# Metropolitan Mosquito Control District

## *Ixodes scapularis* Distribution Study Report

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**Tick Vector Services**

# Metropolitan Mosquito Control District
# *IXODES SCAPULARIS* DISTRIBUTION STUDY
# 2000


## Abstract

A black legged tick (*Ixodes scapularis*) distribution study, designed to detect any changes in *I. scapularis* distribution over a many year period, was conducted in the seven county metropolitan area by the Metropolitan Mosquito Control District. Small mammal sampling was used to collect ticks from 100 wooded areas that have all been sampled since 1990 or 1991. At least one *I. scapularis* was collected from 55 of these sites during 2000; surpassing 1999's (46) previous highest number of tabulated positive sites. Forty-eight of these sites are located north of the Mississippi River, with six of the remaining seven sites located in Dakota County. The one remaining site (2 *I. scapularis* larvae found) is located in a Hennepin County park where *I. scapularis* had been first detected with this study methodology in 1998. A total of 945 *I. scapularis* were removed from 1173 mammals for an overall season mean of .806 *I. scapularis* per mammal; by far the highest total number collected and average compiled to date. Collections of *I. scapularis* nymphs quadrupled over the 1999 total (257 versus 64 in 1999). The majority of *I. scapularis* collections occurred in Anoka County (62% of the total (456 larvae; 127 nymphs)), with Washington County collections accounting for an additional 32% of the total (194 larvae; 112 nymphs). The highest average number of *I. scapularis* per mammal was calculated for Anoka County; a season mean of 2.192 compared with Washington County's season mean of 1.244 overall. The 2000 township averages for Anoka County, except Ramsey township, were all > .500 *I. scapularis* per mammal, with Blaine, Ham Lake, Linwood, and East Bethel townships averaging > 4.0 *I. scapularis* per mammal. Afton, New Scandia, and Grant townships of Washington County maintained averages > 2.0 *I. scapularis* per mammal. Townships maintaining the highest (all > 1.0) 1990-2000 *I. scapularis* per mammal averages include New Scandia, Hugo, May (all Washington County), and East Bethel (Anoka County), with 1990-2000 township averages of > .500 *I. scapularis* per mammal tabulated for Linwood, Saint Francis, Blaine (all Anoka County), Grant, and Afton (both Washington County) townships. *P. leucopus* consistently has been the predominant mammal species collected each year with some variability in the total percentages collected, and no major shifts in the diversity of our small mammal collections seems to have occurred in 2000. Complimenting the large numbers of *I. scapularis* collected as well as the highest tabulated total number of sites where *I. scapularis* were detected in a season, we detected *I. scapularis* from an additional two new areas. The high total *I. scapularis* collections for 2000 could be a lingering influence of the warm El Niño 1997-1998 winter weather pattern, could have been caused by a warmer than normal March 2000 (highest average monthly high and low temperatures for the period between 1989-2000) and/or additional variables that remain elusive. We do know that in 2000 the Minnesota Department of Health tabulated the highest number of human Lyme (463) and ehrlichiosis (77) case totals compiled to date and we feel that the dramatic increase in the number of nymphs apparently questing in 2000 may offer a possible explanation for the increased number of Minnesota residents who contracted a tick-borne illness during the year 2000. Although the volume of *I. scapularis* collected was great, we again conclude that *I. scapularis* range expansion has not been detected because we have seen no significant change in where our tick collections are occurring.


## Introduction

In 1990 the Metropolitan Mosquito Control District initiated a Lyme Disease Tick Surveillance Program to determine the distribution and prevalence of *Ixodes scapularis* and *Borrelia burgdorferi* within the Minneapolis- Saint Paul metropolitan area. District re-structuring in 1996 integrated the former tick surveillance program activities into the District's overall field processes. Small mammal trapping has been the primary sampling method used, with examination of road-killed mammals and dragging flannel cloth along vegetation both used in the past as secondary collection methods.

A total of 545 sites were sampled from 1990 through 1992, including 100 sites that had been selected for repetitive sampling prior to the 1991 or 1992 field season. Baseline *I. scapularis* distribution data for our area was determined from the 1990 and 1991 studies with most of the ticks collected north of the Mississippi River in Anoka, Washington, and northern Ramsey counties. The 1992 study was designed to inspect areas that had not been sampled as intensely in the past, with emphasis on locations south and west of the Mississippi River, but the majority of *I. scapularis* collections continued to be obtained in the northeastern counties.

Since 1993, our distribution study has focused on the re-sampling of 100 sites to detect any potential changes in *I. scapularis* distribution over time. Seventy-five of these sites were re-sampled beginning in 1991 and were selected from the previous study based on three criteria: representative habitat of an area, locations that were unlikely to be developed, and areas where small mammal collections had been sufficient in the past. An additional twenty-five sites were selected from Dakota, Hennepin, Scott, and Carver counties in 1992 to increase our data collections south of the Mississippi River. We plan to monitor these sites indefinitely and will intensify our sampling effort in areas that have shown potential *I. scapularis* range expansion.

Two additional sites were sampled from 1995-1997; section 7 of New Market township in Scott County (where a single adult *I. scapularis* tick had been collected in 1995) and section 19 of West Saint Paul township in Dakota County (Dodge Nature Center- to foster improved relations through providing a general risk assessment). Sampling at these two locations was discontinued in 1998 since zero *I. scapularis* had been collected in either location in this three-year period.

