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# Are There “Hot Spots” of Bovine Tuberculosis in the Free-Ranging White-Tailed Deer (*Odocoileus virginianus*) Herd of Northeastern Michigan?

Brandi Danielle Hughey

# ARE THERE "HOT SPOTS" OF BOVINE TUBERCULOSIS IN THE FREE-RANGING WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) HERD OF NORTHEASTERN MICHIGAN?

By

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## ABSTRACT

ARE THERE "HOT SPOTS" OF BOVINE TUBERCULOSIS IN THE FREE-RANGING WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) HERD OF NORTHEASTERN MICHIGAN?

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This project looks at whether high case frequency areas or "hot spots" of bovine tuberculosis (tb) exist in free ranging white-tailed deer in northeastern Michigan, and examines the factors associated with them. Michigan Department of Natural Resources researchers have been collecting deer heads annually since 1996 in the five county area of Alcona, Alpena, Montmorency, Oscoda, and Presque Isle as part of an effort to manage an outbreak of bovine tb in the wild white-tailed deer population. From these heads a database containing age, sex, and harvest or collection location information was constructed. The townships within these five counties were categorized as having zero case frequency, medium case frequency, or high case frequency. These categories are based on the number of years at least one tb infected deer was detected in that township. Each case frequency category was then examined individually looking at the yearly sample size distributions, yearly case frequency, and cumulative sample size distributions. Using GIS these areas of varying case frequency were compared to five deer use categories, Summer Use (high quality summer habitat), Summer Other (poor summer habitat), Winter Use (high quality winter habitat), Winter Other (poor winter habitat), and Rare Use (includes areas rarely or never used by deer, such as water, urban and industrial areas).

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# CHAPTER 1

## INTRODUCTION

Bovine tuberculosis (tb) (*Mycobacterium bovis*) is a bacterium that generally attacks the respiratory system of mammals. It is most easily transmitted through aerosol created by coughing or sneezing of an infected individual (Michigan Department of Natural Resources, 2000). Historically, tb in Michigan has been associated with cattle. However, in 1975, a hunter-harvested 9.5 year old white-tailed doe (*Odocoileus virginianus*) in Alcona County tested positive for tb. This was thought to be an isolated incident, and no further action was taken. In 1994, a 4.5 year old buck was harvested in Alpena County, and tested tb positive (Schmitt et al., 1997). Since Michigan had been considered a tb free state since 1979 this caused concern. In the spring of 1995, the Michigan Department of Agriculture (MDA) surveyed all livestock within a 10 mile radius of the tb positive deer. None of the livestock were found to be tb positive. In the fall of 1995, the Michigan Department of Natural Resources (MDNR) surveyed hunter-harvested deer within a 10 mile radius of where the tb positive deer was harvested. Of the 354 deer harvested and tested, 18 cultured positive for tb (Fitzgerald et al., 1997).

Tb posses a threat to animal health, as well as the economic success of agriculture and wildlife industries of Michigan. For example costs to the agricultural industry, due to the loss of Michigan's tb Accredited-Free State status, are anticipated to be around $16 million a year (Whitcomb, 1999). In an effort to better understand and manage this outbreak of bovine tb, MDNR

beginning in 1996 systematically expanded their surveillance area, eventually including the entire state of Michigan, with a focus on the five counties of Alcona, Alpena, Montmorency, Oscoda, and Presque Isle. As of February 12, 2003, 449 white-tailed deer, 41 carnivores, 1 captive deer herd, 28 beef and dairy herds, 2 elk, 1 feral cat and 1 human have tested positive for tb within the state. The vast majority of these animals were located in the "core" area of Alcona, Alpena, Montmorency, and Oscoda Counties (Michigan Department of Natural Resources, 2003). Because of the nature of the findings, it is believed that bovine tb is endemic to the white-tailed deer in this region. This is the first occurrence of tb maintained within a free-ranging white-tailed deer population (Schmitt et al., 1997). As a result, Michigan lost its tb Accredited-Free State status in 2000 (Michigan Department of Natural Resources, 2000).

Bovine tb is hypothesized to be prevalent in the tb core area is because of the combined effects of high deer densities, baiting and feeding. Deer densities are beyond that which the natural environment can support increasing the contact rate between deer. This area is known as "club country" with numerous privately owned clubs ranging from 40 – 28,000 acres in size (Fitzgerald et al., 1997). Extensive baiting and feeding and mild winters have helped to lower winter mortality, while the reluctance to harvest antlerless deer has led to a higher ratio of does to bucks. Consequently, this has contributed to the high deer densities in this particular area of Michigan. Increased numbers of deer concentrated into smaller areas, increases the probability of transmitting tb (O'Brien et al., 2002).

Historically the amount of "good" habitat in the tb core area has been limited by the poor quality of the soil for traditional agricultural row crops and vegetation in this area. Therefore, many landowners resorted to feeding and baiting (a cheaper alternative to habitat improvement) to make up for habitat deficiencies, and to maintain deer on their property (Peyton, 2000). Probable pathways of transmitting tb are through face-to-face contacts (Garner, 2001), and consumption of contaminated feed (Michigan Department of Natural Resources, 2001). To decrease the number of face-to-face contacts and the consumption of contaminated feed the Michigan Department of Agriculture banned feeding and the Natural Resource Commission restricted baiting to a 5-gallon bucket maximum in 1998 (Michigan Department of Natural Resources, 1999). The ban was applied to an area east of I-75 and north of M-55, which consists of the aforementioned five county area and a portion of the surrounding counties (Figure 1). Garner (2001) showed that decreasing the amount of bait actually increased the number of face-to-face contacts, because deer were crowding into a smaller area. It is thought that deer crowd into these smaller areas because they have learned that they need to be the first ones to feed, or they would miss out on a free meal. In 1999-2000 both baiting and feeding were banned in this area. In 2001, the MDNR changed its regulations to allow 1 gallon of grain or corn per day to be used October 1 to November 30 in Deer Management Unit (DMU) 452. According to published guidelines, the bait had to be spread over an area at least 100 square feet. The MDNR changed their ban on baiting because

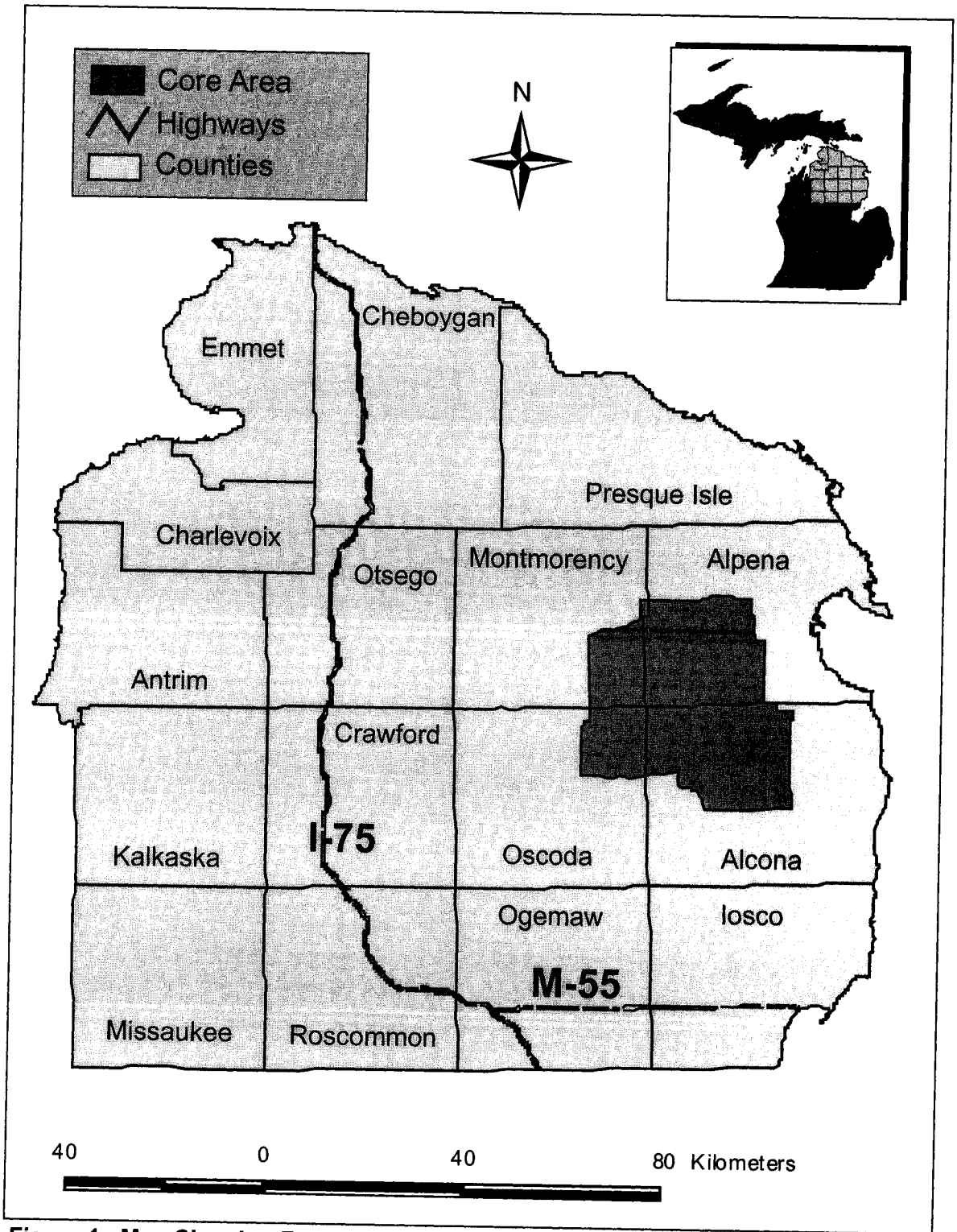



**Figure 1. Map Showing Focal Areas of Baiting and Feeding Regulations**

there was a decrease in bow hunter participation, and some managers were concerned that the ban was negatively impacting the efforts to eradicate tb (Michigan Department of Natural Resources, 2001). In 2002-2003 baiting was banned in the counties of Alcona, Alpena, Crawford, Montmorency, Oscoda, Otsego, and Presque Isle (Figure 1). In the remainder of the state baiting was restricted to a maximum of two gallons in a 100 square feet area at a hunting site. Baiting is allowed in Michigan (except for the previously mentioned 7 counties) October 1 through January 1(MDNR, 2002).

In an effort to manage this outbreak of tb in the wild deer herd, MDNR researchers have been collecting data annually, since 1996, on the deer heads collected for tb monitoring in the five county area of Alcona, Alpena, Montmorency, Oscoda, and Presque Isle. This study will look at whether high case frequency areas (defined by both political and biological boundaries) or "hot spots" of tb exist in free-ranging white-tailed deer in northeastern Michigan, and examine the ecological factors associated with these hot spots.

## OBJECTIVES

The main objectives of this research project are to:

1) Determine if "hot spots" exist by examining the tb database for accuracy and biases,

2) Determine whether a correlation exists between these high case frequency areas of tb, and selected ecological factors, and

3) Make recommendations to the MDNR.

## STUDY SITE

The study area includes the five counties of Alcona, Alpena, Montmorency, Oscoda, and Presque Isle (Figure 2). The average minimum temperature ranges from –11.9 C° in the north to –9.6 C° in the south. The average maximum temperature ranges from 23.4 C° in the north to 25.7 C° in the south (Knapp 1988, Williams 1992). The average snowfall is about 175 cm and rainfall is approximately 72.5 cm (Sitar 1996). The topography of the area was formed by glacial deposits, and is characterized by level and undulating plains and rolling to hillic moraines. The region is dominated by wooded/forested land, with farmland being the second most prevalent land type. The elevation ranges from 150 m to 390 m above sea level (Williams 1992).

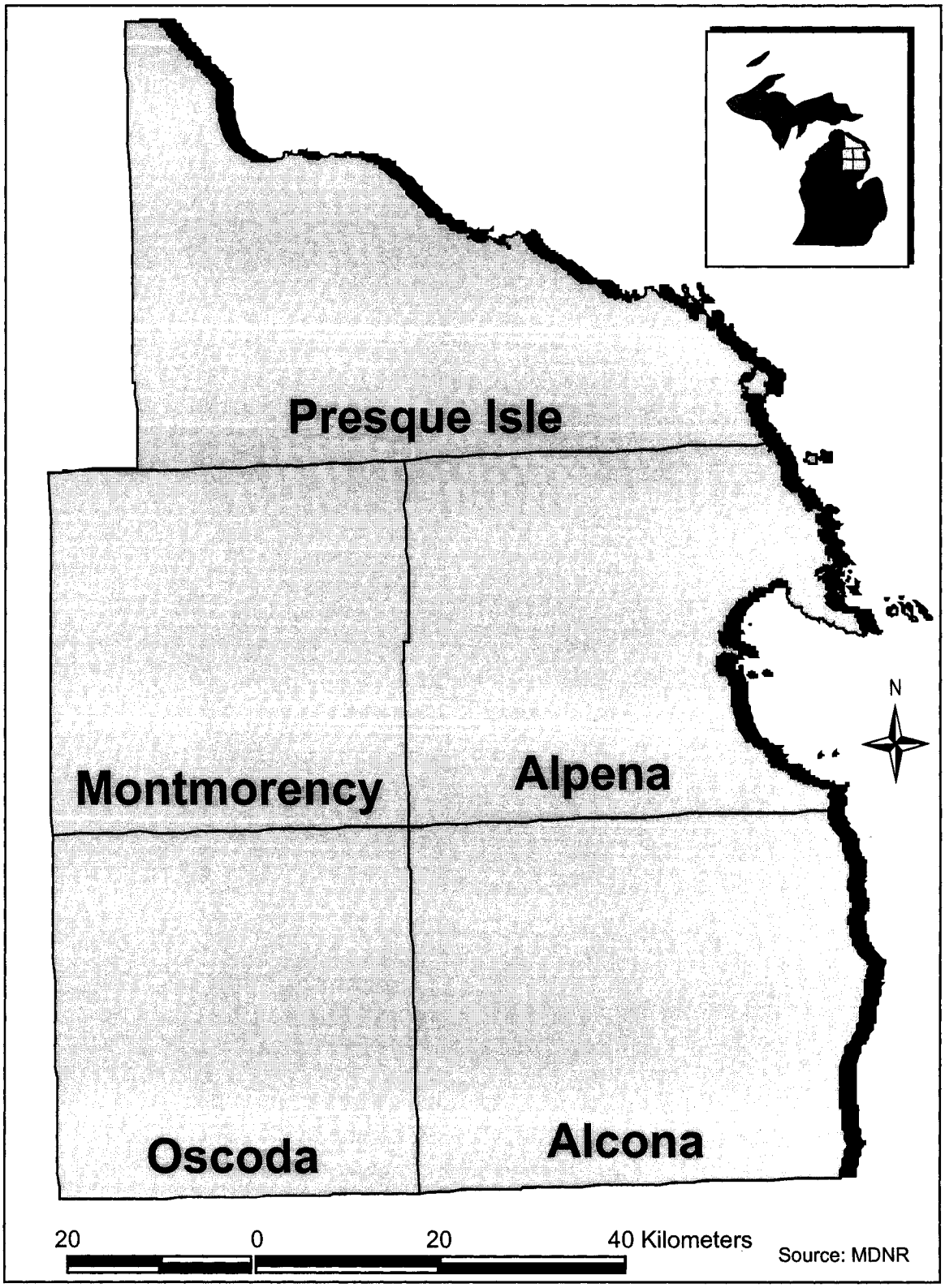



**Figure 2. Study Site: Northeastern Lower Peninsula of Michigan**

# CHAPTER 2

# METHODS

## Databases

MDNR researchers have been collecting data annually on the deer heads collected for tb monitoring in the five county area of Alcona, Alpena, Montmorency, Oscoda, and Presque Isle from 1996-2002. This study examined data collected from 1996-2000. These data were organized into two databases, the tb database and suspicious tissue database. The tb database contains test records for individual deer, consisting of survey type (deer obtained from hunt or non-hunt origin), tb identification number, tb test result (negative or positive), age (aged on the half year), sex, and harvest location (county, township, and section) information. The suspicious tissue database contains data fields for tissue type (head or carcass), survey type (hunt or non-hunt), tb identification number, tb test result (negative or positive), age (aged on the half year), sex, and harvest location information. A Q in any of the data fields indicated no data present.

The first step in determining whether "hot spots" exist is to examine the database and check for errors and detectable biases. Error checking includes examination of data consistency, and correctness of data. For example some sections were listed as _2, 2_, or 02; for data consistency all numbers were changed to 02. Location errors include counties that have townships listed, which are not located in that county. The MDNR was contacted to see if there were any corrections for the location errors, and changes were made to the

database. All changes to the tb database are listed in Appendix 1. If there were no corrections available then the record was deleted (Table 1).

