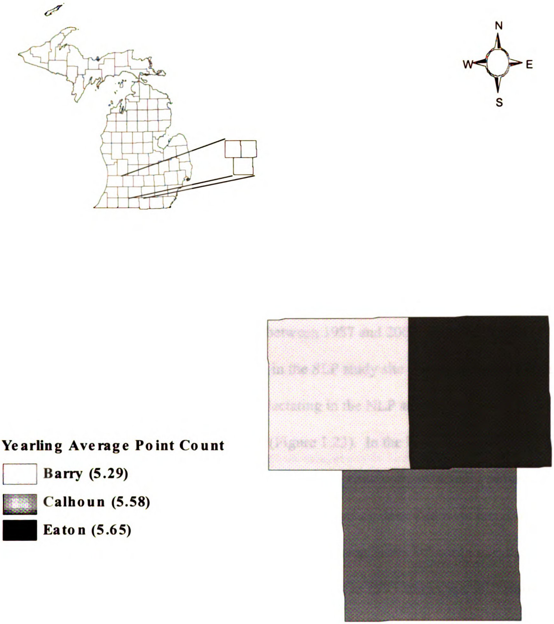

Figure 1.22. Yearling average point count by county in the Southern Lower Peninsula study site for 1987-2000.

The results from the ANOVA model also indicated that the county variable was statistically significant ($F_{2, 4298} = 16.11$; $P < 0.0001$). According to the Tukey-Kramer multiple comparison test, the point count for male yearlings in Barry County was significantly different ($P \leq 0.05$) from the point count in each of the other 2 counties (Table 1.34).

Among Region Comparisons

Temporal Comparisons

Among the 3 study sites, the percent of yearling does that were lactating was the highest in the SLP study site for each year between 1987 and 2000 (Figure 1.23). The percent of yearling does that were lactating in the SLP study site was consistently above 15%, whereas the percent of yearling does lactating in the NLP study site was consistently above 5% but lower than 20% (Figure 1.23). In the UP study site the percent of yearling does lactating was the lowest of the 3 study sites and consistently ranged between 0% and 20% (Figure 1.23). The percent of yearling does that were lactating in the SLP study site was highest in 1993 and 1999; however, in the UP study site, the percent of yearling does that were lactating was highest in 1995 and in the NLP study site, lactation was highest in 1994 (Figure 1.23).

The temporal trend in the percent of yearling does lactating in the SLP and UP study sites tended to be similar. In general, in years that the percent of yearling does lactating in the SLP increased, so the did the percent of yearling does lactating in the UP with the exception of those years in which 0% yearling does were lactating (Figure 1.23). The temporal trend in the percent of yearling does lactating in the NLP, for the most part,

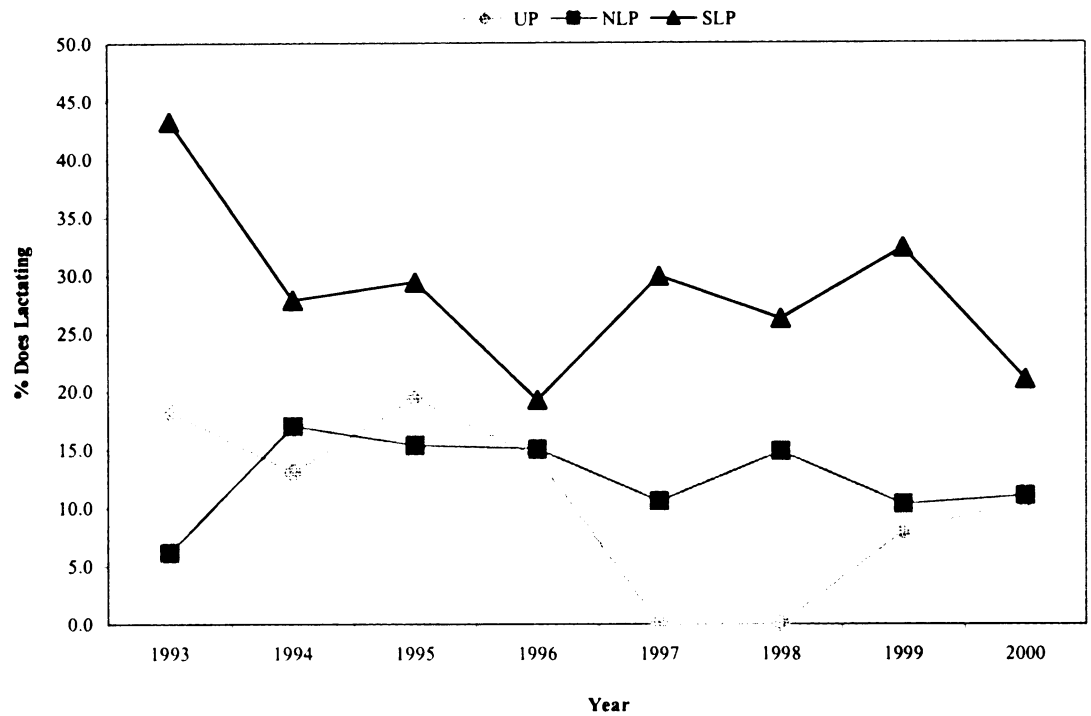

Figure 1.23. Yearly trends in the percentage of yearling does harvested in each of the 3 regional study sites that were lactating from 1993-2000.

tended to be opposite of the trends in the percent of yearling does lactating in the SLP and UP study sites (Figure 1.23). As the percent of yearling does that were lactating in the NLP study site increased, in general, the percent of yearling does lactating decreased in the other 2 study sites (Figure 1.23). In addition, there seemed to be more variation in the percent of yearling does lactating in the SLP study site and the UP study site while the percent of yearling does lactating in the NLP study site appeared to be more consistent from year to year (Figure 1.23).

The mean average beam diameter for male yearlings was also much larger in the SLP study site than in the UP or NLP study sites for each year between 1987 and 2000 (Figure 1.24). The male yearling average beam diameter in the SLP study site was consistently above 21mm, whereas the male yearling average beam diameter in the NLP study site was consistently above 16.5mm but lower than 18.5mm (Figure 1.24). In the UP study site the male yearling average beam diameter was the lowest out of the 3 study sites and consistently ranged between 16mm and 17.5mm (Figure 1.24). The mean average beam diameter for male yearlings in the SLP study site was highest in 1990; however, in the UP study site, the mean average beam diameter for male yearlings was highest in 1987 and in the NLP study site, it was highest in 2000 (Figure 1.24). Despite the differences in the mean average beam diameter for male yearlings among the 3 regional study sites, this population quality index showed the same temporal trends among the 3 study sites. In general, if the mean average beam diameter for male yearlings increased in 1 study site, for the most part, it also increased in the other 2 study sites (Figure 1.24).

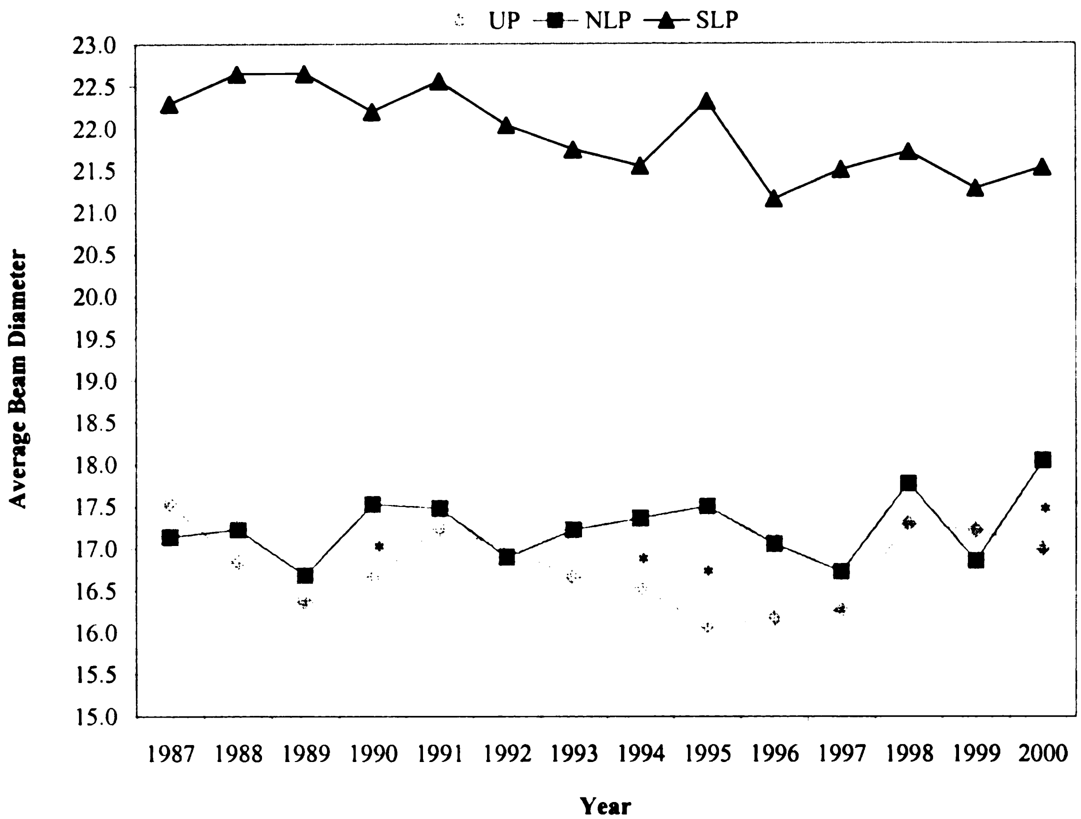

Figure 1.24. Yearly trends in the average beam diameter collected from male yearlings harvested in each of the 3 regional study sites from 1987-2000. The * denotes which years the average beam diameter for male yearlings was significantly different (p-value < 0.05) among the UP and NLP study sites.

Results of the ANOVA model run to determine if there were significant differences in the mean average beam diameter among the 3 regional study sites indicated that the interaction variable (region*year) was statistically significant $F_{26, 36544} = 11.72$; $P < 0.0001$). Although the mean average beam diameter for male yearlings in the SLP study site has decreased slightly during this study, it was still significantly different ($P < 0.0001$) from the mean average beam diameter for male yearlings in both the UP and NLP study sites for each year of the study (Figure 1.24). The mean average beam diameter for male yearlings in the UP and NLP study sites was similar, but there were certain years in which there was a significant difference in the mean average beam diameter for male yearlings between the 2 study sites (Figure 1.24). The results from the Tukey-Kramer multiple comparison test showed that a significant difference in the mean average beam diameter for male yearlings in the UP and NLP study sites occurred in 1990 ($P < 0.0001$), 1994 ($P < 0.0001$), 1995($P < 0.0001$), 1996($P = 0.0434$), and 2000 ($P < 0.0001$) (Figure 1.24).

As with the percent of yearling does lactating and the average beam diameter for male yearlings, the average point count for male yearlings was highest in the SLP study site (Figure 1.25). The male yearling average point count in the SLP study site was consistently above 5, whereas the male yearling average point count in the NLP and UP study sites was consistently above 3 but lower than 4 (Figure 1.25). The point count for male yearlings in the SLP study site was highest in 1991; however, in the UP study site, the mean average beam diameter for male yearlings was highest in 1998 and in the NLP study site, it was highest in 2000 (Figure 1.25). Like the male yearling average beam diameter, the average point count for male yearlings among the 3 regional study sites

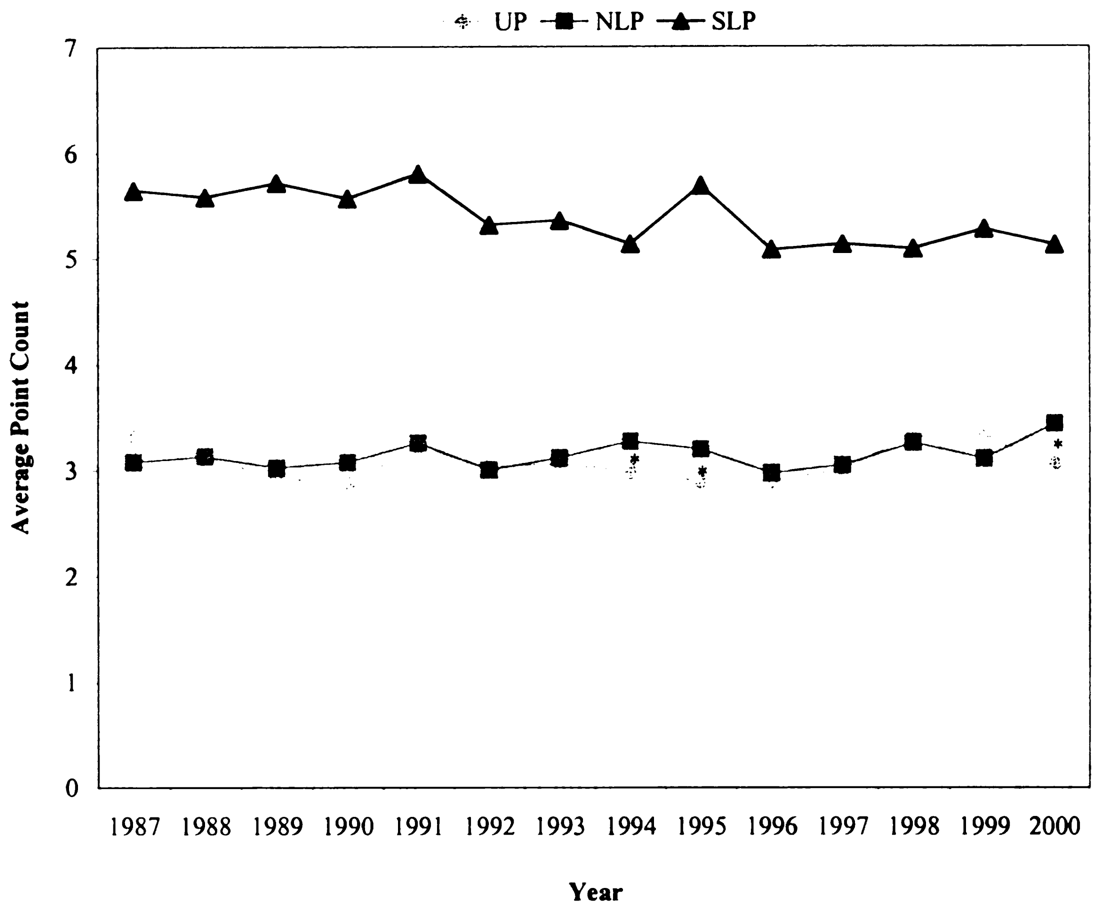

Figure 1.25. Yearly trends in the point count collected from male yearlings harvested in each of the 3 regional study sites from 1987-2000. The * denotes which years the point count for male yearlings was significantly different (p-value < 0.05) among the UP and NLP study sites.

followed similar temporal trends; if the average point count for male yearlings increased in 1 study site, in general, it also increased in the other 2 study sites (Figure 1.25).

The results of the ANOVA model run to determine if there were significant differences in the average point count for male yearlings among the 3 regional study sites indicated that the interaction variable (region*year) was statistically significant ($F_{26, 37096} = 8.68$; $P < 0.0001$). The average point count for male yearlings in the SLP study site has remained constant, and was significantly different ($P < 0.0001$) from the average point count for male yearlings in both the UP and NLP study sites for each year of the study (Figure 1.25). The average point count for male yearlings in the UP and NLP study sites was very similar, although there were certain years in which there was a significant difference in the average point count for male yearlings between the 2 study sites (Figure 1.25). The results from the Tukey-Kramer multiple comparison test showed that a significant difference in the average point count for male yearlings in the UP and NLP study sites occurred in 1994 ($P = 0.0004$), 1995 ($P = 0.0012$), and 2000 ($P < 0.0001$) (Figure 1.25).

Spatial Comparisons

Comparing the long-term average for each region illustrated that the percent of yearling does lactating in each study site increased along a north to south regional gradient in Michigan (Figure 1.26). The UP study site had the lowest percent of yearling does lactating at 10.4%, and the SLP study site had the highest percent of yearling does lactating at 28.7% (Figure 1.26). The percent of yearling does lactating in the NLP study site fell in between that of the other 2 study sites with 12.5%. Although an increase in the

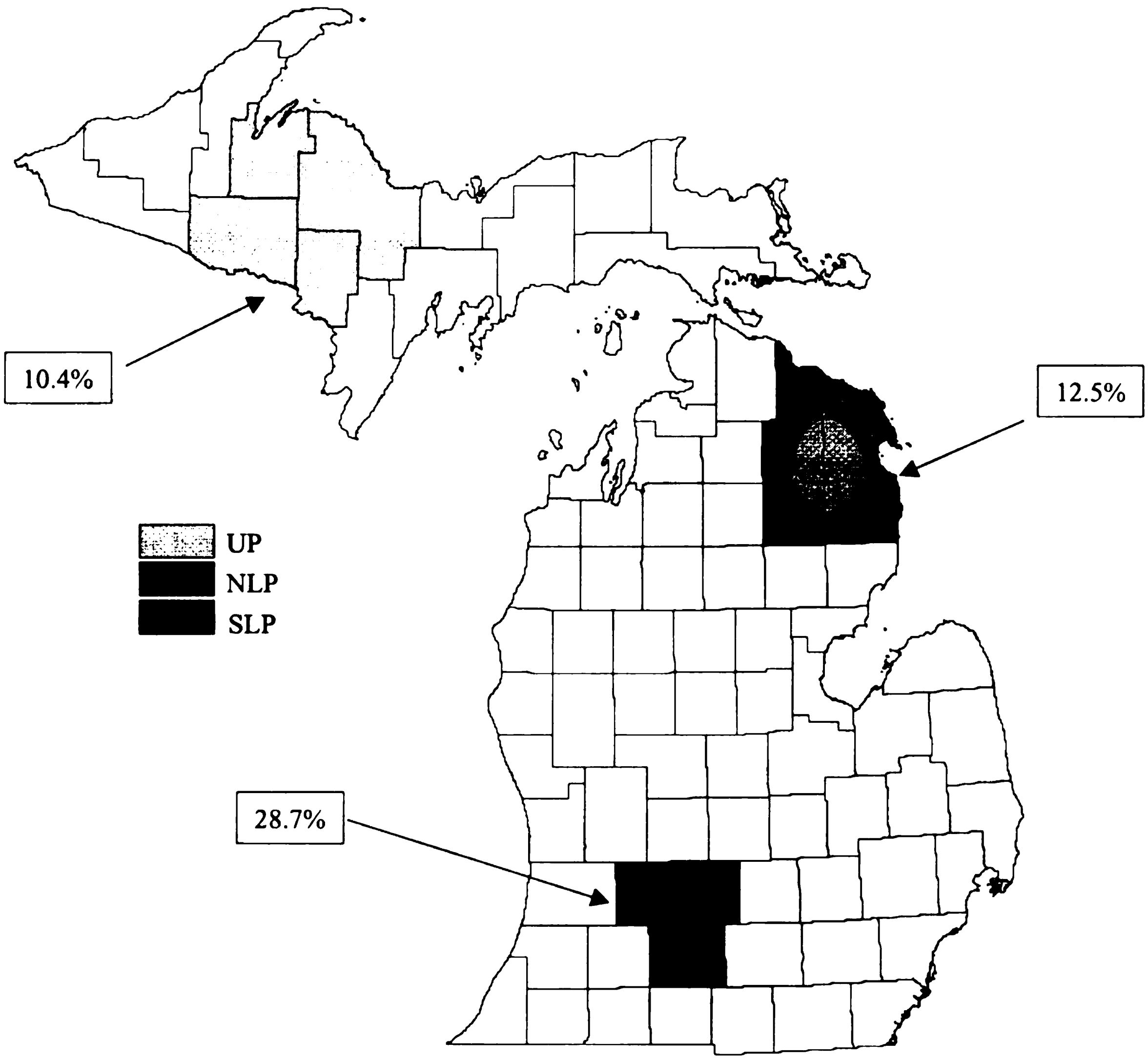

Figure 1.26. The regional comparison of the percentage of yearling does lactating in each of the 3 study sites during 1993-2000.

percent of yearling does lactating existed moving from north to south, the increase was much greater between the NLP and SLP study sites then between the UP and NLP study sites (Figure 1.26). This spatial trend suggested that the percent of yearling does lactating in the UP and NLP study sites was more similar while the percent of yearling does lactating in the SLP study site was dissimilar to the percent of yearling does lactating in the other 2 study sites.

The mean average beam diameter for male yearlings also increased along a north to south regional gradient in Michigan (Figure 1.27). The UP study site had the smallest mean average beam diameter for male yearlings at 16.8mm, and the SLP study site had the largest mean average beam diameter for male yearlings at 21.9mm (Figure 1.27). Male yearlings in the NLP study site had a mean average beam diameter that fell in between the mean average beam diameter for male yearlings in the other 2 study sites at 17.3mm (Figure 1.27). The increase in the mean average beam diameter for male yearlings increased only slightly between the UP and NLP study sites, but increased substantially between the NLP and SLP study sites (Figure 1.27). This spatial trend suggested that the mean average beam diameter for male yearlings in the UP and NLP study sites was similar, but the mean average beam diameter for male yearlings in the SLP study site was dissimilar to the mean average beam diameter for male yearlings in the other 2 study sites. Despite that fact that the mean average beam diameter for male yearlings appeared more similar in the UP and NLP study sites, the results from the Tukey-Kramer multiple comparison test showed that there was a significant difference in the mean average beam diameter for male yearlings among the 3 regional study sites ($P < 0.0001$).

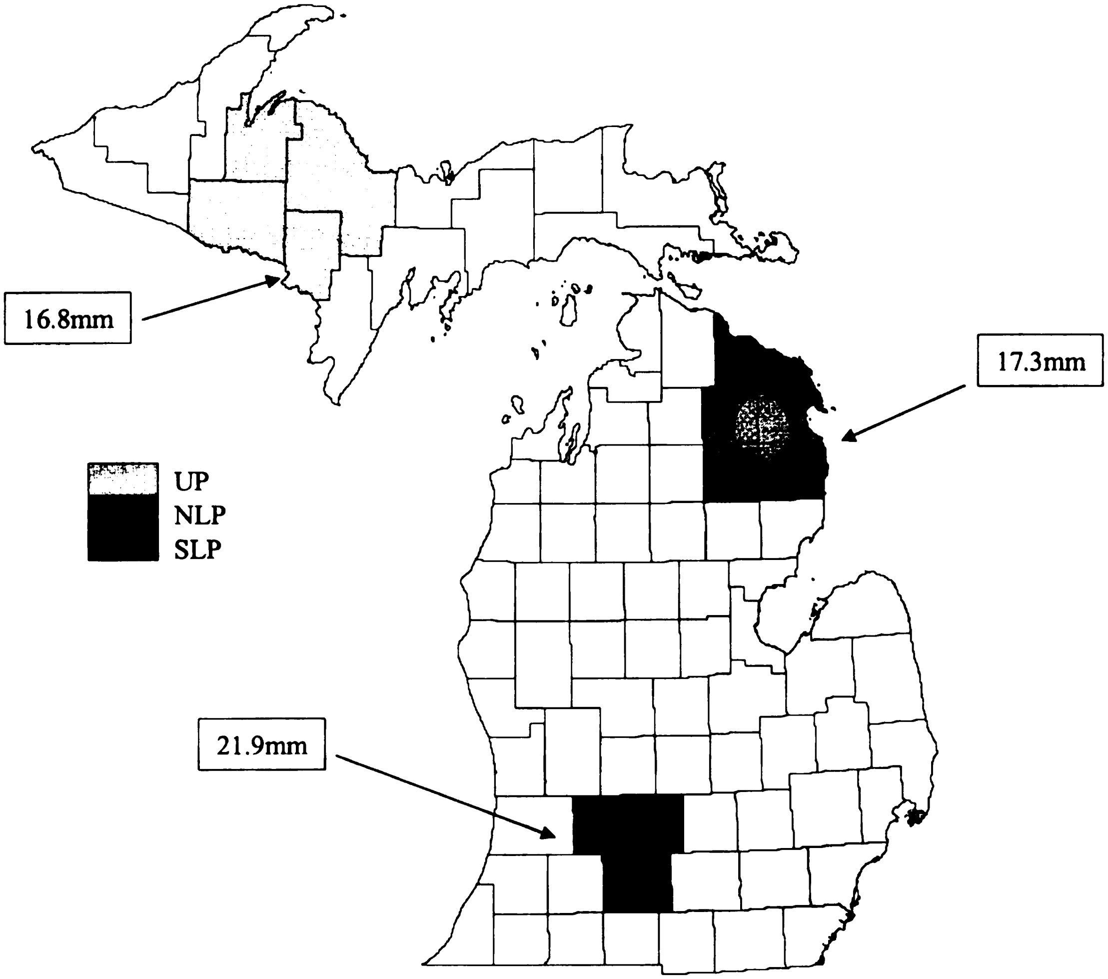

Figure 1.27. The regional comparison of the average beam diameter for male yearlings harvested in each of the 3 study sites during 1987-2000.

Similar to the other 2 population-level quality indices, the average point count for male yearlings increased along the north to south regional gradient in Michigan (Figure 1.28). The average point count for male yearlings was lowest in the UP study site at 3.09 and highest in the SLP study site at 5.38 (Figure 1.28). At 3.16, the average point count for male yearlings in the NLP study site fell in between the average point count for male yearlings in the other 2 study sites (Figure 1.28). Following the same trend as the other 2 quality indices, the increase in the average point count for male yearlings increased only slightly between the UP and NLP study sites, but increased substantially between the NLP and SLP study sites (Figure 1.28). This spatial trend suggested that the average point count for male yearlings in the UP and NLP study sites was similar, and the average point count for male yearlings in the SLP study site was dissimilar to the average point count for male yearlings in the other 2 study sites. Despite that fact that the average point count for male yearlings appeared more similar in the UP and NLP study sites, the results from the Tukey-Kramer multiple comparison test showed that there was a significant difference in the average point count for male yearlings among the 3 regional study sites. The average point count for male yearlings in the SLP study site was significantly different from the average point count for male yearlings in both the UP and NLP study sites ($P < 0.0001$). In addition, the average point count for male yearlings in the UP was significantly different from male yearling average point count in the NLP ($P = 0.0041$).