## Materials and Methods

Of the 100 repeat sites, 56 are located north of the Mississippi River in Anoka (28 sites), Washington (25 sites), and Ramsey (3 sites) counties. The 44 repeat sites located south of the Mississippi River are distributed throughout the counties of Dakota (15 sites), Hennepin (14 sites), Scott (8 sites), and Carver (7 sites).

Sampling was initiated on April 24, 2000 and ended on October 26, 2000 with small mammal trapping used as the primary sampling method. As in past years, the twenty-seven week study was divided into three nine-week sampling periods, and all sites were sampled for twenty-one trap nights (7 traps x 3 consecutive nights) per period. Weeks of site visitation were randomly selected within each sampling period.

One three-hundred foot transect was established at each sampling location, and Sherman live traps (H. B. Sherman Traps, Inc., Tallahassee, Fla.), baited with peanut butter and oats, were placed along these transects at fifty foot intervals. We euthanized all small mammals caught in the traps, removed any ticks found, and stored the ticks in alcohol for later identification.

## Results

### ➢ 2000 Study (Repeat Sites):

We found at least one *I. scapularis* at 55 of 100 sampling sites, with 48 of these positive sites located north of the Mississippi River in Anoka (25 sites positive/28 sites sampled), Washington (22 sites positive/25 sites sampled), and Ramsey (1 site positive/3 sites sampled) counties. Seven additional positive sites were detected south of the river; six in Dakota County and one positive site re-detected in Hennepin County. Zero *I. scapularis* were collected in Scott or Carver counties in 2000.

Overall, 1173 mammals (Figure 1 and 2000 results in Table 2) were inspected: 553 from north of the Mississippi River and 621 from south of the river, and a total of 945 *I. scapularis* (Figure 2 and 2000 results in Table 3) were collected from them. The Anoka County sampling locations accounted for 62% (456 larvae; 127 nymphs) of the total with the greatest number of *I. scapularis* obtained from Linwood (133 larvae; 23 nymphs), Blaine (86 larvae; 13 nymphs), Andover (51 larvae; 13 nymphs), East Bethel (58 larvae; 5 nymphs), Lino Lakes (52 larvae; 10 nymphs), and Ham Lake (41 larvae; 17 nymphs) townships. Collections from Washington County accounted for an additional 32% (306/945) of the total (194 larvae; 112 nymphs), with May (66 larvae; 7 nymphs), Afton (49 larvae; 16 nymphs), Denmark (19 larvae; 32 nymphs), and Grant (7 larvae; 26 nymphs) township collections the highest. Another 4% of the total (30 larvae; 12 nymphs) were collected from Dakota County.

The overall season mean number of *I. scapularis* collected per mammal in 2000 was .806 (larvae: .587, nymphs: .219). The mean increases to 1.527 (larvae: 1.111, nymphs: .415) when all sites negative for *I. scapularis* are excluded (see 2000 results in Figure 6). The highest average number of *I. scapularis* per mammal was calculated for Anoka County, which had a season mean of 2.192, compared with Washington County's season mean of 1.244 overall (see 2000 results in Figure 3). The 2000 township averages for Anoka County, except for Ramsey township, were all > .500 *I. scapularis* per mammal, with Blaine, Ham Lake, Linwood, and East Bethel townships averaging > 4.0 *I. scapularis* per mammal. Afton township maintained the highest 2000 average *I. scapularis* per mammal in Washington County (2.500), with New Scandia and Grant townships maintaining averages > 2.0 *I. scapularis* per mammal. May, Denmark, and Oakdale townships averaged > 1.0 *I. scapularis* per mammal (Figure 4).

➢ **Compiled 1990-2000 Results (Repeat Sites):**

The 1990-2000 mean number of *I. scapularis* collected per mammal was .291, with the highest averages continuing to occur north of the Mississippi River. The yearly season mean for Anoka County as a whole was the highest for the third consecutive year in 2000 and was again followed by Washington County's. Averages for Ramsey County have been consistently low, yet greater overall than those occurring south of the river (Figure 3). The 1990-2000 township averages for New Scandia, Hugo, May (all Washington County), and East Bethel (Anoka County) townships were > 1.0 *I. scapularis* per mammal, while the averages for, Linwood, Saint Francis, Blaine (all Anoka County), Grant, and Afton (both Washington County) townships were > .500 *I. scapularis* per mammal (Figures 4A and B—inserts on Fig. 4).

*I. scapularis* status at the 100 repeat sampling locations is shown on Figure 5[1]. The status has changed at 61 of the sites since 1990 or 1991 (see 2000 results in Table 1). While the number of sites where *I. scapularis* is detected every year has continued to decrease, we continue to detect *I. scapularis* at several new sampling locations each year (Table 1).

Table 1: Comparison of *I. scapularis* Presence/Absence Status at 100 Repeat Sampling Locations: 1992 - 2000

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|
| **No. sites changing status** | 26 | 34 | 38 | 40 | 47 | 53 | 58 | 59 | 61 |
| **Ticks found:** | | | | | | | | | |
| **all years** | 21 | 19 | 17 | 16 | 11 | 6 | 5 | 5 | 5 |
| **most years** | 5 | 15 | 15 | 15 | 19 | 27 | 27 | 31 | 31 |
| **least** | 21 | 19 | 23 | 25 | 28 | 26 | 31 | 28 | 30 |
| **(not found)** | 53 | 47 | 45 | 44 | 42 | 41 | 37 | 36 | 34 |