**Table 1. Record of Missing (Q) or Incorrect Data**

| Data Category | Data Type | Number | % of Total |
|---|---|---|---|
| Section | Incorrect | 2 | 0.01% |
| Town | Incorrect | 401 | 1.07% |
| Range | Incorrect | 407 | 1.09% |
| Sex | Q | 88 | 0.24% |
| Age | Q | 90 | 0.24% |
| Section | Q | 764 | 2.04% |
| Town | Q | 459 | 1.23% |
| Range | Q | 453 | 1.21% |
| Total Deleted Records | all | 860 | 2.30% |

Bias checking was done by looking at sample sizes of each township by sex and age (1½, 2½, 3½, $4\frac{1}{2}^{+}$) categories, and comparing the distributions of each of these categories. Sample sizes of at least 300 are required to detect ≥ 1% prevalence with a 95% confidence interval (Schmitt et al., 1997). In addition, to determine if there was a positive bias in the number of carcasses turned in due to visible lesions (i.e. are hunters more likely to turn a deer into a check station if there were lesions visible in the chest cavity?), the number of tb+ carcasses and heads turned in during the hunt season were examined. For the analyses, 860 records were deleted from the tb and suspicious tissue databases because of incorrect or missing location information. For the tb database, this is 2.30% of the total records in the tb database (Table 1). No tb+ animals were deleted from either database. This left 29,078 usable records for the five county area. There are 356 records from 1994-1995, or 1.22% of the 29,078 records, which were excluded. Fawns comprise 5.32% of the total usable records and were also excluded from the current analysis. Records from 1994-1995 were excluded

because sampling was not over the entire five county area. Fawns were excluded because they were thought too young to exhibit signs (visible lesions) of tuberculosis, and were only collected by mistake or if the hunter insisted. There were 27,085 records that contained all the correct location, sex and age information from 1996-2000. This will be the basis for the sex/age analysis discussed herein (Table 2).

**Table 2. Composition of TB Database**

| Data Category | Number | % of Total |
|---|---|---|
| 1994-2000 records w/correct information | 29078 | 100.00% |
| 1994-1995 Records | 356 | 1.22% |
| 1975 Record | 1 | 0.00% |
| 1996-2000 Missing Sex/Age | 90 | 0.31% |
| Fawns | 1546 | 5.32% |
| 1996-2000 records w/correct information | 27085 | 93.15% |

For the suspicious tissue database, there are 29,071 records (Table 3). There are 27,066 records that contain all the correct information from 1996-2000. There are 355 records from 1995, which comprises 1.22% of the database. Fawns consist of 5.30% of the total suspicious tissue database.

**Table 3. Composition of Suspicious Tissue Database**

| Data Category | Number | % of Total |
|---|---|---|
| Usable Head (1996-2000) | 26540 | 91.29 |
| Usable Carcass (1996-2000) | 526 | 1.81 |
| Unknown Head/Carcass | 15 | 0.05 |
| Unknown Sex/Age (1996-2000) | 93 | 0.32 |
| Fawns(1996-2000) | 1542 | 5.30 |
| 1995 Head/Carcass | 355 | 1.22 |
| Total | 29071 | 100.00 |

Females comprise 78.43% of the non-hunt data, and 46.6% of the hunt data, while males make up 21.25% of the non-hunt data, and 53.17% of the hunt data.

A new column, case frequency, was added to the tb database, which denoted the case frequency category of each township. Case frequency categories are defined by the number of years a tb positive animal has been harvested in that township. Zero case frequency townships are defined as never having a tb+ animal in that township. Medium case frequency is defined as having at least one tb+ animal in up to each of two years in that township. High case frequency is defined as having at least one tb+ animal in each of three or more years in that township. There are 59 townships classified as zero case frequency townships, 21 townships are medium case frequency, and 20 townships are high case frequency. Case frequency differs from prevalence. Prevalence is calculated as the number of tb+ deer present in any variously defined area divided by the total number of deer tested in that area.

For each case frequency category, sample size distributions were determined yearly and cumulatively using 1996-2000 data. Yearly data were broken into five distribution categories: n = 0, 1-25, 26-50, 51-100, or > 100 deer checked. Cumulative data were also broken into five distribution categories, n = 0, 1-100, 101-200, 201-300, or > 300. This is based on a sample size of at least 300 being required to detect a ≥ 1% prevalence with a 95% confidence interval (Schmitt et al., 1997). Sex and age distributions were classified into their respective case frequency category.

GIS

County, township, section coverages, and Northern Lower Peninsula 1993 land cover grid were downloaded from the Michigan Geographic Data Library (http://www.state.mi.us/webapp/cgi/mgdl/).

Case Frequency Coverages

Three case frequency coverages were created: original case frequency (using politically defined boundaries), home range case frequency (using biologically defined boundaries), and new case frequency (using a combination of political and biological boundaries) (Appendix 2).

*Original Case Frequency Coverage*

The tb database provides town and range information for dead deer. In ArcView™ a shapefile for zero, medium and high case frequency townships was created by linking the tb database to the township coverage by the town and range column. ArcInfo™ was used to *clean* and *build* the coverage (Figures 3 and 4).

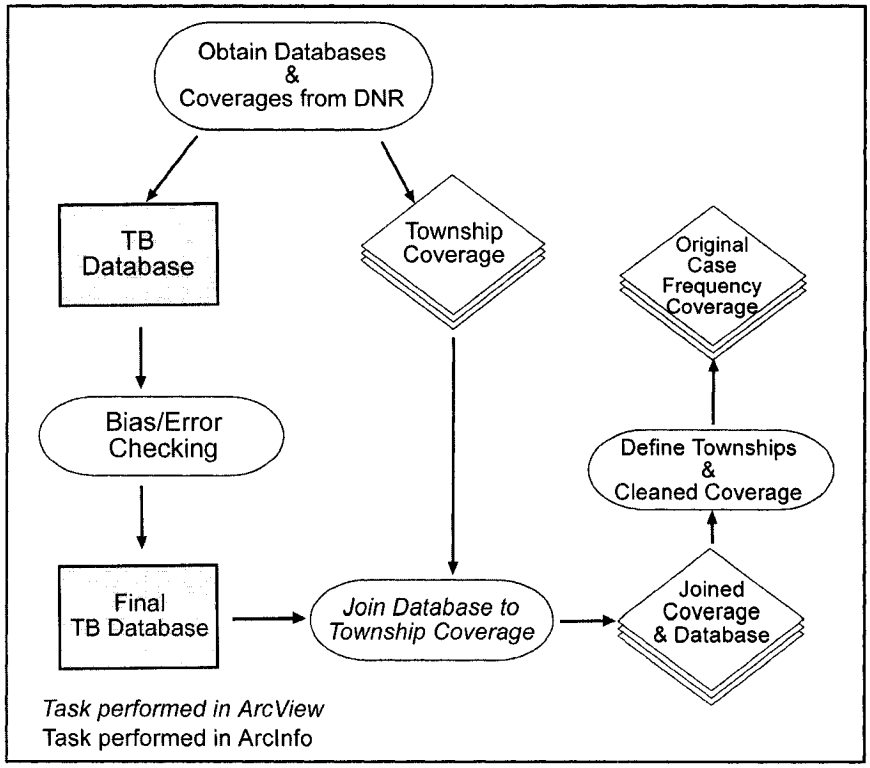



**Figure 3. Data Flow Diagram for Original Case Frequency Coverage**

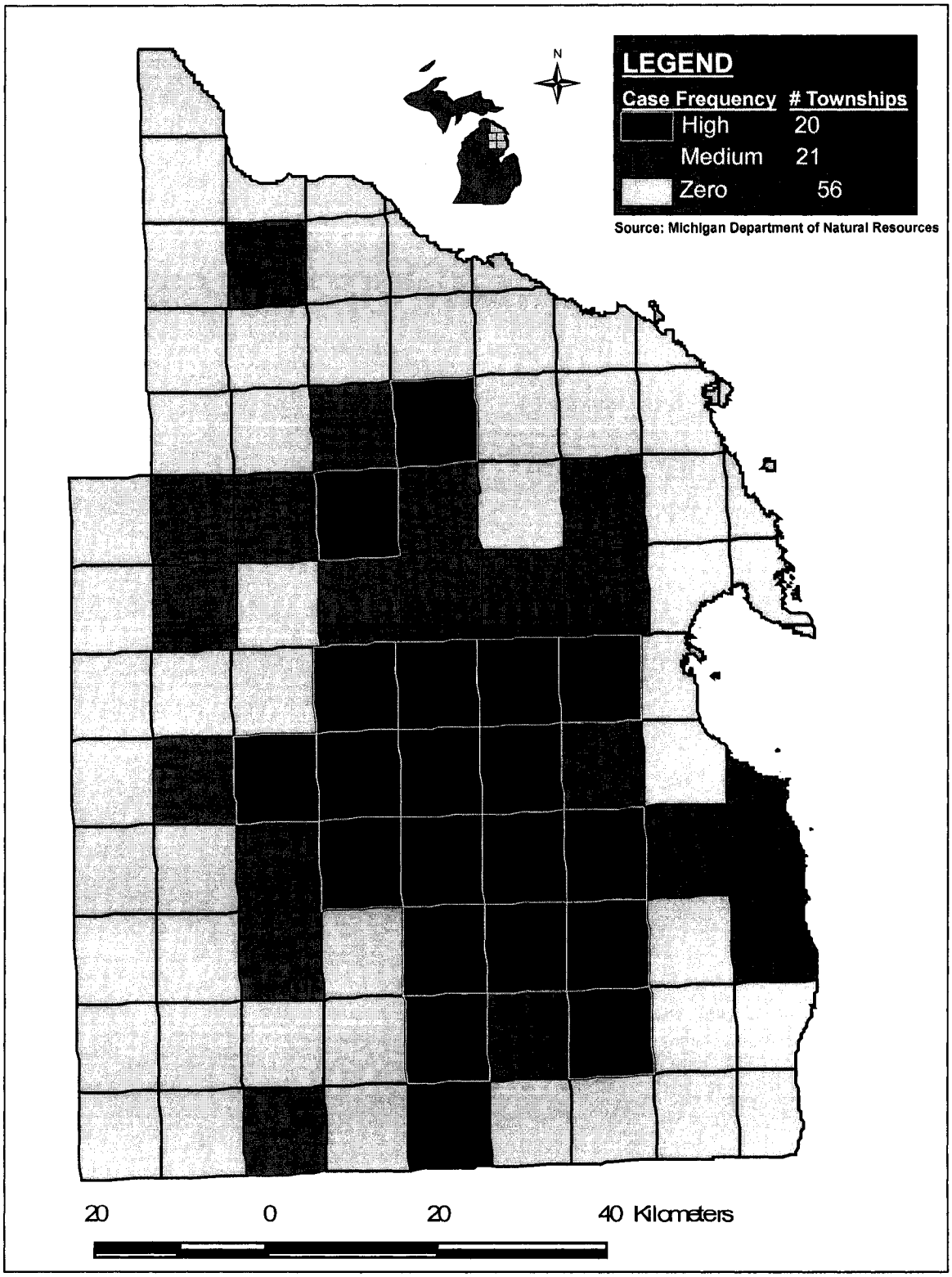



**Figure 4. Original Case Frequency Coverage for the Five County Area**

*Tb+ Deer Point Coverage*

The tb database gives locations of deer to the section (this is not a point location). To have actual point locations for which to generate the home range case frequency coverage, the tb+ deer point coverage was constructed. To create a coverage for tb+ deer point locations (Figure 5) several steps were taken. First, a table of tb+ deer locations was created, and linked to the section coverage. Point locations were created in ArcInfo™ by using the *createlabel, centroidlabel* (places the location of the tb+ deer in the center of the section in which it was harvested), and *build* (creates topology) commands.

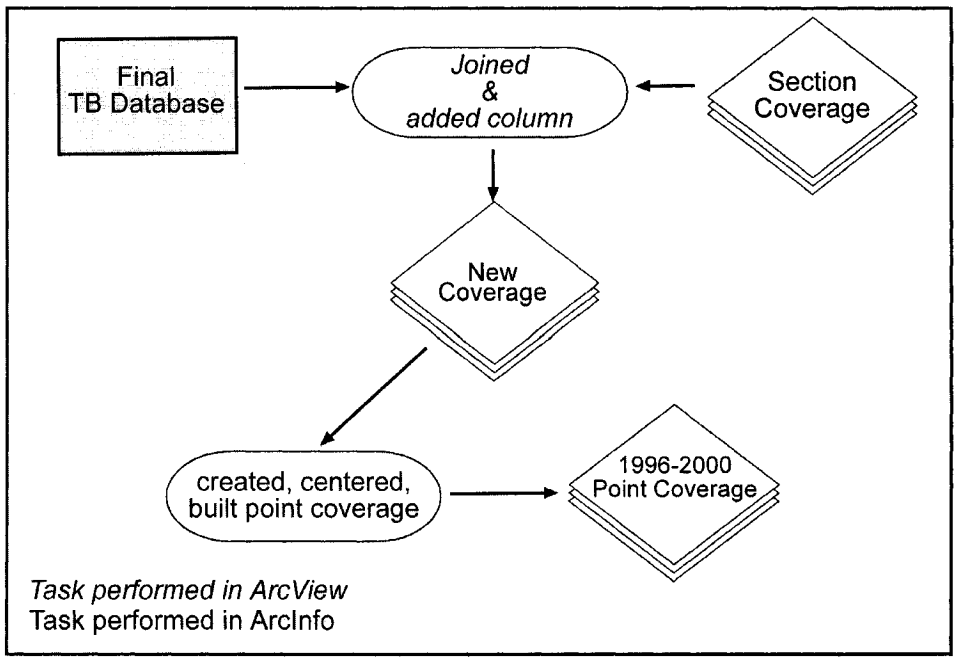



**Figure 5. Data Flow Diagram for TB+ Deer Point Coverage**

*Home Range Case Frequency Coverage*

Home range data for deer in this area, provided by previous radiotelemetry studies (Garner 2001, Muzo unpublished data, Sitar 1996), were incorporated to create the home range case frequency coverage (Figures 6 and

7). The reasoning behind this methodology is that deer are not stationary objects. Point locations by themselves take into account only one instance in

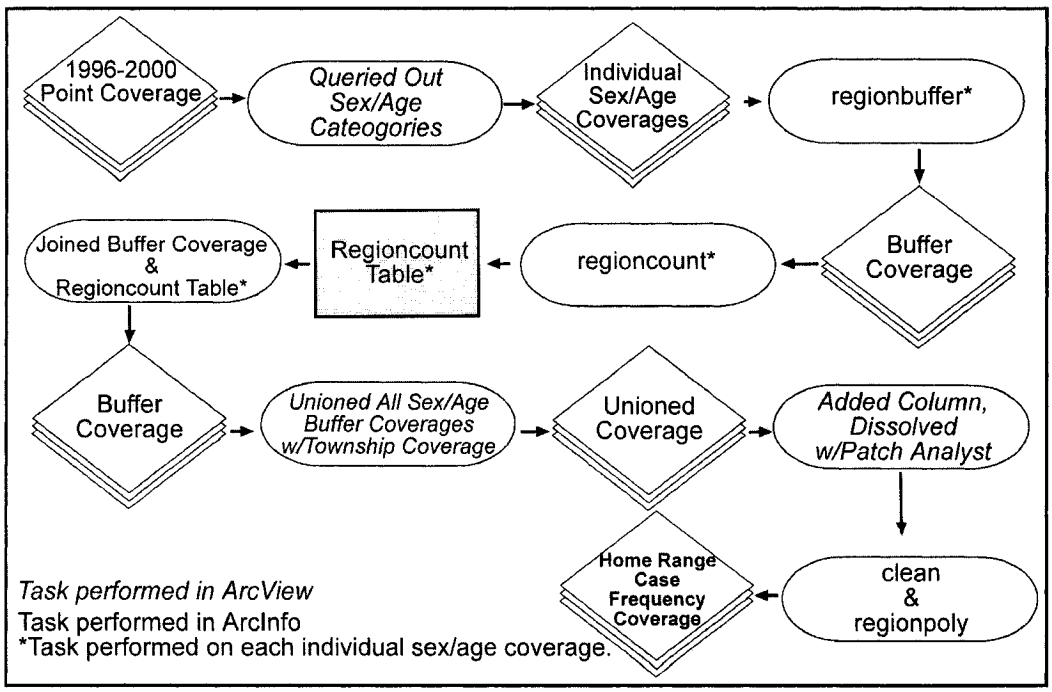



**Figure 6. Data Flow Diagram of Home Range Case frequency Coverage**

time, and for example if that deer had been harvested a day earlier, it may have been in an entirely different township. Using home range estimates takes into account that deer are mobile and that one fixed location (i.e. harvest site) does not accurately reflect the ecology of deer. This study does not take into account that approximately 19% of the deer in this region are migratory (Garner 2001), however a conservative estimate can be deduced. Migratory deer are defined as having separate summer and winter home ranges, that are at least 1 km apart (Sitar 1996). The complexity of incorporating the direction and distance of migration into the spatial modeling is beyond the scope of this project.