Relationship Among Quality Indices

There did not appear to a strong relationship between the percent of yearling does lactating and the mean average beam diameter of male yearlings in any of the 3 regional

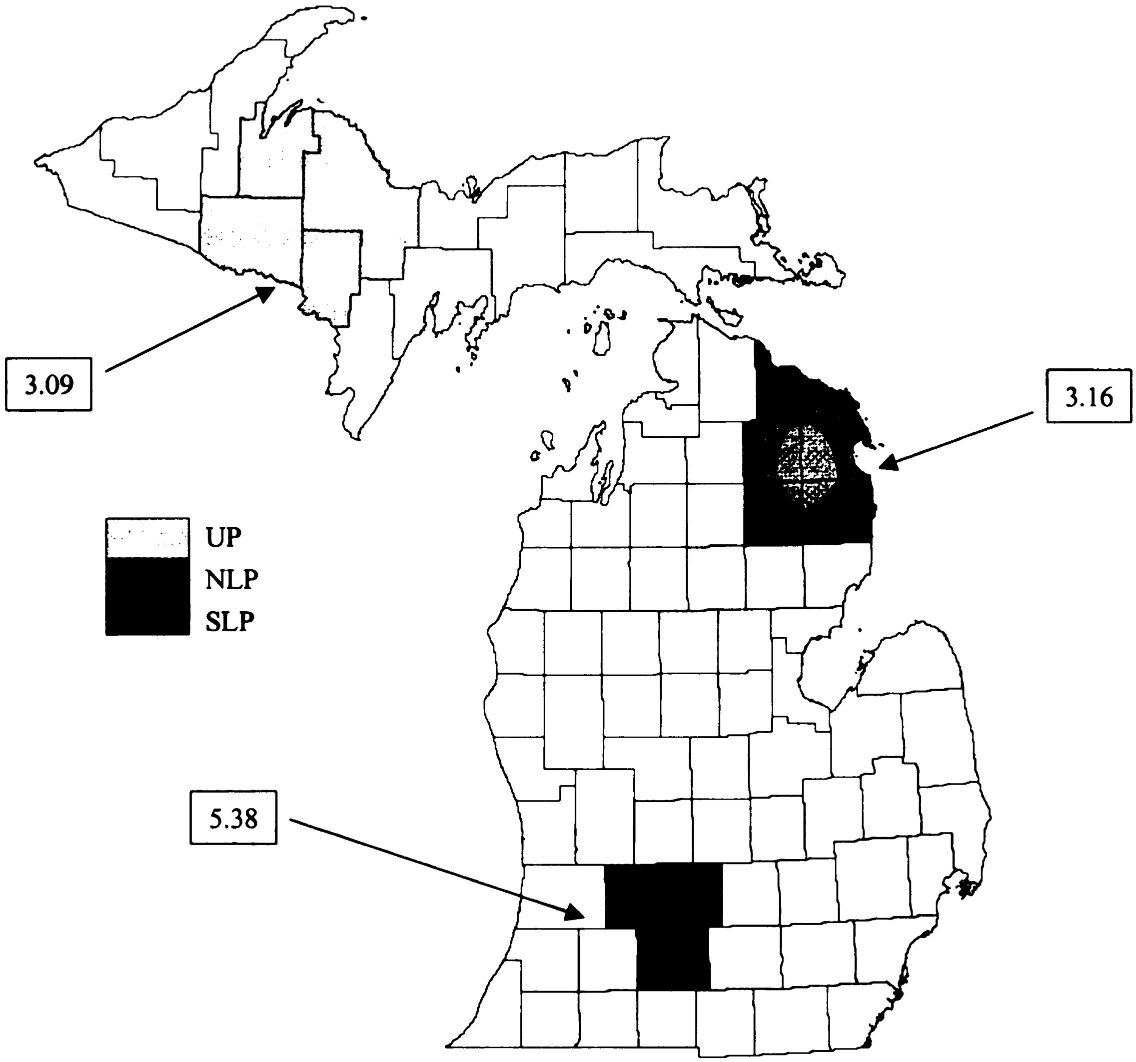

Figure 1.28. The regional comparison of the average point count for male yearlings harvested in each of the 3 study sites during 1987-2000.

study sites (Figure 1.29). In the UP study site, it looked as if there was a very slight negative relationship between the 2 quality indices, but that was more than likely an artifact of the 2 years in which no yearling does were lactating ($R^2 = 0.20$; $P = 0.26$) (Figure 1.29a). The relationship between the percent of yearling does lactating and the mean average beam diameter for male yearlings in the NLP and SLP study sites, on the other hand, looked as if was slightly positive; however, there was not a significant trend between the 2 quality indices in either regional study site ($R^2 = 0.06$; $P = 0.55$ and $R^2 = 0.10$; $P = 0.44$, respectively) (Figure 1.29b&c).

The relationship between the percent of yearling does lactating and the male yearling average point count was similar to the relationship between the percent of yearling does lactating and the mean average beam diameter for male yearlings; there did not appear to be a strong relationship between the 2 quality indices (Figure 1.30). In the UP study site, there appeared to be a slight negative relationship between the percent of yearling does lactating and the average point count for male yearlings ($R^2 = 0.36$; $P = 0.12$); although, this trend was probably due to the fact that for 2 years there were no lactating yearling does in this study site (Figure 1.30a). Conversely, there appeared to be a slight positive relationship between the percent of yearling does lactating and the male yearling average beam diameter in the SLP study site ($R^2 = 0.21$; $P = 0.26$) (Figure 1.30c). In addition, there appeared to be no relationship between the percent of yearling does lactating and the average point count for male yearlings in the NLP study site ($R^2 = 0.02$; $P = 0.73$) (Figure 1.30b).

Unlike the relationship between the percent of yearling does lactating and the 2 antler measurements, there was a strong positive relationship between the mean average

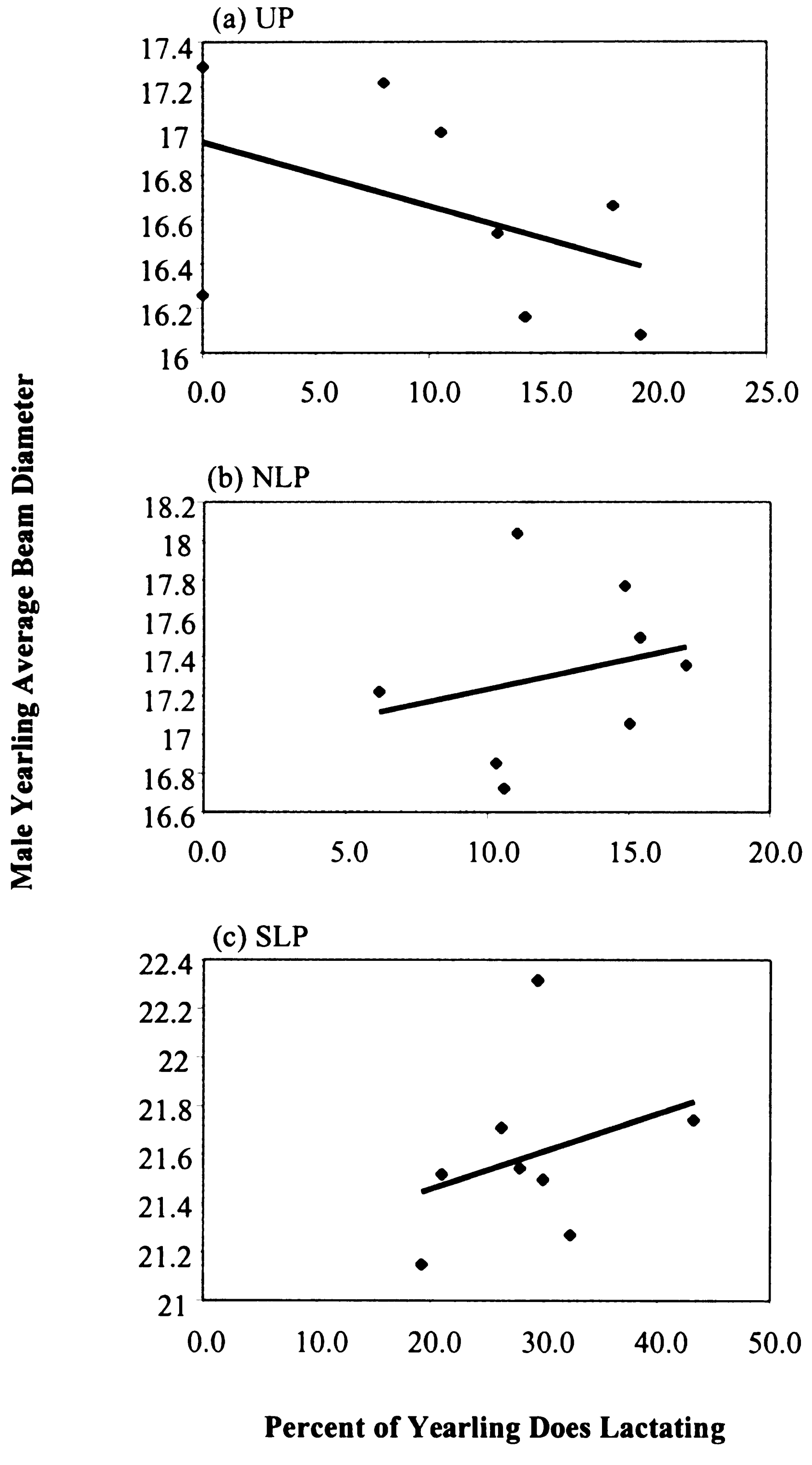

Figure 1.29. The relationship between the percent of yearling does lactating and the mean average beam diameter for male yearlings in the (a) UP study site, the (b) NLP study site, and the (c) SLP study site.

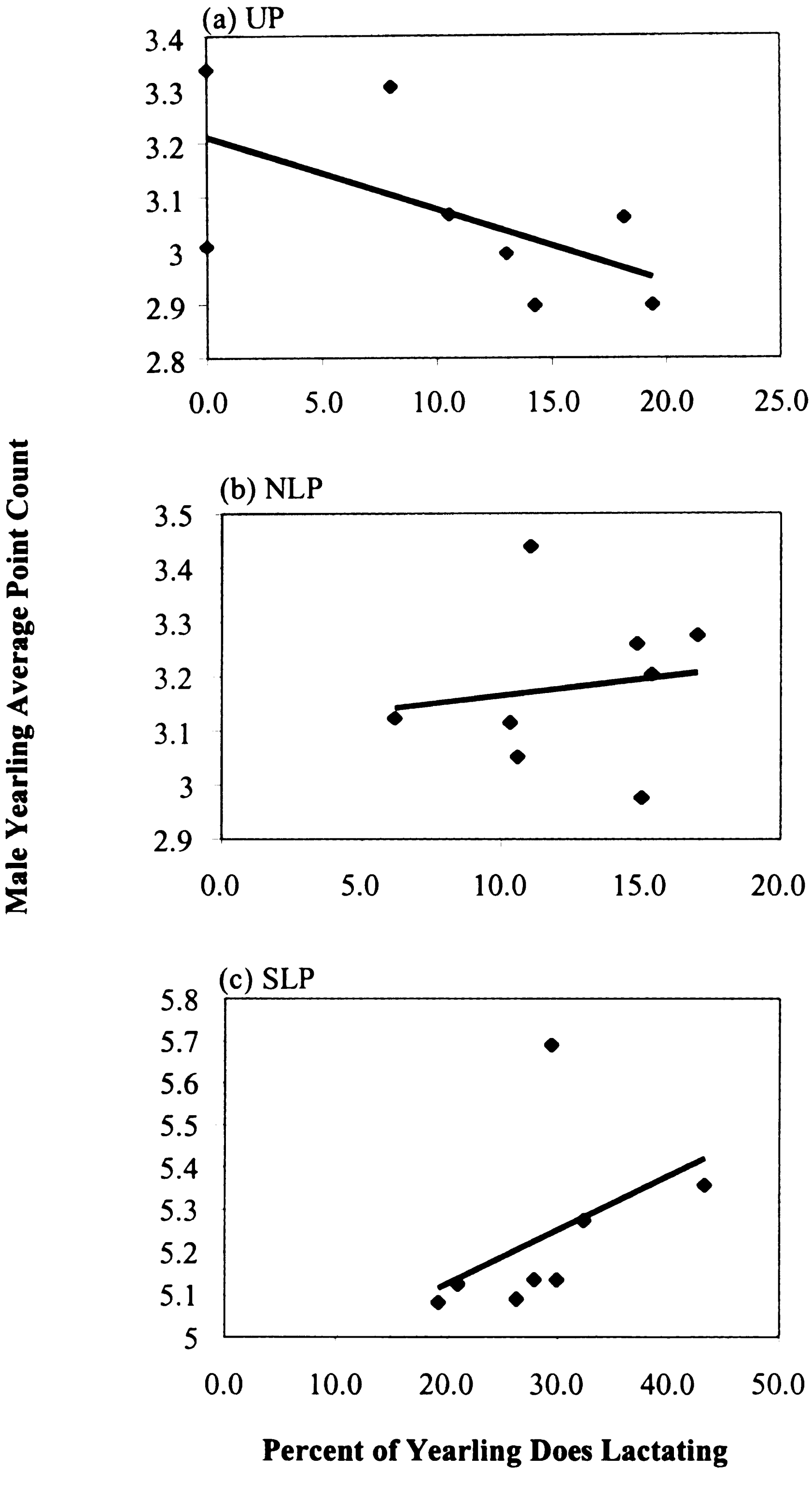

Figure 1.30. The relationship between the percent of yearling does lactating and the average point count for male yearlings in the (a) UP study site, the (b) NLP study site, and (c) the SLP study site.

beam diameter for male yearlings and the male yearling average point count (Figure 1.31). In each of the 3 regional study sites, there was a significant correlation between the 2 antler measurement quality indices; although, the relationship between the mean average beam diameter for male yearlings and male yearling average point count was more significant in the UP and NLP study sites ($R^2 = 0.78$; $P < 0.0001$ and $R^2 = 0.69$; $P = 0.0003$, respectively) than in the SLP study site ($R^2 = 0.81$; $P < 0.0001$).

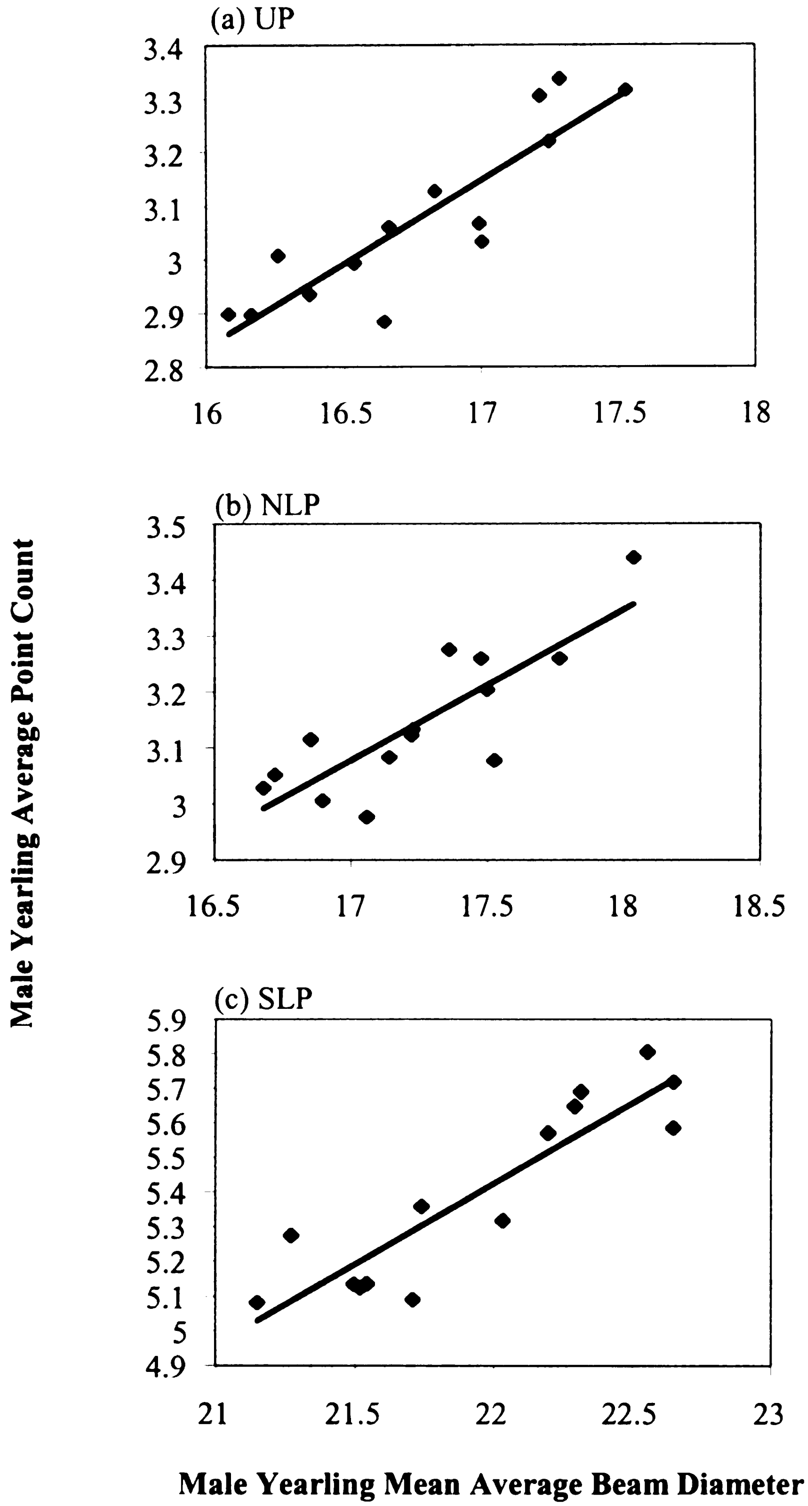

Figure 1.31. The relationship between the mean average beam diameter for male yearlings and male yearling average point count in the (a) UP study site, (b) NLP study site and (c) the SLP Study site.

DISCUSSION

Fall Recruitment

The summer driving transects were developed to determine if road survey methodology for deer could be used to obtain fall recruitment, as measured by fawn-to-doe ratios. The main goal of the summer driving transects was to maximize the number of does observed along each route so that there would be a greater likelihood that fawns would also be seen in the same area; therefore, translating into relatively accurate fawn-to-doe ratios, as a measure of fall recruitment. In the summer of 2000, however, only during the evening transects throughout the entirety of July and August in the NLP1 route did the number of does exceed 100; there were no months in which during the morning transects the number of does exceeded 100. Even though the transect procedures were modified for the summer of 2001, there were no months in which the number of does observed exceeded 100. This was problematic because the predetermined sample size of 100 does was not met and although fawn-to-doe ratios could be calculated, they were probably not very accurate due to the fact that the sample sizes of does were so small. Because there was some question as to how accurate the fawn-to-doe ratios were, they were not translated into fall recruitment. Thus, deer reproductive potential, expressed as fall recruitment, and measured by fawn-to-doe ratios was not examined as a deer condition index in this study.

Land Unit Classification

Although this study originally sought to utilize a hierarchical land classification system to develop an ecosystem-based deer management strategy based on ecological units in which the spatial variation was minimized, the way in which the data were collected and, subsequently, aggregated only allowed the difference in the quality indices to be compared across broad ecological regions. All of the data used in this study were not, by design, collected within defined ecological boundaries, or ecoregions, but were collected within political boundaries. Even though these data do fall within differing ecoregions it is simply an artifact of the political boundaries overlapping the ecological boundaries. Therefore, in theory, the data that are collected within the political boundaries can be transformed into ecological boundaries by determining in which ecoregion the data exists.

The problem in this study, however, was that the lactation data were examined at a regional level and the antler measurements were examined at a county level by necessity of the data collection and sample sizes. The scales used were much too broad to transform the data from political to ecological boundaries because the political boundaries overlapped multiple ecoregions, which made it difficult to assign a region or county to only 1 ecoregion. Since 1999, the biodata have been collected at a township level, which is a smaller scale than either the regional or county level. Data that exists at smaller scales means that there will not be as much multiple overlap between political boundaries and ecoregions. Therefore, collecting data at smaller scales over the long-term suggests that eventually it will be more feasible to transform data from political boundaries to ecological boundaries.

Condition Indices

It has been established through previous research that population-level quality indices such as lactation status and antler measurements can be used to assess the physical condition of deer (Severinghaus 1955, Cowan and Long 1962, McCullough 1982, Severinghaus and Moen 1983, Rasmussen 1985). Of the quality indices examined in this study, the lactation status of yearling does provided the least insight into the condition of the Michigan deer herd. This was, in part, due to the fact that there were relatively few yearling does checked for lactation at MDNR check stations. Thus, it was difficult to draw conclusions based on such small sample sizes. Also, it has been shown that as fall progresses, there are fewer does that still show signs of lactation; thus, although the firearm season in late November provides the largest amount of biophysical data, the lactation rates probably do not accurately reflect the true number of yearlings that produced offspring (Cook and Winterstein 2000).

The antler measurement indices, on the other hand, seemed to be better indicators of herd condition. This was, in part, due to the fact that antler measurements were obtained and recorded from a relatively large number of yearling males checked at MDNR check stations. Also, average beam diameter has been correlated with weight, which is 1 of the best indicators of deer condition (Moen and Severinghaus 1981). This suggests that the average beam diameter of yearlings is even a better index of herd condition because this age-class has the added burden of body growth while growing their first set of antlers; therefore, a yearling that has a larger average beam diameter indicates that he is in better physical condition. In addition, the number of points that exist on a set of antlers is directly correlated with the average beam diameter; thus, this suggests that the number of points, especially for yearling deer, is also a good indicator of physical condition.

Although the antler measurements were better indicators of herd condition than lactation status, all of these indices could be used as relative measures of herd quality in Michigan. The broad trends that exist in these indices among the different regions of the state suggest they could be used to compare the condition of deer in 1 area of the state relative to the condition of deer in another area of the state, but that these indices should not be used as definitive measures of herd condition or quality. In addition, it may be difficult to translate the population-level quality indices as relative measures of herd condition into a definitive quantification of white-tailed deer survival or reproduction, even though both are related to herd quality. For example, it would be difficult to determine if a yearling buck with a relatively large average beam diameter and point count would have a greater chance of surviving a harsh winter than a yearling buck that had a relatively small average beam diameter and point count. Theoretically, a deer in better physical condition should have an improved chance to survive adverse weather and time periods when resources are scarce. There are, however, multiple factors that influence the survival of deer or their ability to reproduce; therefore, it would be difficult to determine if survival or reproduction was a factor of physical condition or some other influence.

Temporal and Spatial Trends

Within each of the 3 regional study sites, all of the quality indices tended to track one another. For example, if the average beam diameter for male yearlings increased in the UP study site, in general, the point count for male yearlings and the percent of does lactating also increased in the same study site. Over the 14 years that comprised this study, it was apparent that the quality indices in some of the study sites were increasing while in other study sites they were decreasing. In the UP and NLP study sites, the male yearling average beam diameter and point count, as well as the percent of does lactating has generally increased over the 14 years of this study. The increase in the quality indices of deer in the UP and NLP study sites may be due to the fact that since 1998 there has been a larger number of deer checked at MDNR stations. This was probably a result of the discovery of Bovine TB in Michigan because hunting pressures were increased to reduce deer density and, hence, the transmission of the disease in the NLP study site. Also, there has been an increase in the general willingness of hunters to check their deer out of concern for Bovine TB in all parts of the state.

Although the male yearling average beam diameter, point count, and the percent of does lactating has remained high in the SLP study site, these indices have, in general, decreased over the 14 years of this study. Deer densities in this area of the state have traditionally been high because the agriculture that exists supplements the natural food sources. It is possible that the decrease in the quality indices of deer in the SLP study site may be attributed to deer densities that have become so high that the competition for resources has increased so much that the resources utilized by deer in that area have become more difficult to find and the deer herd cannot be sustained in such good condition.

Among the 3 regional study sites, only the antler measurements tended to follow the same trends. For example, if the male yearling average beam diameter increased in the UP study site, in general it also increased in the NLP and SLP study sites. Overall, the male yearling point count followed the same sort of pattern, but the percent of yearling does lactating did not. One reason the percent of yearling does lactating did not follow this trend may be attributed to the small sample sizes; it is possible that if the sample sizes had been larger that this index would follow similar trends in all 3 regional study sites.

The long-term averages of the male yearling average beam diameter, male yearling point count, and percent of does lactating revealed that all 3 of these quality indices followed a regional gradient. As you move from north to south in Michigan, each of the condition indices increased. This suggests that deer in the southern part of the state are in better physical condition than their more northern counterparts. In addition, even though some of the long-term averages do not appear to be very different, especially between the UP and NLP study sites, both antler measurements were statistically different among the 3 regional study sites, which implies that in actuality the condition of deer in these areas are distinct.

Sample Sizes and Aggregation of Data

There were problems with ensuring an adequate sample size to conduct data analyses when the data were broken down into components, such as spatial scale. The biodata could not be aggregated below a county level in most instances due to the low number of deer checked. This resulted in small sample sizes, which were inadequate to conduct data analyses. Therefore, the dynamics of the quality indices at finer scales were not examined in this study. Also, the lactation status data were really only useful at the regional level because the sample sizes were too small when these data were broken into smaller spatial components (e.g., county). Likewise, the fawn-to-doe ratio data provided only questionable sample sizes at the regional level. The number of does observed was, in general, very low and never exceeded 90 in any 1 transect. This was also the case for the number of fawns observed in any 1 transect. According to the MDNR and other studies conducted in the transect survey area, the density of deer is very high in the SLP study site (J. Pusateri, unpublished data). Therefore, there is some question as to how well the deer observed along the transects represent the deer composition and density that actually exists in those areas. In addition, the transect data were probably influenced by the existing vegetation types along each of the routes. This suggests that if a route consisted of vegetation types not preferred by deer, then it was less likely that deer would be observed. These limitations need to be considered when performing data analyses; otherwise, the results may not accurately reflect the actual condition of the deer herd. This may be problematic if managers then use these results to develop deer management strategies.

Biases

Biodata

Ideally, the biodata would accurately represent the true composition of the white-tailed deer herd in Michigan. This, however, is not likely due to many potential biases that may be inherent within the data. First, the biodata consist of information collected only from deer that were harvested and checked by hunters. Therefore, bias is introduced because the sample of deer collected is based on only one segment of the population.

Furthermore, many hunters may select for a specific type of deer. According to Bull and Peyton (2000), hunters would rather take large bucks than does or fawns. Males may also be more susceptible to harvest due to larger home ranges and greater movements (Roseberry and Klimstra 1974). Another potential bias is introduced because the information collected on where deer were harvested does not necessarily reflect where they ranged throughout the rest of the year.

Other biases are introduced because the biodata are collected from deer checked voluntarily; thus, the checked deer may not be a random representation of the population of harvested deer. In actuality, approximately 7% of the deer harvested are checked, and older, larger and antlered deer are more likely to be checked than younger, smaller or antlerless deer (Bull and Peyton 2000). Also, hunters are more likely to check deer when it is convenient for them, in terms of location and the amount of time it takes to check a deer.

In addition, the percent of deer checked varies between those harvested on public and private land, which also may bias the biodata. Theoretically, hunters are more likely to check deer harvested on public land. This is due to the fact that hunters hunting on public land leave the property and are more likely to pass a check station while transporting their deer (Cook and Winterstein 2001). In some areas of the state, however, there is very little public land available for hunting. So, in actuality, more deer are harvested and checked from private lands. Plus, many hunters believe that the composition of deer differs on public and private land. Therefore, hunters that are selecting for a specific type of deer may be more inclined to hunt in a particular area.

Not only do biases exist in the biodata due to the voluntary nature of deer checking, but biases also exist due to the spatial distribution of check stations (Cook and Winterstein 2001). There are certain counties that account for more or less of the biodata than is reflected from the estimated harvest. Most counties in the UP and SLP are under-represented; this is most likely due to inaccessibility to or lack of check stations. Several counties in the NLP, however, are over-represented due to hunters checking their deer for Bovine TB, which is a self-sustaining disease in the deer herd in that region (Schmitt et al. 1997). Also, there are a greater number of check stations, overall, within the NLP region. So, when analyses are conducted, the results may be heavily biased to this region of the state.