Comparing our 2000 small mammal and immature *I. scapularis* collection results with past study efforts, we collected similar percentages of small mammals (Table 2) along with the highest percentages to date of nymphal *I. scapularis* (Table 3). In particular, *I. scapularis* nymph collections quadrupled over the 1999 total (257 versus 64 in 1999) and is the largest number of nymphs collected during all years of this study, including earlier years where the data was compiled from up to 270 sampling locations. Correspondingly, our overall season mean of .806 *I. scapularis* per mammal is by far the highest yearly mean that we have compiled to date (Figure 3). *P. leucopus* consistently has been the predominant mammal species collected each year with some variability in the total percentages collected[2]. The 2000 average number of mammals collected per site (11.73) appears to be within low normal parameters for yearly collection levels. Our compiled average small mammal collection success level per site for 1990 through 2000 is 14.44 (1991-2000 average of 13.81 for 100 repeat sites only), with results ranging from the low of 7.28 mammals collected per site in 1997 to the high of 20.61 (23.54 at the 100 repeat sites only) in 1991.

## Discussion

Our results seem to indicate that *I. scapularis* populations are established within northeastern Anoka and northern Washington counties while remaining localized or nonexistent in areas south of the Mississippi River. Although our study was not designed to specifically answer the question of tick establishment, we feel that our relative *I. scapularis* density estimates are accurate enough for a general risk assessment. Given the consistency of our results over the years, where greater numbers of *I. scapularis* continue to be collected in the northeastern metropolitan area each season, we believe that the greatest Lyme disease risk continues to occur in the northeastern metropolitan area.

Re-detecting *I. scapularis* (two larvae) in one Hennepin County park where one larva was collected in 1998 was a mildly interesting finding. We believe that it is plausible that *I. scapularis* are

[1]sites where *I. scapularis* have been detected all or most years have been combined into one color scheme for the first time as the author feels they seem to both represent areas of *I. scapularis* establishment. Additionally, the colors were difficult to differentiate on past maps.

[2]see the discussion sections in the 1993 (*I. scapularis* population estimates) and 1994 (mammal density equality across sites) *I. scapularis* distribution study reports.

established in this area although we acknowledge that the number of *I. scapularis* collected in this location has been small and we seemed to have experienced another above average collection season in 2000. For these reasons we have not completely eliminated any of several possible interpretations that were discussed in our 1998 report.[3]

Our total collections of immature *I. scapularis* have increased in each of the last three years from 506 (439 larvae; 67 nymphs) in 1998 to 945 (688 larvae; 257 nymphs) in 2000. We were especially surprised to find that the total number of *I. scapularis* nymphs collected in 2000 had quadrupled compared with the 1999 (and generally going back to 1990) results. We feel that this high nymphal collection total represents more than expected year-to-year variability since we have maintained the same study methodology over the years and have not noticed a change in the overall diversity or percentages of small mammals collected which could in turn influence our collection results.

In our 1998 report we reported that we did not detect any significant impact of the 1997-1998 El Niño warm winter weather pattern on either the small mammal or ultimately *I. scapularis* populations. We propose that we could have misinterpreted the impact of our 1998 results by mistakenly comparing our 1998 collection totals to overall collection totals from all other years of this study rather than looking only at the increase (three to four-fold depending on the stage) when compared to the previous (1997) season totals. We suggest another possibility, which is that there was not an immediate effect noted, but perhaps a lingering effect to the El Niño warm weather conditions has occurred via higher survivability of the various stages of *I. scapularis* during the winter of 1997-1998 leading to the increases in our larval collections over the following three-year period and the high number of nymphs collected in 2000. An additional consideration for us was to examine independent yearly variables that could lead to larger or smaller volumes of immature *I. scapularis* collected in a particular season. The yearly variable we chose to examine most thoroughly was average spring (March) monthly temperature fluctuations. We found that the warmest high and low average monthly March temperature over the last twelve years (1989-2000) occurred in March 2000, which in and of itself could have potentially caused higher survivability in the immature *I. scapularis* compared to an average year. Our results do not fully support any of these conclusions, however, and we believe that multiple factors are involved in causing the increases in our immature *I. scapularis* collections from the 1998 to the 2000 season.

To explain our thought processes in greater detail, an examination of Table 3 shows over a four-fold increase in the number of *I. scapularis* larvae and approximately a three-fold increase on the total nymphal collections in 1998 versus the 1997 total. We are, however, still uncertain of the significance of that observation. Explaining our thoughts regarding potential lingering effects requires a bit more effort.

To clarify, we believe that higher survivability in the overwintering 1997-1998 adult *I. scapularis* population would theoretically have led to a higher level of egg production and ultimately more larvae in the spring of 1998, leading to more nymphs in the spring of 1999, and more adults (and their ensuing larvae) in the spring of 2000. Likewise, greater numbers of surviving nymphs in the spring of 1998 would have lead to more adults and their ensuing larvae in the spring of 1999, and more nymphs in the spring of 2000. Therefore our data shows mixed results to the hypothesis that a lingering El Niño effect has occurred, as the larval collections seem to have continued to increase beginning with the 1998 season, which fits, but the nymph collections increased in 1998 then remained static in 1999 before increasing dramatically in 2000.