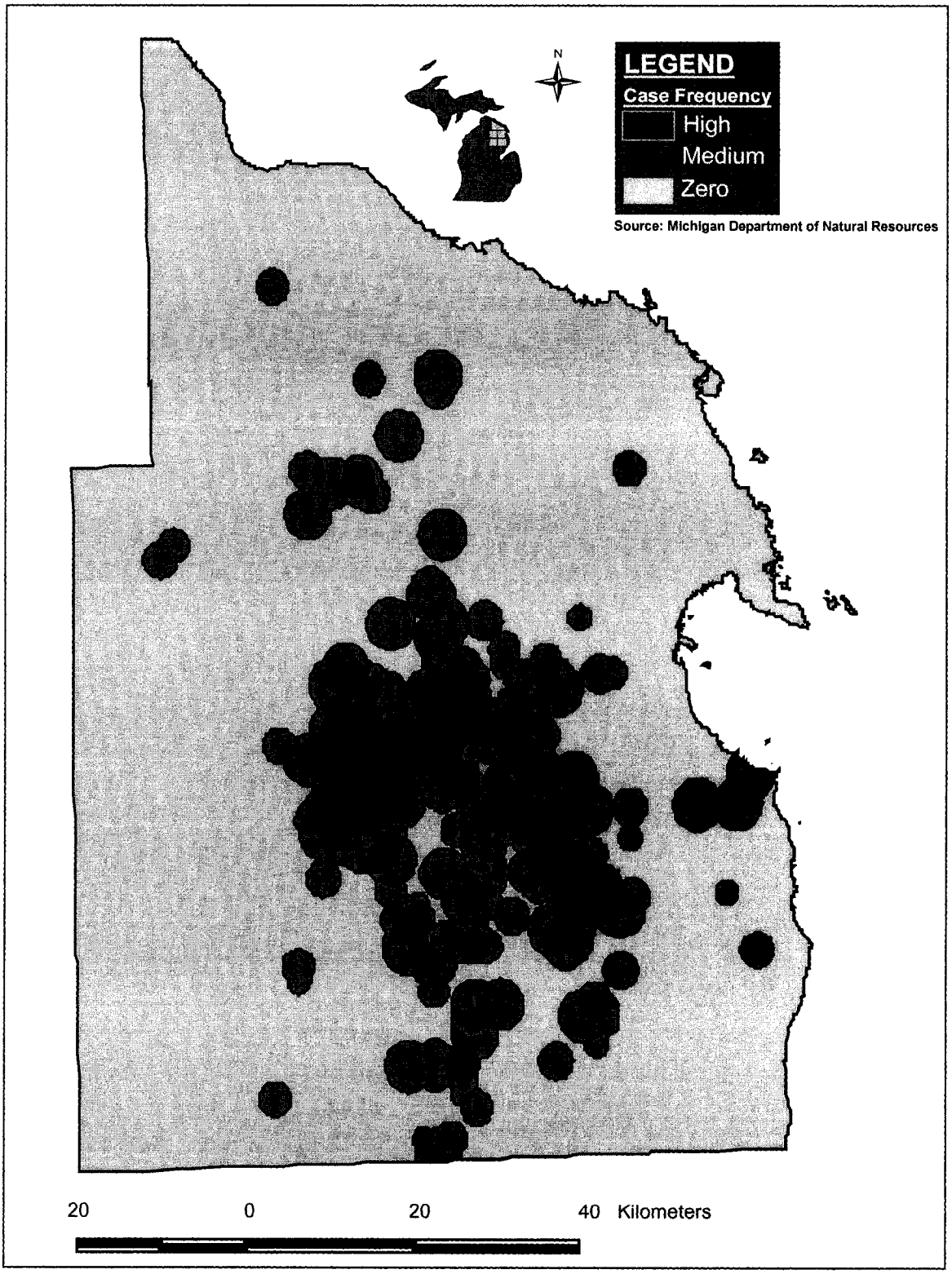



**Figure 7. Home Range Case Frequency Coverage for the Five County Area**

Home range sizes were calculated and averaged within age and sex categories. In ArcView™, using the animal movement extension (Hooge 2000), home ranges were determined by the kernel method with a 95% probability contour and a least-squares cross-validation (LSCV) choice of *h* (smoothing parameter). Age categories were females 1½, 2½ and 3½$^{+}$ and males 1½ and 2½$^{+}$; each category was a separate coverage. The age categories differed between the tb database and GIS evaluations. This difference was due to inadequate sample sizes from radio-collared deer. For this study, non-migratory home range estimates were used for the females, and both migratory and non-migratory season-specific home range estimates were used for the males. This difference was again due to the small sample size of radio-collared male deer. This gives a conservative approximation of area utilized by deer in this region.

The average home range area was used to calculate a radius, which was used to create a sex/age specific buffer around the tb positive deer locations (Table 4). For each point coverage a new buffer coverage was created with the *regionbuffer* (for more information on regions see Appendix 3) command in Arcinfo™. Then using *regioncount*, a table was created and joined to each coverage. In ArcView™, each coverage was combined using *union*, and an additional case frequency column was placed in the attribute table, which added all polygons that intersected. Using this new column, case frequency was determined for each polygon using the same criteria as were used to determine the original case frequency. Zero case frequency is defined as never having a tb+ animal in that polygon. Medium case frequency is defined as having one or

two tb+ animals in that polygon. High case frequency is defined as having three or more tb+ animals in that polygon. Once this was completed the shapefile was dissolved by the case frequency column using the patch analyst extension (Elkie et al. 1999), and was clipped to fit the five county area using xtools extension (DeLaune 2001). Finally, the home range case frequency coverage was cleaned in Arcinfo™.

**Table 4. Estimated Home Ranges and Their Averages Based on Age and Sex Categories**

| Sex | Age | Radius ($m^2$) | Sample Size | Home Range | | |
|---|---|---|---|---|---|---|
| | | | | $\hat{X}$ ($m^2$) | Minimum Value ($m^2$) | Maximum Value ($m^2$) |
| Female | 1.5 | 1,706 | 10 | 9,141,251 | 1,406,601 | 23,399,887 |
| Female | 2.5 | 1,347 | 20 | 5,700,450 | 1,119,122 | 25,541,237 |
| Female | 3.5+ | 1,884 | 35 | 11,143,857 | 668,693 | 141,231,996 |
| Male | 1.5 | 2,064 | 19 | 13,380,289 | 641,953 | 89,628,439 |
| Male | 2.5+ | 2,813 | 5 | 24,853,722 | 6,523,754 | 31,109,171 |

*New Case Frequency Coverage*

In ArcView™ the new case frequency coverage was created by overlaying the home range case frequency coverage over a copy of the original case frequency coverage. A new case frequency column was added to the original case frequency attribute table, which categorized townships based on the number of individual home ranges. Zero case frequency townships are defined as never having a tb+ home range in that township. Medium case frequency is defined as having one or two tb+ home ranges in that township. High case frequency is defined as three or more tb+ home ranges in that township.

ArcInfo™ was used to clean and build the New Case frequency Coverage (Figures 8 and 9).

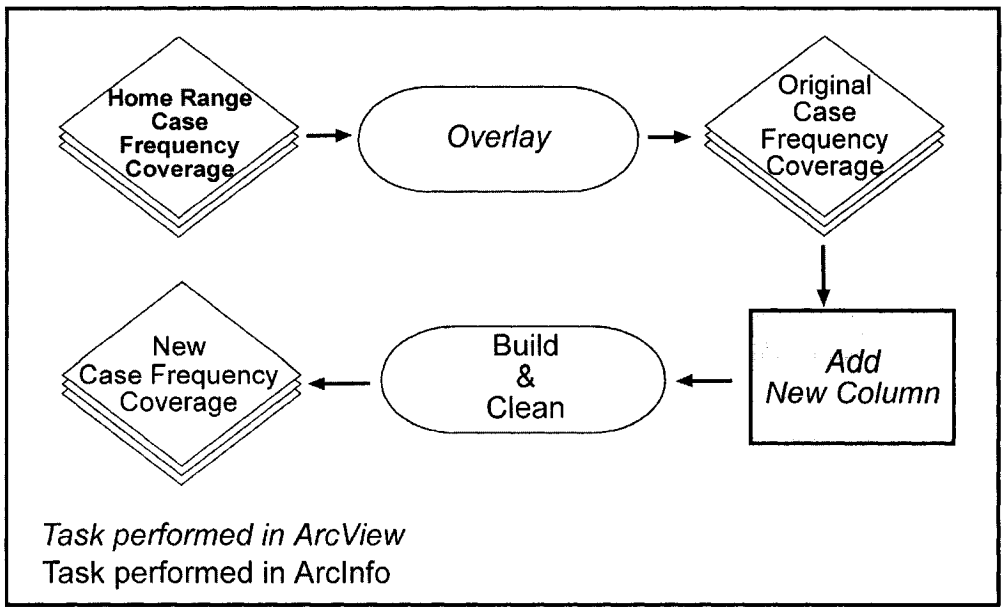



**Figure 8. Data Flow Diagram for New Case frequency Coverage**

Deer Use Grid/Coverage

In ArcView™, the NLP 1993 land cover grid was reclassified into five deer use categories (see Appendix 4), Summer Use (high quality summer habitat), Summer Other (poor summer habitat), Winter Use (high quality winter habitat), Winter Other (poor winter habitat), and Rare Use (includes areas rarely or never used by deer, such as water, urban and industrial areas). These deer use categories are based on habitat use literature (Kohn et al., 1971, McCaffery et al., 1974, Rogers et al., 1981, Stormer et al., 1980, Van Deelen et al., 1996, and Davenport, 1941). In cases where land cover types overlapped in seasonal use, the more frequently used season was applied. For the habitat use analysis, the deer use grid was converted to a vector coverage using ArcInfo™.

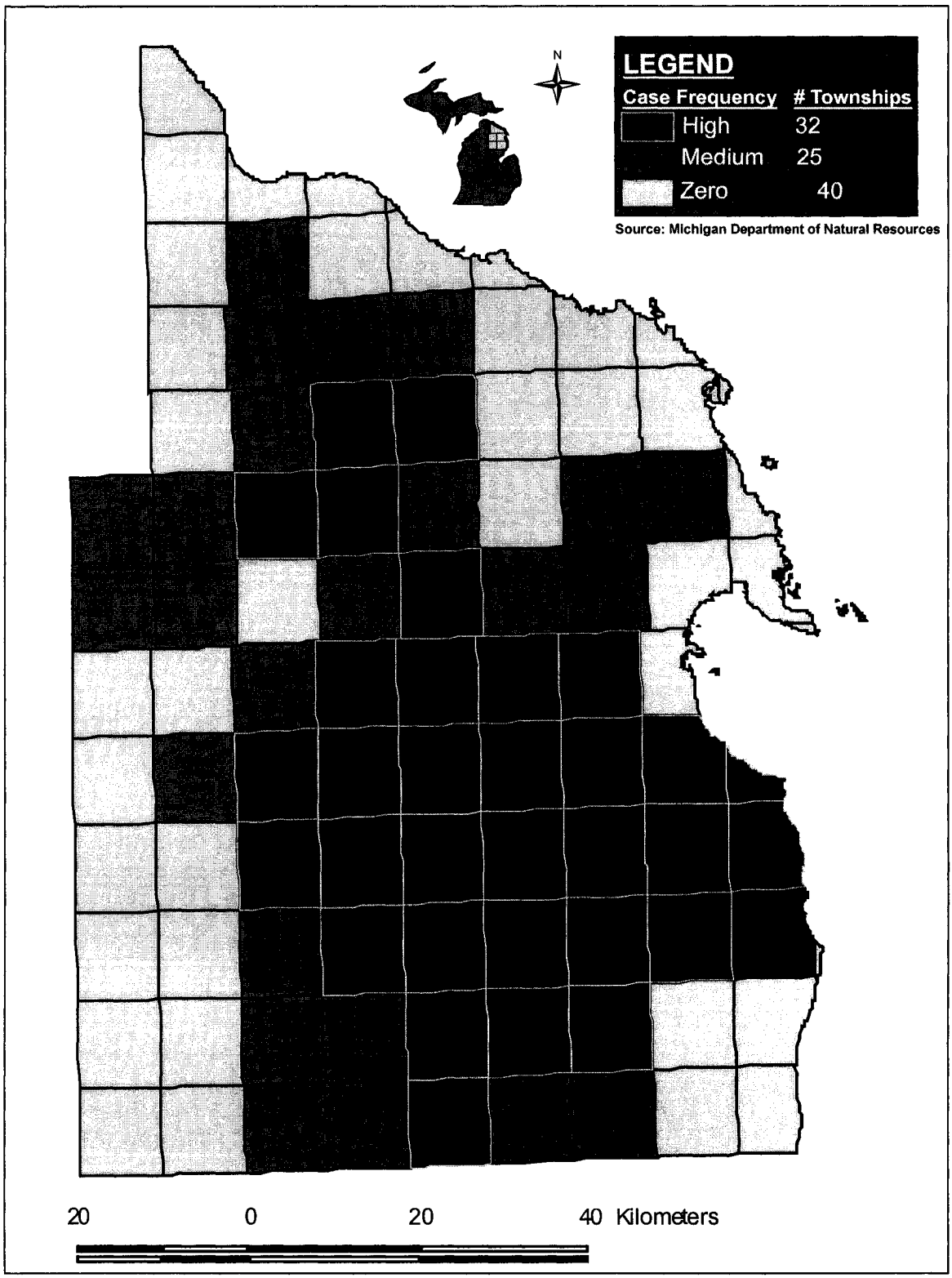



**Figure 9. New Case frequency Coverage for the Five County Area**

Kernel Core Area

The kernel (Worton 1989) and minimum convex polygon (MCP) (Mohr 1947) core area coverages (Figure 10) were created as a way to compare the individual case frequency values, and to determine the most significant polygons.

In Arcview™ using the animal movement extension and the tb+ deer point locations a fixed kernel range estimate with a 95% probability contour was calculated. The resulting shapefile was clipped from the home range case frequency coverage. This new shapefile was used to compare case frequencies and deer use within the kernel core area.

MCP Core Area

In Arcview™ using the animal movement extension a minimum convex polygon using 95% of the tb+ deer points was calculated. The resulting shapefile was clipped from the home range case frequency coverage. This new shapefile was used to compare case frequencies and deer use within the MCP core area.

Seasonal Home Ranges & Habitat Use

To better understand the patterns observed in the three case frequency coverages (original, new, and home range), movement patterns and habitat use of radio-collared adult does in the study area were examined. Use is defined as any time a deer is present in a specified habitat type. Deer were placed into each of three categories: range season (summer or winter), migratory status (non-migratory or migratory), and tb area (y=yes in tb area, n=not in tb area, or p=partial tb area). The tb area was defined by the kernel core area. Those deer whose home range was inside the kernel core area were delineated as y, those

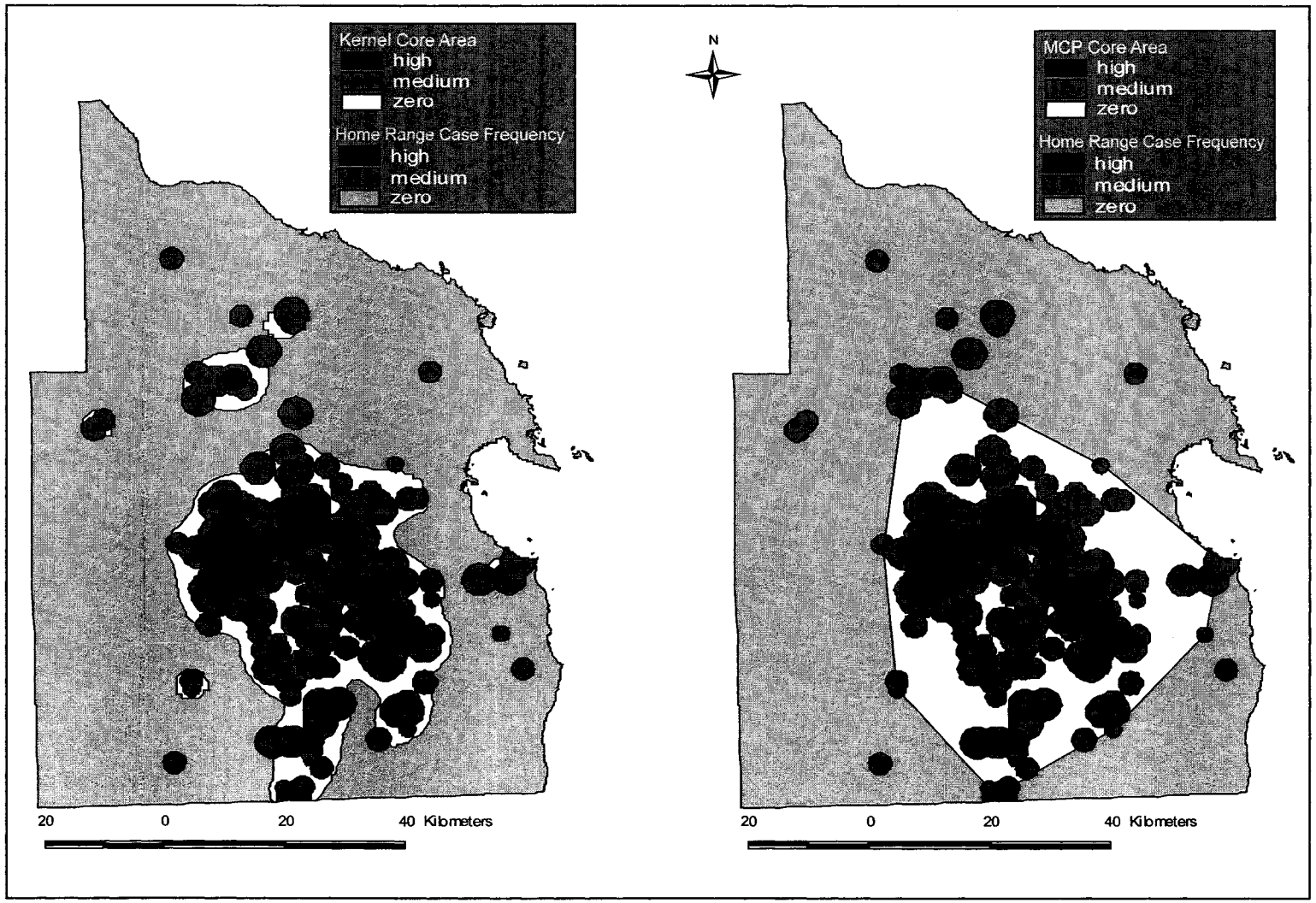



**Figure 10. Kernel and MCP Core Areas Overlayed onto the Home Range Case Frequency Coverage**

outside the kernel core area were delineated as n, and those that had a home range that were partially inside the kernel core area were delineated as p. These three categories were used in statistical comparisons.