The seasonal distribution of the hunting seasons may also affect the biological information collected from the deer for the biodata. Over 80% of the biodata are collected during firearm season, with the majority of the non-firearm season biodata being collected during archery season. The composition of the harvest differs among the various hunting seasons, which suggests that the time of year influences biological characteristics. Also, the age structure of harvested bucks as well as the sex structure differs among the hunting seasons (Cook and Winterstein 2001). Therefore, if data analyses are conducted using a combination of the hunting seasons, the results could be heavily biased toward the data collected during the firearm season.

The biodata also may not represent the true composition of the deer population because the deer that are checked are subject to potential measurement error. Even though check station volunteers are trained on how to age deer, agers tend to under-age older deer (over 4 years old) and to over-age younger deer (Cook and Winterstein 2001).

The measurement error for yearlings, however, was low (Cook and Winterstein 2001). Measurement error could also be introduced when the volunteers measure the beam diameter (mm) on bucks. Since the measurement units are so small, there is some question as to whether the volunteers are able to accurately read the calipers. There is also an issue of how consistent the volunteers are when taking the beam measurements.

Summer Driving Transects

Data collected from the summer driving transects also have potential biases. The routes themselves may introduce bias to the data collected. Since the routes are driven, the only deer that are observed are those that can be seen from the road. This may skew the data collected on fawn-to-doe ratios because the deer observed are only a small subset of the deer present in an area and may not be representative of the entire deer population. Therefore, it may appear that deer near roads have either more or fewer fawns than what is, in reality, a true representation of number of fawns in the overall deer population. Although, the routes were chosen to maximize the number of deer observed, they were limited by driving accessibility and the need to encompass a variety of habitat types. So, there may have been sections of each route that were not ideal for deer observation and, thus, the number of deer observed while driving the route may have been much lower than the number of deer actually present.

The time of day that the data were collected may have also biased the fawn-to-doe transect data. Deer are usually most visible from the road during the early morning and in the evenings because they tend to be more active during these times of day. Based on year 1 results, in year 2 the routes were only driven in the evening, which may have affected the number and type of deer observed. It is difficult to see deer at sunset. Thus, there are probably a lot of deer that do not get counted simply because they cannot be seen, and if they are observed, it is difficult to differentiate what age and/or sex they are.

Bias Reduction

The overall quality of the biodata could potentially be improved and the effects of biases reduced if the number of points or average beam diameter values were weighted by the amount of harvest within a geographic area or by season (Cook and Winterstein 2001). Other ways to reduce biases are to alter the logistics of the check stations. If the MDNR added check stations in certain areas of the state (e.g., SLP and UP), the biodata would be a better representation of the deer population throughout the state. Plus, adding stations may make checking deer more convenient for hunters, and possibly more deer would be checked (Cook and Winterstein 2001). Enticing hunters to check their harvested deer would also reduce biases. Having some sort of reward program, or an education program aimed to inform hunters of the importance of checking their deer could increase the number of deer checked. Another option may be for the MDNR to condsider making the deer check mandatory.

Given that we stratified the state into 3 regions, the geographical biases that exist in the biodata were not problematic for this study. The nature of the data defined how they should be aggregated for analyses. Since there are spatial and seasonal biases in the biodata, when conducting analyses, it made sense to break the data down into spatial and/or seasonal components. To avoid results biased heavily on biological information taken from deer in the Northern Lower Peninsula, the data were broken down into regions of the state and initial statistical analyses were conducted at this regional level. Similarly, to avoid results biased heavily on the biological information taken from deer in the firearm season, the biodata can be broken down into the different hunting seasons in order to conduct data analyses.

Assumptions

Despite all of these potential biases, the biodata are the largest, most comprehensive, and most readily available data on the composition and physical condition of the Michigan deer herd, and were used to approximate the true population parameters of the deer population. Likewise, the fawn-to-doe transects, in spite of biases, also provided valuable information on the deer herd in Michigan because these data complemented the biological information collected for the biodata. These data, however, can only be used appropriately if the biases and limitations of the data are recognized and understood. So, for the most part, the biodata and the fawn-to-doe transect data are best used to provide an indication of general trends among the entire population instead of true estimates of population parameters.

Most data collected have some sort of associated bias; therefore, making assumptions about the data was necessary to perform analyses. According to Cook and Winterstein (2001), the biological information contained within the biodata generally followed the expected trend of deer population parameters in the 3 distinct regions of the state. Thus, it was assumed that, even though the Biodata consists of information collected from a portion of the deer harvested, it was more or less representative of the entire deer population. So, if it can be assumed that the biodata were representative of the entire deer population, it can also be assumed that if measurement errors occurred, they were negligible.

There were also assumptions made about the fawn-to-doe transect data. Fawns are large enough to move around, and thus have a greater likelihood of being seen from the road during the latter part of the summer. So, even though transects are performed only during late August and September, it was assumed that this time of year provides the best opportunity to observe fawns and does together. It was also assumed that the number of deer observed in the evening were probably representative of the number of deer that would be observed in the morning. Deer have home ranges; therefore, it was assumed that the does and fawns observed in a particular area in the evening would most likely be in the same vicinity during a morning transect.

Alternative Indices

There are several population-level quality indices that were not used in this study, but may still be useful in determining white-tailed herd quality in Michigan. One alternative is to determine the physical condition of white-tailed deer by collecting weight (Severinghaus 1979, Moen and Severinghaus 1981). Growth and maintenance of individuals requires a certain amount of food intake and nutrition. If these needs are not met, weight, along with other characteristics that indicate physical condition will be substandard (Rasmussen 1985). For example, there is a close relationship between weight, reproductive rates and antler growth (Hesselton and Sauer 1973). Females that are underweight will conceive fewer fawns, if any, and bucks will produce inferior quality antlers with fewer points, smaller spread and diameter (Severinghaus et al. 1950, Severinghaus and Moen 1983).

One method of collecting weight data is to weigh hunter-killed deer on standard platform scales at deer harvest check stations during the fall harvest. However, there are some considerations that must be recognized when using weight as an index of physical condition. The first is age. Weight increases until a deer reaches its prime and then levels off. Thus, it is important to record an accurate age along with weight (Severinghaus 1955, Severinghaus 1979). Another is tarsal length. Hind foot measurements should be taken to compensate for size (height). In addition, season should be taken into account because fluctuations in body weight occur throughout the year (Fowler et al. 1967).

It is not always feasible to set up a weigh station at a harvest check station. Therefore, another way to assess physical condition of white-tailed deer is to examine fat deposits. If range conditions are poor, resulting in low food intake, deer lose fat deposits (Harris 1945). Thus, another physical condition index that can used to determine the quality of white-tailed deer is measurement of the fat reserves in the animals body, traditionally femur marrow fat (Nichols and Pelton 1972, Purol, et al. 1977, Watkins et al. 1991). This, however, is a highly invasive procedure that requires dissection of the hindquarter. The result is a substantial loss of edible venison, which makes a less invasive method more desirable.

The fat content of the mandibular cavity tissue (MCT) is an alternative method to the traditional femur marrow fat assessment (Purol et al. 1977). Mandibles are collected from hunter-killed deer, and can be removed without defacing the trophy, when necessary. Usually, the tissue samples are dried and ether extraction is used to estimate the fat concentration of marrow (Baker and Lueth 1966). However, marrow dry matter percentage of the mandible can also be used as an index of body fat concentration, and is determined by oven-drying or reagent methods (Watkins et al. 1991).

There is an indication that MCT fat has limited usefulness as an index because it is not mobilized until body fat declines to approximately 12%. This suggests that a deer with a high percentage of body fat may have the same percentage of manibular fat as a deer with a low percentage of body fat (Nichols 1974, Watkins et al. 1991). Consequently, marrow fat cannot be used to discriminate among animals with high body fat concentrations, but is more useful for deer in poor condition (Baker and Lueth, 1966). On the other hand, if this index has a relatively good correlation with other factors related to body condition, such as antler growth or lactation rates; it may be very useful to build a more complete index of herd quality.

Conclusion

This project evolved based on the nature of the data and the results from analyses. Initially, the scope of this project only encompassed determining whether population quality indices (e.g. point counts, average beam diameter and lactation status) could be used to define white-tailed deer herd quality in Michigan. After examining the data, however, it was apparent that the spatial and temporal trends in deer population parameters could be important to determine fluctuations in herd condition. The spatial and temporal trends in herd condition may also be beneficial for examining how deer herd condition corresponds with the ecological and social aspects of deer management.

Studying temporal and spatial variation in herd quality may also help to isolate some of the underlying mechanisms (e.g., habitat quality, deer density and weather) that cause shifts in the biological carrying capacity of the deer population.

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CHAPTER 2

AN EXAMINATION OF UNDERLYING MECHANISMS THAT MAY INFLUENCE WHITE-TAILED HERD CONDITION IN MICHIGAN

INTRODUCTION

One of the best methods to determine white-tailed deer herd quality is to evaluate the physical growth of deer (Cowan and Long 1962, Severinghaus and Moen 1983, Rasmussen 1985). Some of the more easily obtainable measurements of herd condition in Michigan include average beam diameter, point count, and lactation status of does from harvest data (Hill et al.1981, McCullough 1982, Cook and Winterstein 2000). These population-level quality indices vary by age-class (e.g., in general older deer have larger antler measurements) but in yearling deer they are more pronounced because this age-class has the added burden of body growth while growing their first set of antlers or producing their first offspring (French et al. 1956, Cowan and Long 1962, Ullrey 1983). Therefore, population-level quality indices for yearling deer such as average beam diameter, point count, and lactation status can be used as a measure of the overall deer herd quality in Michigan (chapter 1).

In Michigan, male yearling average beam diameter, male yearling point count, and lactation status of yearling does increases as you move along a north to south regional gradient. It has been recognized for some time that these quality indices increase in the more southern regions of the state (Ullrey 1983, Ozoga et al. 1995, Cook and Winterstein 2000, chapter 1). This suggests that the overall condition of deer in the southern part of the state is better than the condition of deer in the northern part of the state. The real question, however, is why does this north to south trend in the population-level quality indices exist? From the literature, there have been 3 major underlying mechanisms identified that have the potential to influence white-tailed deer herd quality in Michigan: population density, winter severity, and habitat quality (Blouch 1984, Matschke et al., 1984, Ozoga et al. 1995). These 3 factors vary among the 3 main regions in the state and may, at least partially, explain the regional trends in deer population-level quality indices in Michigan.

Herd density, or the number of deer that exist in a specified area, can affect the ability of deer to either find or utilize suitable resources, which can, subsequently influence the physical condition of deer. Higher population densities, in general, lead to a decrease in deer growth, survival, and reproduction because the competition for resources can become so great that not all deer are able to obtain adequate food and shelter (Johnson 1937, Leberg and Smith 1993, Jacobson and Guynn, 1995). Specifically, high deer densities can affect forage production and the availability of cover as well as increase stress-levels (Cheatum and Severinghaus 1950, Sams et al. 1998).

When deer densities exceed the capacity of the land to sustain a healthy deer herd, there are noticeable affects on reproduction: younger does breed later in life and newborn fawn mortality increases (Payne 1970, Miller et al. 1995). There are also detrimental affects on antler development; a larger percentage of yearling deer have spike antlers (less than 3 inches) and deer in other age-classes may not produce antlers to their full potential (Ozoga et al. 1995). In addition, overcrowding is often associated with the outbreak of disease because these deer are more likely to be in poorer physical condition and there is more opportunity for disease to be spread because of close physical contact (Leopold 1933, Jacobson and Guynn 1995).

Winter severity, which includes temperature and snowfall, influences deer mobility, productivity, and mortality (Blouch 1984). As temperatures drop, deer move into wintering yards and once snowfall accumulates, the movement of deer may be restricted, making it difficult to find suitable food or shelter (Verme 1968, Marchington and Hirth 1984). The temperature and amount of snowfall can also affect the ability of deer to find and utilize resources because these factors can not only change the growth and seasonal availability of food but also can cover nourishing food, in some cases making this resource unavailable to the deer (Cheatum and Severinghaus 1950, Matschke et al.1984). The unavailability of resources, in turn, can cause starvation and weaken the deer so that mortality increases and a subsequent decline in deer numbers occur (Ozoga 1968, Karns 1980).

In addition, as temperature decreases and snowfall increases, deer expend more energy trying to find suitable resources, especially if subzero temperatures, harsh winds, and large amounts of snowfall are sustained throughout the winter (Verme 1968, Ozoga and Gysel 1972, Ozoga et al. 1995). This can greatly affect the physical condition of deer because as body fat is depleted, body weight decreases and if adequate resources are not acquired eventually there may be detrimental effects on other population characteristics such as reproduction and antler development (Severinghaus et al. 1950).

There is a direct relationship between the productivity of deer and the quality of the habitat they utilize (Ford et al. 1997). Deer require proper nutrition from forage and browse to obtain optimal physical condition. As the habitat quality increases, in general, the level of nutrition also increases because high quality deer habitat provides optimum levels of nutrients required for growth, reproduction, and, hence, survival (Harlow 1984, Leberg and Smith 1993). This suggests that when deer are found in high quality habitat, they are more likely to be in better physical condition. Indeed, there have been numerous studies that show a detrimental effect on deer growth and overall physical condition when the deer range consists of poor quality habitat that provides poor nutrition (Cheatum and Severinghaus 1950, French et al. 1956, Shea and Osborne 1995). Specifically, deer that range in poor quality habitat are likely to have below average weight and antler development, both the number of points and the average beam diameter (Kie et al. 1983, Sams et al. 1998). Reproductive performance is also related to habitat quality, a doe that ranges in better quality habitat has the ability to produce not only more offspring but healthier offspring than a doe that ranges in poorer quality habitat (Cheatum and Severinghaus 1950, Leberg 1993, Shea and Osborne 1995).

The quality of forage is important in determining the physical condition of deer, but so is the quality of thermal cover in the winter. Deer migrate to areas of thermal cover when the temperature starts to turn cold (Marchington and Hirth 1984). Yarding in quality thermal cover can greatly enhance the ability of deer to survive long, harsh winters, especially as body weights and fat reserves decrease to render deer in relatively poor physical condition (Severinghaus 1947, Verme 1965). In some cases, deer will often forgo higher quality forage and browse to bed in higher quality thermal cover throughout the winter (Ozoga and Gysel 1972).

There is, obviously, a great deal of interaction among the 3 major underlying mechanisms that have the potential to influence white-tailed deer herd condition. High population densities affect the quantity of forage and browse that is available for deer consumption and since deer prefer high quality forage, high deer densities can also mean that the better quality habitat is consumed more quickly (Cheatum and Severinghaus 1950, Jacobson and Guynn 1995). This, in turn, makes the overabundant deer population more susceptible to "die-offs" during cold winters with a large amount of snowfall (Severinghaus 1955, Verme 1968). If deer densities are low, however, more resources may be available to a greater number of deer. Thus, harsh winters may not necessarily signify that there will be severe reductions in deer density if adequate resources are available, whereas an overabundance of deer coupled with a nutritional shortage may decrease the ability of deer to withstand long, harsh winters (Johnson 1937). These interactions suggest that a combination of deer density, winter severity, and habitat quality may in fact be at work in influencing deer herd condition.

Objectives

This study will explore why a north to south regional pattern exists in the white-tailed deer herd quality in Michigan by evaluating underlying mechanisms that have the potential to influence deer herd quality in relation to indices of herd condition. Specifically, the following objectives will be met:

1) Examine the temporal and spatial trends in the underlying mechanisms that have the potential to influence white-tailed deer herd quality in Michigan;
2) Determine if these underlying mechanisms can account for the regional differences in the indices of herd quality.

By meeting these objectives, this study will help the MDNR to develop scientifically sound deer management strategies that take into consideration the factors that may influence deer distribution or demographics.

METHODS

Data Sources

Quality Indices

The lactation status of yearling does was not examined in relation to underlying mechanisms that have the potential to influence deer herd condition because small sample sizes for this quality index meant that any conclusions based on these data were broad in nature and further analyses may not be overly meaningful at this time. Male yearling average beam diameter and point count measurements, however, were examined in relation to underlying mechanisms that have the potential to influence deer herd condition. Male yearling average beam diameter was chosen because this measurement is one of the best indices of deer herd quality, and male point count was chosen because this measurement is highly correlated with male yearling average beam diameter. These measurements were obtained from the biophysical data (biodata) collected from hunter-killed deer that are voluntarily brought into check stations throughout Michigan (refer to Chapter 1 for complete details). The mean average beam diameter for male yearlings and the mean point count for male yearlings were calculated for every county in the 3 study sites from 1987 through 2000.

Population Density

Population density estimates were calculated based on the sex-age-kill estimate method as described by Mattson-Hansen (1998). This method uses biological information collected from hunter-killed deer during the firearm season to estimate the deer population size before the hunting season and can be used to project future population numbers. There are 3 main components to the sex-age-kill estimate method. The first component is the sex ratio. Only yearling bucks and does are used to determine the sex ratio because it is assumed that the harvest data reflect each age group proportionally to its abundance in the population (Severinghaus and Maguire 1955). The second component is the age ratio, in which the number of yearlings is divided by the total number of known age adult deer for both bucks and does. The third component is the annual population survival rate, which for deer in Michigan is 0.90. This accounts for natural mortality that occurs throughout the year. We used information from the biodata and the MDNR mail harvest survey to calculate population density estimates. The number of bucks, does, and fawns was calculated separately, then added together to get a total population density estimate for each county in each study site from 1987 to 2000 except for Baraga County in the UP study site. A density estimate could not be calculated for this county because some of the data required to use the SAK estimate method were not available.

Temperature

The mean monthly temperature data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) website in tenths of a degree Fahrenheit for every county in the 3 study sites from 1987 to 2000 (http://www.ncdc.noaa.gov). The mean monthly data were summed from January through September in each county in the 3 study sites from 1987 to 2000 to get 1 cumulative temperature reading for each county in each year. These data were then converted from Fahrenheit into centigrade. Figure 2.1 is an example of how the cumulative mean monthly temperature in Alpena County

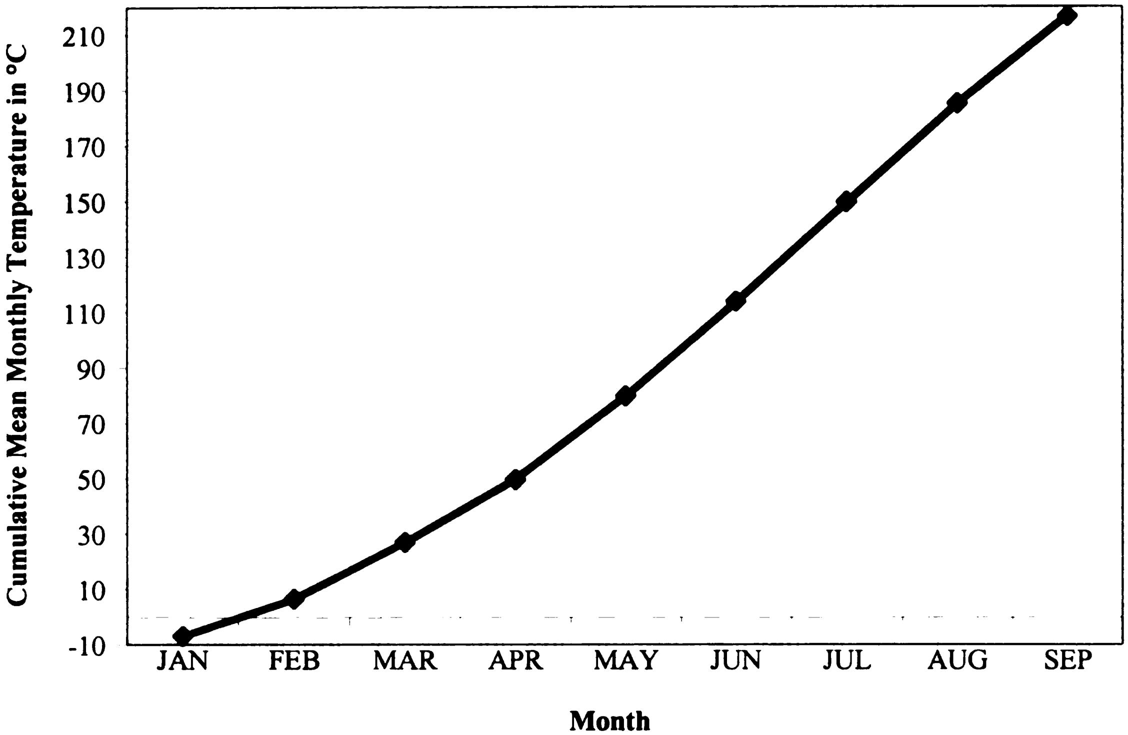

Figure 2.1. The cumulative mean monthly temperature for Alpena County, Michigan in 2000.

increased over the 9-month period in 2000. The mean monthly temperature data were aggregated from January through September because by late summer (i.e., September), antler growth has subsided and temperature no longer has an impact on antler development (Weeks 1995).

Snowfall

The total monthly snowfall data were also downloaded from the NOAA website in tenths of an inch for each county in all 3 study sites from 1987 to 2000. These monthly data were then summed from January through April in each county in the 3 study sites from 1987 to 2000 to get 1 cumulative total snowfall reading for each county in each year. These data were then converted from inches to centimeters. Figure 2.2 is an example of how the cumulative total monthly snowfall in Marquette County increased over the 4-month period in 2000. The total monthly snowfall data were aggregated from January through April because that is when the majority of snow falls in Michigan regardless of region (Blouch 1984).

Winter Severity

Winter severity is based on a combination of temperature and snowfall. In 1968 Verme devised a method in which winter severity could be quantitatively measured based on these 2 factors. To obtain temperature and snowfall information, atmospheric chill and snowfall levels were collected at MDNR stations. For this study, these data were available in the UP and NLP study sites starting in the winter of 1986-1987 (winters will from now on be identified from the first year), but in the SLP study site these data were

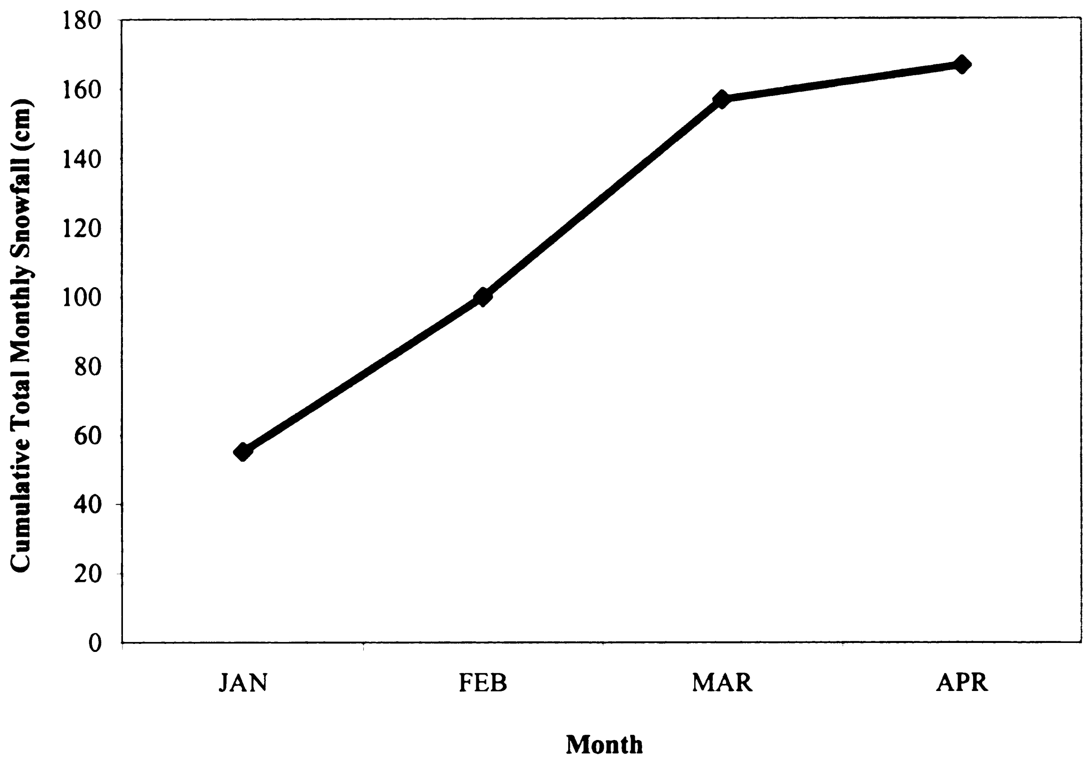

Figure 2.2. The cumulative total monthly snowfall for Marquette County, Michigan in 2000.

only available since 1988. Atmospheric chill and snowfall data were combined into a weekly value, and over the course of the winter these weekly values were cumulated to form a winter severity index (WSI) for each station where data were collected. The WSI for each station within a specific region were then averaged together to obtain an overall WSI for that region.

A corrected WSI was developed by Cook et al. in 2001. This index is based on the same technique as the regular WSI, except only data collected from approximately day 42 (mid-December) to day 168 (mid-April) are used in its development. The corrected WSI was used in this study because the data used for the regular WSI did not cover the same time period in each of the 3 regions, whereas the time period for calculating the corrected WSI was standardized among all 3 regions. Therefore, based on the corrected WSI, an average WSI for each region was calculated; in the UP and NLP study sites a corrected WSI was calculated for each year from 1986 to 1999, and in the SLP study site a corrected WSI was calculated for each year from 1988 to 1999. Figure 2.3 illustrates how the weekly corrected cumulative WSI increased in each region in 2000.