To address our thought that perhaps an independent event of some sort may have occurred in the year 2000 which had an impact on the immature *I. scapularis* population, we investigated several ideas. The data with the most clarity was the finding that the warmest high and low average monthly March[4] temperatures over the last twelve years (1989-2000) had occurred in March 2000. The average monthly high (53.5° F) and low (31.6° F) temperatures for March 2000 are both higher

[3]see the discussion section in the 1998 *I. scapularis* distribution study report for particulars for this and the following discussion paragraphs.
[4]the month of March was selected somewhat arbitrarily as the month where changes in the break between winter and spring would be most likely to be noticed and could have the most dramatic impact on survivability of *I. scapularis*.

when compared with the average March monthly high (44° F; range 36.5° F-53.5° F) and low (22.5° F; range 13.9° F-31.6° F) temperatures over the period from 1989-2000. The yearly numbers of small mammals collected does not seem to be influenced by the March average high or low temperatures, and, to a lesser degree, we found that our immature *I. scapularis* collection data did not seem to strongly fit this hypothesis either[5]. We do know that the Minnesota Department of Health tabulated the highest number of human Lyme (463) and ehrlichiosis (77) case totals[6] that have been recorded in their databases, that it appears our results show an upward swing in the *I. scapularis* populations since 1998, and that an exceptionally high volume of immature *I. scapularis* appear to have been present during the 2000 collection season. Although we did examine several theories to explain the increases that we have seen since the 1998 season, we are not satisfied that our theories hold up well under scrutiny. We believe it is likely that additional factors or variables that we did not consider have caused our results to show an upward swing. Although the volume of *I. scapularis* collected was great in 2000, we did not see a significant change in where our tick collections occurred. Therefore, we again conclude that *I. scapularis* range expansion has not been detected.

[5] The second warmest March period was 1990, 1994 third warmest, with 1999 the 4th warmest March period. And, although our 1998 tick collections seemed similar to our 1994 totals, March of 1998 was one of the coldest average March periods seen over the twelve-year period.

[6] personal communication, although tick-borne disease case totals continue to change over time as new information is collected.

## ADDITIONAL UPDATES/RESEARCH:

### CONTINUING STUDIES FOR 2001.

- ***Ixodes scapularis* distribution study** (sites unchanged from 1993).

- **Cooperative studies with Dr. Russell Johnson (University of Minnesota-Mpls) and Marty Skoglund and Jay Brezinka (Dept of Military Affairs, Little Falls, MN):**
  Our cooperative study regarding the distribution and prevalence of *B. burgdorferi* and the HGE agent continued. (one within; one outside of the Minneapolis – Saint Paul metropolitan area).

- **Small mammal trapping and dragging for questing ticks in Little Falls and Arden Hills, Minnesota. (continuation)**
  Small mammals were collected from a total of six sites (4 in Little Falls; 2 in the metro area) approximately monthly from April 16 – October 24, 2001 for one trapnight each sample period. Sera was collected and processed and results are pending. Results of tick load comparisons between the Little Falls and metro area samples will be made after all of the ticks have been removed and identified. Dragging/flagging results are also pending, and nymphs collected in the dragging effort will be tested in an attempt to determine the specific host that each larva had fed on.

- **Re-sampling North Oaks (Ramsey county)--added to the effort in July.**

Background: North Oaks is a residential community in Ramsey county that was extensively examined by the District and Dr. Russell Johnson (UM-Mpls) from 1992 - 1997. It is parceled into larger acreage lots; those located on the eastern half of the community consisting generally of woody-stemmed vegetation (trees and bushes), with the western side tending towards a more open vegetative environment. Past research results found a *B. burgdorferi* small mammal infection rate ranging overall from 4.5% - 15% (rates seemingly site specific and localized). Most of the *I. scapularis* collections as well as higher *B. burgdorferi* infection rates were found on the eastern side of North Oaks. Surveys regarding Lyme disease in North Oaks residents performed by the MN Dept Health also seemed to establish a pattern of higher risk in the eastern side of the community. Several locations were re-sampled in 2000 and these sites were again sampled in 2001.

We re-initiated sampling in North Oaks beginning July 9 and ending September 12, 2001 at two areas located on the eastern side of North Oaks. These areas had been sampled for the entire 2000 season in conjunction with the Little Falls/Arden Hills research study. Tick load, serology and culture results are pending.

GRANT PROPOSAL STATUS.

Although this effort was approved for 2001, no Minnesota field research occurred.

- **Approved--Risk Assessment of the Expanding Distribution of Lyme Disease in the North – Central US:**

The goal of this potential effort is to expand the known risk model and maps developed for Illinois and Wisconsin to include the rest of the north-central U.S. and areas south as far as Tennessee using digitized data bases available from the USGS, GAP programs, etc. Known negative and positive sites from Michigan, Indiana, Minnesota, Ohio and Tennessee would be overlaid on the risk maps.

**Co-investigators**: Uriel Kitron, Ph.D. University of Illinois-Urbana Champaign
Edward D. Walker, Ph.D. Michigan State University
Mark L. Wilson, SC.D. University of Michigan-Ann Arbor

**Collaborators**: Richard L. Berry, Ph.D. VBDP-Ohio Dept Health
Robert Pinger, Ph.D. Ball State University
David Neitzel, M.S. Minnesota Dept Health
Janet Jarnefeld, Mpls-St Paul Metropolitan Mosquito Control District
Carl Jones, Ph.D. The University of Tennessee

No funding was granted for this project so it was not undertaken.

- **Not Approved-- Cooperative efforts with the Minnesota Department of Health- Lyme Disease Prevention Plan February 15, 2001 - February 14, 2002**

In addition to providing their ongoing activities, MDH wanted to create & implement a sustainable Lyme disease prevention program that would reduce Lyme disease incidence to < 9.6 per 100,000 population in two endemic counties (Pine and Washington). The feasibility of implementing various tick control strategies were to be examined, and in May 2001, MDH planned to work with the District to initiate monitoring of tick abundance and tick infection rates. By February 2004, the MDH planned to implement population-based educational activities in these 2 counties, focusing on community participation, personal protection measures, and tick habitat modification to reduce the Lyme disease incidence in each county. The level of District involvement was not fully established.