Habitat use was determined by calculating summer and winter home ranges for 29 does, 15 non-migratory and 14 migratory. Summer and winter home ranges were defined using the average migration dates of radio-collared deer in the area, March 29 and October 28 (Garner 2001). In ArcView™, using the animal movement extension, home ranges were determined by the kernel method with a 95% probability contour and a least-squares cross-validation (LSCV) (Seaman et al. 1996) choice of *h* (smoothing parameter). Each home range was used to clip an area from the deer use coverage. The percent area of each deer use category was calculated from the clipped coverages. The point coverage used to estimate the home ranges were overlayed on the clipped coverages, and the percent points contained in each deer use category was calculated (Figures 11 and 12).

Statistical Analyses

Databases

The tb database and suspicious tissue database were evaluated for biases by comparing samples sizes by sex and age categories for statistical differences using chi-square analyses.

GIS

For both the original and new case frequency coverages, *tabulate areas* in Spatial Analyst was used to calculate the area of each deer use category per

township. This was converted to percentages per township. MANOVA (multivariate analysis of variance) and Tukey's HSD analyses were performed using the GLM procedure in the SAS™ statistical package (SAS, 1999) to determine if there were correlations or differences in deer use categories among case frequency categories. MANOVA is a technique used for assessing group differences across multiple metric dependent variables (deer use categories) at the same time, based on a set of categorical independent variables (case frequency) (Johnson et al., 1982). *Tabulate areas* in Spatial Analyst was used to calculate the area of each deer use category per area of case frequency for the home range, kernel & MCP core area coverages. The data were evaluated using chi-square analysis to determine differences among deer use categories by case frequencies. ArcInfo™ was used to calculate Moran's *I* for the home range case frequency coverage. Moran's *I* (Moran 1950) is a weighted correlation coefficient that identifies deviations from spatial randomness.

To determine differences in habitat use a usage index was calculated as $\frac{\%\ \text{points}}{\%\ \text{area}}$ (<1 no to low use, 1 moderate use, >1 high use). For each deer use category the index was ranked, starting with one as the lowest number for that category (Figures 11 and 12). An ANOVA was run, in SAS™ using the GLM procedure, on the ranks for each deer use category and migratory status, range season, and tb area sub-categories (Conover et al., 1981). Interactions between these sub-categories were also tested and identified.

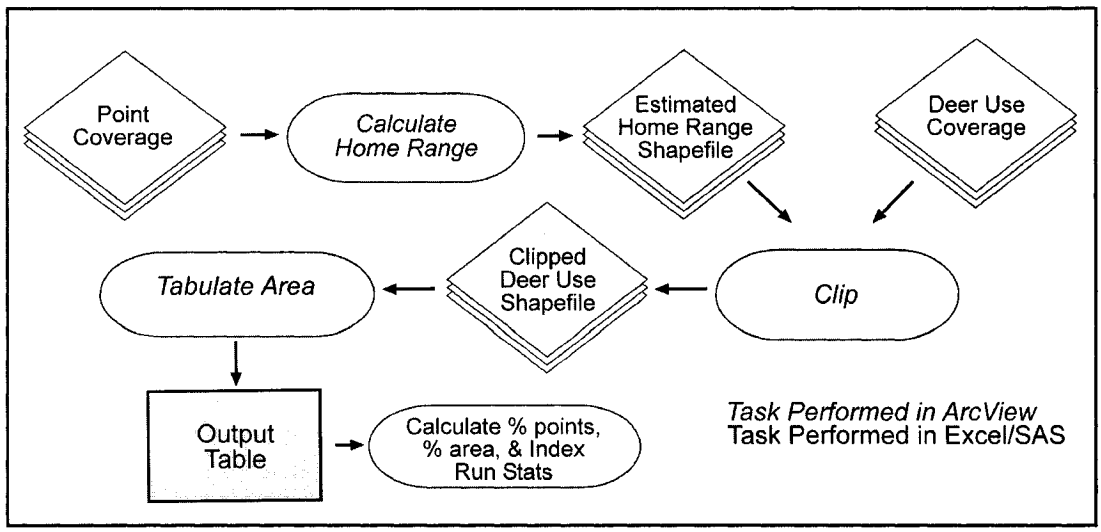
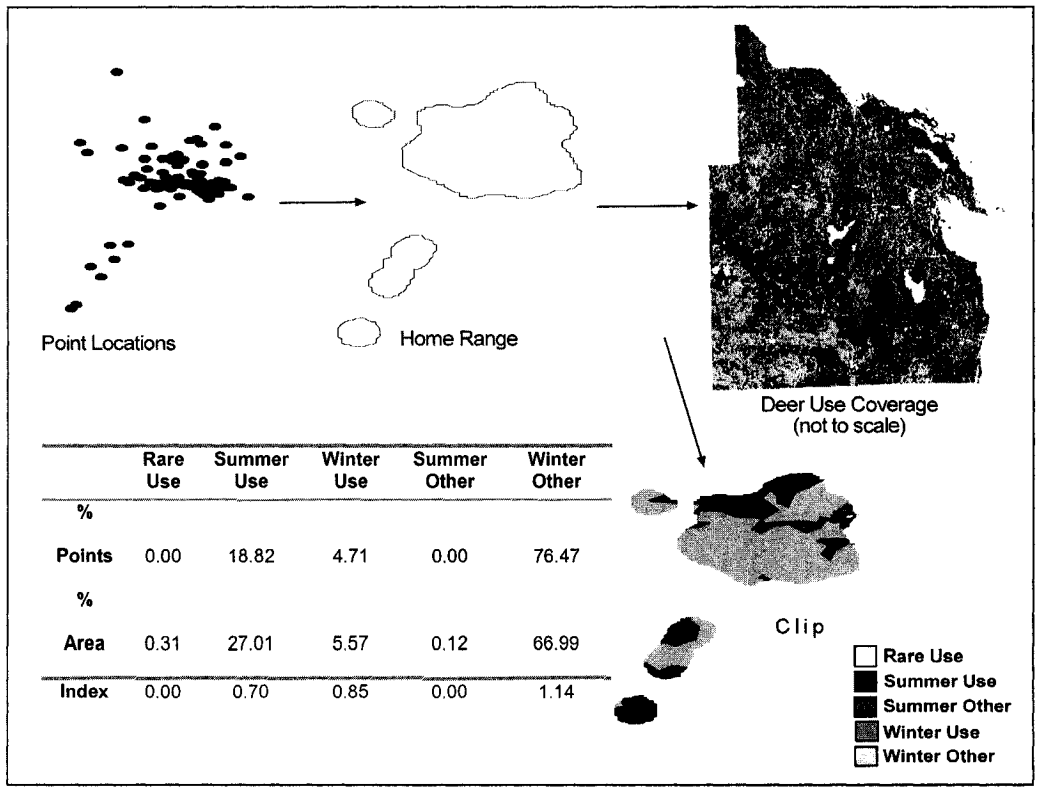



**Figure 11. Data Flow Diagram for Seasonal Home Range and Habitat Use Analyses**




| | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other |
|---|---|---|---|---|---|
| % Points | 0.00 | 18.82 | 4.71 | 0.00 | 76.47 |
| % Area | 0.31 | 27.01 | 5.57 | 0.12 | 66.99 |
| Index | 0.00 | 0.70 | 0.85 | 0.00 | 1.14 |

**Figure 12. Example of How Percent Points, Percent Area, and Index Were Calculated**

# CHAPTER 3

# RESULTS

## Databases

Bias checking was done by looking at sample size distributions, and performing chi-square analyses comparing sample sizes of sex and age categories among the different case frequency groups. Comparing the case frequency categories cumulatively, high case frequency areas are well sampled, medium case frequency will have adequate sample sizes in a year or two, and zero case frequency areas will likely require at least two years to reach adequate sample sizes (Figures 13 and 14). This is based on Schmitt et al. (1997) finding that sample sizes of at least 300 are required to detect ≥ 1% prevalence with a 95% confidence interval. Comparing the yearly sample size distributions within the high case frequency category shows a marked decrease in sampling in 1999 and 2000 (Figures 15 and 16). Figure 17 illustrates high case frequency townships broken down into sections. This shows that sampling is inadequate for statistically significant analysis at the section level.

To determine if "hot spots" really existed or if they were an artifact of over sampling in the high case frequency areas and under sampling in the medium and zero case frequency categories, chi-square analysis was done. Another concern was that since older males (≥5 years) are more likely to be infected with bovine tb (O'Brien et al., 2002), over sampling of older males would overestimate tb case frequency. Chi-square analyses show no differences ($\chi^2$=2.64, p=0.8524) among age groups in the female sample sizes (Table 5).

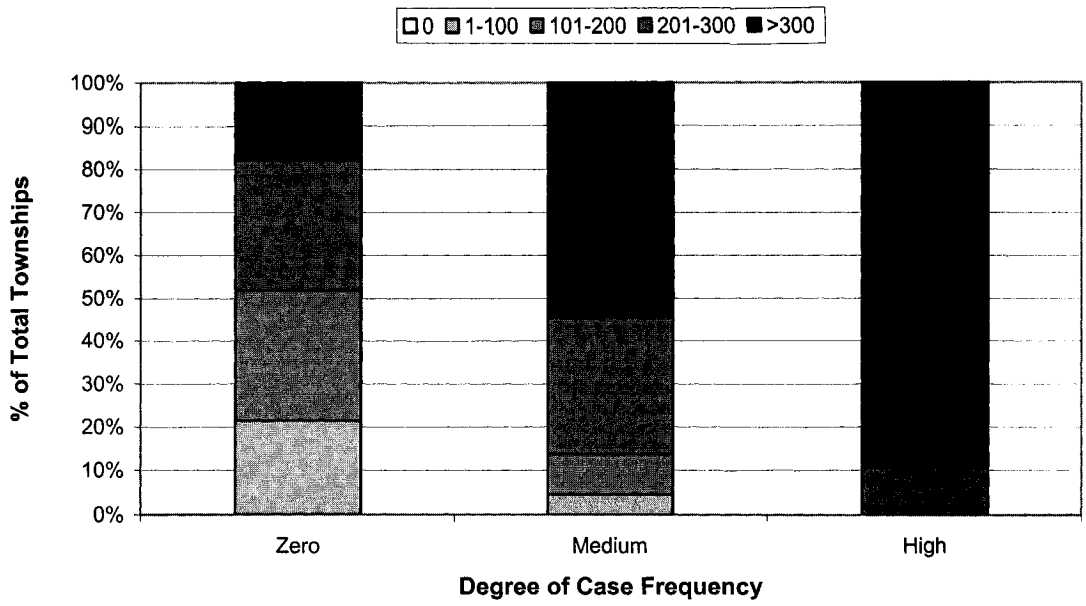



**Figure 13. Percent Sample Size Categories for All Case Frequency Distributions 1996-2000**

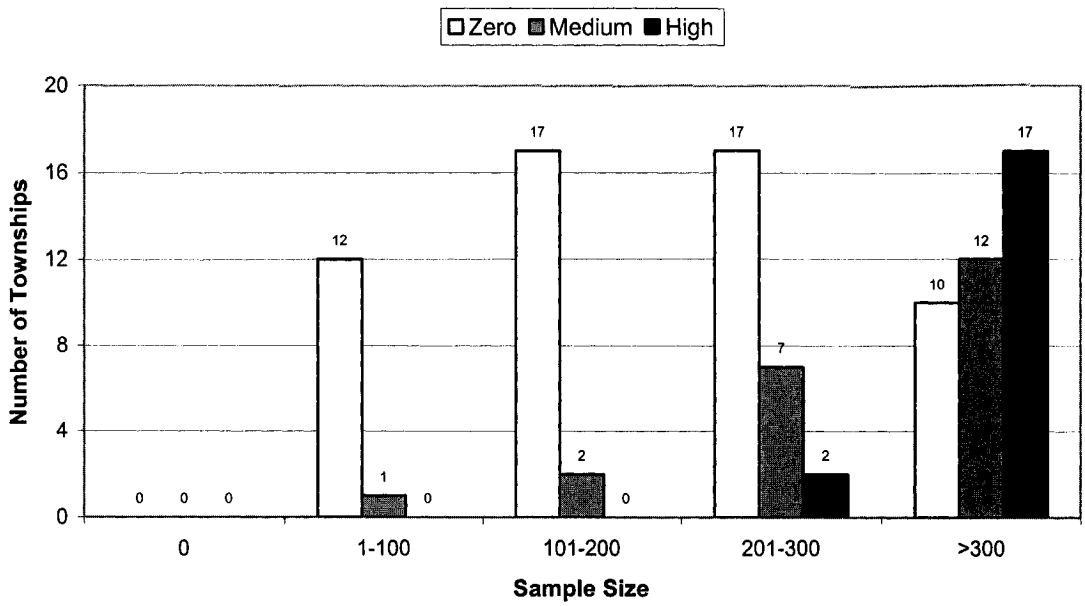



**Figure 14. Sample Size Distribution of Deer Tested for TB in All Townships of the Five County Area 1996-2000**

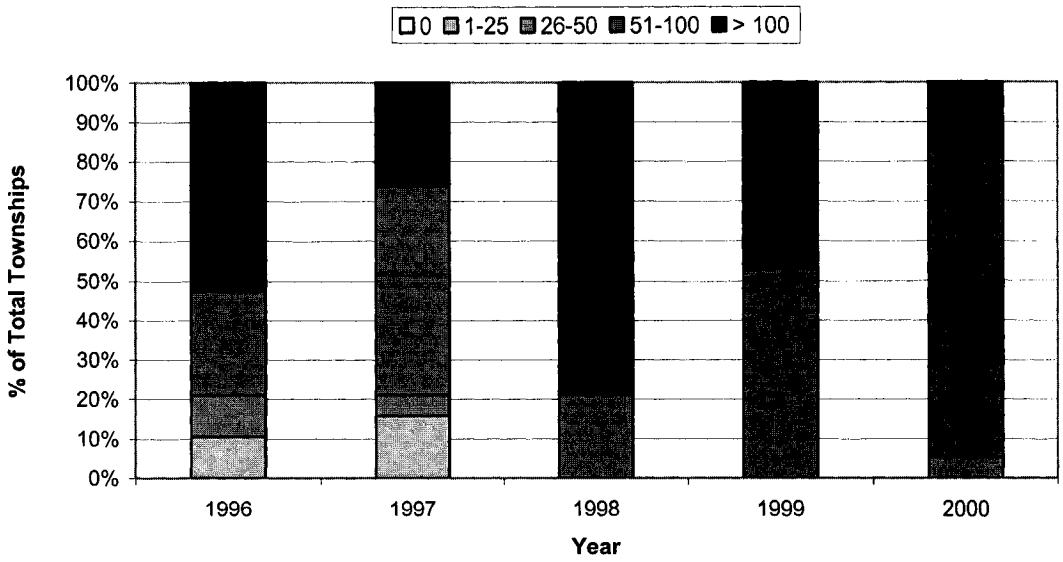



**Figure 15. Percent Sample Size Categories for High Case Frequency Townships**

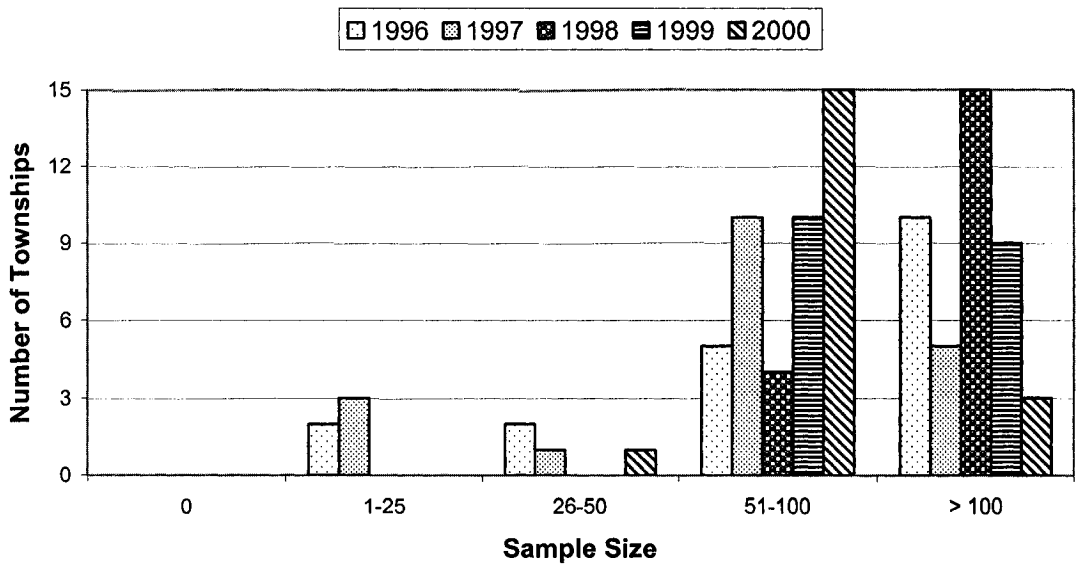



**Figure 16. Distribution of Sample Sizes for High Case Frequency Townships**

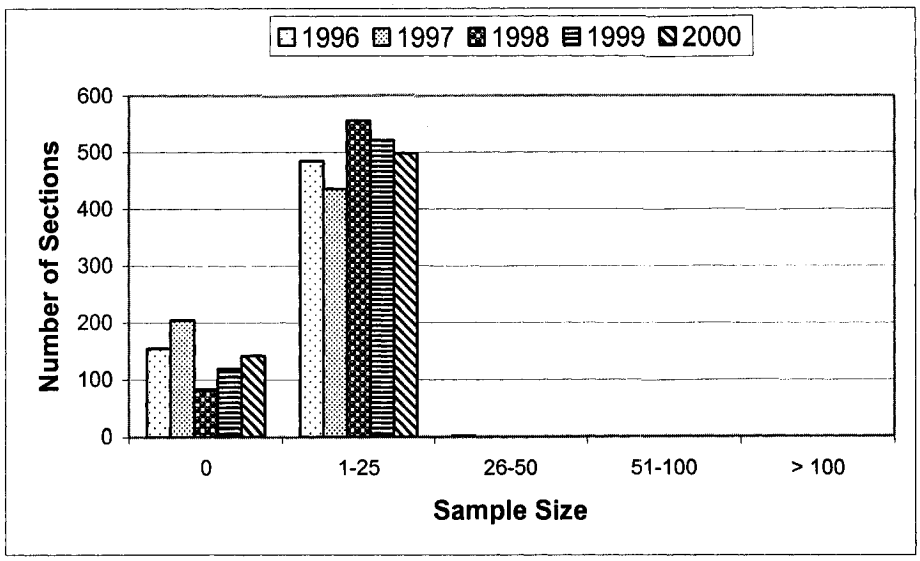



**Figure 17. Distribution of Sample Sizes of Sections within High Case frequency Townships**

**Table 5. Chi-Square Tests Comparing the Number of Deer Tested for Tb by Sex among the 3 Case Frequency Areas**

| Females | Observed | | | | Expected | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.5 | 3.5 | 4.5+ | 1.5 | 2.5 | 3.5 | 4.5+ | Total | P | $\chi^2$ |
| Zero | 1209 | 1136 | 1125 | 1946 | 1181 | 1162 | 1113 | 1960 | 5416 | 0.8524 | 2.64 |
| Medium | 741 | 752 | 709 | 1245 | 752 | 739 | 709 | 1247 | 3447 | | |
| High | 913 | 928 | 865 | 1559 | 930 | 915 | 877 | 1543 | 4265 | | |
| Total | 2863 | 2816 | 2699 | 4750 | 2863 | 2816 | 2699 | 4750 | 13128 | | |