Habitat Potential

Habitat potential is essentially a measure of the ability of habitat types to provide fall and winter food, spring and summer food, and thermal cover requirements for white-tailed deer. Habitat potential models for white-tailed deer were developed by Felix et al. (*in press*), and currently are only available for the NLP study site. To build habitat potential models, habitat types must first be defined. Habitat types were delineated by

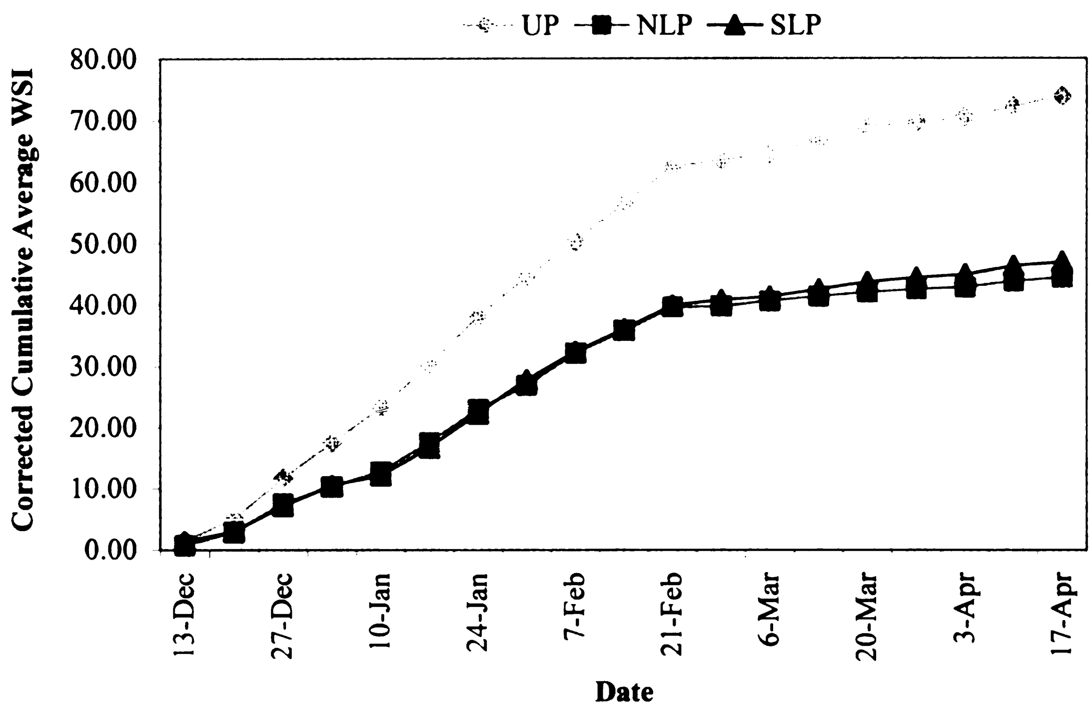

Figure 2.3. The corrected cumulative winter severity index (WSI) for each of the 3 regional study sites in 2000.

overlaying maps of ecoregions, land-type associations, soil associations, and presettlement vegetation (Figure 2.4). Based on the resulting 24 number of habitat types, models were developed to predict the suitability for each white-tailed deer habitat requirement throughout succession, 0 being the lowest suitability and 1 being the highest suitability (Figure 2.4). To make the habitat potential data compatible with the demographic data, the suitability for each deer habitat requirement was rescaled from a smaller spatial scale (i.e., habitat types) to a larger spatial scale (i.e., county boundaries). A weighted average for fall and winter food, spring and summer food, and thermal cover potential was calculated based on the area of each potential value. This resulted in 1 habitat potential for each habitat requirement in every county in the NLP study site (Figure 2.5).

Within Regions

In each study site, an analysis of variance (ANOVA) was conducted to examine the relationship between male yearling average beam diameter or male yearling point count and population density, temperature, and snowfall. Regression analyses were conducted to determine the relationship between male yearling average beam diameter or male yearling point count and the corrected WSI in all 3 regions. The long-term average value of the yearling average beam diameter and point count in each county was also regressed against the habitat potential for fall and winter food, spring and summer food, and thermal cover in the NLP study site only. To determine in which counties the antler measurements were related to a specific underlying mechanism, both the ANOVA and regression analyses were run by county. Significance levels were determined at an alpha

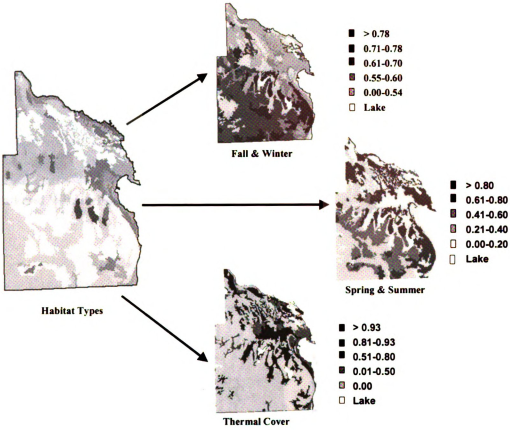

Figure 2.4. The habitat types for the Northern Lower Peninsula study site as defined by Felix et al. (unpublished data) and the habitat potential for fall and winter food, spring and summer food, and thermal cover based on the habitat types delineation.

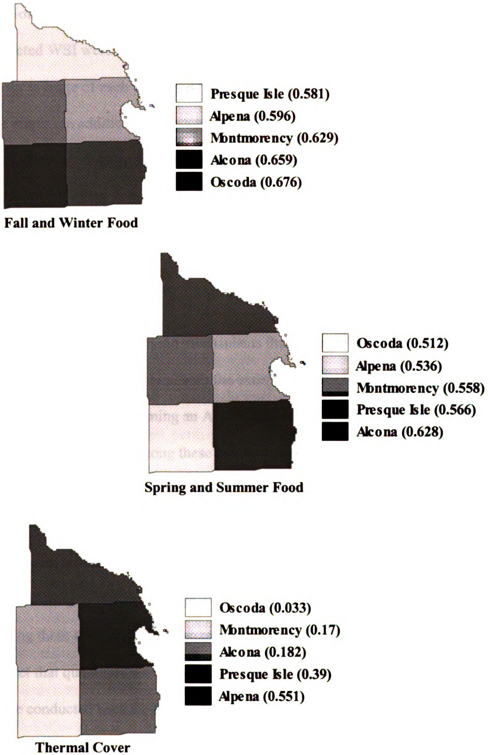

Figure 2.5. The weighted habitat potential for fall and winter food, spring and summer food, and thermal cover for each county in the Northern Lower Peninsula study site.

level of 0.10. Yearly trends in deer population density, temperature, snowfall, and the corrected WSI were also examined in each of the 3 regional study sites by calculating the yearly average of each underlying mechanism in each region and plotting these data in a line graph. In addition, a long-term average was calculated for each of the underlying mechanisms (except habitat potential) in the regional study sites. This accomplished by averaging all of the values for each underlying mechanisms over the 14 years of the study, which resulted in 1 average value for each underlying mechanism for each region.

Among Regions

Each of the underlying mechanisms that have the potential to influence male yearling antler measurements, with the exception of the habitat potential mechanism, were compared by performing an ANOVA to determine if there were statistically significant differences among these factors among the 3 regional study sites at an alpha level of 0.10. Mean comparisons of the underlying mechanisms among regions were also examined using a Tukey-Kramer multiple comparison test at an alpha level of 0.10. Yearly comparisons were also made among the underlying mechanisms in the 3 regions by calculating the yearly average of each underlying mechanism in each region and plotting these data in a line graph to examine trends. This method was necessary due to the fact that quantitative analyses (e.g., Tukey-Kramer multiple comparison test) could not be conducted because there were not enough data points and, thus, not enough degrees-of-freedom (df).

RESULTS

Comparisons within Study Sites

UP

The number of deer, as estimated by the sex-age-kill estimate method, in the UP study site ranged between 26,411 in 1997 and 62,131 in 1991; the long-term average number of deer from 1987 through 2000 was estimated to be 46,332 (Table 2.1). In general, the number of deer tended to be higher from 1987 to 1993 due to the fact that in only 1 year (1988) was the number of deer below the long-term regional average (Figure 2.6). Conversely, the number of deer tended to be lower from 1994 to 2000; in only 2 out of the 5 years was the number of deer above the long-term regional average. The deer numbers were at the lowest in the study from 1997 through 2000 (Figure 2.6).

Iron and Marquette Counties, the larger counties in the UP study site, had larger overall average numbers of deer ($\bar{x}$ = 50,084 and $\bar{x}$ = 50,762, respectively) than did Dickinson County, the smaller county ($\bar{x}$ = 40,823) (Figure 2.7). Although Marquette County had the highest number of deer, in actuality the deer density in this county was the lowest in the UP study site at 11 deer/km^2 (28 deer/mi^2). The number of deer in Iron County was slightly below that in Marquette County, but this county had the highest density of deer in the UP study site at 17 deer/km^2 (43 deer/mi^2). Dickinson County had the lowest number of deer, but the density of deer fell in between that of Marquette and Iron Counties at 14 deer/km^2 (35 deer/mi^2). Even though there were counties in the UP study site that had higher deer densities, in actuality, the difference in deer density among the counties did not exceed approximately 6 deer/km^2 (15 deer/mi^2).

Table 2.1. The total number of deer, as estimated from the sex-age-kill estimate method, in each county in the Upper Peninsula study site between 1987 and 2000; the yearly average total number of deer and standard deviation (StDev) for the entire study site, and the average total number of deer for each county.

	Baraga	Dickinson	Iron	Marquette	Yearly Average	StDev
1987	n/a	48529	35262	83279	55690	24797
1988	n/a	48684	49986	28376	42348	12118
1989	n/a	52866	55623	48784	52424	3441
1990	n/a	42445	48076	49700	46740	3807
1991	n/a	62883	61236	62273	62131	833
1992	n/a	56885	69391	51492	59256	9182
1993	n/a	30266	n/a	86156	58211	39520
1994	n/a	25683	54499	35895	38692	14610
1995	n/a	52481	41638	69396	54505	13989
1996	n/a	35079	55507	61815	50800	13975
1997	n/a	34602	n/a	18221	26411	11583
1998	n/a	18043	39749	n/a	28896	15348
1999	n/a	30075	38803	26481	31787	6336
2000	n/a	32993	51241	38041	40758	9423
Total	n/a	40823	50084	50762	46332	5553

*n/a denotes that the data were not available

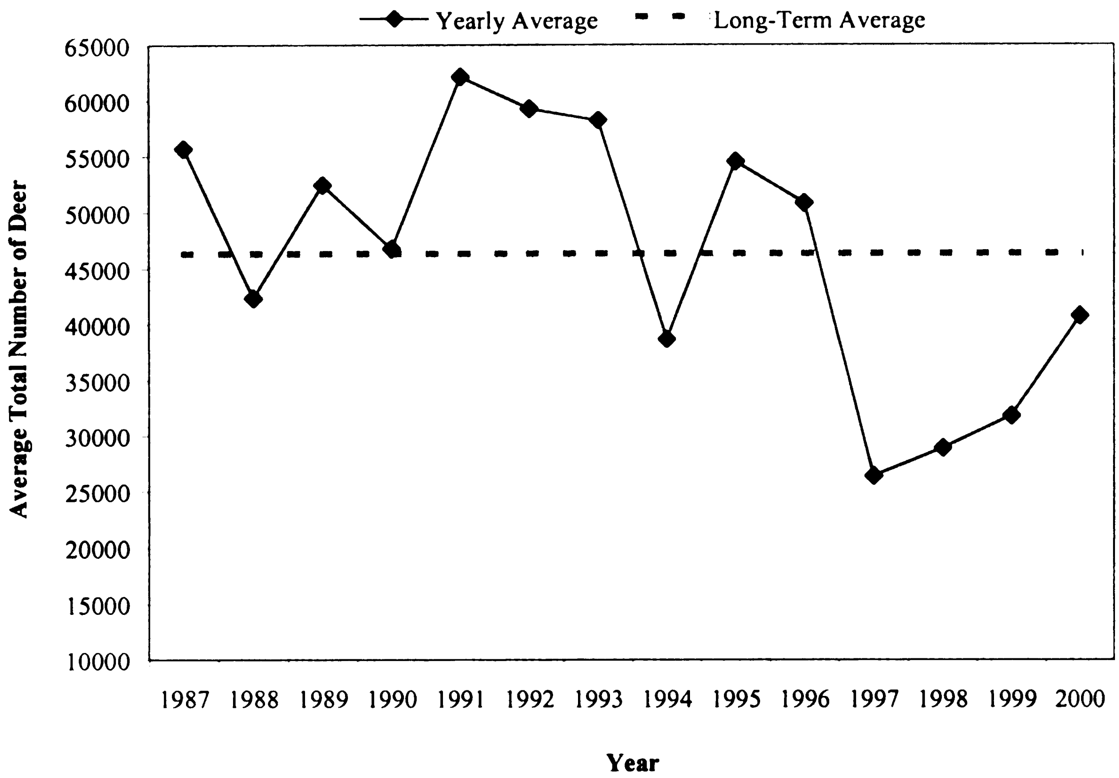

Figure 2.6. The temporal trend in the average total number of deer, as estimated by the sex-age-kill estimate method, for the Upper Peninsula study site except Baraga County between 1987 and 2000.

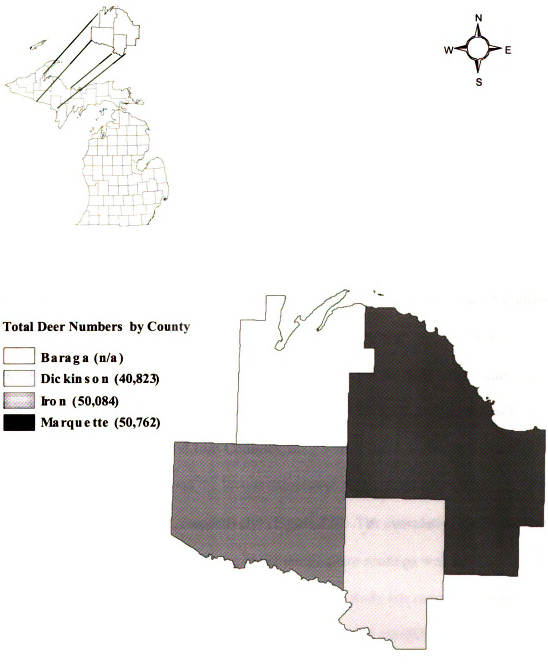

Figure 2.7. The average total number of deer by county in the Upper Peninsula study site for 1987 through 2000.

The overall cumulative mean monthly temperature for the UP study site was 198.63 °C and the yearly averages ranged between 185.50 °C in 1996 and 217.44 °C in 1987 (Table 2.2). The temporal trend in the cumulative mean monthly temperature appeared to be cyclical, and oscillated around the long-term regional average (Figure 2.8). In the majority of years, the cumulative mean monthly temperature was at or slightly below the long-term average. However, in those years in which the cumulative mean monthly temperature was above the long-term regional average, it was within 20 °C (Figure 2.8).

The highest temperature readings occurred in Marquette and Dickinson Counties, the eastern-most counties in the UP study site ($\bar{x}$ = 213.09 °C and $\bar{x}$ = 209.18 °C, respectively) (Figure 2.9). Even though the cumulative mean monthly temperature was higher in Marquette County than in Dickinson County, the overall average for each county was similar. Baraga and Iron Counties, on the other hand, the western-most counties in the UP study site had the lowest cumulative mean temperature readings ($\bar{x}$ = 183.47 °C and $\bar{x}$ = 188.77 °C, respectively) (Figure 2.9). The cumulative mean monthly temperature in these 2 counties with the lower temperature readings was similar.

The cumulative total monthly snowfall in the UP study site ranged between 98.43cm in 1991 and 289.05cm in 1996, with an overall total monthly snowfall for the region of 169.73cm (Table 2.3). In 9 out of the 14 years of this study, the average cumulative total monthly snowfall per year was below the regional average. For example, in 1991, the snowfall was approximately 70cm below the regional average; although, in the majority of years that the snowfall was below the regional average, it was within 30cm of the regional average (Figure 2.10). In the majority of years in which the

Table 2.2. The cumulative mean monthly temperature (summed from January through September) in °C for each county in the Upper Peninsula study site from 1987 to 2000; the yearly average cumulative mean monthly temperature and standard deviation (StDev) for the entire study site, and the average cumulative mean monthly temperature for each county.

	Baraga	Dickinson	Iron	Marquette	Yearly Average	StDev
1987	219.30	214.94	208.11	227.39	217.44	8.08
1988	136.89	208.33	191.06	211.50	186.94	34.56
1989	195.56	200.00	182.39	203.00	195.24	9.09
1990	207.61	210.67	194.83	214.44	206.89	8.51
1991	208.22	215.83	170.33	216.22	202.65	21.86
1992	194.61	204.72	183.28	206.83	197.36	10.80
1993	158.33	203.39	182.22	204.22	187.04	21.68
1994	191.61	200.33	179.11	197.61	192.17	9.44
1995	208.61	213.50	193.17	213.89	207.29	9.72
1996	180.00	194.33	173.06	194.61	185.50	10.74
1997	182.00	202.61	182.44	207.94	193.75	13.49
1998	106.28	230.06	211.06	233.89	195.32	60.19
1999	210.72	217.72	198.06	224.78	212.82	11.39
2000	168.89	212.11	193.72	226.94	200.42	25.03
Total	183.47	209.18	188.77	213.09	198.63	14.69

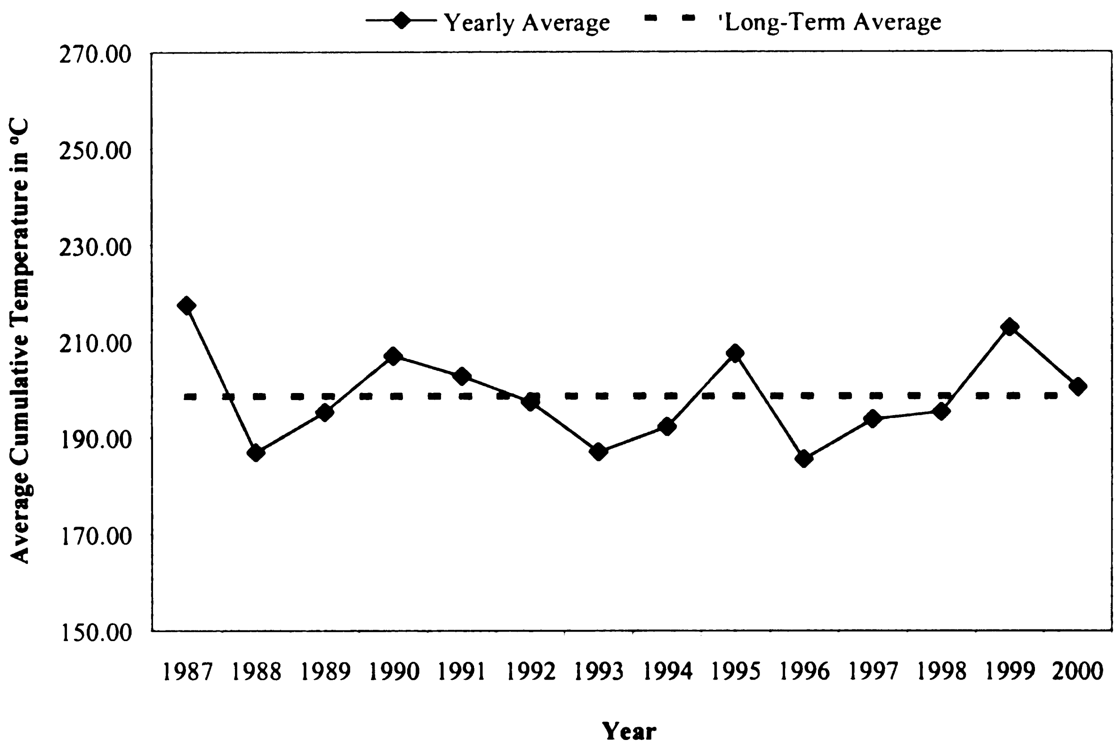

Figure 2.8. The temporal trend in the average cumulative temperature (summed from January through September) in °C for the Upper Peninsula study site between 1987 and 2000.

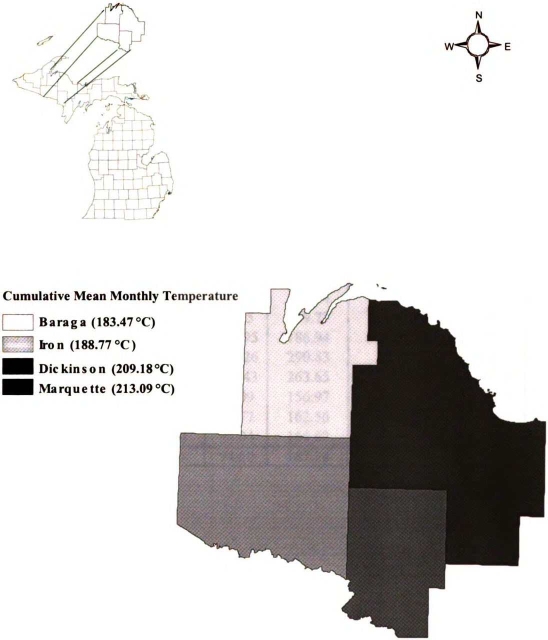

Figure 2.9. Cumulative mean monthly temperature (summed from January through September) in °C by county in the Upper Peninsula study site from 1987 through 2000.

Table 2.3. The cumulative total monthly snowfall (summed from January through April) in cm for each county in the Upper Peninsula study site from 1987 to 2000; the yearly average cumulative total monthly snowfall and the standard deviation (StDev) for the entire study site, and the average cumulative total monthly snowfall for each county.

	Baraga	Dickinson	Iron	Marquette	Yearly Average	StDev
1987	246.38	51.56	60.45	144.53	125.73	90.69
1988	494.79	76.71	90.17	212.34	218.50	194.03
1989	322.58	112.27	111.76	190.25	184.21	99.34
1990	226.06	47.24	53.09	182.88	127.32	90.85
1991	204.47	61.21	0.00	128.02	98.43	87.93
1992	213.36	112.01	107.95	203.71	159.26	57.06
1993	222.25	93.73	105.41	173.74	148.78	60.37
1994	196.85	97.54	95.25	159.77	137.35	49.67
1995	358.14	69.09	107.95	186.94	180.53	128.16
1996	518.16	171.96	175.26	290.83	289.05	162.43
1997	505.46	123.95	138.43	263.65	257.87	176.57
1998	205.74	140.21	85.09	156.97	147.00	49.76
1999	188.98	92.46	96.77	162.56	135.19	48.11
2000	265.94	137.41	98.04	166.62	167.01	71.69
Total	297.80	99.10	94.69	187.34	169.73	95.45

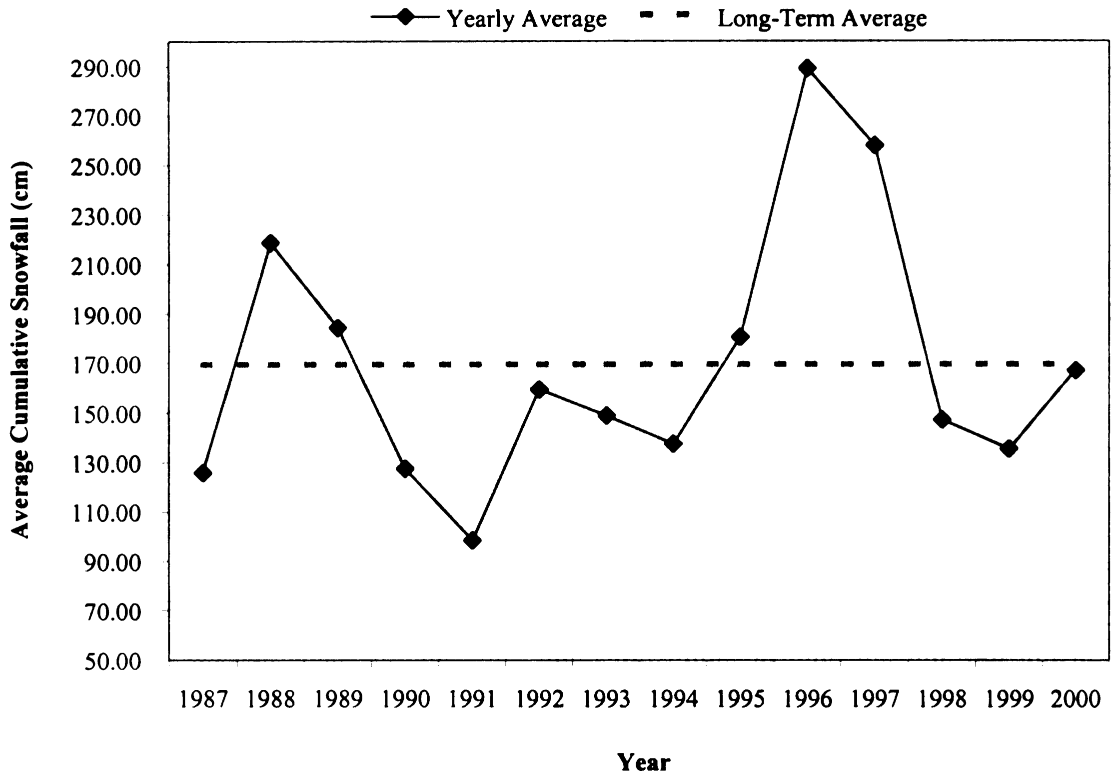

Figure 2.10. The temporal trend in the average cumulative snowfall (summed from January through April) in cm for the Upper Peninsula study site between 1987 and 2000.

average cumulative total monthly snowfall was above the regional average, the snowfall was within 30cm above the regional average; however, in 1996 and 1997, the snowfall exceeded the regional average by almost 100cm (Figure 2.10).

The more northern counties in this study site, Baraga and Marquette, had the highest amount of snowfall ($\bar{x}$ = 297.8cm and $\bar{x}$ = 187.34cm, respectively), whereas the more southern counties in this study site, Iron and Dickinson Counties, had the lowest amount of snowfall ($\bar{x}$ = 94.69cm and $\bar{x}$ = 99.10cm, respectively) (Figure 2.11). The snowfall in Iron and Dickinson Counties, the 2 counties with the lowest overall amount of snowfall, was similar. However, the snowfall in Marquette and Baraga Counties, the 2 counties with the highest overall amount of snowfall, was not; the snowfall in Baraga County exceeded the snowfall in Marquette County by over 110cm (Table 2.3; Figure 2.11).

The overall corrected average WSI for the UP study site was 82.69 and the yearly average WSI ranged between 55.33 in 1997 and 116.35 in 1995 (Table 2.4). For the majority of years in this study, the corrected average WSI was below the long-term regional average (Figure 2.12). Of the years with a below average WSI, most had a WSI that was approximately 15 WSI points below the regional average. The exceptions were in 1986 and 1997 in which the WSI was over 20 points below the long-term average for the study site (Table 2.4; Figure 2.12). Of the years with an above average WSI, most had a WSI that was within approximately 20 points of the long-term average WSI (Figure 2.12). In 1995 and 1996, however, the WSI exceeded the regional WSI by 24 (Table 2.4; Figure 2.12).

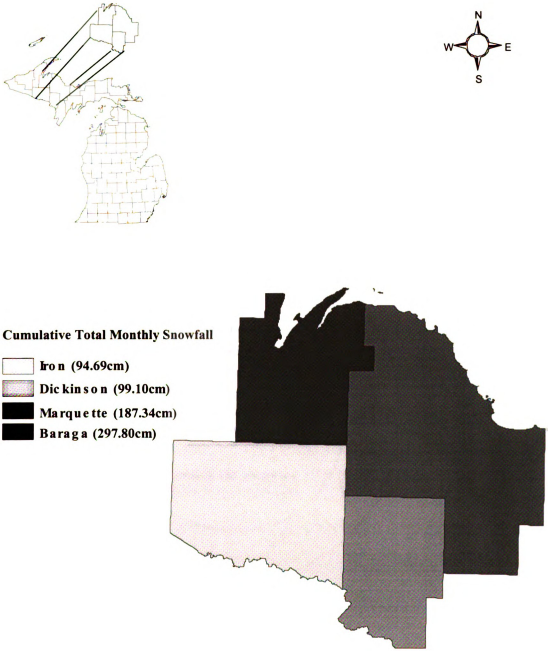

Figure 2.11. Cumulative total monthly snowfall (summed from January through April) in cm by county in the Upper Peninsula study site from 1987 through 2000.

Table 2.4. The mean corrected Winter Severity Index for each year between 1986 and 1999 in the Upper Peninsula study site.