DEER SEROLOGY EFFORT

**University of Minnesota and the Department of Military Affairs, Little Falls, MN—fall & winter 1999/2000/2001.**

The District is not a collaborator on this project but we felt this information would be valuable for you: Jay Brezinka and fellow Camp Ripley staff collected blood samples from several October, 1999 hunts and one white-tailed deer live-trapping effort from January, 2000. Testing results from the October 1999 collections showed 52% of the deer PCR-positive for the HGE agent. *B. burgdorferi* PCR is pending. 78% of the October deer were seropositive for anti-HGE antibodies. For the samples collected in the January live-trapping effort, none were HGE PCR-positive, but preliminary serology results were 100% positive for the HGE agent. Collections occurred again in October 2000 as well as 2001.

PLANS FOR 2002.

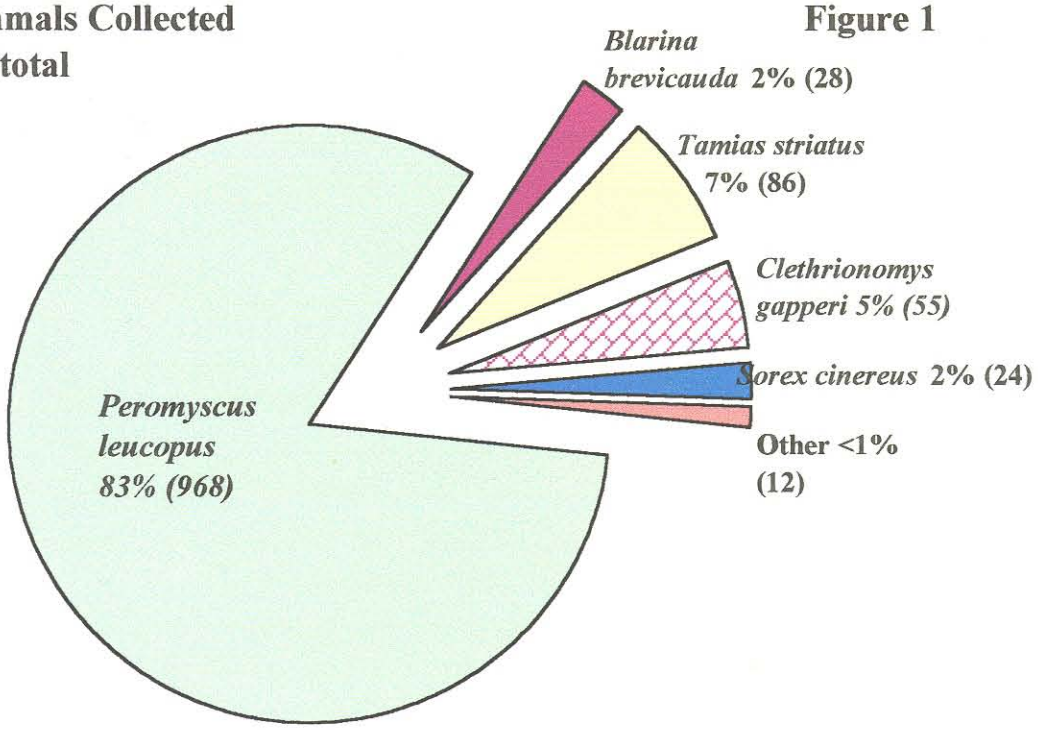
- ***Ixodes scapularis* distribution study** (sites unchanged from 1993) will continue.

- **Cooperative studies with Dr. Russell Johnson (University of Minnesota-Mpls) and Marty Skoglund and Jay Brezinka (Dept of Military Affairs, Little Falls, MN):** At this time it is not determined whether 2002 field collections for this cooperative study regarding the distribution and prevalence of *B. burgdorferi* and the HGE agent will occur. Results from 2000 and 2001 will continue to be compiled and summarized and will eventually be compared with previously collected site habitat information.

  **Risk Assessment of the Expanding Distribution of Lyme Disease in the North – Central US:** Minnesota field research may take place in 2002.

**Small Mammals Collected**
**2000: 1173 total**

**Figure 1**

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**Ticks, by Species and Stage, Removed from Small Mammals**
**2000: 2207 total**