| Males | Observed | | | | Expected | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.5 | 3.5 | 4.5+ | 1.5 | 2.5 | 3.5 | 4.5+ | Total | P | $\chi^2$ |
| Zero | 3680 | 1204 | 423 | 141 | 3516 | 1321 | 488 | 124 | 5448 | >0.0001 | 141.69 |
| Medium | 2570 | 809 | 316 | 77 | 2434 | 914 | 338 | 86 | 3772 | | |
| High | 2757 | 1370 | 511 | 99 | 3057 | 1148 | 424 | 108 | 4737 | | |
| Total | 9007 | 3383 | 1250 | 317 | 9007 | 3383 | 1250 | 317 | 13957 | | |

In the males, the sample sizes differed ($\chi^2$=141.69, p>0.0005) among age categories, with the number of males tested decreasing with age. Table 6 compares “hot spots” (high case frequency townships) with "non-hot spots” (zero and medium case frequency townships). The same trends were exhibited here; females were not different, with the number of males tested decreasing with age.

**Table 6. Chi-Square Tests Comparing Sample Sizes by Sex Between Hot Spots vs. Not Hot Spots**

| Females | Observed | | | | Expected | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.5 | 3.5 | 4.5+ | 1.5 | 2.5 | 3.5 | 4.5+ | Total | P | $\chi^2$ |
| "Non-Hot spots" | 1950 | 1888 | 1834 | 3191 | 1933 | 1901 | 1822 | 3207 | 8863 | 0.7472 | 1.22 |
| "Hot spots" | 913 | 928 | 865 | 1559 | 930 | 915 | 877 | 1543 | 4265 | | |
| Total | 2863 | 2816 | 2699 | 4750 | 2863 | 2816 | 2699 | 4750 | 13128 | | |

| Males | Observed | | | | Expected | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.5 | 3.5 | 4.5+ | 1.5 | 2.5 | 3.5 | 4.5+ | Total | P | $\chi^2$ |
| "Non-Hot spots" | 6250 | 2013 | 739 | 218 | 5950 | 2235 | 826 | 209 | 9220 | >0.0001 | 137.31 |
| "Hot spots" | 2757 | 1370 | 511 | 99 | 3057 | 1148 | 424 | 108 | 4737 | | |
| Total | 9007 | 3383 | 1250 | 317 | 9007 | 3383 | 1250 | 317 | 13957 | | |

Due to the difference in age groups among the males, a chi-square test was used to determine if there was a positive bias in the number of carcasses turned in due to visible lesions. Older bucks have the potential of being infected longer, and therefore may be more likely to exhibit visible symptoms (e.g. lesions in the chest cavity). Chi-square analyses of the suspicious tissue database showed that the higher case frequency of tb in older bucks is not due to a greater number of carcasses being turned in ($\chi^2$ =2.15, p=0.5426) (Table 7). Based on these results, hot spots of tb do exist and are not an artifact of sampling.

**Table 7. Chi-Square Tests for Biases by Sex in the Number of TB+ Carcasses vs. Heads Turned in by Hunters**

| Females | Observed | | | | Expected | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.5 | 3.5 | 4.5+ | 1.5 | 2.5 | 3.5 | 4.5+ | Total | P | $\chi^2$ |
| Carcass | 4 | 14 | 14 | 29 | 6 | 13 | 13 | 29 | 61 | 0.7698 | 1.13 |
| Head | 6 | 10 | 10 | 23 | 4 | 11 | 11 | 23 | 49 | | |
| Total | 10 | 24 | 24 | 52 | 10 | 24 | 24 | 52 | 110 | | |

| Males | Observed | | | | Expected | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 2.5 | 3.5 | 4.5+ | 1.5 | 2.5 | 3.5 | 4.5+ | Total | P | $\chi^2$ |
| Carcass | 21 | 47 | 23 | 4 | 22 | 47 | 20 | 6 | 95 | 0.5426 | 2.15 |
| Head | 19 | 38 | 13 | 6 | 18 | 38 | 16 | 4 | 76 | | |
| Total | 40 | 85 | 36 | 10 | 40 | 85 | 36 | 10 | 171 | | |

GIS

Case Frequency Coverage Analyses

Once it was determined that "hot spots" did exist, potential correlations between case frequency areas and deer use categories were established. MANOVA analyses of the two township coverages (original case frequency coverage and new case frequency coverage) compared percent deer use categories per township among each case frequency category. Tukey's HSD was used to determine where these differences lie. Results for the original case frequency coverage show rare use ($F_{2,98}$=2.16, p=0.1207), winter use ($F_{2,98}$=0.61, p=0.5480), summer other ($F_{2,98}$=0.83, p=0.4399), and winter other ($F_{2,98}$=1.56, p=0.2155) exhibited no differences among case frequency categories. However, summer use ($F_{2,98}$=4.08, p=0.0198) showed differences between high and zero case frequency categories (Table 8). Results for the new case frequency coverage showed winter use ($F_{2,98}$=0.72, p=0.4897) and summer other ($F_{2,98}$=0.46, p=0.6346) revealed no differences among case frequency categories. Conversely, for the new case frequency coverage, rare use

($F_{2,98}$=5.82, p=0.0041), summer use ($F_{2,98}$=5.96, p=0.0036), and winter other ($F_{2,98}$=3.24, p=0.0435) showed differences. Rare use differed between high and zero, and medium and zero case frequency categories. Summer use differed between high and zero case frequency categories. Winter other differed between high and medium case frequency categories. Figures 18 and 19, which show the percentages of deer use categories for each case frequency category and the entire five county area, help illustrate why these differences are present.

**Table 8. Summary of MANOVA and Tukey's HSD Analyses for Differences of % Deer Use Among Case frequency Categories**

| | Overall Model For Original Case frequency Coverage | | | | |
|---|---|---|---|---|---|
| | **Rare Use** | **Summer Use** | **Winter Use** | **Summer Other** | **Winter Other** |
| F(p) | 2.16(0.1207) | 4.08(0.0198) | 0.61(0.5480) | 0.83(0.4399) | 1.56(0.2155) |
| | | **Tukey's HSD*** | | | |
| **Case frequency** | **Rare Use** | **Summer Use** | **Winter Use** | **Summer Other** | **Winter Other** |
| Zero | a | a | a | a | a |
| Medium | a | ab | a | a | a |
| High | a | b | a | a | a |
| | **Overall Model For New Case frequency Coverage** | | | | |
| | **Rare Use** | **Summer Use** | **Winter Use** | **Summer Other** | **Winter Other** |
| F(p) | 5.82(0.0041) | 5.96(0.0036) | 0.72(0.4897) | 0.46(0.6346) | 3.24(0.0435) |
| | | **Tukey's HSD*** | | | |
| **Case frequency** | **Rare Use** | **Summer Use** | **Winter Use** | **Summer Other** | **Winter Other** |
| Zero | a | a | a | a | a |
| Medium | b | ab | a | a | a |
| High | b | b | a | a | b |

*Within a deer use category case frequency categories with the same letter do not differ ($\alpha$=0.05).

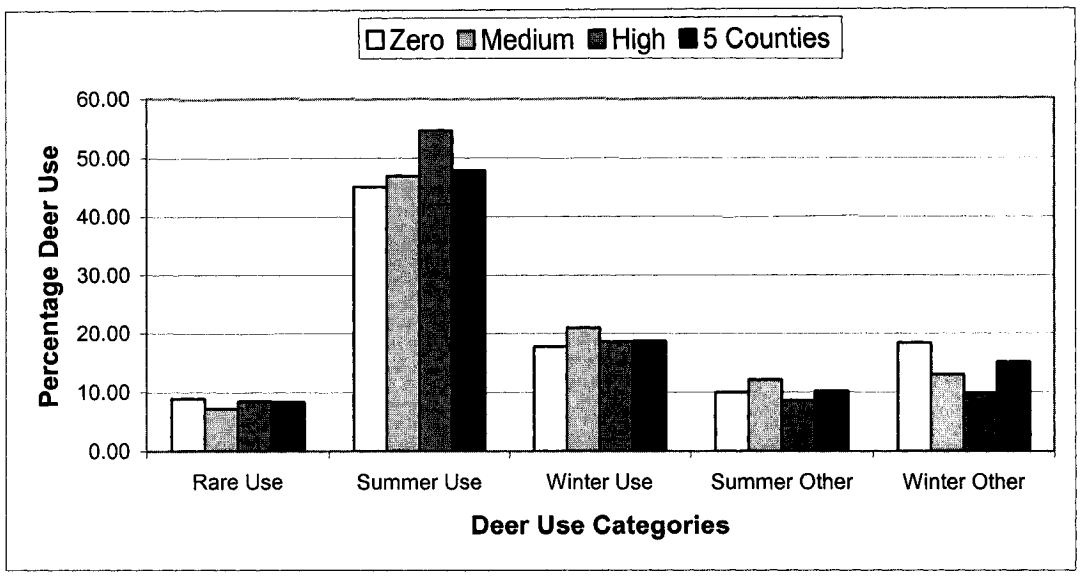



**Figure 18. Percentage of Deer Use Categories for Original Case Frequency Coverage**

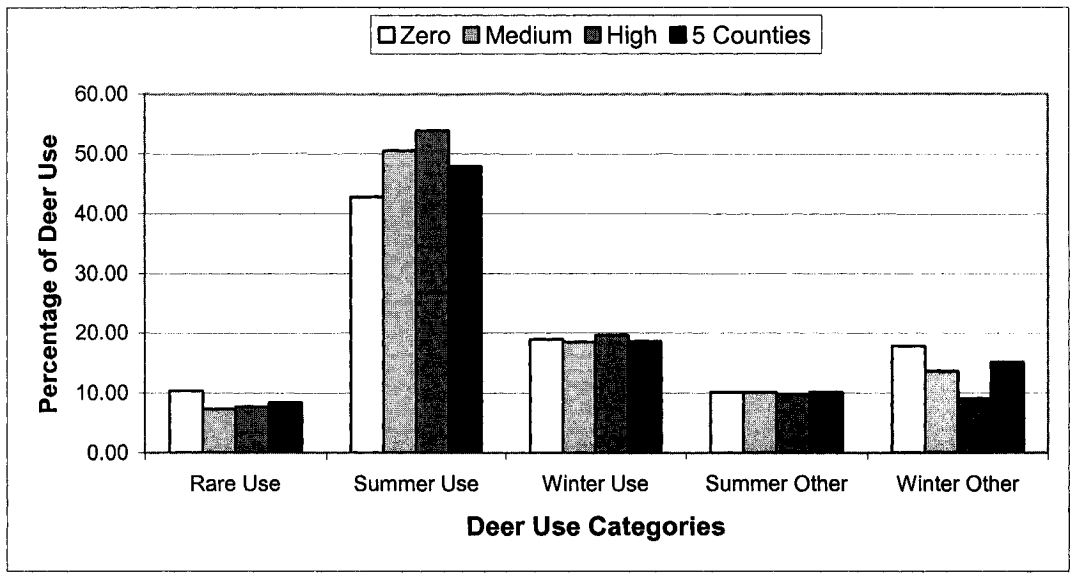



**Figure 19. Percentage of Deer Use Categories for New Case Frequency Coverage**

Chi-square analysis was used to compare deer use categories among zero, medium, and high case frequency areas for the home range case frequency coverage (Appendix 5a). Results of the analysis show differences among deer use categories ($\chi^2$=83.63, p>0.0001). Figure 20 shows high case

frequency has the largest amount of summer use, and the least amount of summer other and winter other use.

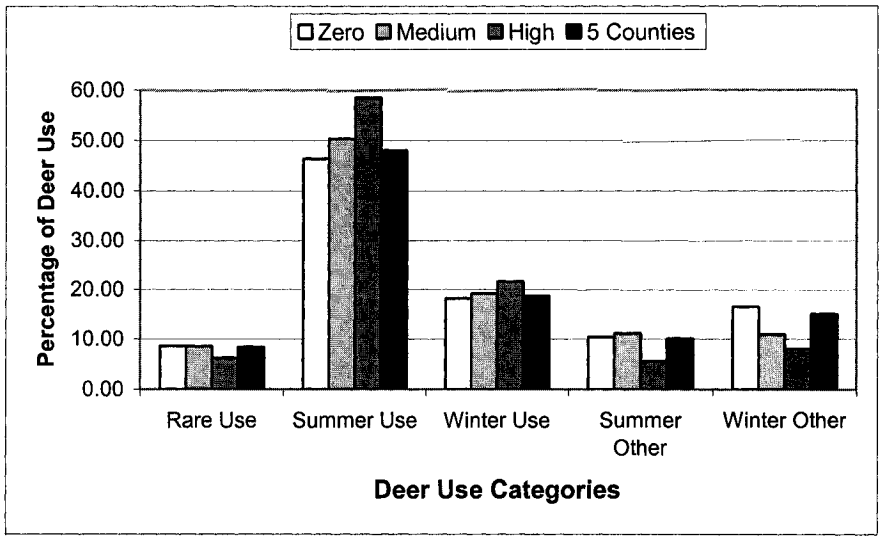



**Figure 20. Percentage of Deer Use Categories for Home Range Case Frequency Coverage**

Trends observed over all three case frequency coverage analyses were as follows:

1. Rare use was evenly distributed among high, medium and zero case frequency for the original case frequency coverage and home range case frequency coverage. However, there was a significantly larger portion of rare use for zero case frequency (10.36%), than high and medium case frequency (7.70% and 7.33%, respectively) for the new case frequency coverage.

2. Summer use increased as case frequency level increased, with the most dramatic increase exhibited by the home range case frequency coverage.

3. Winter use was evenly distributed among high, medium and zero case frequency for all coverages.

4. Summer other use was evenly distributed among high, medium and

zero case frequency for original and new case frequency coverages. The home range case frequency coverage showed a significantly smaller amount of summer other use (5.57%) for high case frequency compared to the medium and zero case frequencys (11.10% and 10.41%, respectively).

5. Winter other use decreased as case frequency increased. This trend was consistent for all coverages.

Moran's *I* was performed on the home range case frequency coverage, which was used to determine the spatial distribution (random vs. clustered distribution) of bovine tb in the area. The Moran's *I* = 0.9958, which shows that case frequency categories are clustered (Figure 7). For example, high case frequency areas have a higher probablility of being next to another high case frequency area (i.e. positive spatial autocorrelation).

Core Area Analyses

Core area analyses were used to compare the individual case frequency values, and to determine the most significant polygons, significant polygons were those that are correctly categorized into their respective case frequency category, and are not an artifact of how the home range coverage was calculated. For example if there is a 25 $km^2$ area categorized as medium case frequency surrounding a 1ha high case frequency area, is this area truly high case frequency or an artifact of overlapping home ranges? This analysis did not succeed in answering the question of significance. However, it did provide a useful means of comparing central areas of high case frequency.

Chi-Square analyses were used to compare deer use categories in the

kernel core area and the MCP core area (Appendix 5b and 5c). While this does not tell which polygons are most significant, it does demonstrate areas of high tb activity, and excludes areas (polygons) of low activity. Both kernel and MCP analyses showed differences of deer use among case frequency categories ($\chi^2$=34.36, p>0.0001; $\chi^2$=44.78, p>0.0001, respectively). Figures 21 and 22 show similar trends for both analyses. Rare use and summer other use categories decrease as case frequency increases. Winter use category increases as case frequency increases. In the MCP core area analysis, summer use follows the same trends as the three case frequency analyses. The winter other use category also exhibits similar trends to the case frequency analyses. Zero and medium case frequencies are similar, with high case frequency significantly smaller.