Year	Mean WSI
1986	59.85
1987	96.47
1988	100.08
1989	89.14
1990	71.57
1991	76.79
1992	77.68
1993	86.92
1994	68.62
1995	116.35
1996	104.45
1997	55.33
1998	73.48
1999	73.84

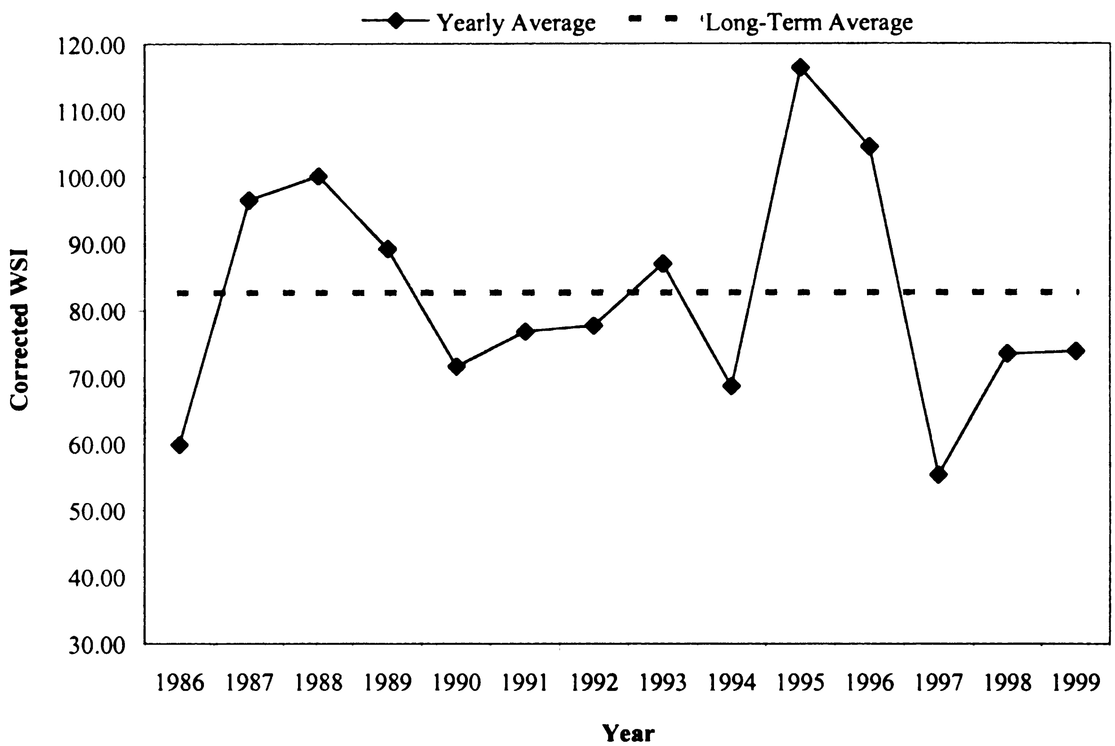

Figure 2.12. The temporal trend in the corrected WSI for the Upper Peninsula study site between 1987 and 2000.

The results of the ANOVA model run to examine the relationship between male yearling average beam diameter and each underlying mechanism that has the potential to influence this index as a measure of herd quality indicated that in the UP study site both the year ($F_{13, 23} = 2.17$; $P = 0.05$) and snowfall ($F_{1, 23} = 4.85$; $P = 0.04$) variables were statistically significant; there were no statistically significant interactions. When this ANOVA model was run by county in the UP study site it was clear that weather was having an impact on male yearling average beam diameter. In each of Dickinson, Iron, and Marquette Counties, both the temperature and WSI variables were statistically significant (Table 2.5). In addition, the snowfall variable was statistically significant in Iron County (Table 2.5).

The results of the ANOVA analysis to determine which underlying mechanisms have the potential to influence yearling point count as a measure of deer herd quality in the UP study site were statistically significant and indicated that the year ($F_{13, 23} = 3.29$; $P = 0.006$) and snowfall ($F_{1, 23} = 3.09$; P-value = 0.09) variables were significant; however, there were no statistically significant interactions. When the ANOVA model was run by county, it was apparent that a mixture of weather and density was impacting male yearling point count as an index of herd quality. In Dickinson and Iron Counties, deer density was a statistically significant variable and in Dickinson, Iron, and Marquette Counties, the temperature variable was statistically significant (Table 2.6). Snowfall and WSI were also statistically significant variables in Baraga County (Table 2.6).

NLP

Based on the sex-age-kill estimate method, the number of deer in the NLP study site ranged between 19,897 in 1999 and 48,561 in 1991; while the long-term regional

Table 2.5. Results of the ANOVA model run by county in the Upper Peninsula study site to determine which underlying mechanisms that have the potential to influence male yearling average beam diameter as a measure of deer herd quality in Michigan were significant at an alpha level of 0.10.

Mechanism	Baraga	Dickinson	Iron	Marquette
Density	X	X	X	X
Temperature	X	0.03	0.07	0.001
Snowfall	X	X	0.02	X
WSI	X	0.08	0.02	0.01

Table 2.6. Results of the ANOVA model run by county in the Upper Peninsula study site to determine which underlying mechanisms that have the potential to influence male yearling point count as a measure of deer herd quality in Michigan were significant at an alpha level of 0.10.

Mechanism	**Baraga**	**Dickinson**	**Iron**	**Marquette**
Density	X	0.04	0.03	X
Temperature	X	0.07	0.03	0.03
Snowfall	0.07	X	X	X
WSI	0.03	X	X	X

average number of deer in the NLP study site was estimated to be 30,843 (Table 2.7). The temporal trend in the average number of deer in the NLP study site illustrated that in 9 out of the 14 years of this study, the number of deer was at or below the long-term average for the study site (Figure 2.13). For most of these years, the number of deer was within 5,000 deer of the average, although, the number of deer never exceeded 10,000 deer below the average for the study site (Table 2.7; Figure 2.13). In the years that the number of deer was above the long-term average for the NLP study site, it was within 5,000 deer for each of those years except in 1991 when the average was exceeded by approximately 20,000 deer (Table 2.7; Figure 2.13).

The counties along the coast, Alcona, Alpena, and Presque Isle Counties, had the highest deer numbers ($\bar{x}$ = 39,278, $\bar{x}$ = 33,869, and $\bar{x}$ = 29,701, respectively), whereas inland counties, Montmorency and Oscoda Counties, had lower deer numbers ($\bar{x}$ = 26,539 and $\bar{x}$ = 25,034, respectively) (Figure 2.14). Alcona and Alpena Counties had the highest number of deer, as well as the highest deer densities in the NLP study site at 22 deer/km^2 (58 deer/mi^2) and 23 deer/km^2 (59 deer/mi^2), respectively. Montmorency County, however, had a lower number of deer, but a higher deer density at 19 deer/km^2 (49 deer/mi^2). Oscoda County had the lowest number of deer and the lowest deer density in the NLP study site at 17 deer/km^2 (44 deer/mi^2); the deer density in Presque Isle County was similar to that in Oscoda County at 17 deer/km^2 (45 deer/mi^2). Although were differences in deer densities among the counties in the NLP study site, the difference between the county with the lowest deer density and the county with the highest deer density was only approximately 6 deer/km^2 (15 deer/mi^2).

Table 2.7. The total number of deer, as estimated from the sex-age-kill estimate method, in each county in the Northern Lower Peninsula study site between 1987 and 2000; the yearly average total number of deer and the standard deviation for the entire study site, and the average total number of deer for each county.

	Alcona	Alpena	Montmorency	Oscoda	Presque Isle	Yearly Average	StDev
1987	29579	46888	21212	15628	36607	29983	12378
1988	38996	28581	27046	21752	27311	28737	6304
1989	53534	35584	30022	24348	29042	34506	11362
1990	52123	38918	31512	36102	20237	35779	11585
1991	61735	44072	49950	44422	42625	48561	7874
1992	29248	54854	25696	14383	55317	35900	18355
1993	43809	22593	30134	24368	32954	30772	8412
1994	26182	24432	n/a	27902	16151	23667	5207
1995	46763	41768	13768	35386	22981	32133	13588
1996	36841	31939	24683	20602	39610	30735	8013
1997	41754	34917	23665	26752	27318	30881	7354
1998	39274	27953	22959	23619	26284	28018	6608
1999	19994	20653	21136	15133	22572	19897	2827
2000	30055	21008	23226	20075	16803	22233	4945
Total	39278	33869	26539	25034	29701	30843	5785

*n/a denotes that the data were unavailable

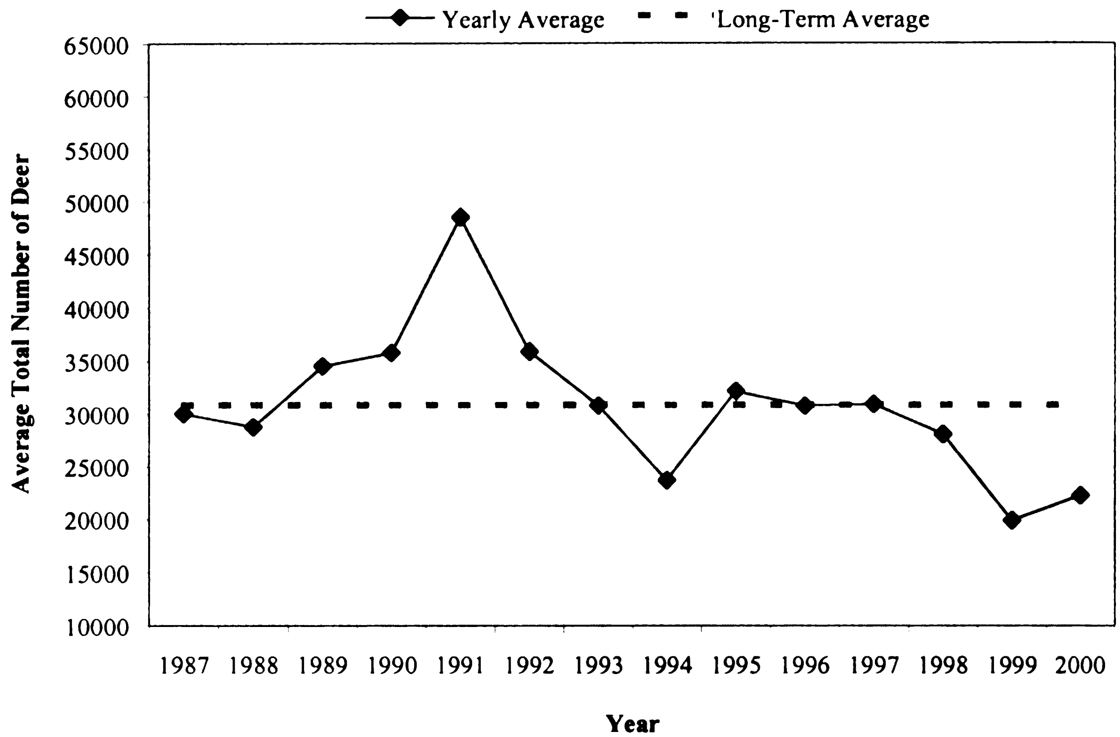

Figure 2.13. The temporal trend in the average total number of deer, as estimated by the sex-age-kill estimate method, for the Northern Lower Peninsula study site between 1987 and 2000.

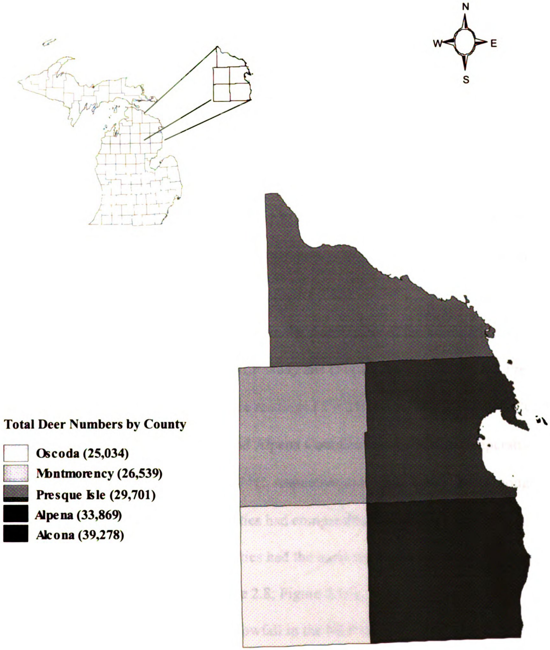

Figure 2.14. The average number of deer by county in the Northern Lower Peninsula study site from 1987 through 2000.

The overall cumulative mean monthly temperature in the NLP study site was 208.72 °C and ranged between 169.88 °C in 1988 and 232.17 °C in 1998 (Table 2.8). In the majority of years in this study, the yearly average cumulative mean monthly temperature was at or below the long-term average for the NLP study site (Figure 2.15). For most of these years, the average cumulative mean monthly temperature was within 5 °C of the long-term regional average, except in 1987 and 1988 when it exceeded the study site average by 30 °C to 40 °C (Table 2.8; Figure 2.15). Of those years in which the average cumulative mean monthly temperature was above the long-term regional average, it was still within 25 °C (Table 2.8; Figure 2.15).

There was no distinct spatial pattern in the distribution of the cumulative mean monthly temperature by county in the NLP study site (Figure 2.16). Oscoda and Presque Isle Counties had the highest temperature readings ($\bar{x}$ = 216.50 °C and $\bar{x}$ = 223.75 °C, respectively), whereas Montmorency and Alpena Counties had the lowest temperature readings ($\bar{x}$ = 180.45 °C and $\bar{x}$ = 214.17 °C, respectively) (Figure 2.16). Even though Alpena, Oscoda, and Presque Isle Counties had comparable cumulative mean monthly temperatures, Alpena and Oscoda Counties had the most similar temperature readings of the counties in the NLP study site (Table 2.8; Figure 2.16).

The cumulative total monthly snowfall in the NLP study site ranged between 68.26cm in 2000 and 236.98cm in 1997 while the overall cumulative total monthly snowfall for the NLP study site was 110.67cm (Table 2.9). In almost every year, the snowfall was within ± 20cm of the long-term NLP study site average, except in 1987, 1999, and 2000 when the cumulative total monthly snowfall exceeded 25cm below the

Table 2.8. The cumulative mean monthly temperature (summed from January through September) in °C for each county in the Northern Lower Peninsula study site from 1987 to 2000; the yearly average cumulative mean monthly temperature and the standard deviation (StDev) for the entire study site, and the average cumulative mean monthly temperature for each county.

	Alcona	Alpena	Montmorency	Oscoda	Presque Isle	Yearly Average	StDev
1987	n/a	226.44	44.50	231.67	237.33	184.98	93.76
1988	n/a	216.50	18.72	218.78	225.50	169.88	100.84
1989	n/a	209.89	187.61	210.39	220.72	207.15	13.95
1990	n/a	219.11	200.06	222.28	230.50	217.99	12.88
1991	n/a	224.94	220.33	226.39	233.50	226.29	5.46
1992	n/a	205.11	203.67	194.06	214.33	204.29	8.30
1993	n/a	206.78	202.28	209.89	216.78	208.93	6.09
1994	n/a	204.00	202.39	204.94	208.61	204.99	2.64
1995	n/a	216.50	183.22	218.94	222.67	210.33	18.25
1996	n/a	201.94	194.72	204.33	210.28	202.82	6.44
1997	n/a	204.11	201.83	207.61	212.83	206.60	4.79
1998	n/a	227.72	227.44	235.78	237.72	232.17	5.35
1999	n/a	218.89	224.22	223.94	230.94	224.50	4.95
2000	n/a	216.44	215.33	221.94	230.78	221.12	7.05
Total	n/a	214.17	180.45	216.50	223.75	208.72	19.28

*n/a denotes that the data were not available

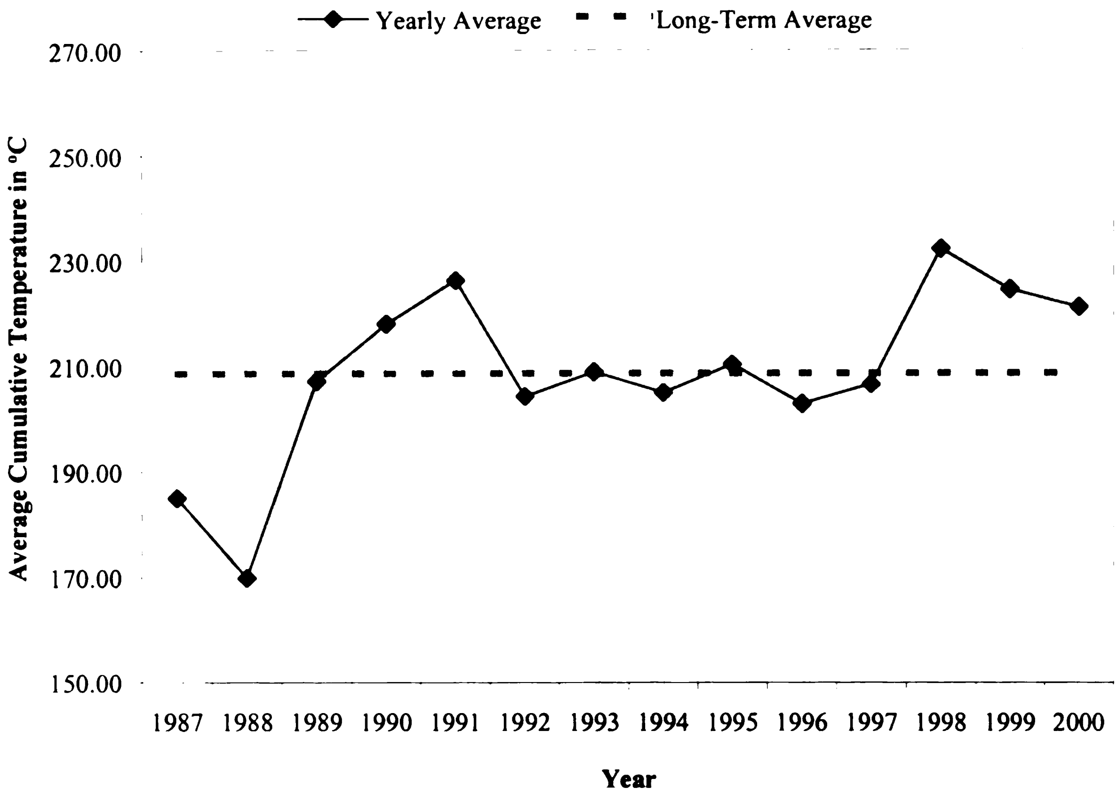

Figure 2.15. The temporal trend in the average cumulative temperature (summed from January through September) in °C for the Northern Lower Peninsula study site between 1987 and 2000.

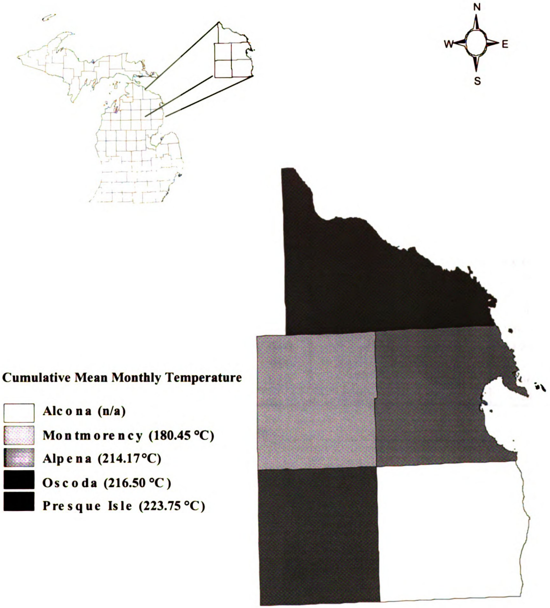

Figure 2.16. Cumulative mean monthly temperature (summed from January through September) in °C by county in the Northern Lower Peninsula study site from 1987 through 2000.

Table 2.9. The cumulative total monthly snowfall (summed from January through April) in cm for each county in the Northern Lower Peninsula study site from 1987 to 2000; the yearly average cumulative total monthly snowfall and the standard deviation (StDev) for the entire study site, and the average cumulative total monthly snowfall for each county.

	Alcona	Alpena	Montmorency	Oscoda	Presque Isle	Yearly Average	StDev
1987	n/a	103.89	35.56	68.58	119.63	81.92	37.56
1988	n/a	160.02	49.53	63.50	207.77	120.21	76.30
1989	n/a	171.45	48.26	91.44	207.77	129.73	72.88
1990	n/a	138.43	139.70	5.08	185.67	117.22	77.92
1991	n/a	96.77	90.17	46.48	158.75	98.04	46.21
1992	n/a	141.73	161.29	2.54	162.56	117.03	76.92
1993	n/a	142.24	148.59	0.00	85.09	93.98	68.85
1994	n/a	199.39	153.67	0.00	115.57	117.16	85.29
1995	n/a	122.43	84.58	5.08	164.34	94.11	67.70
1996	n/a	134.87	163.07	1.78	76.71	94.11	71.29
1997	n/a	n/a	540.24	0.00	170.69	236.98	276.16
1998	n/a	n/a	173.99	0.00	152.40	108.80	94.84
1999	n/a	n/a	133.10	0.00	82.30	71.80	67.17
2000	n/a	93.98	105.41	0.00	73.66	68.26	47.36
Total	n/a	136.84	144.80	20.32	140.21	110.67	60.24

*n/a denotes that the data were not available

long-term average and in 1997 when the cumulative total monthly snowfall exceeded 120cm above the long-term average (Table 2.9; Figure 2.17).

The northern counties in the NLP study site had a higher amount of snowfall (Figure 2.18). Alpena, Presque Isle, and Montmorency Counties had the highest cumulative total monthly snowfall ($\bar{x}$ = 136.84cm, $\bar{x}$ = 140.21cm, and $\bar{x}$ = 144.80cm, respectively), whereas Oscoda County had the lowest cumulative total monthly snowfall ($\bar{x}$ = 20.32cm) (Table 2.9; Figure 2.18). In addition, the difference among the snowfall in Alpena, Presque Isle, and Montmorency Counties was very slight; the amount of snowfall among the 3 counties was within 8cm (Table 2.9; Figure 2.18). Conversely, the amount of snowfall in Oscoda County was very different than the snowfall in each of the other 3 counties in the NLP study site for which temperature data were available (Table 2.9; Figure 2.18).

The overall corrected average WSI for the NLP study site was 56.85 and ranged between 35.20 in 1997 and 78.41 in 1993 (Table 2.10). For the majority of years in this study, the yearly average corrected WSI was below the NLP study site average (Figure 2.19). In the years that the corrected average WSI was below the long-term regional average, most had a corrected average WSI that was approximately 5 to 10 points below the long-term average; however, in 1986 and 1997 the corrected average WSI was over 20 points below the long-term regional average (Table 2.10; Figure 2.19). Conversely, in the years in which the corrected average WSI was above the long-term average, most had a corrected average WSI that was approximately 15 points above the long-term average, except in 1993 when the corrected average WSI exceeded 20 point above the study site average (Table 2.10; Figure 2.19).

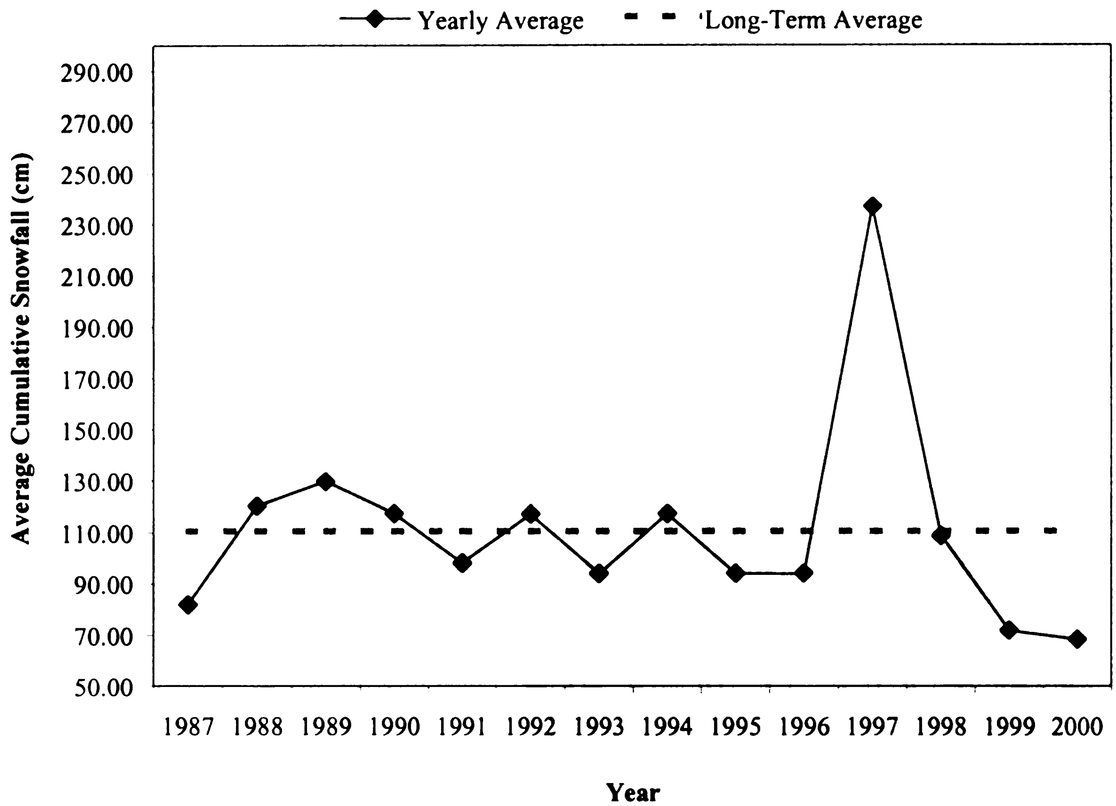

Figure 2.17. The temporal trend in the average cumulative snowfall (summed from January through April) in cm for the Northern Lower Peninsula study site between 1987 and 2000.

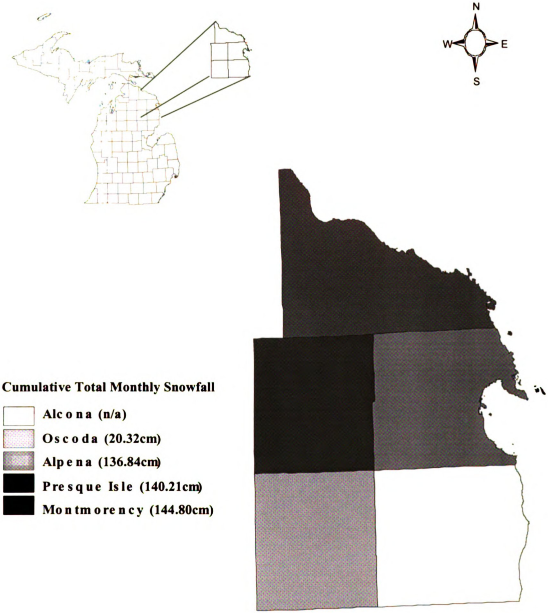

Figure 2.18. Cumulative total monthly snowfall (summed from January through April) in cm by county in the Northern Lower Peninsula study site from 1987 through 2000.

Table 2.10. The mean corrected Winter Severity Index for each year between 1986 and 1999 in the Northern Lower Peninsula study site.