**Figure 2**

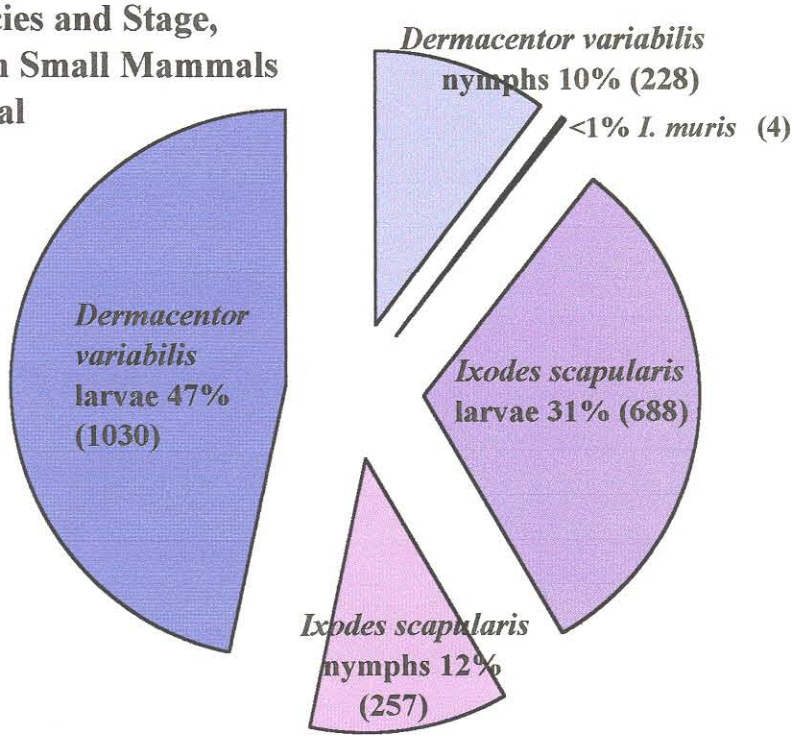
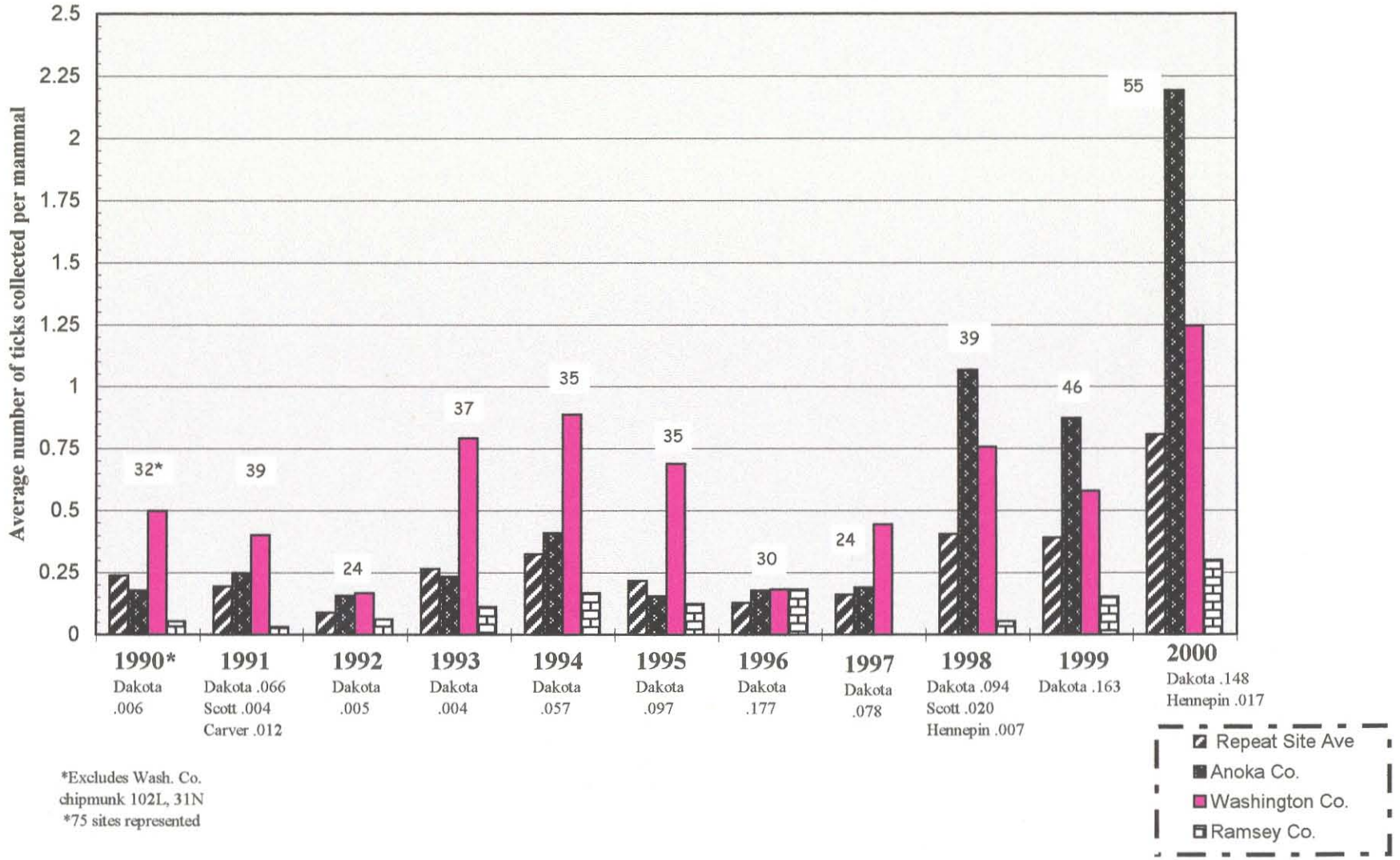