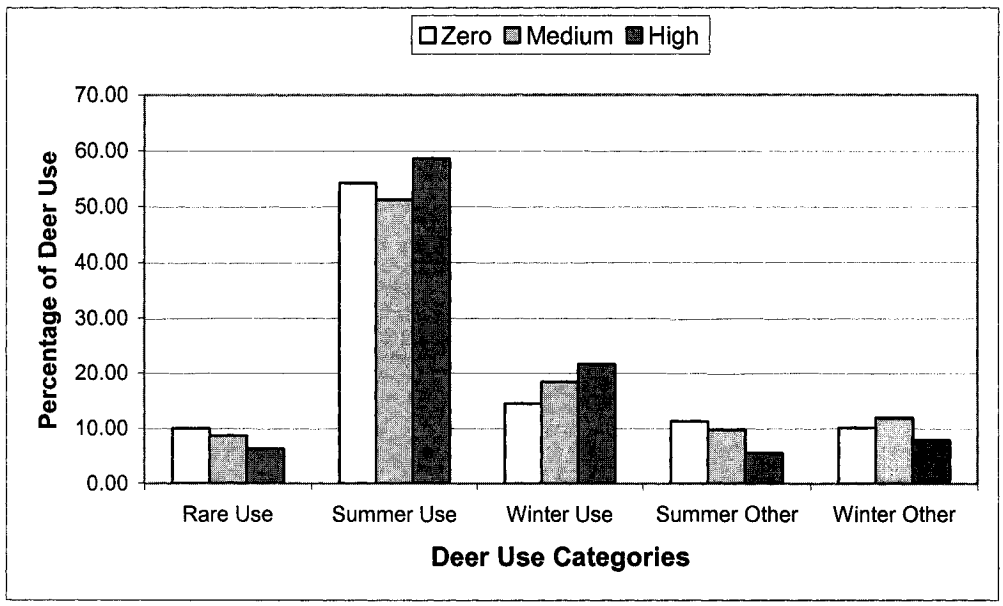



**Figure 21. Percentage of Deer Use Categories for Kernel Core Area**

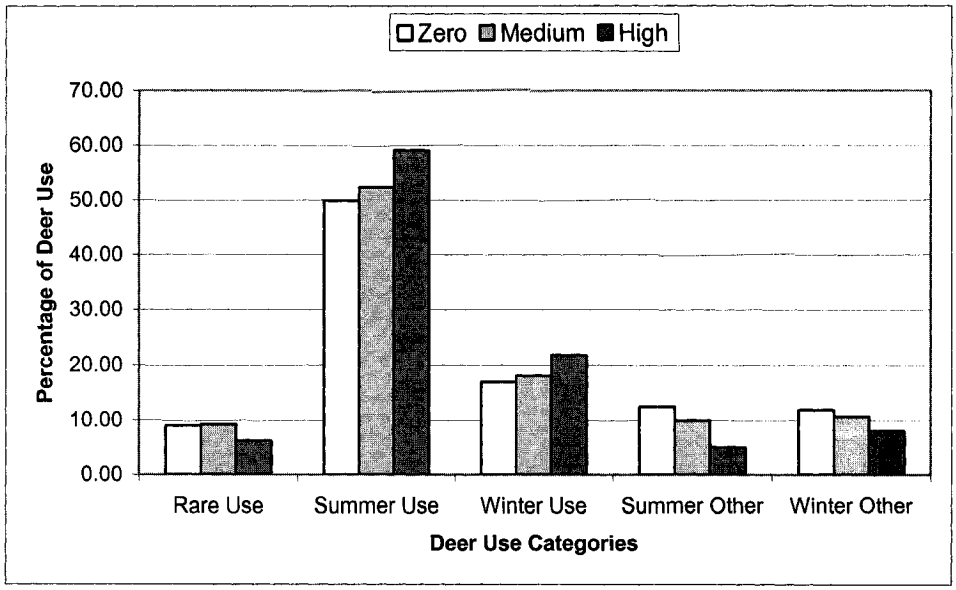



**Figure 22. Percentage of Deer Use Categories for MCP Core Area**

Seasonal Home Ranges & Habitat Use

To better understand the relationships observed in the previous analyses, movement patterns and habitat use of radio-collared deer in the study area were examined. To determine differences in habitat use a usage index ($\frac{\%\ \text{points}}{\%\ \text{area}}$; <1 no to low use, 1 moderate use, >1 high use) was calculated. For each deer use category the index was ranked starting with one for the smallest index value. An ANOVA was run on the ranks for each deer use category and migratory status, range season, and tb area sub-categories. Interactions among these sub-categories (SR*MS, SR*TB, MS*TB, SR*MS*TB) were also tested.

*Rare Use*

Results from the ANOVA show a difference (F=2.15, p=0.0390) for the overall model, and for seasonal range (F=14.52, p=0.0004) for rare use. It is the

only category that shows significant differences in seasonal ranges. Figure 23 shows the average index value plotted for migratory status and tb area sub-categories. Average index value varies substantially by migratory status between tb and non-tb areas. However, it did not show up as being statistically different (Table 9). In the tb area non-migratory deer not only use rare use more often than did migratory deer in the tb area, but they also have the highest use of all of the four groups.

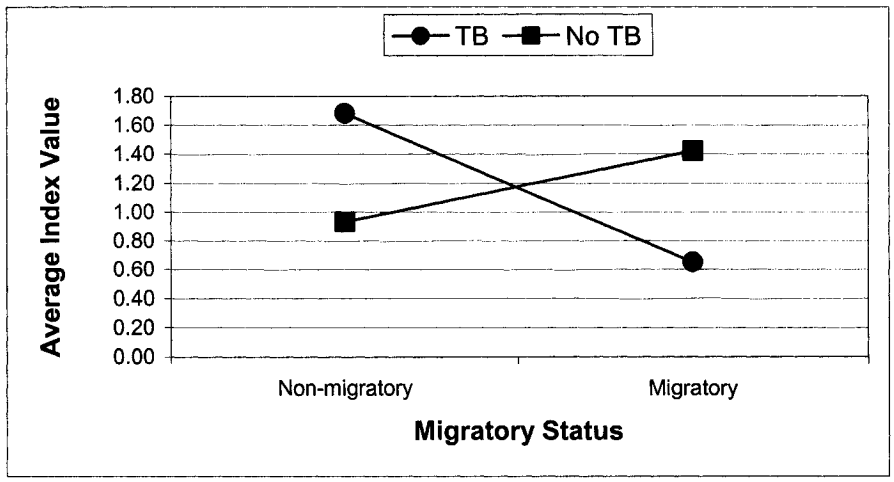



**Figure 23. Rare Use Interaction Between TB Areas & Migratory Status**

*Summer Use*

Results from the ANOVA show that the overall model is not significant ($F=1.31$, $p=0.2569$). Figure 24 illustrates high quality summer habitat use of deer in the five county area. Deer in the no tb area are consistent in summer habitat use regardless of migratory status. Non-migratory deer in the tb area show a substantially larger amount of high quality summer habitat use than any other group.

**Table 9. Summary of ANOVA Testing for Differences in Habitat Use**

| | F(p-values) * | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | MAIN EFFECTS | | | | INTERACTIONS | | | |
| **Deer Use** | **Overall Model** | **Seasonal Range** | **Migratory Status** | **TB Area** | **SR*MS** | **SR*TB** | **MS*TB** | **SR*MS*TB** |
| **Rare Use** | 2.15(0.0390) | 14.52(0.0004) | 1.20(0.2795) | 0.77(0.4686) | 2.04(0.1597) | 1.28(0.1597) | 2.97(0.0608) | 3.27(0.0771) |
| **Summer Use** | 1.31(0.2569) | 0.67(0.4181) | 0.21(0.6495) | 1.53(0.2261) | 0.38(0.5419) | 0.58(0.5654) | 0.17(0.8473) | 4.20(0.0460) |
| **Winter Use** | 0.63(0.7793) | 0.47(0.4972) | 0.62(0.4350) | 0.42(0.6589) | 0.35(0.5561) | 1.35(0.2695) | 0.55(0.5805) | 0.17(0.6843) |
| **Summer Other** | 3.70(0.0011) | 2.52(0.1188) | 2.50(0.1206) | 5.81(0.0056) | 0.04(0.8346) | 1.73(0.1885) | 8.78(0.0006) | 1.22(0.2759) |
| **Winter Other** | 3.77(0.0009) | 1.10(0.2991) | 0.93(0.3392) | 13.78(<0.0001) | 1.99(0.1647) | 0.04(0.9626) | 1.34(0.2723) | 1.33(0.2550) |

*DF=10, 47; $\alpha$=0.05

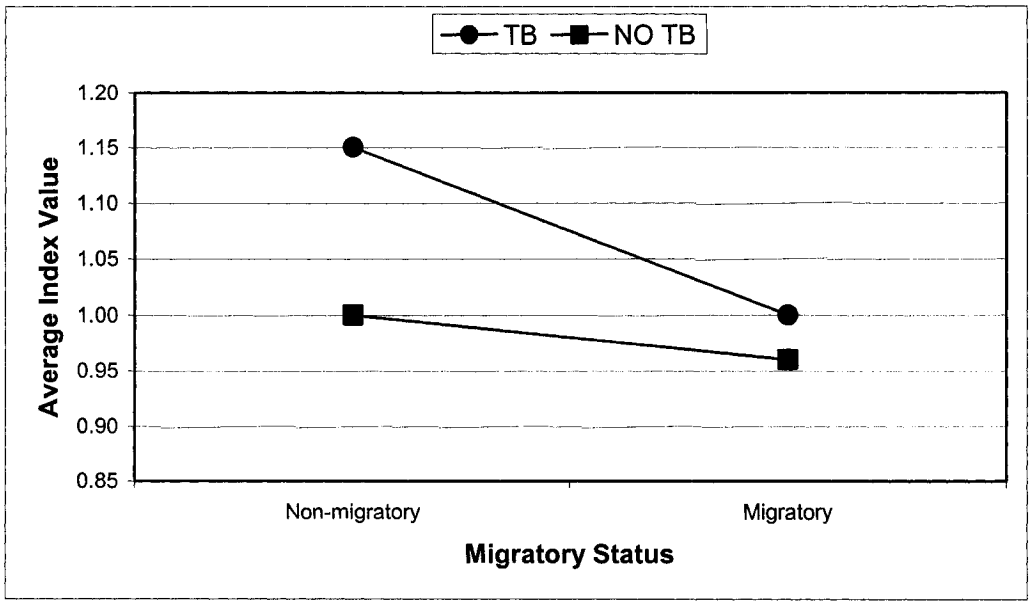



Figure 24. Summer Use Interactions between Migratory Status and TB Area

*Winter Use*

The outcome of the statistical analysis for winter use shows no differences ($F=0.63$, $p=0.7793$) or interactions (Table 9). Figure 25 demonstrates the use of high quality winter habitat. Again, non-migratory and migratory deer in the no tb area have similar winter use patterns. Migratory deer in the tb area show a considerably larger difference of high quality winter habitat use than any other group.

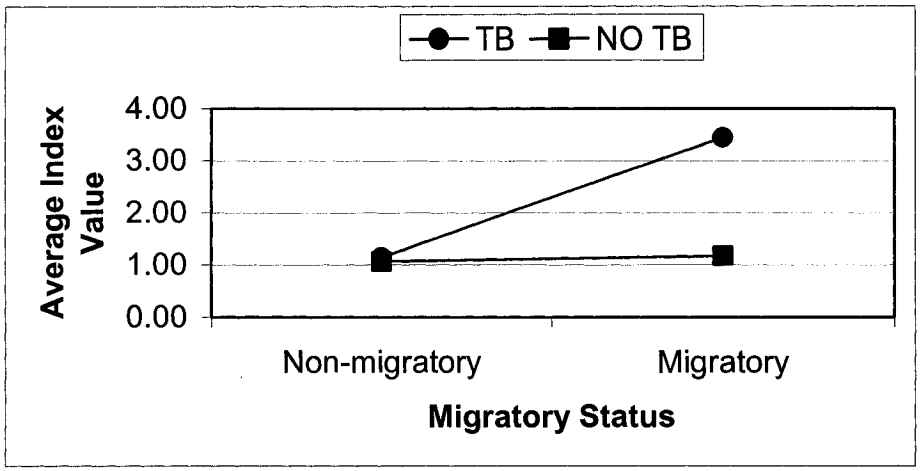



**Figure 25. Winter Use Interaction Between TB Areas & Migratory Status**

*Summer Other*

Results of the ANOVA show an interaction (F=8.78, p=0.0006) between migratory status and tb area. Poor summer habitat use is illustrated in Figure 26. Non-migratory deer in both the no tb and tb areas exhibit low to moderate use of poor summer habitat. While migratory deer in the tb area have very low use, and non-migratory deer in the no tb area have high use of poor summer habitat.

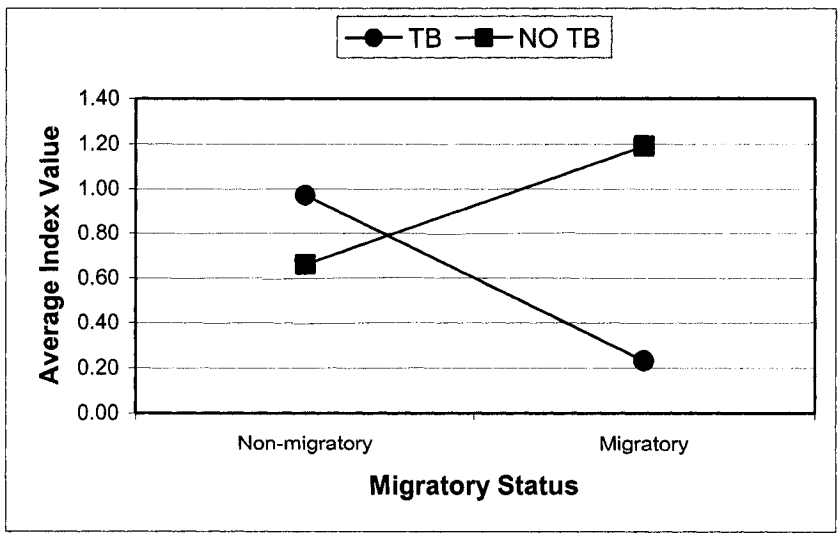



**Figure 26. Summer Other Interaction Between TB Areas & Migratory Status**

*Winter Other*

Results of the ANOVA show differences (F=3.77, p=0.0009) in the overall model, and differences (F=13.78, p=<0.0001) between no tb and tb areas. Figure 27 shows low use of poor winter habitat by deer in the no tb area, with no differences between non-migratory and migratory deer. While deer in the tb area also show no difference between non-migratory and migratory deer, they use poor winter habitat by a substantially larger amount (Figure 28). This is even more unusual considering that there is a considerably smaller amount of winter other habitat available in the tb area.

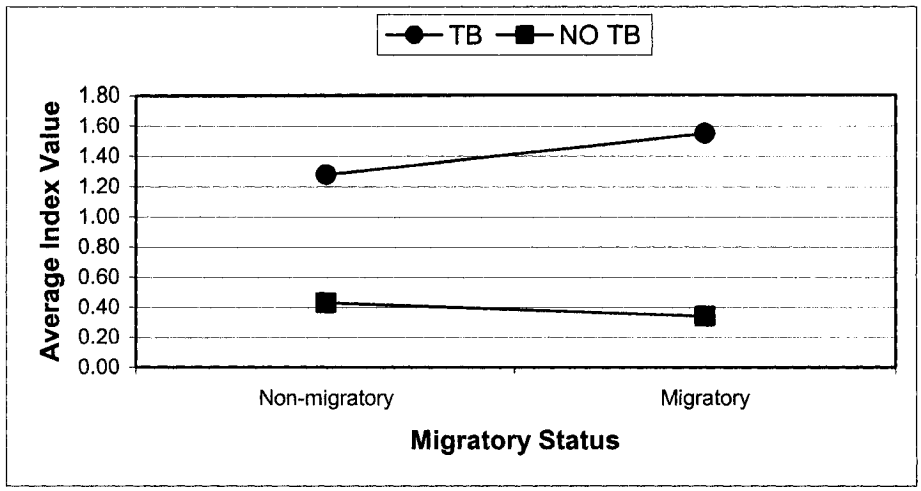



**Figure 27. Winter Other Interaction Between TB Areas & Migratory Status**

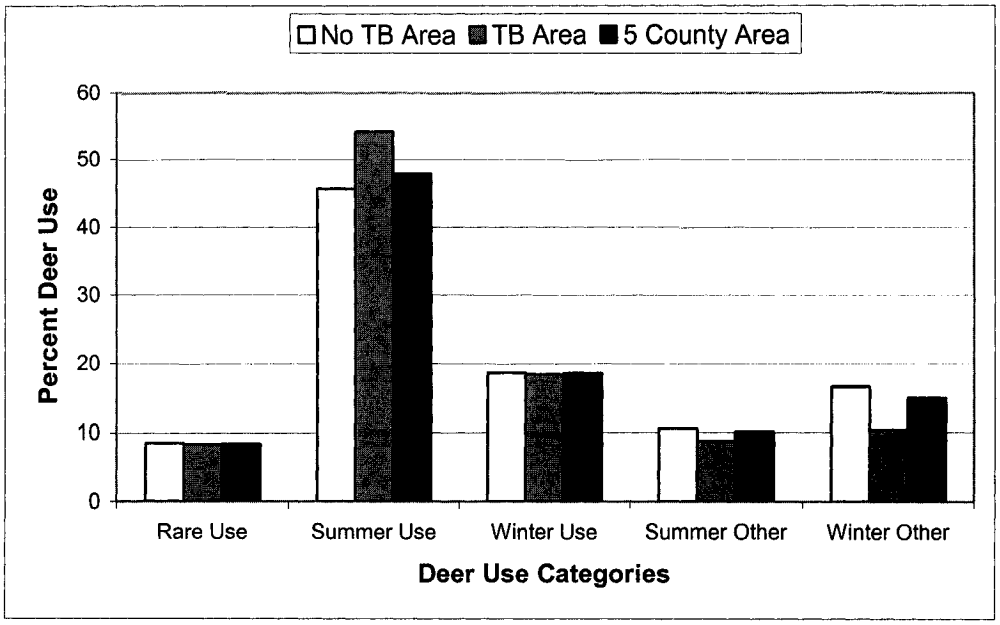



**Figure 28. Percent Deer Use in the No TB, TB, and 5 County Areas**

# CHAPTER 4
# DISCUSSION

## Case Frequency Vs. Prevalence

Why use case frequency (number of infected animals in a given area) instead of prevalence (% of infected animals in a given area)? Prevalence (in this case apparent prevalence) has the potential to greatly over estimate actual prevalence, depending on how effectively areas are sampled. For example if 3 tb+ deer were found in a township, and that was also the total number of deer sampled for that township, that township would have a prevalence of 100%. At the beginning of this project affects of sampling on detected levels of tb were unknown. In an attempt to deal with this uncertainty and potential bias, case frequency levels were created. While the above mentioned issues with calculating prevalence are not completely eliminated, it is believed that this is a more objective way of looking at the intensity of disease. The original case frequency coverage map was compared, visually, to an apparent prevalence map created by the MDNR, and similar patterns were observed. Attempts at categorizing disease are generally subjective, and are based on the researchers knowledge and perceptions of what is high or low (whether it be prevalence or case frequency). This study attempts to move away from what has already been done, while still effectively measuring case frequency.