Year	Mean WSI
1986	39.20
1987	49.18
1988	63.51
1989	60.45
1990	54.99
1991	53.03
1992	55.28
1993	78.41
1994	51.94
1995	69.52
1996	67.21
1997	35.20
1998	51.19
1999	42.73

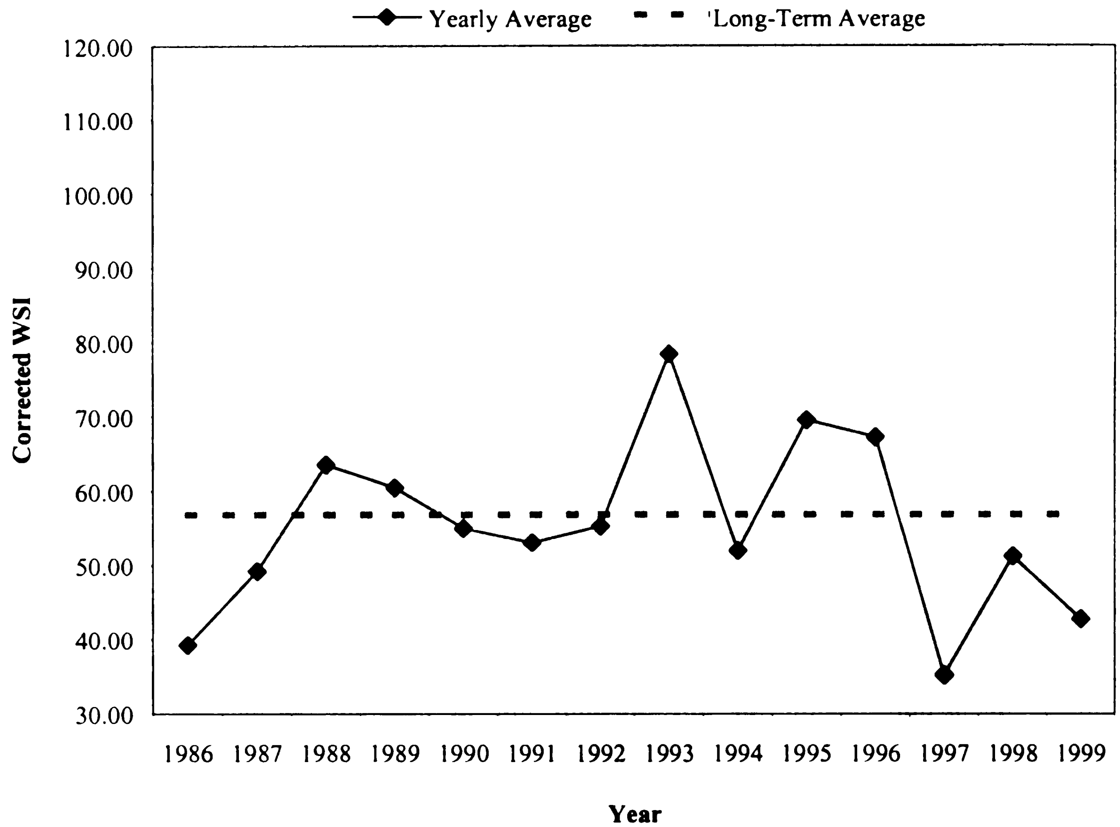

Figure 2.19. The temporal trend in the corrected WSI for the Northern Lower Peninsula study site between 1987 and 2000.

According to Felix (unpublished data) the habitat potential for the fall and winter food requirement was similar among the 5 counties in the NLP study site (Table 2.11). While there was a small range in the fall and winter food potential for the counties in the NLP study site, in general, the southern-most counties, Oscoda and Alcona Counties, and the western-most county, Montmorency, had the highest fall and winter food potential, whereas Alpena and Presque Isle Counties had the lowest (Table 2.11). The habitat potential for the spring and summer food requirement was also similar among the 5 counties in the NLP study site (Table 2.11). There, however, did not appear to be a distinct spatial pattern to the distribution of this habitat potential. Alcona County had the highest spring and summer food potential, followed by Presque Isle, Montmorency, Alpena, and Oscoda Counties, respectively (Table 2.11). There was a greater range in the thermal cover potential among the 5 counties in the NLP study site and, for the most part, the counties along the coast had a higher thermal cover potential (Table 2.11). Alpena and Presque Isle Counties had the highest thermal cover potential and Oscoda County had the lowest, while the thermal cover potential in Alcona and Montmorency Counties fell in between (Table 2.11).

The results from the ANOVA model run to examine the relationship between male yearling average beam diameter and each underlying mechanism that has the potential to influence this index as a measure of herd quality in the NLP study site showed that year ($F_{13, 34} = 2.90$; $P = 0.006$) and county ($F_{4, 24} = 6.22$; $P = 0.0007$) were statistically significant; there were no statistically significant interactions. When the ANOVA model was run by county, it showed that both density and weather were influencing male yearling average beam diameter as a measure of herd quality. In

Table 2.11. The potential of the fall and winter food, spring and summer food, and thermal cover to provide suitable habitat for white-tailed deer in each county in the Northern Lower Peninsula study site (0 is the lowest suitability and 1 is the highest suitability) according to Felix (unpublished data).

	F&W	S&S	Therm
Alcona	0.659	0.628	0.182
Alpena	0.596	0.536	0.551
Montmorency	0.629	0.558	0.17
Oscoda	0.676	0.512	0.033
Presque Isle	0.581	0.566	0.39

Alpena and Presque Isle Counties, both the temperature and WSI variables were statistically significant, and in Oscoda County the density variable was statistically significant (Table 2.12).

The results from the regression analyses run with the habitat potential value for each of the 3 habitat requirements illustrated that the habitat potential for fall and winter food, spring and summer food, and thermal cover had different affects on male yearling average beam diameter. The fall and winter food potential was significantly negatively correlated with male yearling average beam diameter, whereas the thermal cover potential was significantly positively correlated with male yearling average beam diameter (Table 2.13). There was, however, no relationship between spring and summer food potential and male yearling average beam diameter (Table 2.13).

The results of the ANOVA analysis to determine the relationship between each underlying mechanism that has the potential to influence male yearling point count and this index as a measure of herd quality in the NLP study site showed that both the year ($F_{13, 34} = 1.84$; $P = 0.08$) and county ($F_{4, 34} = 6.51$; $P = 0.0005$) variables were statistically significant; there were no statistically significant interactions. When the ANOVA model was run by county, it was apparent that density and weather were influencing male yearling point count as a measure of herd quality. In Montmorency and Presque Isle Counties, the density variable was statistically significant, and in Alpena County, both the temperature and WSI variable were statistically significant (Table 2.14).

The results from the regression analyses run with the habitat potential value for each of the 3 habitat requirements illustrated that the habitat potential for fall and winter food, spring and summer food, and thermal cover had different affects on male yearling

Table 2.12. Results of the ANOVA model run by county in the Northern Lower Peninsula study site to determine which underlying mechanisms that have the potential to influence male yearling average beam diameter as a measure of deer herd quality in Michigan were significant at an alpha level of 0.10.

Mechanism	Alcona	Alpena	Montmorency	Oscoda	Presque Isle
Density	X	X	X	0.04	X
Temperature	X	0.1	X	X	0.03
Snowfall	X	X	X	X	X
WSI	X	0.04	X	X	0.08

Table 2.13. Results of the regression analyses conducted to determine the relationship between each habitat requirement and male yearling average beam diameter in the Northern Lower Peninsula study site at an alpha level of 0.10.

Habitat Potential	β_0	β_1	P-Value	R^2
Fall & Winter	24.49	-11.48	0.05	0.79
Spring & Summer	16.17	1.98	0.79	0.03
Thermal Cover	16.62	2.51	0.003	0.96

Table 2.14. Results of the ANOVA model run by county in the Northern Lower Peninsula study site to determine which underlying mechanisms that have the potential to influence male yearling point count as a measure of deer herd quality in Michigan were significant at an alpha level of 0.10.

Mechanism	Alcona	Alpena	Montmorency	Oscoda	Presque Isle
Density	X	X	0.04	X	0.03
Temperature	X	0.09	X	X	X
Snowfall	X	X	X	X	X
WSI	X	0.04	X	X	X

point count. The fall and winter food potential as well as the spring and summer food potential were not correlated with male yearling point count, whereas the thermal cover potential was significantly positively correlated with male yearling point count (Table 2.15).

SLP

Based on the sex-age-kill estimate method, the overall number of deer for the SLP study site was 25,745 and the yearly average number of deer for this study site ranged between a minimum of 16,080 in 1990 and a maximum of 41,424 in 1998 (Table 2.16). The temporal trend in the yearly average number of deer in the SLP study site showed that, in general, the average number of deer for each year between 1987 and 1997 was at or below the average number of deer for the study site, except 1988 in which the average number of deer was slightly above the long-term study site average (Table 2.16; Figure 2.20). In 1998 there was a sharp increase in the average number of deer for the SLP study site and, although, there was a slight decline in the average number of deer for 1999 and 2000, the density of deer was still at least 10,000 deer above the long-term average (Table 2.16; Figure 2.20).

Calhoun County, the southern-most county in the study site, and Barry County, the western-most county in the study site, had the highest overall numbers of deer ($\bar{x}$ = 27,970 and $\bar{x}$ = 25,392, respectively) (Figure 2.21). Eaton County, the eastern-most county in the study site, had the lowest overall number of deer of the 3 counties in the SLP study site ($\bar{x}$ = 23,978) (Figure 2.21). Calhoun County, which had the highest number of deer in the SLP study site, had the lowest density of deer at 15 deer/km^2 (40 deer/mi^2). Eaton County, however, had the smallest number of deer in the SLP study

Table 2.15. Results of the regression analyses conducted to determine the relationship between each habitat requirement and male yearling point count in the Northern Lower Peninsula study site at an alpha level of 0.10.

Habitat Potential	β_0	β_1	P-Value	R^2
Fall & Winter	5.29	-3.41	0.17	0.52
Spring & Summer	1.99	2.07	0.42	0.22
Thermal Cover	2.94	0.80	0.06	0.74

Table 2.16. The total number of deer, as estimated from the sex-age-kill estimate method, in each county in the Southern Lower Peninsula study site between 1987 and 2000; the yearly average total number of deer and the standard deviation for the entire study site, and the average total number of deer for each county.

	Barry	Calhoun	Eaton	Average	StDev
1987	28592	18563	16876	21344	6334
1988	24997	21453	34839	27096	6936
1989	29803	20484	14325	21538	7792
1990	17948	20030	10262	16080	5145
1991	15693	27449	18210	20451	6190
1992	22554	22433	n/a	22494	86
1993	14256	38015	13693	21988	13883
1994	18894	22848	20462	20735	1991
1995	33700	24907	16431	25013	8635
1996	23033	26237	24110	24460	1631
1997	22362	31134	24618	26038	4555
1998	32862	35260	56150	41424	12809
1999	37461	41145	29921	36176	5722
2000	33335	41617	31815	35589	5276
Total	25392	27970	23978	25745	2024

*n/a denotes that the data were unavailable

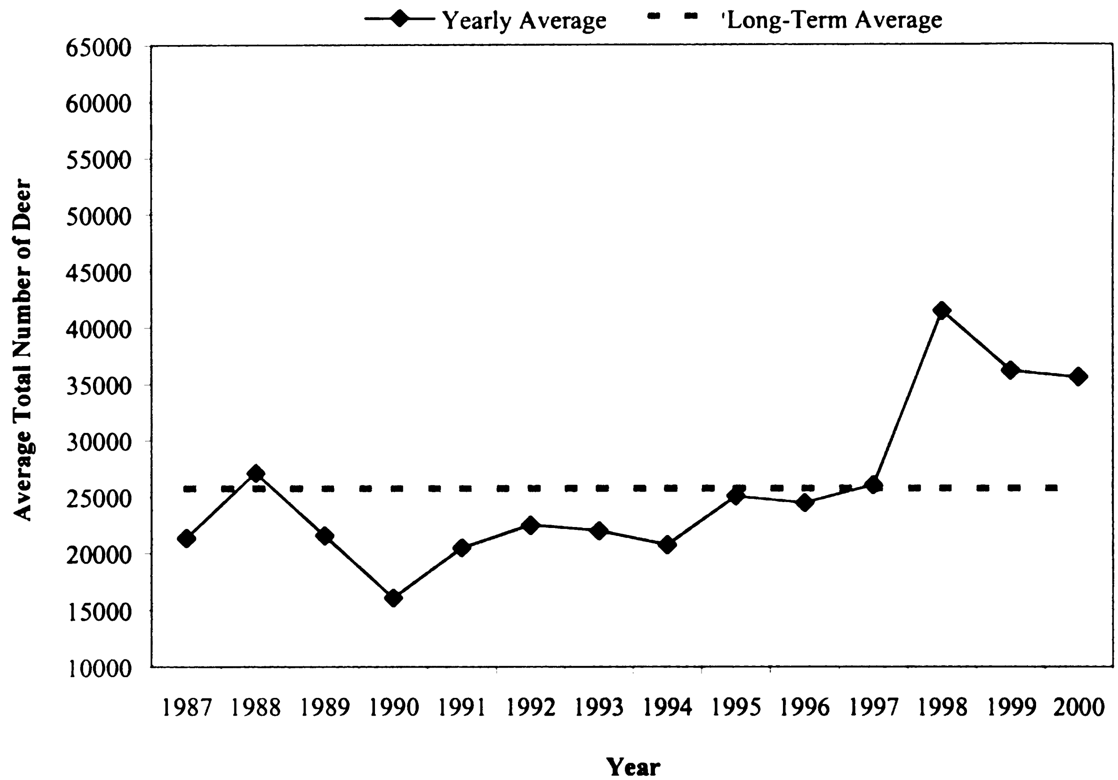

Figure 2.20. The temporal trend in the average total number of deer, as estimated by the sex-age-kill estimate method, for the Southern Lower Peninsula study site between 1987 and 2000.

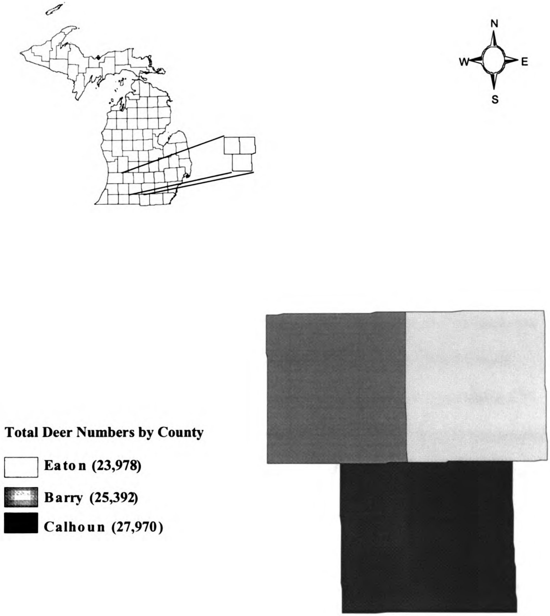

Figure 2.21. The average total number of deer by county in the Southern Lower Peninsula study site from 1987 through 2000.

site, but had a slightly higher deer density than Calhoun County at 16 deer/km^2 (42 deer/mi^2). Barry County had the highest deer density of the 3 counties in this study site at 18 deer/km^2 (46 deer/mi^2). While there were differences in deer densities among the 3 counties in the SLP study site, the difference, however, was only approximately 3 deer/km^2 (6 deer/mi^2).

The cumulative mean monthly temperature in the SLP study site ranged between a minimum of 204.26 °C in 1999 and a maximum of 252.43 °C in 1998, with an overall cumulative mean monthly temperature of 231.54 °C (Table 2.17). In general, the temporal trend in the yearly average cumulative mean monthly temperature oscillated around the long-term average cumulative mean monthly temperature for the study site (Figure 2.22). In 9 out of the 14 years of this study, the average cumulative mean monthly temperature was below the long-term study site average, but was within 5 °C, with the exception of 1999 in which the average cumulative mean monthly temperature was 25 °C below the long-term average (Table 2.17; Figure 2.22). For those years in which the average cumulative mean monthly temperature was above the long-term average, it was within approximately 20 °C (Table 2.17; Figure 2.22).

The western-most county, Barry County, and the southern-most county, Calhoun County, had the highest temperature readings ($\bar{x}$ = 235.69 °C and $\bar{x}$ = 232.66 °C, respectively) (Figure 2.23). Eaton County, the eastern-most county in the SLP study site, had the lowest cumulative mean monthly temperature of the 3 counties in the study site ($\bar{x}$ = 226.26 °C) (Figure 2.23).

The overall cumulative total monthly snowfall for the SLP study site was 81.17cm; the minimum was 52.83cm in 1991 and the maximum was128.10cm in 1999

Table 2.17. The cumulative mean monthly temperature (summed from January through September in °C for each county in the Southern Lower Peninsula study site from 1987 to 2000; the yearly average cumulative mean monthly temperature and the standard deviation (StDev) for the entire study site, and the average cumulative mean monthly temperature for each county.

	Barry	**Calhoun**	**Eaton**	**Average**	**StDev**
1987	249.89	255.00	241.61	248.83	6.76
1988	238.89	239.83	200.94	226.56	22.18
1989	228.44	232.78	225.28	228.83	3.77
1990	238.50	242.61	235.56	238.89	3.54
1991	244.67	245.11	240.94	243.57	2.29
1992	227.22	231.06	224.06	227.44	3.51
1993	227.22	228.50	223.11	226.28	2.82
1994	224.22	232.11	220.56	225.63	5.90
1995	235.67	243.22	231.44	236.78	5.97
1996	224.44	231.67	220.61	225.57	5.61
1997	226.44	230.00	222.67	226.37	3.67
1998	251.83	256.89	248.56	252.43	4.20
1999	241.11	175.56	196.11	204.26	33.53
2000	241.17	212.89	236.22	230.09	15.10
Total	235.69	232.66	226.26	231.54	4.82

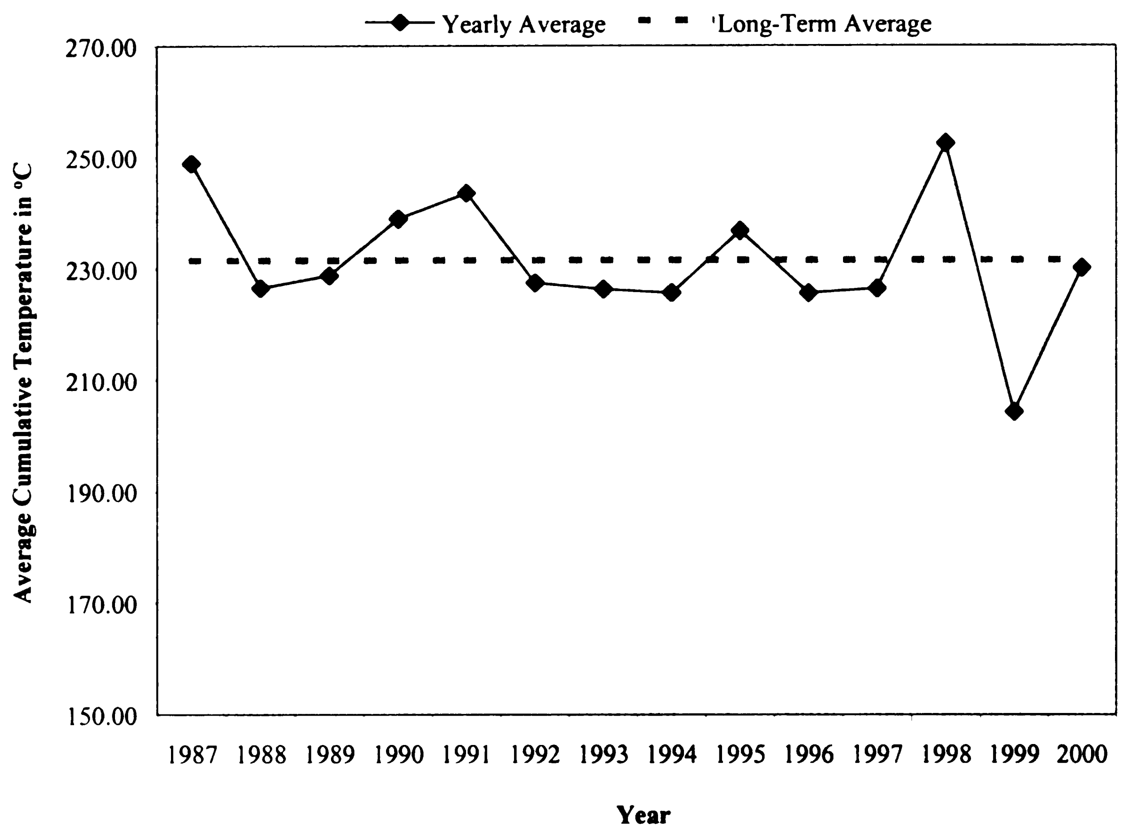

Figure 2.22. The temporal trend in the average cumulative temperature (summed from January through September) in °C for the Southern Lower Peninsula study site between 1987 and 2000.

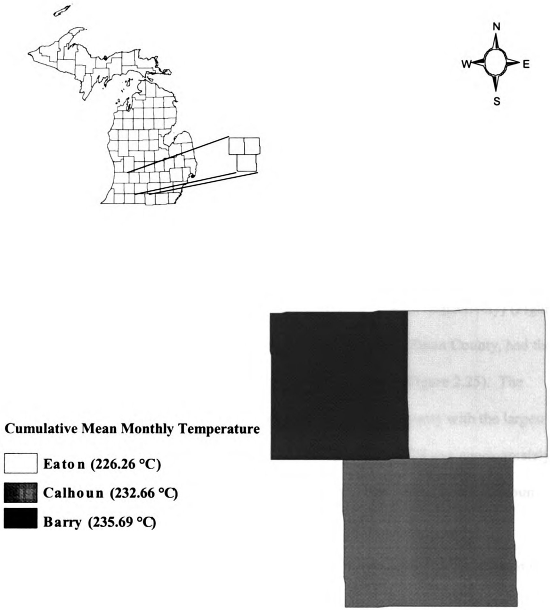

Figure 2.23. Cumulative mean monthly temperature (summed from January through September) in °C by county in the Southern Lower Peninsula study site from 1987 through 2000.

(Table 2.18). From 1987 through 1992, the yearly average cumulative total monthly snowfall was approximately 5cm to 20cm below the long-term average for the study site (Figure 2.24). After that time period, the temporal trend in the yearly average cumulative total monthly snowfall more or less oscillated around the long-term average (Figure 2.24). There were peaks in snowfall in 1993, 1997, and 1999, some of which were more than 50cm above the study site average, whereas the lows in the yearly average cumulative total monthly snowfall never exceeded a 30cm difference (Table 2.18; Figure 2.24).

The western and southern-most counties, Barry and Calhoun Counties, had the highest overall amount of snowfall ($\bar{x}$ = 99.71cm and $\bar{x}$ = 77.34cm, respectively) (Figure 2.25). Conversely, the eastern-most county in the SLP study site, Eaton County, had the lowest overall cumulative total monthly snowfall ($\bar{x}$ = 66.44cm) (Figure 2.25). The difference in the cumulative total monthly snowfall between the county with the largest amount of snowfall and the county with the least amount of snowfall was approximately 33cm. However, the overall cumulative total monthly snowfall in Eaton and Calhoun Counties was within approximately 11cm (Table 2.18; Figure 2.25).

The corrected average WSI for the SLP study site ranged between a minimum of 33.05 in 1997 and a maximum of 69.49 in 1993, with an the overall corrected average WSI for this study site of 47.03 (Table 2.19). The temporal trend in the corrected average WSI showed that, in general, the yearly corrected average WSI was within ± 10 points of the long-term study site average, except in 1993, 1995 and 1997 (Figure 2.26). In those years in which the yearly corrected average WSI exceeded 10 points of the long-term, it was within ± 25 points (Table 2.19; Figure 2.26).

Table 2.18. The cumulative total monthly snowfall (summed from January through April) in cm for each county in the Southern Lower Peninsula study site from 1987 to 2000; the yearly average cumulative total monthly snowfall and the standard deviation (StDev) for the entire study site, and the average cumulative total monthly snowfall for each county.

	Barry	Calhoun	Eaton	Yearly Average	StDev
1987	33.53	75.44	54.61	54.53	20.96
1988	73.91	74.17	73.66	73.91	0.25
1989	88.65	78.99	57.15	74.93	16.14
1990	93.47	55.88	74.17	74.51	18.80
1991	71.63	49.28	37.59	52.83	17.29
1992	85.09	68.33	53.34	68.92	15.88
1993	119.63	120.14	82.55	107.44	21.56
1994	121.67	97.79	61.47	93.64	30.31
1995	123.19	64.26	59.69	82.38	35.42
1996	84.33	62.48	53.34	66.72	15.92
1997	179.32	97.79	94.49	123.87	48.06
1998	78.23	38.61	50.80	55.88	20.29
1999	155.19	107.70	121.41	128.10	24.45
2000	88.14	91.95	55.88	78.66	19.82
Total	99.71	77.34	66.44	81.17	16.96

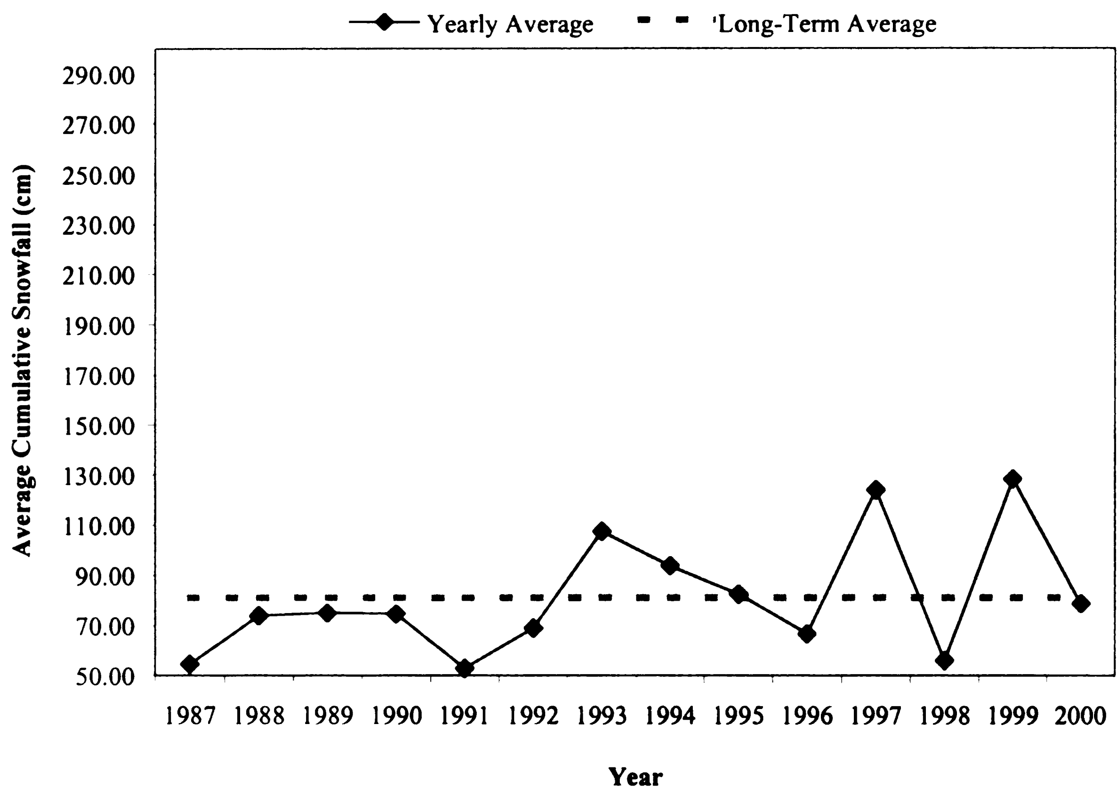

Figure 2.24. The temporal trend in the average cumulative snowfall (summed from January through April) in cm for the Southern Lower Peninsula study site between 1987 and 2000.