Figure 3

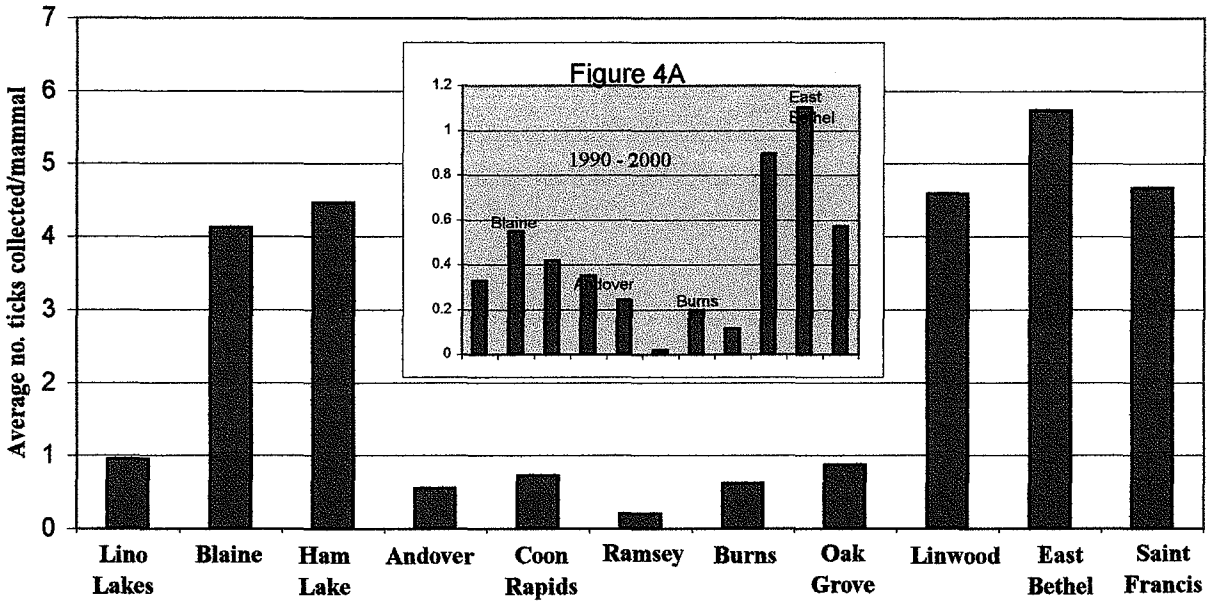
**Average number of *I. scapularis* collected per mammal at 100* sampling locations in Anoka, Washington, and Ramsey counties: 1990 - 2000**
**(white box shows the total number of sites where at least one *I. scapularis* was found: by year)**