## Databases

"Hot spots" are not an artifact of sampling. Results of analyses show that sampling is not overestimating case frequency in females. Sample sizes did not differ among case frequency categories and age groups. A recent study by

O'Brien et al. (2002), shows that the risk of being infected with tb, was not different between sexes among the fawn and yearling age groups. There was a small increase in tb risk for females from age 2-2.5 years, which leveled off at ≥4 years (Odd ratio (O.R.)=1.7, 95% CI 0.9, 3.1 for 2-2.5 yrs; O.R.=2.5, 95% CI 1.4, 4.7 for 4-4.5 yrs; O.R.=2.5, 95% CI 1.4, 4.3 for ≥5 yrs; O'Brien et al., 2002). Males, however, showed a n increase in risk at age 2-2.5 years which continued to increase with age (O.R.=4.5, 95% CI 2.7, 7.4 for 2-2.5 yrs; O.R.=11.3, 95% CI 3.2, 40.3 for ≥5 yrs; O'Brien et al., 2002). Even though (for this study) a difference was found for males among the different age categories, sample sizes were shown to decrease as age increased. This reduced the probability of over estimating case frequency due to over sampling animals with higher rates of infection.

Another factor that was examined was whether this increased risk of infection was due to the sampling method. Deer samples are obtained, voluntarily, from hunters, and therefore what is sampled is based on hunter skills and their willingness to submit samples for testing. One potential way hunters could influence sampling is that their perception of tb will make them more likely to have a deer tested if it has visible lesions. This would mean that there would be differences in the proportion of carcasses turned in relative to heads. There was, however, no difference found between the proportion of carcasses and heads by age class, which means the sampling method, in this instance did not influence sampling. Other issues of sampling such as; "Do hunter harvest

surveys accurately reflect wild deer populations?", have been addressed by O'Brien et al. (2002), who suggest that the bias is negligible.

GIS

Case Frequency Coverages

Several correlations were observed among the three case frequency coverages, the most prominent being that summer use of quality summer habit increases as case frequency increases. While interesting, these observed correlations alone do not demonstrate cause and effect. These results coupled with habitat use of deer in the study area, which will be discussed later, present interesting insights into what may be driving levels of tb in this area.

Moran's *I*

The Moran's *I* shows that case frequency categories for the home range case frequency coverage are clustered . These results are similar to those of O'Brien et al. (2002), who found central areas of high prevalence surrounded by larger areas of low prevalence. The region known as the core area by the MDNR (essentially the portions of Montmorency, Alpena, Oscoda and Alcona counties where their boundaries intersect) demonstrates this clumped pattern, and the peak concentration of high case frequency in the home range case frequency coverage resembles the shape of the MDNR's core area. This helps to support other analyses done on tb in this area, which show the core area as having the highest levels of tb (Hickling, 2002; O'Brien et al., 2002; Schmitt et al., 1997).

Core Area

Core area (defined as kernel and MCP), while not fulfilling their original purpose, provided more support that the main area of tb activity is centralized in the five county area. The kernel core area analysis results show that summer use category did not differ among case frequency categories. This is explained by the distribution of the summer use category within the five county area. Summer use category is most densely concentrated in the central areas of Montmorency, Alpena, Alcona, and Oscoda, which are almost completely encompassed by the kernel core area.

Habitat Use

The seasonal range and habitat use analyses proved to be one of the more telling analyses of this study. A study done by Felix and Hughey (unpublished data) also examined seasonal home ranges and habitat use of does in this area. Habitat was broken down into three coverages: Spring and Summer Food Potential (SSFP), Fall and Winter Food Potential (FWFP), and Thermal Cover Potential (TCP) (Felix, 2003). Each of these coverages had five different levels of habitat quality; low, medium low, medium, medium high, and high. Habitat quality levels were based on an index created by Felix (unpublished). Results of analyses showed that migratory deer tend to use poorer habitat, and that all deer regardless of migratory status showed a shift in seasonal habitat use (e.g. higher quality winter habitat in the winter, and higher quality summer habitat in the summer) . Distributions of habitat potential (quality

of the habitat) among these three coverages (SSFP, FWFP, and TCP) were similar to those in the deer use coverage.

The tendency for non-migratory deer to use higher quality habitat is illustrated by both tb and no-tb area groups only in the summer use category (Figure 22). In contrast, non-migratory deer in the tb area showed moderate-high use (index $\geq 1$) to the highest use of poor quality habitat (rare use, summer other, and winter other). Also, deer in the tb area show high use of poor quality winter habitat, even though it makes up a smaller percentage of habitat than in the no-tb area. This lends support to the belief that baiting and supplemental feeding influence deer behavior in this area.

What does it all mean? The correlations observed among the summer use category and case frequency levels for all three coverages (original case frequency, new case frequency, and home range case frequency) are most likely due to the distribution of summer use present in each case frequency area (meaning the percent of that area composed of that habitat type). Correlations between rare use, summer other, and winter other could also be influenced by distribution. However, those correlations, coupled with the increase in deer activity in these areas, specifically non-migratory deer in the tb area, may be showing two things. One, deer behavior in the tb area has been influenced by practices such as baiting and supplemental feeding, and thus deer are being lured into these areas with prospects of an easy meal. Two, since the majority of this use is by non-migratory deer it may explain why tb is centralized and not as wide spread. Of course this is only speculation and should be tested further.

One of the limitations to this analysis was that bucks were not included, due to small sample sizes. Since males have much different movement patterns, and life histories it would have been interesting to see the differences in habitat use.

Case Frequency and Scale

Several studies have examined the effect of changing scale on pattern and results, or the Modifiable Areal Unit Problem (MAUP) (Openshaw et al, 1979; Turner et al., 1989; Malanson et al., 1997). Openshaw and Taylor (1979), termed MAUP as being two distinct, but interrelated issues. The first issue is looking at an area of study at the same scale, but aggregating the units of measure differently (e.g. township case frequency is defined by number of infected deer or the number of infected deer home ranges). The second issue being, when the same area of study (extent) is looked at with increasingly larger areal units of measurement (e.g. looking at the same five county area starting at the section level and moving to the county level).

This study also attempts to address MAUP, with the three case frequency coverages. Both the original and new case frequency coverage are at the same scale. However, they differ in how township case frequency is defined. The statistical analyses show differing results dependant on how township case frequency was defined. Information is gained or lost depending on which coverage is chosen. Which scale is correct? Levin (1992) states that this (changing scale) is the "principal technique of science", moving from one scale to another helps us shift from variable, unrepeatable phenomena to a compilation of

information for which general statements can be made. He also states that there is no one correct scale, and that several scales should be examined in order to truly understand an ecological system.

Looking at disease on a township level has several advantages:

1) Data collection is easier.
2) Comparing data is easier, because larger sample sizes facilitate statistical analyses.
3) Boundaries are easily identifiable, landowners (as a general rule) know what township they are in, which makes implementing and enforcing regulations easier.

Despite these advantages examining data on only a township level has two major limitations:

1) The smallest area that can be examined is a township, so information on biological phenomena that occur at smaller scales is lost.
2) Looking at an ecological issue on a political scale can mask what is actually happening in the real world.

The home range case frequency coverage addresses these issues by using smaller units of measure and using a "biological scale" to look at tb. This helps identify specific areas of clustering that are not evident with townships. It also provides a new perspective, which helps support previous findings, and uncovers new ones.

One main problem with applying the home range case frequency coverage in a management situation are tiny polygons that may be a result of

how the coverage was created, and do not represent what is actually occurring in the real world. A possible solution to this problem would be to set the minimum mapping unit (mmu)(smallest polygon) to that of the smallest area of management. The smallest area of management is determined by the managers goals and knowledge of the area. Once this is determined, the polygons smaller than the mmu could be dissolved into the largest adjacent polygon or according to a set of dissolve criteria (decision tree).

## CONCLUSIONS AND RECOMMENDATIONS TO MDNR

1) Attempts to create a data entry system for the tb database should be made to standardize data, and eliminate entry of incorrect information. This would facilitate the use of such data, and increase confidence in the quality of the data collected.
2) Geographic "hot spots" of tb do exist, and are not merely an artifact of sampling.
3) The correlations observed among the summer use category are most likely due to it's distribution in each case frequency area. Correlations between rare use, summer other, and winter other could also be influenced by their distributions. Deer behavior in the tb area is influenced by practices such as baiting and supplemental feeding, and since the majority of increased activity is by non-migratory deer it may explain why tb appears to be centralized.
4) Kernel & MCP core area analyses provide more support that the main area of tb activity is centralized in the five county area.
5) Patterns of bovine tb should be examined at multiple scales to get a better understanding of the mechanisms driving the disease.

# APPENDICES

## APPENDIX 1
## CHANGES MADE TO THE TB DATABASE

1. Section numbers were corrected from single digits to two digits, e.g. "2 " and " 2" are now "02"
2. Deleted incorrect town and range values; a file of incorrect town and range values was created; the file name is incorrectTwnRng.xls
3. Changed the following location information as per instructions from Jean Fierke, Lab Scientist, Rose Lake Wildlife Disease Lab, MDNR

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a. | Alcona | 28N | 04E | 24 to | Oscoda | 28N | 04E | 24 |
| b. | Alpena | 28N | 04E | 07 to | Montmorency | 29N | 04E | 07 |
| c. | Alpena | 28N | 04E | 25 to | Montmorency | 29N | 04E | 25 |
| d. | Montmorency | 31N | 05E | 21 to | Alpena | 31N | 05E | 21 |

4. Changed ages 1, 2, 3, 4, to 1.5, 2.5, 3.5, 4.5, respectively

## APPENDIX 2
## METADATA

Original Case Frequency Coverage

**Identification Information**

*Citation:*

*Citation Information:*

*Originator*:

Brandi D. Hughey, Graduate Research Assistant, Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources, East Lansing, MI 48824-1222

Scott R. Winterstein, Professor, Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources, East Lansing, MI 48824-1222

*Date*: 2003

*Title*: Original Case Frequency Coverage

*Title of File*: prevalence

*Format*: ArcInfo coverage and all associated files

Description:

*Abstract*: This digital map and associated database describes and projects case frequency of bovine tuberculosis based on township boundaries in Alcona, Alpena, Montmorency, Oscoda, and Presque Isle counties. Townships are categorized into one of 3 tb case frequency categories zero, medium, and high. Zero case frequency townships are defined as never having a tb+ animal in that township. Medium case frequency is defined as having at least one tb+ animal in up to each of two years in that township. High case frequency is defined as having at least one tb+ animal in each of three or more years in that township.

*Purpose*: Provides spatial distribution of bovine tuberculosis for five county area (Alcona, Alpena, Montmorency, Oscoda, and Presque Isle).

Status:

*Progress*: Complete

*Keywords*:

*Theme:*

*Theme Keyword*: bovine tuberculosis

*Theme Keyword*: township

*Place:*

*Place Keyword*: Michigan

*Place Keyword*: Northern Lower Peninsula

*Point of Contact:*

*Contact Information:*

*Contact Organization:* Michigan State University, Department of Fisheries and Wildlife

*Contact Address:*
*Address*: 13 Natural Resources
*City:* East Lansing
*State*: MI
*Postal Code*: 48824-1222
*Contact Voice Telephone*: 517-353-2042
*Contact Facsimile Telephone:* 517-432-1699

*Native Data Set Environment*: Windows NT version 4.0; ESRI ArcView 3.2

*Cross Reference:*
*Citation Information:*
*Originator:*
Michigan DNR - Resource Mapping and Aerial Photography
Publication Date: Unpublished Material
Title: Trs24 - PLSS Coverage of Michigan
*Series Information:*
*Publication Information:*
*Publisher:*
Data Quality Information
*Accuracy Report:*
*Lineage:*
*Source Information:*
*Source Citation:*
*Originator*: Michigan DNR - Resource Mapping and Aerial Photography.
*Publication Date*: Unpublished Material
*Title*: sectionsup.e00
*Geospatial Data Presentation Format*: Vector Digital Database

*Geospatial Data Presentation Format*: Digital Database
*Publication Information:*
*Publication Place:* Lansing, Michigan
*Publisher*: Michigan Natural Features Inventory

*Source Information:*
*Source Citation:*
*Originator*: Michgan Department of Natural Resources
Publication Date: Unpublished
*Title*: State tb data base
*Geospatial Data Presentation Format:*
*Publication Information:*
*Publication Place:*
*Publisher:*
*Source Contribution:*

This was used to identify case frequency level for each polygon.

Spatial Data Organization Information
*Direct Spatial Reference Method:* Vector
Spatial Reference Information
*Spatial Reference*: Michigan GeoRef from Oblique Mercator projection
Scale factor at center = 0.9996
Azimuthal angle = 337.25556
False easting = 2546731.496
False northing = -4354009816
Horizontal datum name = North American Datum 1983 (NAD83)
*Planar Distance Units*: meters

Entity and Attribute Information

*Attribute Description:*
*Attribute:*
*Attribute Label:* Town
*Attribute Definition*: Township
*Attribute:*
*Attribute Label:* Range
*Attribute Definition*: Range
*Attribute:*
*Attribute Label:* Town_range
*Attribute Definition*: Township and Range
*Attribute:*
*Attribute Label:* Prevalence
*Attribute Definition*: Prevalence refers to number of tb+ deer found in that township

Distribution Information
*Distributor:*
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*Contact Person:* Brandi D. Hughey
*Contact Organization*: Michigan State University, Department of Fisheries and Wildlife
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*Address*: 13 Natural Resources
*City*: East Lansing
*State*: MI
*Postal Code*: 48824-1222
*Contact Voice Telephone*: 517-432-4959
*Contact Electronic Mail*: hugheybr@msu.edu

Contact Information:
*Contact Person*: Scott R. Winterstein

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*Postal Code*: 48824-1222
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Metadata Reference Information
Metadata Date: 20030125

*Metadata Contact:*
*Contact Information:*
*Contact Organization:* Michigan State University, Department of Fisheries and Wildlife
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*Contact Electronic Mail*: hugheybr@msu.edu

*Contact*: Scott R. Winterstein
*Contact Address*:
*Address*: 13 Natural Resources
*City*: East Lansing
*State*: MI
*Postal Code*: 48824-1222
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*Contact Electronic Mail*: winterst@msu.edu

New Case Frequency Coverage
**Identification Information**

*Citation:*
*Citation Information:*
*Originator:*
Brandi D. Hughey, Graduate Research Assistant, Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources, East Lansing, MI 48824-1222
Scott R. Winterstein, Professor, Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources, East Lansing, MI 48824-1222

*Date:* 2003
*Title:* New Case Frequency Coverage
*Title of File:* new_prev
*Format:* ArcInfo coverage and all associated files

*Description:*
*Abstract:* This digital map and associated database describes and projects case frequency of bovine tuberculosis based on township boundaries and estimated average home ranges for white-tailed deer in Alcona, Alpena, Montmorency, Oscoda, and Presque Isle counties. Townships are categorized into one of 3 tb case frequency categories zero, medium, and high. Zero case frequency townships are defined as never having a tb+ animal home range in that township. Medium case frequency is defined as having at least one tb+ animal home range in up to each of two years in that township. High case frequency is defined as having at least one tb+ animal home range in each of three or more years in that township.
*Purpose:* Provides spatial distribution of bovine tuberculosis for five county area (Alcona, Alpena, Montmorency, Oscoda, and Presque Isle)

*Status:*
*Progress:* Complete
*Keywords:*
*Theme:*
*Theme Keyword:* bovine tuberculosis
*Theme Keyword:* township
*Place:*
*Place Keyword:* Michigan
*Place Keyword:* Northern Lower Peninsula
*Point of Contact:*
*Contact Information:*
*Contact Organization:* Michigan State University, Department of Fisheries and Wildlife
*Contact Address:*

*Address:* 13 Natural Resources
*City:* East Lansing
*State:* MI
*Postal Code:* 48824-1222
*Contact Voice Telephone:* 517-353-2042
*Contact Facsimile Telephone:* 517-432-1699

*Native Data Set Environment:* Windows NT version 4.0; ESRI ArcView 3.2

*Cross Reference:*
*Citation Information:*
*Originator:*
Michigan DNR - Resource Mapping and Aerial Photography
*Publication Date:* Unpublished Material
*Title:* Trs24 - PLSS Coverage of Michigan
*Series Information:*
*Publication Information:*
*Publisher:*

Data Quality Information
*Accuracy Report:*
*Lineage:*
*Source Information:*
*Source Citation:*
*Originator:* Michigan DNR - Resource Mapping and Aerial Photography.
*Publication Date:* Unpublished Material
*Title:* sectionsup.e00
*Geospatial Data Presentation Format:* Vector Digital Database

*Geospatial Data Presentation Format:* Digital Database
*Publication Information:*
*Publication Place:* Lansing, Michigan
*Publisher:* Michigan Natural Features Inventory

*Source Information:*
*Source Citation:*
*Originator:* Michgan Department of Natural Resources
*Publication Date:* Unpublished
*Title:* State tb data base
*Geospatial Data Presentation Format:*
*Publication Information:*
*Publication Place:*
*Publisher:*
*Source Contribution:*

This was used to identify case frequency level for each polygon.