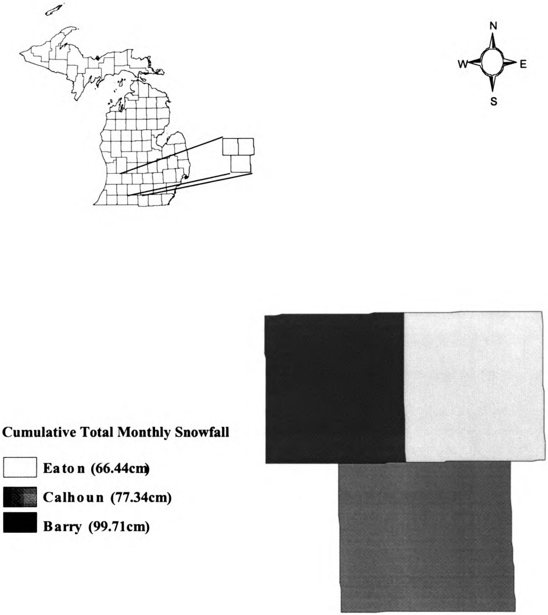

Figure 2.25. Cumulative total monthly snowfall (summed from January through April) in cm by county in the Southern Lower Peninsula study site from 1987 through 2000.

Table 2.19. The mean corrected Winter Severity Index for each year between 1986 and 1999 in the Southern Lower Peninsula study site.

Year	Mean WSI
1986	n/a
1987	n/a
1988	42.16
1989	49.17
1990	41.68
1991	41.37
1992	49.91
1993	69.49
1994	45.88
1995	57.71
1996	n/a
1997	33.05
1998	47.41
1999	45.18

*n/a denotes that the data were not available

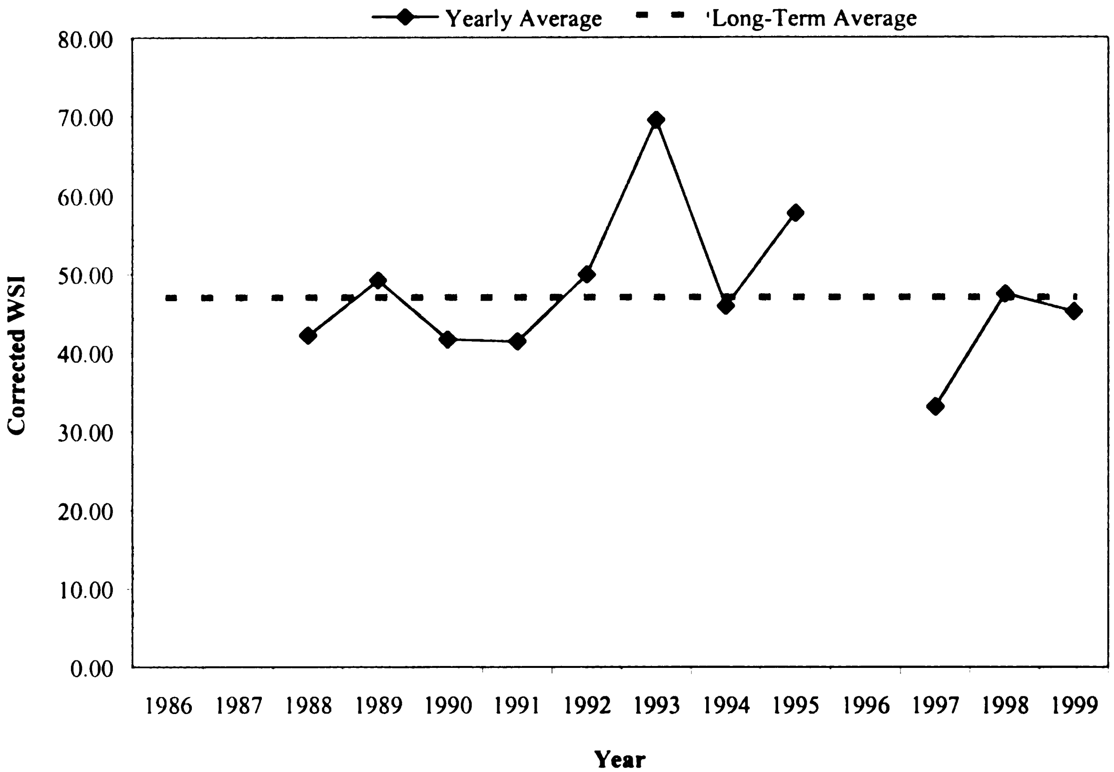

Figure 2.26. The temporal trend in the corrected WSI for the Southern Lower Peninsula study site between 1987 and 2000.

The results of the ANOVA analysis to examine the relationship between the underlying mechanisms that have the potential to influence male yearling average beam diameter and this index as a measure of herd quality in the SLP study site revealed that the county ($F_{2, 22} = 1.75$; $P = 0.06$) and density ($F_{1, 22} = 4.05$; $P = 0.06$) variables were statistically significant; there were no significant interactions. When the ANOVA model was run by county, it was apparent that there was a mixture of factors influencing male yearling average beam diameter; in each county a different factor was statistically significant. In Barry County, the snowfall variable was statistically significant, whereas in Calhoun County the WSI variable was statistically significant (Table 2.20). The density variable was statistically significant in Eaton County (Table 2.20).

The results of the ANOVA analysis to determine the relationship between each underlying mechanism that has the potential to influence male yearling point count and this index as a measure of herd quality in the SLP study site showed that the year ($F_{13, 22} = 3.19$; $P = 0.008$), county ($F_{2, 22} = 4.46$; $P = 0.02$), and temperature ($F_{1, 22} = 3.31$; $P = 0.08$) variables were statistically significant; there were no statistically significant interactions. When the ANOVA model was run by county, however, no variables were detected as being statistically significant (Table 2.21).

Comparisons Among Regions

Deer Numbers

In each year from 1987 through 1996, the number of deer in the UP study site was consistently the highest out the 3 regional study sites, while the number of deer in the SLP study site was consistently the lowest (Figure 2.27). Furthermore, during the time

Table 2.20. Results of the ANOVA model run by county in the Southern Lower Peninsula study site to determine which underlying mechanisms that have the potential to influence male yearling average beam diameter as a measure of deer herd quality in Michigan were significant at an alpha level of 0.10.

Mechanism	Barry	Calhoun	Eaton
Density	X	X	0.06
Temperature	X	X	X
Snowfall	0.05	X	X
WSI	X	0.08	X

Table 2.21. Results of the ANOVA model run by county in the Southern Lower Peninsula study site to determine which underlying mechanisms that have the potential to influence male yearling point count as a measure of deer herd quality in Michigan were significant at an alpha level of 0.10.

Mechanism	Barry	Calhoun	Eaton
Density	X	X	X
Temperature	X	X	X
Snowfall	X	X	X
WSI	X	X	X

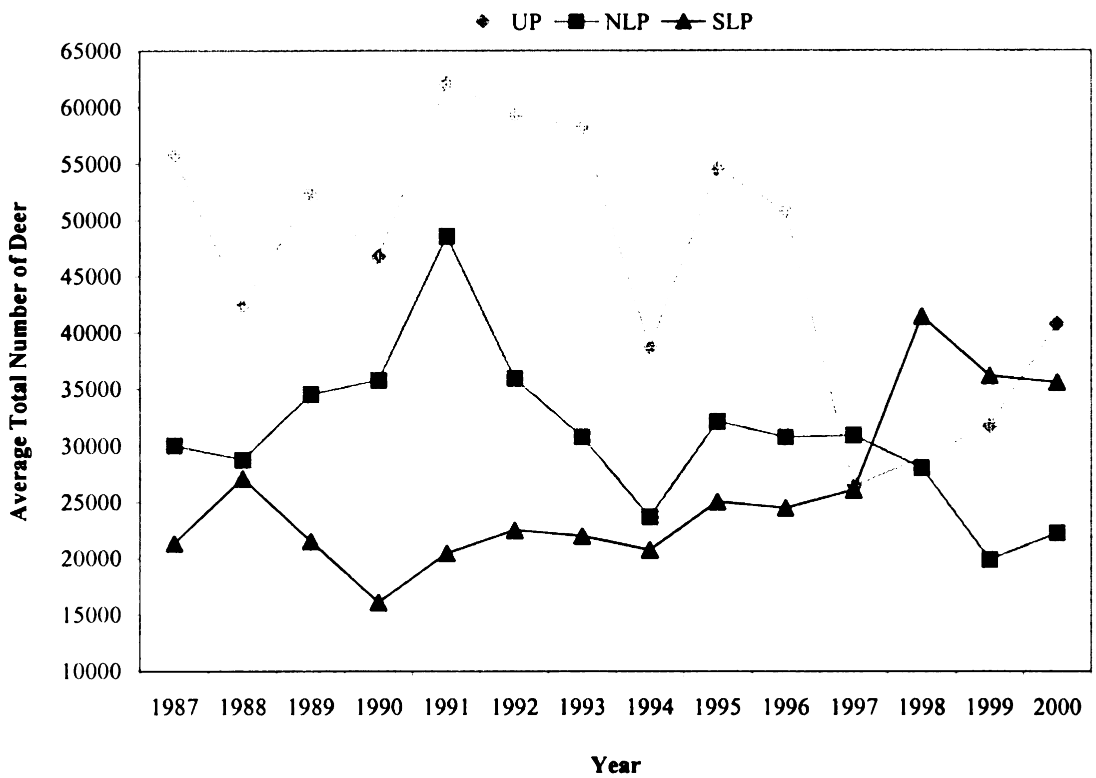

Figure 2.27. The comparison of yearly trends in the average total number of deer, as estimated by the sex-age-kill estimate method, for each of the 3 regional study sites between 1987 and 2000.

period from 1987 through 1996, the deer density among the 3 regional study sites generally appeared to follow similar patterns, especially in the UP and NLP (Figure 2.27). Specifically, if the number of deer in 1 study site increased or decreased, in general, so did the number of deer in at least 1 of the other study sites. In 1997, however, there was a sharp decline in the number of deer in the UP study site and in 1998 there was a sharp increase in the number of deer in the SLP study site (Figure 2.27). After 1997, deer numbers in the UP study site increased, but were still lower than in the previous years, whereas deer numbers in the SLP study site decreased slightly in 1999 and 2000, but were still higher than in the previous years (Figure 2.27). Unlike the trends in deer numbers in the UP and SLP study sites, deer numbers in the NLP study site did not undergo any sharp increases or decreases; instead, they steadily declined throughout the 14 years of the study (Figure 2.27).

Although deer numbers followed a north to south regional gradient in Michigan, the actual density of deer did not follow the same trend. The density of deer per regional study site was lowest in the UP study site at 13 deer/km^2 (34 deer/mi^2) and highest in the NLP study site at 20 deer/km^2 (51 deer/mi^2), while density of deer in the SLP study site fell in between the deer density for the other 2 study sites at 16 deer/km^2 (42 deer/mi^2) (Figure 2.28). Based on the Tukey-Kramer multiple comparison test, the density of deer in the UP and NLP study sites was statistically different, whereas the deer density in the UP and SLP study sites was not statistically different (Table 2.22; Figure 2.28). In addition, the deer density in the NLP study site and the SLP study site was not statistically different (Table 2.22).

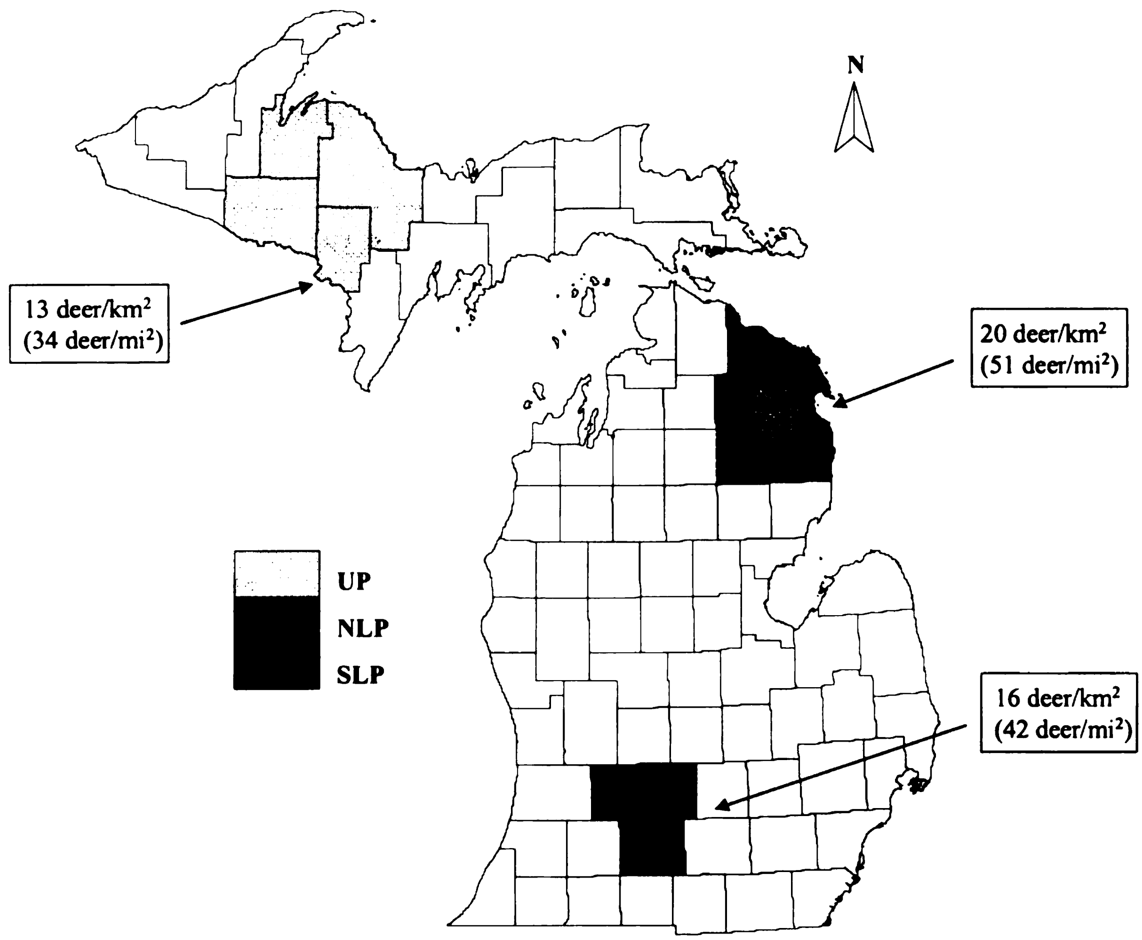

Figure 2.28. The regional comparison of the density of deer present in each of the 3 regional study sites averaged across years from 1987 to 2000.

Table 2.22. The mean comparison of (a) deer population density, (b) temperature, (c) snowfall, and (d) the winter severity index among the 3 regional study sites at an alpha level of 0.10.

(a) Density

	UP	NLP	SLP
UP	X	0.04	0.54
NLP	0.04	X	0.26
SLP	0.54	0.26	X

(b) Temperature

	UP	NLP	SLP
UP	X	0.15	<0.0001
NLP	0.15	X	<0.0001
SLP	<0.0001	<0.0001	X

(c) Snowfall

	UP	NLP	SLP
UP	X	<0.0001	<0.0001
NLP	<0.0001	X	0.22
SLP	<0.0001	0.22	X

(d) WSI

	UP	NLP	SLP
UP	X	<0.0001	<0.0001
NLP	<0.0001	X	0.36
SLP	<0.0001	0.36	X

Temperature

The trend in the yearly average cumulative mean monthly temperature among the 3 regional study sites was basically what was expected. In almost every year of this study, the UP study site had the overall coolest temperature readings and the SLP study site had the overall warmest temperature readings, with the temperature readings for the NLP study site falling in between the temperature readings for the other 2 study sites (Figure 2.29). There were, however, a few exceptions such as in 1987 and 1988 when the average cumulative mean monthly temperature in the NLP study site was warmer than it was in the UP study site, and in 1999 when there was a sharp decrease in the average cumulative mean monthly temperature in the SLP study site so that it was warmer in both the UP and NLP study sites (Figure 2.29). Overall, though, the yearly average cumulative mean monthly temperature among the 3 regional study sites appeared to follow similar patterns. For example, if the yearly average cumulative mean monthly temperature in 1 study site increased or decreased, in general, so did the temperature in at least 1 of the other study sites (Figure 2.29).

In general, as you move from north to south in Michigan, the temperature increased. The overall temperature reading for the UP study site was the coolest of the 3 regional study sites at 199 °C and the overall temperature reading for the SLP study site was the warmest at 232 °C while the temperature reading for the NLP study site was in the middle of the temperature readings for the other 2 regional study sites at 209 °C (Figure 2.30). The cumulative mean monthly temperature for the UP study site and the NLP study site was more similar to each other than the temperature for either of these study sites was to the cumulative mean monthly temperature in the SLP. Based on the

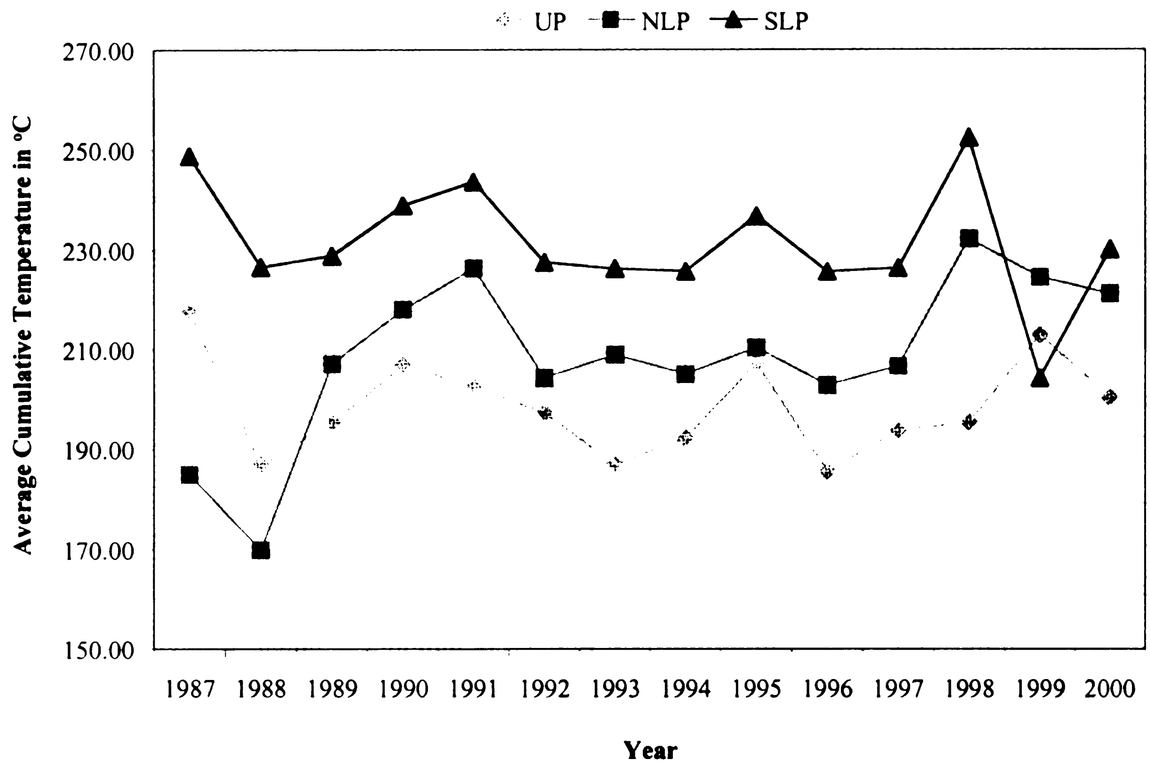

Figure 2.29. The comparison of yearly trends in the average cumulative temperature (summed from January through September) for each of the 3 regional study sites between 1987 and 2000.

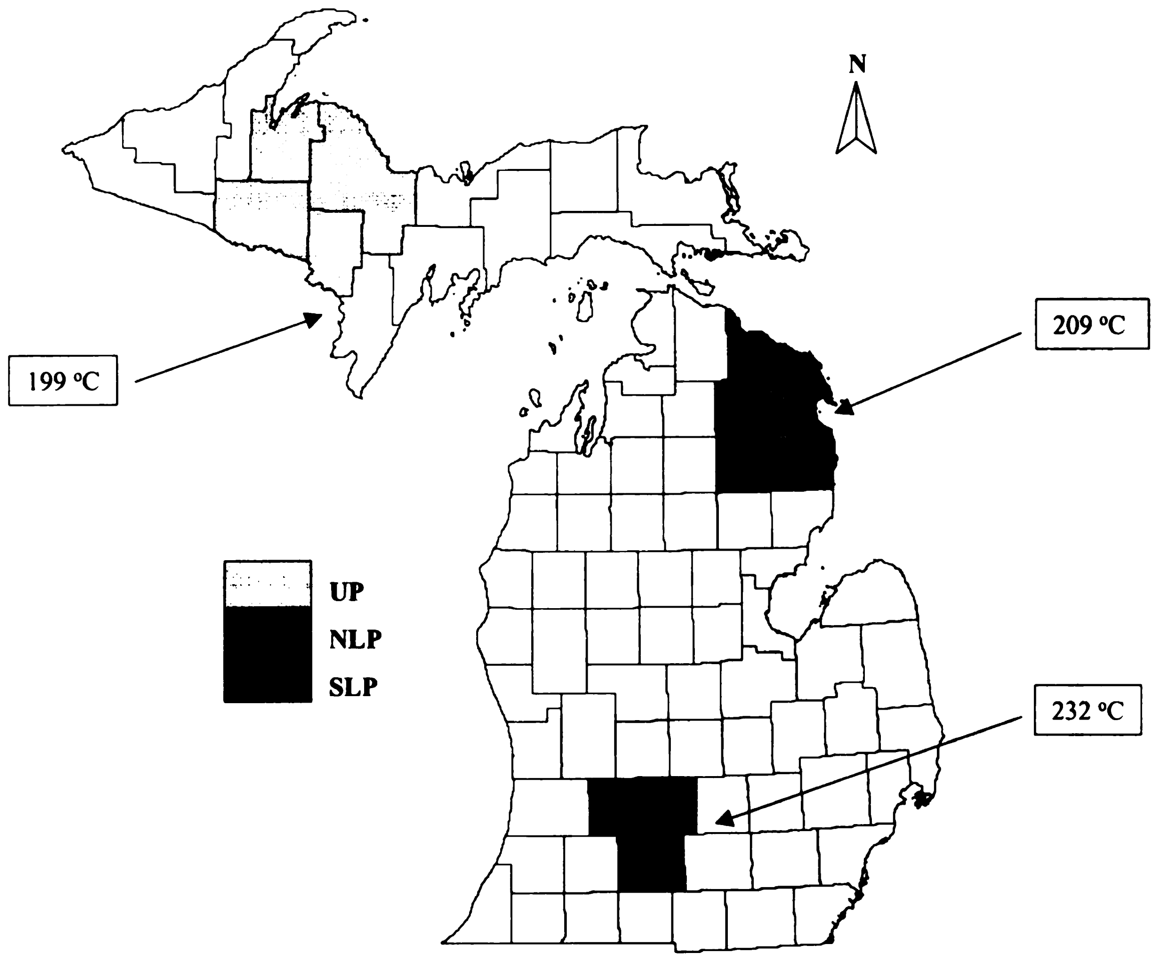

Figure 2.30. The regional comparison of the cumulative temperature (summed from January through September) in °C averaged across years from 1987 to 2000 among each of the 3 regional study sites.

Tukey-Kramer multiple comparison test, the cumulative mean monthly temperature was statistically different between the UP and SLP study sites as well as between the NLP and SLP study sites (Table 2.22). There was, however, no statistical difference between the cumulative mean monthly temperature for the UP and NLP study sites (Table 2.22).

Snowfall

The trend in the yearly average cumulative total monthly snowfall among the 3 regional study sites was also basically what was expected. Of the 3 regional study sites, the average cumulative total monthly snowfall for each year was highest in the UP study site and lowest in the SLP study site while the snowfall each year in the NLP study site fell in middle of the other 2 regional study sites (Figure 2.31). Also, the yearly average cumulative total monthly snowfall among the 3 regional study sites appeared to follow similar patterns. For instance, if the yearly average cumulative total monthly snowfall in 1 study site increased or decreased, in general, so did the snowfall in at least 1 of the other study sites (Figure 2.31). There were, however, exceptions in 1993, 1999, and 2000 when the average cumulative total monthly snowfall in the SLP study site exceeded that in the NLP study site (Figure 2.31).

The trend in cumulative total monthly snowfall decreased as you move along a north to south regional gradient in Michigan. The UP study site had the highest amount of cumulative total monthly snowfall at 170cm and the SLP study site had the least at 81cm. At 111cm, the cumulative total monthly snowfall for the NLP study site was in between the amount of snowfall for the other 2 regional study sites (Figure 2.32). The cumulative total monthly snowfall was more similar between the NLP and SLP study

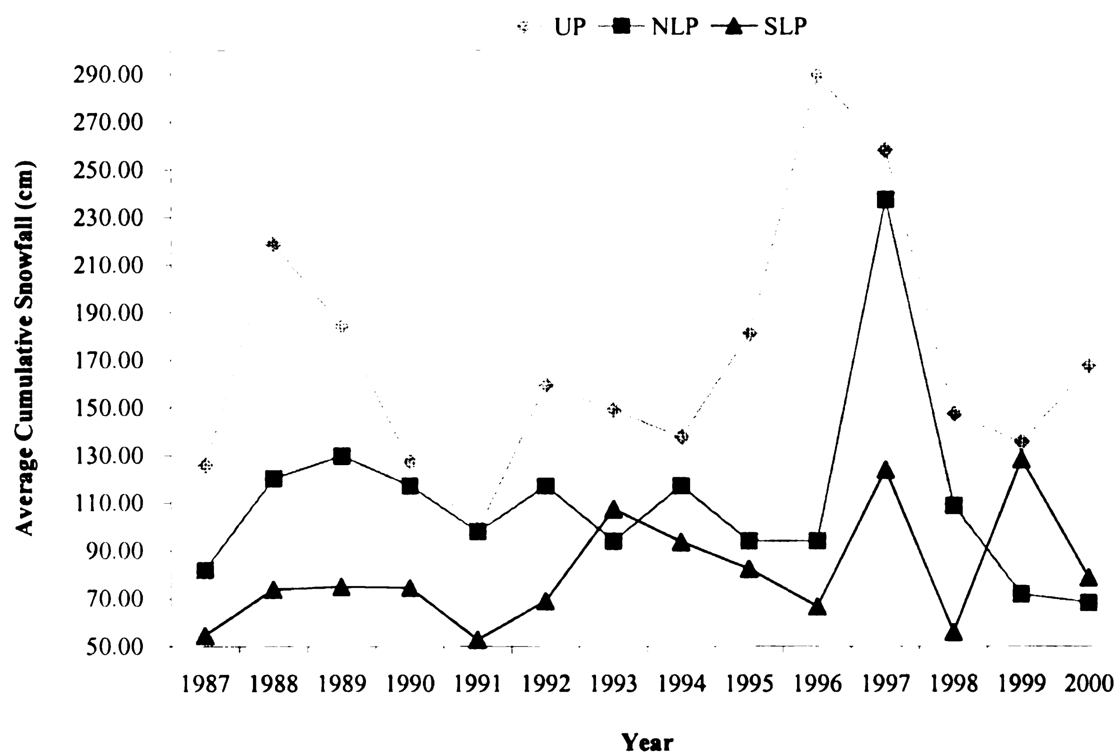

Figure 2.31. The comparison of yearly trends in the average cumulative snowfall (summed from January through April) for each of the 3 regional study sites between 1987 and 2000.

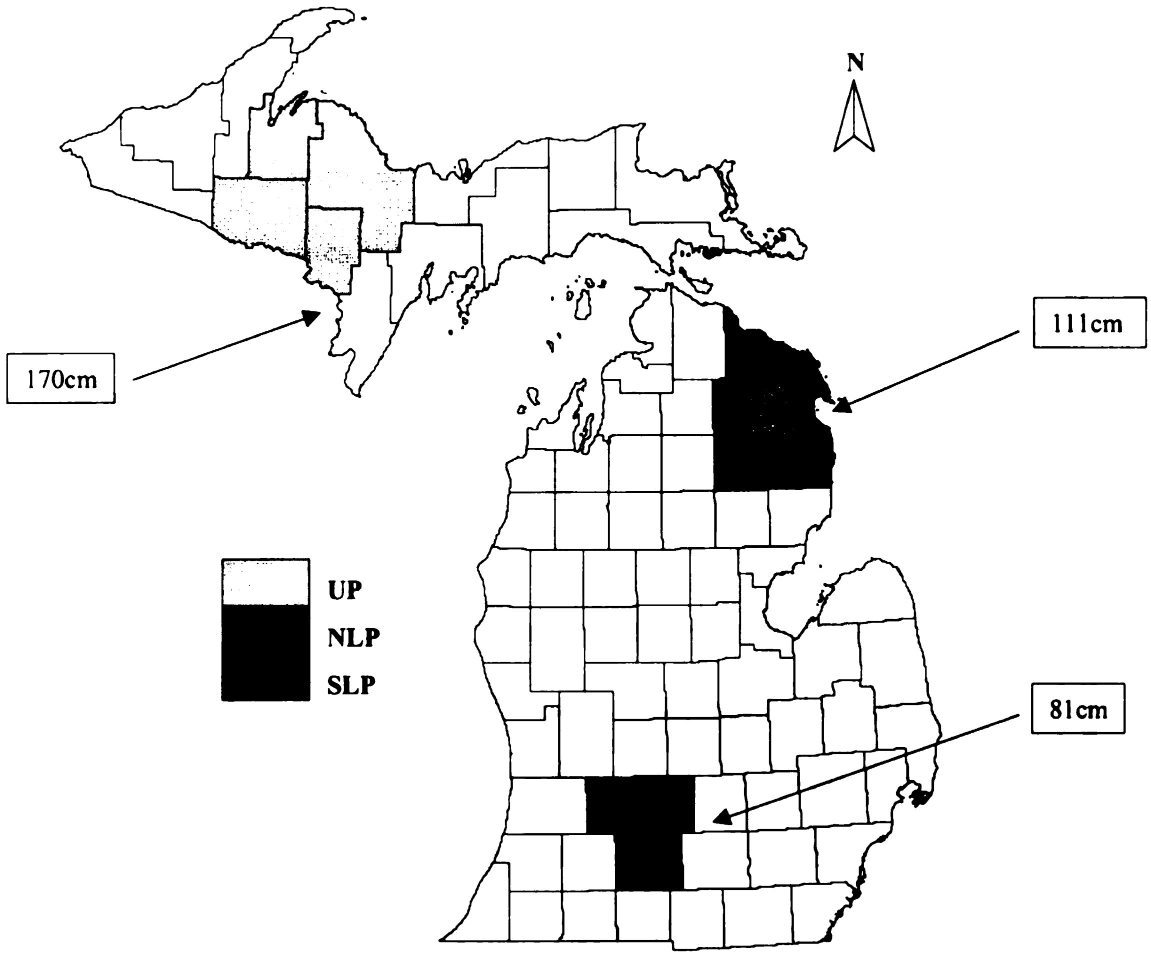

Figure 2.32. The regional comparison of the cumulative snowfall (summed from January through April) in cm averaged across years from 1987 to 2000 among the 3 regional study sites.

sites than the amount of snowfall in either of those 2 study sites was to the amount of snowfall in the UP study site (Figure 2.32). According to the Tukey-Kramer multiple comparison test, the cumulative total monthly snowfall was statistically different between the UP and NLP study sites as well as between the UP and SLP study sites (Table 2.22). There was, however, no statistical difference in the cumulative total monthly snowfall between the NLP and SLP study sites (Table 2.22).

Winter Severity Index

The trend in the corrected WSI among the 3 regional study sites was exactly what was expected. In each year of the study, the UP study site had the highest corrected average WSI, whereas the SLP study site, overall, had the lowest (Figure 2.33). The corrected average WSI for the NLP study site fell in between the corrected average WSI for the other 2 regional study sites (Figure 2.33). The only exception was in 1999 when the corrected average WSI in the SLP exceeded the corrected average WSI in the NLP, but only slightly (Figure 2.33). Therefore, the yearly average corrected average WSI among the 3 regional study sites tended to follow similar patterns. For instance, if the yearly corrected average WSI in 1 study site increased or decreased, in general, so did the snowfall in at least 1 of the other study sites (Figure 2.33).

The trend in corrected average WSI decreased as you move along a north to south regional gradient in Michigan. The UP study site had the highest corrected average WSI at 82.69 and the SLP study site had the least at 47.03. At 56.85, the corrected average WSI for the NLP study site was in between the corrected WSI for the other 2 regional study sites (Figure 2.34). The corrected average WSI was more similar between the NLP

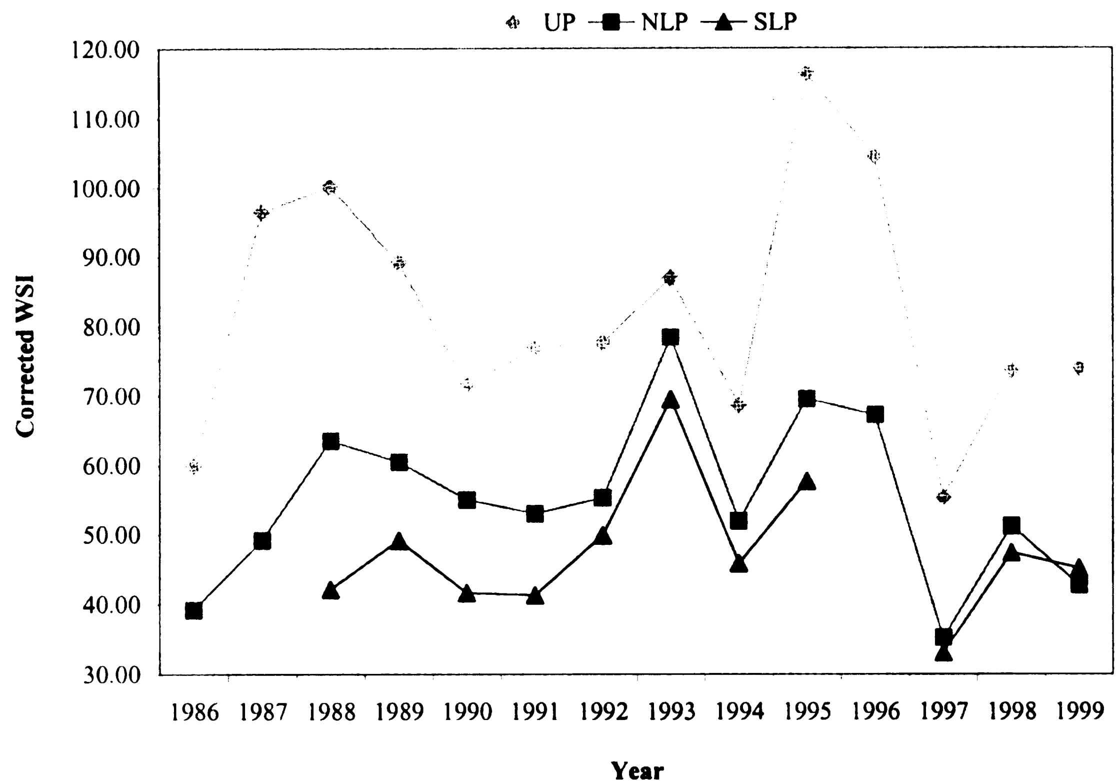

Figure 2.33. The comparison of yearly trends in the corrected WSI for each of the 3 regional study sites between 1987 and 2000.

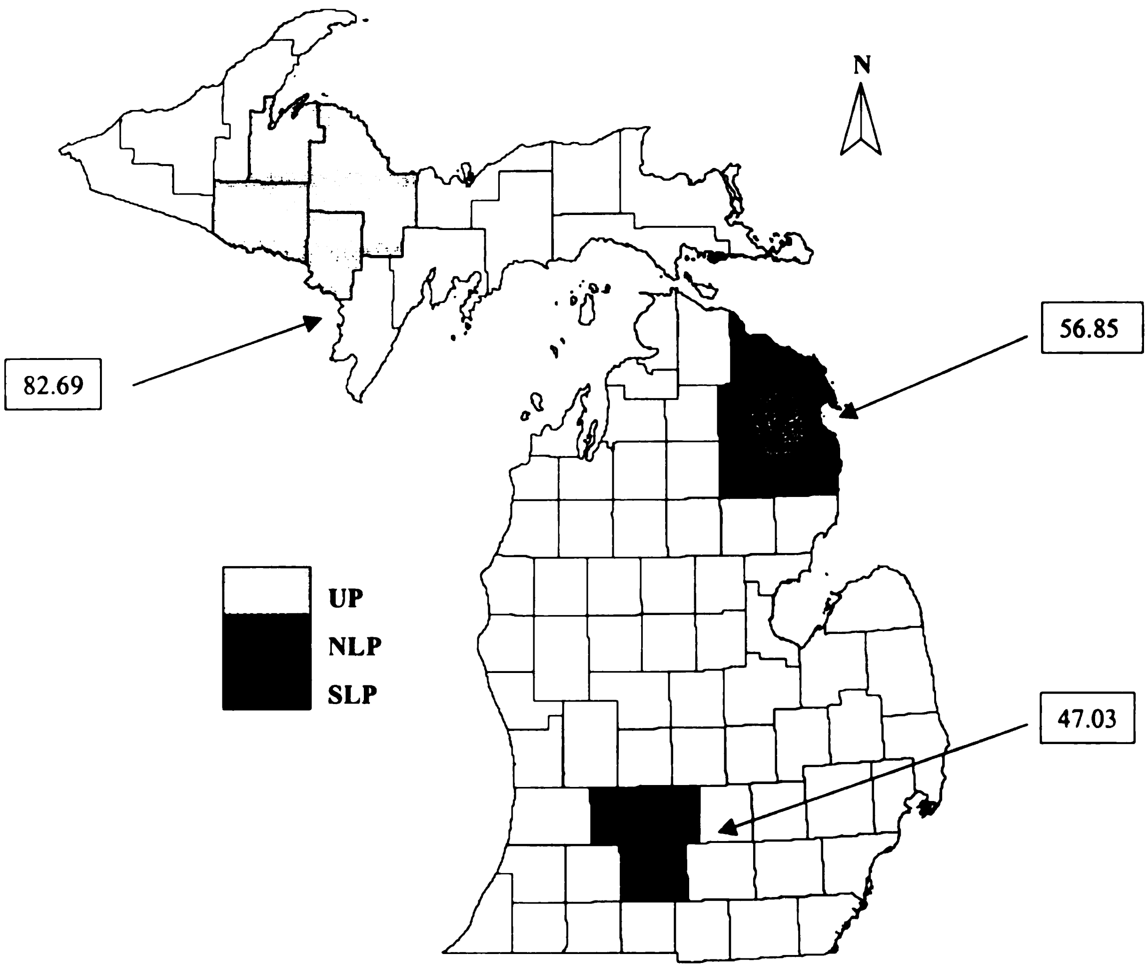

Figure 2.34. The regional comparison of the corrected WSI averaged across years from 1987 to 2000 among the 3 regional study sites.

and SLP study sites than the corrected average WSI in either of those 2 study sites was to the corrected average WSI in the UP study site (Figure 2.34). According to the Tukey-Kramer multiple comparison test, the corrected average WSI was statistically different between the UP and NLP study sites as well as between the UP and SLP study sites (Table 2.22). There was, however, no statistical difference in the corrected average WSI between the NLP and SLP study sites (Table 2.22).

DISCUSSION

As you move along a north to south regional gradient in Michigan, some of the underlying mechanisms that have the potential to influence white-tailed deer herd quality increased while others decreased. The mean monthly temperature was highest in the southern-most region of the state, and of the 3 regional study sites, the SLP study site was the only site that showed a consistent increase in the number of deer over the course of this study. Conversely, the total monthly snowfall and the winter severity index were lowest in the southern-most study site, and in the UP and NLP study sites, the number of deer, in general, decreased over the course of this study.

Clearly there were temporal and spatial differences in each of the underlying mechanisms, but which of these factors can account for the trends that exist in both male yearling average beam diameter and point count as measures of herd quality in Michigan? For male yearling average beam diameter, the results suggest that in each regional study site, multiple factors were having an influence. In the UP study site, temperature, snowfall, and winter severity were the mechanisms that had the most influence on male yearling average beam diameter. Whereas, the underlying mechanisms that had the most influence in the NLP study site were temperature, winter severity, and density. In the SLP study site, density had the most influence on the male yearling average beam diameter.

The underlying mechanisms that had an influence on male yearling point count in each regional study site were similar to those that had an influence on male yearling average beam diameter. Weather was the dominant factor that influenced male yearling point count in the UP study site. Snowfall, temperature, winter severity, and density were all factors that affected male yearling point count in this study site. Temperature, winter severity, and density influenced the male yearling point count in the NLP study site. These underlying mechanisms were the same as those that had an influence on male yearling average beam diameter in the same study site. In the SLP study site, there were no underlying mechanisms detected that had an influence on male yearling point count.

These results suggest that, in general, as you move from north to south in Michigan, the dominant influence on the male yearling antler measurements in the northern part of the state was weather, which gave way to a mixture of weather and density in the mid-part of the state, and in the southern-most part of the state, density had the most impact. The results also suggest that since there were counties in each of the 3 regional study sites in which temperature and/or snowfall were influencing the yearling antler measurements as a measure of herd quality but winter severity was not having an influence and vice versa. This implies that the winter severity index did not encompass all of the impacts of snow and temperature. In addition, habitat potential for the 3 habitat requirements had an influence on the male yearling antler measurements as a measure of herd quality in the NLP study site. Thermal cover had the most influence on both male yearling average beam diameter and point count; as thermal cover potential increased, the antler measurements also increased. Fall and winter food potential had an influence on male yearling average beam diameter; although, there was a negative relationship between the habitat potential and the index of herd quality.

Data Limitations

Incomplete Data

Broad temporal and spatial trends exist in the underlying mechanisms that may influence yearling male antler measurements as indices of herd condition and, in general, there was a mixture of factors affecting these indices in each of the 3 regional study sites. There were, however, some potential limitations to this study. One limitation was incomplete, or missing, data. This is problematic because having incomplete data might mean that certain analyses can not be conducted or that the results may not be comprehensive. For example, in the SLP study site, there were several years in which a corrected average WSI could not be calculated because of missing data. Thus, there were fewer years in which analyses could be conducted with the corrected average WSI in relation to the other underlying mechanisms or the antler measurements as indices of herd condition.

Incomplete data were also a problem in that the habitat potential data were only available for the NLP study site. Therefore, comparisons of fall and winter food potential, spring and summer food potential, and thermal cover potential cannot be made among the 3 regional study sites in Michigan. Also, to date, there is only 1 habitat potential for each of the 3 habitat requirements in each county in the NLP study site for the entire course of this study; they do not change on any temporal basis. Thus, no yearly comparisons can be made among fall and winter food potential, spring and summer food potential, and thermal cover potential in the NLP study site. Since there can be no regional or yearly comparisons of the habitat potential for each of the 3 habitat requirements, at this point and time, we can only draw limited conclusions as to how habitat quality influences male yearling antler measurements as indices of herd condition.

Data Aggregation

Aggregating data was also a possible limitation to this study. The temperature data were aggregated into a 9-month time period, and the snowfall data were aggregated into a 4-month time period so that analyses could be conducted. By aggregating these data, however, some of the detail that existed at a finer level (e.g., months) was overlooked in the analyses and, hence, affected the final outcomes. The habitat potential for fall and winter food, spring and summer food, and thermal cover was aggregated from a fine scale (i.e., habitat types) to a broad scale (i.e., counties). Thus, how habitat quality may influence male yearling antler measurements as indices of herd condition at finer scales was completely overlooked and some of the finer nuances that could more accurately explain this relationship were lost.

Biased Data

Some of the data used in the study was extracted from the biodata. There are, however, various biases associated with this data set. This includes compositional, seasonal, and geographical biases which may have impacted the results and, subsequently, the conclusions drawn from these results. The biases in the biodata and ways in which these biases could be improved are discussed at length in Chapter 1.

Assumptions

To conduct analyses, assumptions about the data were necessary because of the data limitations. Several assumptions were necessary for the SAK estimate method to accurately estimate deer density. These assumptions include: 1) the population is at stable age distribution; 2) the sample sexed and aged at the check stations is representative of the population; 3) fawn production is accurately measured; 4) nonharvest mortality, or the survival rate, is known and constant throughout the year; 5) buck harvest pressure is uniform from year to year (Eberhardt 1960, Creed et al. 1984, Mattsen-Hanson 1998). For this study, these assumptions were not tested and it was assumed they were met.

There were also assumptions associated with the temperature, snowfall, and winter severity data. It was assumed that all of these data were appropriately and accurately collected and recorded. In addition, even though these data were obtained from only 1 weather station from within each county in the 3 regional study sites, it was assumed that these data, more or less, accurately represented the weather conditions in each study site.

The ecoregion, land-type association, soil association, and presettlement vegetation layers used to develop the habitat types for the habitat potential models were assumed to be accurate and that the resulting habitat types are in fact valid. It was also assumed that the habitat models used to predict the habitat potential for fall and winter food, spring and summer food, and thermal cover in the NLP study site do accurately reflect the habitat potential of the 3 habitat requirements in that area of the state.

Additional Approaches

In addition to the underlying mechanisms we examined in relation to the herd quality in Michigan, there are other possible influences on herd quality that could be examined. For example, the amount of rainfall may indirectly influence herd condition by altering the growth and distribution of forage and browse for deer. Deer that have little access to nutritious forage during a harsh winter may experience detrimental effects such as loss of body weight, low productivity, and undersized antler growth (Cheatum and Severinghaus 1950, Severinghaus et al. 1950). However, if deer can obtain adequate nutrition during the spring and summer, often they can recover from the nutritional stress brought on by a harsh winter and will not experience such detrimental effects (Verme and Ullrey 1984). During this period of time, 1 of the limiting factors for adequate forage growth becomes rainfall, especially in dryer regions. The amount of rainfall can affect both the quantity and quality of forage and/or browse available to deer (Shea and Osborne 1995) and long periods of drought can negatively affect deer habitat and, hence, deer condition (Teer 1984). Although rainfall is generally not a limiting factor in Michigan, it is another possible underlying mechanism that has the potential to influence herd condition (Kammermeyer and Thackston 1995). Therefore, it may be beneficial to examine rainfall in relation to male yearling antler measurements as indices of herd quality, especially in areas of Michigan that have experienced drought, to gain more insight into which underlying mechanisms that are driving deer herd condition.

The lag time between changes in deer density and range condition in relation to herd quality in Michigan is another aspect that could be examined. Some studies suggest that there may be as much as a 2-year lag between the time that range conditions change and quality indices such as antler measurements show a significant response (Jacobson and Guynn 1995). For example, bucks that are undernourished or stressed due to overcrowding may have undersized antler measurements the subsequent year (Ozoga et al. 1995). This may be partially due to the fact that antler growth is influenced by the quality and quantity of forage deer are able to access during the previous winter, and that changes in deer density do not affect changes in habitat quantity or quality for almost a year (Severinghaus et al. 1950, Jacobson and Guynn 1995). Thus, conducting analyses that stagger deer density, habitat potential for each of the 3 habitat requirements, and both male yearling average beam diameter and point count on a yearly basis may actually provide a more accurate picture of the interactions between the underlying mechanisms and herd quality.

Conclusion

Understanding the underlying mechanisms that drive white-tailed deer herd condition in Michigan will enable mangers to develop scientifically sound management strategies that incorporate not only population numbers but also those factors that influence population characteristics. And although data limitations exist, the data used in this study were the most readily available, and the basic trends in the data supports the overall pattern in both the antler measurements as indices of herd condition and the underlying mechanisms than influence the characteristics of populations.

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CONCLUSIONS AND MANAGEMENT IMPLICATIONS

In 1996, the Michigan voters passed Proposal G, a ballot initiative, to ensure that wildlife would be managed based on scientifically sound information and procedures. The processes used, and conclusions reached in this study, may aid managers in developing better scientifically sound management strategies that incorporate deer population numbers and the condition of deer. Along with social and ecological considerations, herd condition can be incorporated into a more holistic deer management strategy that addresses deer management at a landscape-level, rather than simply manipulating local deer numbers. Also, better understanding the relationship between underlying mechanisms such as deer density, winter severity, and habitat quality that drive changes in deer population-level quality indices and herd condition could provide additional information for managers to incorporate into a deer management strategy.

These results may also be beneficial to managers for communicating with the public as to how and why management decisions are made as well as how different management strategies will sustain a healthy deer herd. Having a definition of herd condition that uses quality indices that the public understands and can visually identify enables managers to more easily communicate and maybe gain credibility with the public. In addition, understanding the underlying mechanisms that are influencing herd quality may enable managers to explain more details to the public as to why deer are in a certain physical condition and how different management strategies will alter that physical condition of deer in a specific area.

In Chapter 1, it was determined that population-level quality indices such as yearling average beam diameter, point count, and lactation status can reflect the relative condition of the deer herd in the 3 distinct regions of Michigan. Furthermore, it was determined that the differences in each of the quality indices among the 3 regional study sites were detectable. In Chapter 2, it was determined that not only did the influences of herd condition differ among the distinct 3 regions in Michigan but also that these influences were likely to be predictable.

The results of this study indicate that there are differences in the quality indices among the 3 distinct regions of Michigan. This suggests that deer management strategies should, at the largest spatial scale, be tailored to each distinct region. In reality, though, there are differences in the quality indices even within regions. Therefore, managers need to consider the appropriate scale at which to collect meaningful data and manipulate deer populations. Deer management decisions should be based on a combination of population dynamics, herd condition, life requisites, and public desires at the appropriate scale in which management makes the most sense.

There is some question, though, as to how well the results of this study represent the condition of the deer herd across all of Michigan. The basic trend in each of the quality indices does support the overall pattern in which the percent of yearling does lactating, the male yearling average beam diameter and point count increased as one moves from north to south. This is also the case for the underlying mechanisms; for the most part, temperature, and deer density increased as you move from north to south, whereas snowfall and winter severity decreased. These broad trends appear logical, but the basic trends for both the quality indices and the factors that influence herd condition were based solely on data gathered within each of the 3 regional study sites. Therefore, when managers are targeting a specific area for management more information may need

to be gathered to develop a deer management strategy that is appropriate for that area. For example, if managers are targeting an area for management that falls outside of the 3 study sites used in this study, managers may want to gather specific information on the herd condition, the factors that influence herd condition (e.g., density, weather, habitat), and the public attitudes that exist in that area.

If the biodata were collected at a finer scale than county level at either political boundaries (e.g., township or section) or ecological boundaries (e.g., ecoregions) over a significant period of time, those data could be used to predict the overall quality of the deer herd at specific spatial scales. After quantifying herd condition by examining quality indices such as lactation status and antler measurements, these indices could be put into a model to quantify the overall condition of the deer herd in different management areas on an annual basis. The underlying mechanism data, collected at an appropriate scale, could also be used in this capacity. Starting with a population number in a specific area, the underlying mechanisms that influence herd condition could be manipulated through a predictive model to determine how they would affect the deer herd over the long-term. This may be useful for managers who are trying to pinpoint management in areas that require special consideration. For example, knowing the quality of the deer herd may enable managers to pinpoint current areas where there is the potential for disease (e.g., Bovine TB or Chronic Wasting Disease) to be introduced or to be spread. Being able to predict where deer will be in poor condition in the future may help managers take preventative actions to diminish the risk of disease in that area.

Even though this study may only provide guidelines to managers on ways to approach a more holistic deer management strategy, the processes and parameters used in this study may be applied as a template for managers to develop management strategies for other species by examining population trends and other factors that influence populations at different scales.

Recommendations

By examining the physical condition of deer as well as those underlying mechanisms that influence herd quality and incorporating these factors into a deer management strategy, managers can devise deer management strategies that move beyond simply manipulating the number of deer in a specific area. This, however, is only 1 aspect of deer management; to truly make it a holistic approach to deer management, managers need to consider the ecological and social aspects of deer management. When the 3 sections of the "umbrella" project are complete, they will be integrated into a model to quantify deer management decisions based on herd condition, factors that influence herd condition, habitat quality, and public desires. This will allow managers to tailor deer management because knowing how these different aspects of deer management interact with one another will enable managers to set population goals, assign hunting pressures, initiate habitat manipulations, and develop public outreach in different areas of the state.

To determine the target population number for deer in a specific area, managers should take into consideration the current condition of the herd, habitat quality, and public tolerance as well as the desired future status of the population. Using all of this information, managers could then determine what kind of actions need to be taken to ensure that the desired status of the deer herd is achieved. For example, if the management goal is to improve the condition of a deer herd that is in poor condition because the population is so large that resources have become scarce, and the public in that area tends to support that goal, then a logical approach would be to reduce the number of deer to ensure that the deer have adequate resources. Hunting pressures could then be assigned accordingly to ensure that the appropriate number of deer is maintained to sustain a healthy population. Promoting habitat improvements in conjunction with using appropriate hunting pressures to control deer numbers, could increase quantity and quality of resources; subsequently allowing for an improvement in the physical condition of the deer herd in that area. This scenario may change if the public were not supportive of actions needed to improve the condition of the deer herd. In this case, it may be appropriate to first address the public and decide what kind of educational or hands-on programs would be effective in trying to educate the public on how and why these actions should be taken to ensure the existence of a healthy deer herd.