Spatial Data Organization Information
*Direct Spatial Reference Method:* Vector

Spatial Reference Information

*Spatial Reference:* Michigan GeoRef from Oblique Mercator projection
Scale factor at center = 0.9996
Azimuthal angle = 337.25556
False easting = 2546731.496
False northing = -4354009816
Horizontal datum name = North American Datum 1983 (NAD83)

*Planar Distance Units:* meters
Entity and Attribute Information
*Attribute Description:*
*Attribute:*
*Attribute Label:* Town
*Attribute Definition:* Township
*Attribute:*
*Attribute Label:* Range
*Attribute Definition:* Range
*Attribute:*
*Attribute Label:* Town_range
*Attribute Definition:* Township and Range
*Attribute:*
*Attribute Label:* New_Prev
*Attribute Definition:* Prevalence refers to number of tb+ deer home ranges found in that township

Distribution Information
*Distributor:*
*Contact Information:*
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*Contact Organization:* Michigan State University, Department of Fisheries and Wildlife
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Metadata Reference Information
*Metadata Date:* 20030125

Metadata Contact:
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*State:* MI
*Postal Code:* 48824-1222
*Contact Voice Telephone:* 517-353-2042
*Contact Electronic Mail:* winterst@msu.edu

Home Range Case Frequency Coverage
**Identification Information**

*Citation:*
*Citation Information:*
*Originator:*
Brandi D. Hughey, Graduate Research Assistant, Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources, East Lansing, MI 48824-1222
Scott R. Winterstein, Professor, Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources, East Lansing, MI 48824-1222

*Date:* 2003
*Title:* Home Range Case Frequency Coverage
*Title of File:* hr_prev
*Format:* ArcInfo coverage and all associated files

*Description:*
*Abstract:* This digital map and associated database describes and projects case frequency of bovine tuberculosis based on estimated average home ranges for white-tailed deer in Alcona, Alpena, Montmorency, Oscoda, and Presque Isle counties. Polygons are categorized into one of 3 tb case frequency categories zero, medium, and high. Zero case frequency is defined as never having a tb+ animal home range for that polygon. Medium case frequency is defined as having at least one tb+ animal home range in up to each of two years for that polygon. High case frequency is defined as having at least one tb+ animal home range in each of three or more years for that polygon.
*Purpose:* Provides spatial distribution of bovine tuberculosis for five county area (Alcona, Alpena, Montmorency, Oscoda, and Presque Isle).
*Status:*
*Progress:* Complete

*Keywords:*
*Theme:*
*Theme Keyword:* bovine tuberculosis
*Theme Keyword:* home range
*Place:*
*Place Keyword:* Michigan
*Place Keyword:* Northern Lower Peninsula

*Point of Contact:*
*Contact Information:*
*Contact Organization:* Michigan State University, Department of Fisheries and Wildlife
*Contact Address:*

*Address:* 13 Natural Resources
*City:* East Lansing
*State:* MI
*Postal Code:* 48824-1222
*Contact Voice Telephone:* 517-353-2042
*Contact Facsimile Telephone:* 517-432-1699

*Native Data Set Environment:* Windows NT version 4.0; ESRI ArcView 3.2

*Cross Reference:*
*Citation Information:*
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Michigan DNR - Resource Mapping and Aerial Photography
*Publication Date:* Unpublished Material
*Title:* Trs24 - PLSS Coverage of Michigan
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Data Quality Information
*Accuracy Report:*
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*Originator:* Michigan DNR - Resource Mapping and Aerial Photography.
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*Geospatial Data Presentation Format:* Vector Digital Database

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*Source Citation:*
*Originator:* Michgan Department of Natural Resources
*Publication Date:* Unpublished
*Title:* State tb database
*Geospatial Data Presentation Format:*
*Publication Information:*
*Publication Place:*
*Publisher:*
*Source Contribution:*

This was used to identify case frequency level for each polygon.

Spatial Data Organization Information
*Direct Spatial Reference Method:* Vector

Spatial Reference Information
*Spatial Reference:* Michigan GeoRef from Oblique Mercator projection
Scale factor at center = 0.9996
Azimuthal angle = 337.25556
False easting = 2546731.496
False northing = -4354009816
Horizontal datum name = North American Datum 1983 (NAD83)
*Planar Distance Units:* meters

Entity and Attribute Information

*Attribute Description:*
*Attribute:*
*Attribute Label:* Area
*Attribute Definition:* Area of poly/region in square coverage units
*Attribute:*
*Attribute Label:* Perimeter
*Attribute Definition:* perimeter of poly/region in coverage units
*Attribute:*
*Attribute Label:* Prevalence
*Attribute Definition:* Prevalence refers to number of tb+ deer home ranges found in that township

Distribution Information
*Distributor:*
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*Address:* 13 Natural Resources
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Metadata Reference Information
*Metadata Date:* 20030125

Metadata Contact:
*Contact Information:*
*Contact Organization:* Michigan State University, Department of Fisheries and Wildlife
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*City:* East Lansing
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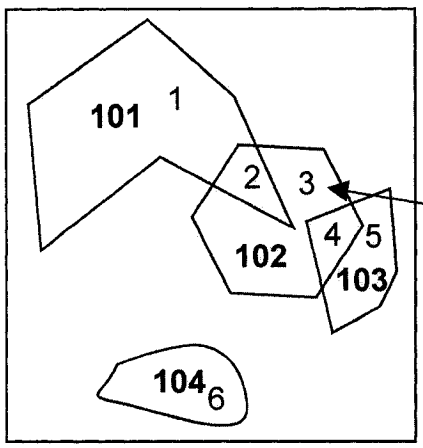
## APPENDIX 3
## REGIONS

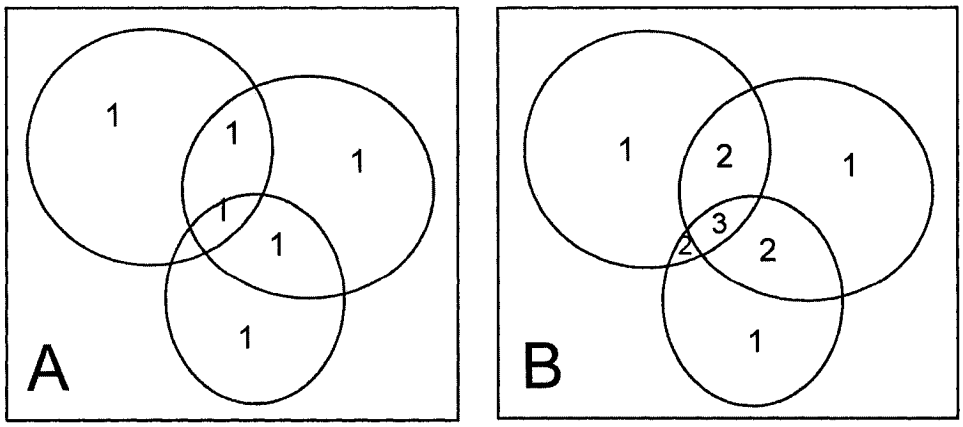
Regions are vector data objects, and are used to represent areal geographic features. Regions are comprised of one or more polygons, just as polygons are made up of lines, and lines are made up points. There are three main features of regions nested feature, associated feature, and overlapping feature. The overlapping feature was used in this study, which is illustrated in Figures 1 and 2.




**Attribute Table**

| Region # | Polygon List |
|---|---|
| 101 | 1, 2 |
| 102 | 2, 3, 4 |
| 103 | 4, 5 |
| 104 | 6 |

**Appendix Figure 1. Example of the Overlapping Feature for Regions Data Model.**




**Appendix Figure 2A. Example of the Home Range Case frequency Coverage With Polygons. 2B. Example of the Home Range Case frequency Coverage With Regions.**

## APPENDIX 4

**Reclassifications of Land Use to Deer Use**

| New Code | New Class Name | Old Code | Old Class Name |
|---|---|---|---|
| 0 | Background | 0 | Background |
| 1 | Rare Use | 1 | High Intensity Urban |
| 1 | Rare Use | 2 | Low Intensity Urban |
| 1 | Rare Use | 3 | Extractive |
| 1 | Rare Use | 44 | Barren Land |
| 1 | Rare Use | 45 | Water |
| 1 | Rare Use | 46 | Urban Grassland |
| 2 | Summer Use | 8 | Herbaceous Openland |
| 2 | Summer Use | 9 | Shrubland |
| 2 | Summer Use | 14 | Northern Hardwood |
| 2 | Summer Use | 15 | Northern Hardwood/Conifer |
| 2 | Summer Use | 16 | Aspen/Birch |
| 2 | Summer Use | 19 | Oak |
| 2 | Summer Use | 31 | Emergent Wetland/Wet Meadow |
| 2 | Summer Use | 33 | Lowland Broad-Leaved Deciduous Shrubland |
| 2 | Summer Use | 37 | Mixed Lowland Hardwood |
| 3 | Winter Use | 42 | Mixed Lowland Conifer/Hardwood |
| 3 | Winter Use | 35 | Other Forested Wetland |
| 3 | Winter Use | 39 | Black Spruce |
| 3 | Winter Use | 23 | White Pine |
| 3 | Winter Use | 29 | Cedar/Spruce/Fir |
| 3 | Winter Use | 34 | Lowland Broad-Leaved Evergreeen Shrubland |
| 3 | Winter Use | 38 | Lowland Jack Pine |
| 3 | Winter Use | 41 | Northern White Cedar |
| 3 | Winter Use | 47 | Lowland Needle-Leaved Evergreen Shrubland |
| 4 | Summer Other | 4 | Agricultural Crops |
| 4 | Summer Other | 6 | Orchard/Vineyard |
| 4 | Summer Other | 13 | Other Broad-Leaved Deciduous Forest |
| 4 | Summer Other | 32 | Other Lowland Shrub |
| 5 | Winter Other | 22 | Other Coniferous Forest |
| 5 | Winter Other | 25 | Upland Jack Pine |
| 5 | Winter Other | 24 | Red Pine |

# APPENDIX 5
# CHI-SQUARE ANALYSES

**Appendix 5a. Chi-Square Tests Comparing Deer Use Categories in the 3 Case Frequency Areas for the Home Range Case Frequency Coverage**

| Observed | | | | | | | |
|---|---|---|---|---|---|---|---|
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 544.20 | 2925.14 | 1151.08 | 657.87 | 1043.16 | 6321.46 | |
| Medium | 93.08 | 547.67 | 208.50 | 120.84 | 118.55 | 1088.65 | |
| High | 40.24 | 372.02 | 137.35 | 35.41 | 51.24 | 636.26 | |
| Total | 677.52 | 3844.83 | 1496.93 | 814.13 | 1212.95 | 8046.36 | |
| **Expected** | | | | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 532.28 | 3020.62 | 1176.03 | 639.60 | 952.93 | 6321.46 | |
| Medium | 91.67 | 520.19 | 202.53 | 110.15 | 164.11 | 1088.65 | |
| High | 53.57 | 304.03 | 118.37 | 64.38 | 95.91 | 636.26 | |
| Total | 677.52 | 3844.83 | 1496.93 | 814.13 | 1212.95 | 8046.36 | |
| **Chi-Square** | | | | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 0.27 | 3.02 | 0.53 | 0.52 | 8.54 | 12.88 | |
| Medium | 0.02 | 1.45 | 0.18 | 1.04 | 12.65 | 15.33 | |
| High | 3.32 | 15.21 | 3.05 | 13.03 | 20.81 | 55.41 | **p-value** |
| Total | 3.61 | 19.67 | 3.75 | 14.59 | 42.00 | 83.63 | < 0.0001 |
| **Percent Deer Use** | | | | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 8.61 | 46.27 | 18.21 | 10.41 | 16.50 | 100.00 | |
| Medium | 8.55 | 50.31 | 19.15 | 11.10 | 10.89 | 100.00 | |
| High | 6.32 | 58.47 | 21.59 | 5.57 | 8.05 | 100.00 | |

## APPENDIX 5 (cont'd)

**Appendix 5b. Chi-Square Tests Comparing Deer Use Categories in the 3 Case Frequency Areas for the Kernel Core Area**

| | | | Observed | | | | |
|---|---|---|---|---|---|---|---|
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 50.48 | 273.58 | 72.94 | 56.75 | 51.02 | 504.77 | |
| Medium | 75.86 | 449.65 | 161.64 | 85.80 | 104.53 | 877.48 | |
| High | 40.05 | 373.23 | 137.37 | 35.21 | 50.40 | 636.26 | |
| Total | 166.39 | 1096.46 | 371.96 | 177.76 | 205.95 | 2018.51 | |
| | | | Expected | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 41.61 | 274.19 | 93.02 | 44.45 | 51.50 | 504.77 | |
| Medium | 72.33 | 476.65 | 161.70 | 77.27 | 89.53 | 877.48 | |
| High | 52.45 | 345.61 | 117.25 | 56.03 | 64.92 | 636.26 | |
| Total | 166.39 | 1096.46 | 371.96 | 177.76 | 205.95 | 2018.51 | |
| | | | Chi-Square | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 1.89 | 0.00 | 4.33 | 3.40 | 0.00 | 9.63 | |
| Medium | 0.17 | 1.53 | 0.00 | 0.94 | 2.51 | 5.15 | |
| High | 2.93 | 2.21 | 3.45 | 7.73 | 3.25 | 19.57 | p-value |
| Total | 5.00 | 3.74 | 7.79 | 12.08 | 5.76 | 34.36 | < 0.0001 |
| | | | Percent Deer Use | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 10.00 | 54.20 | 14.45 | 11.24 | 10.11 | 100.00 | |
| Medium | 8.65 | 51.24 | 18.42 | 9.78 | 11.91 | 100.00 | |
| High | 6.29 | 58.66 | 21.59 | 5.53 | 7.92 | 100.00 | |

**Appendix 5c. Chi-Square Tests Comparing Deer Use Categories in the 3 Case Frequency Areas for the Minimum Convex Polygon Core Area**

| Observed | | | | | | | |
|---|---|---|---|---|---|---|---|
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 102.73 | 574.19 | 194.67 | 143.41 | 136.68 | 1151.68 | |
| Medium | 77.13 | 440.46 | 151.64 | 83.82 | 89.71 | 842.77 | |
| High | 38.85 | 370.82 | 136.49 | 31.57 | 50.57 | 628.31 | |
| Total | 218.72 | 1385.48 | 482.80 | 258.79 | 276.96 | 2622.75 | |
| **Expected** | | | | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 96.04 | 608.38 | 212.00 | 113.64 | 121.62 | 1151.68 | |
| Medium | 70.28 | 445.20 | 155.14 | 83.16 | 89.00 | 842.77 | |
| High | 52.40 | 331.91 | 115.66 | 62.00 | 66.35 | 628.31 | |
| Total | 218.72 | 1385.48 | 482.80 | 258.79 | 276.96 | 2622.75 | |
| **Chi-Square** | | | | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 0.47 | 1.92 | 1.42 | 7.80 | 1.86 | 13.47 | |
| Medium | 0.67 | 0.05 | 0.08 | 0.01 | 0.01 | 0.81 | |
| High | 3.50 | 4.56 | 3.75 | 14.93 | 3.75 | 30.50 | **p-value** |
| Total | 4.64 | 6.53 | 5.25 | 22.74 | 5.62 | 44.78 | < 0.0001 |
| **Percent Deer Use** | | | | | | | |
| Case Frequency | Rare Use | Summer Use | Winter Use | Summer Other | Winter Other | Total | |
| Zero | 8.92 | 49.86 | 16.90 | 12.45 | 11.87 | 100.00 | |
| Medium | 9.15 | 52.26 | 17.99 | 9.95 | 10.64 | 100.00 | |
| High | 6.18 | 59.02 | 21.72 | 5.02 | 8.05 | 100.00 | |

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