*Excludes Wash. Co. chipmunk 102L, 31N
*75 sites represented

**Figure 4**

**Average number of *I. scapularis* collected per mammal in Anoka county (by township): 2000 results only**




**Average number of *I. scapularis* collected per mammal in Washington county (by township): 2000 results only**

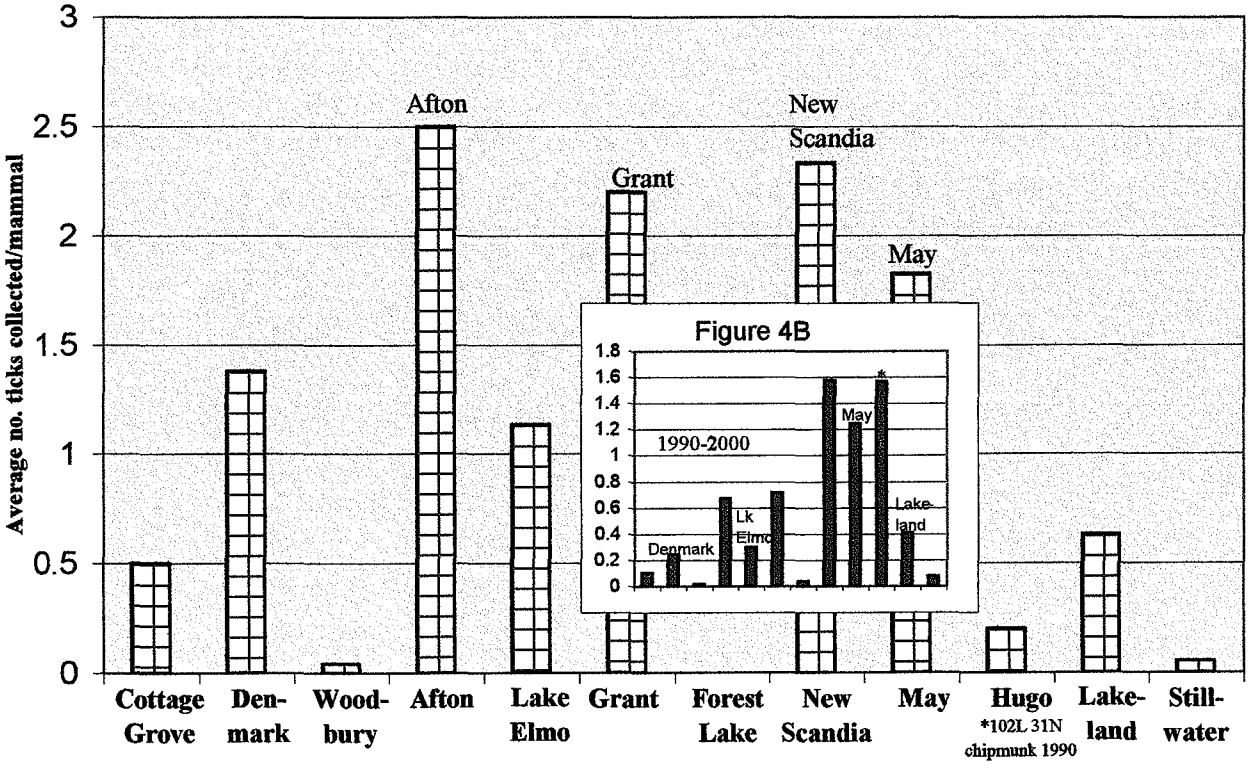
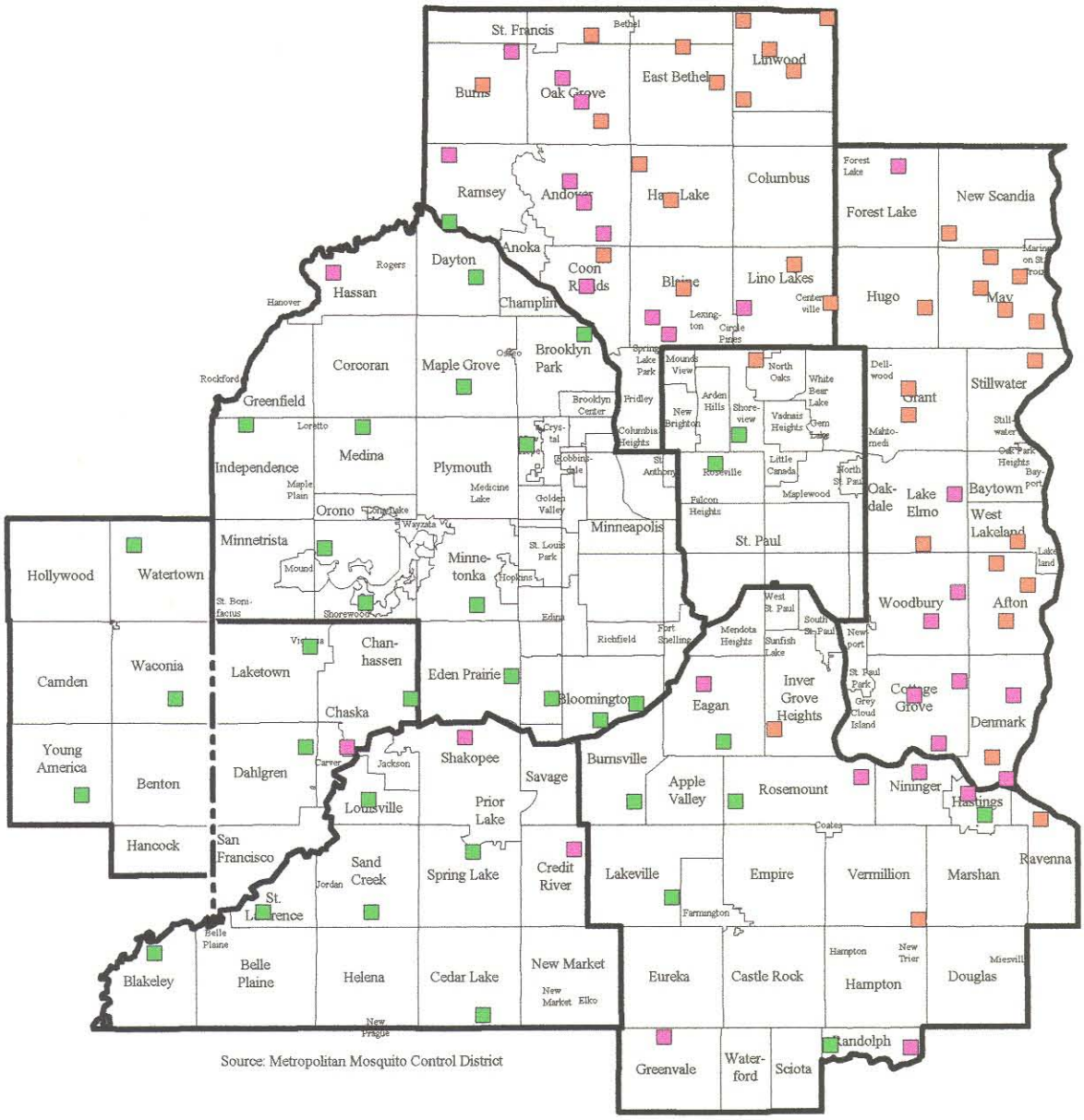


**Figure 5**

*Ixodes scapularis* Presence/Absence status: 1990 - 2000

*(present if at least one Ixodes scapularis collected during a year)*




Source: Metropolitan Mosquito Control District

At least one tick found during:

- all/most years (36)
- at least 1 year (30)
- (not found) (34)

## Table 2. Numbers and Percentages of Small Mammals Collected by Year

| Year | No. sites | Total mammals collected | Ave collected per site and [100 repeat sites only] | *Peromyscus leucopus* percent (n) | *Tamias striatus* percent (n) | *Clethrionomys gapperi* percent (n) | *Blarina brevicauda* percent (n) | Other* percent (n) |
|---|---|---|---|---|---|---|---|---|
| [1] 1990 | 250 | 3651 | 14.6 [17.15 @75 sites] | 80% (2921) | 6% (224) | 7% (240) | 4% (155) | 3% (111) |
| 1991 | 270 | 5566 | 20.61 [23.54] | 77% (4308) | 7% (395) | 5% (264) | 7% (402) | 4% (197) |
| 1992 | 200 | 2544 | 12.72 [12.68] | 71% (1804) | 9% (223) | 4% (103) | 13% (329) | 3% (85) |
| 1993 | 100 | 1543 | [15.43] | 81% (1243) | 4% (69) | 7% (101) | 7% (107) | 1% (23) |
| 1994 | 100 | 1672 | [16.72] | 78% (1309) | 10% (171) | 5% (79) | 5% (76) | 2% (37) |
| 1995 | 100 | 1406 | [14.06] | 79% (1115) | 11% (156) | 4% (55) | 4% (61) | 1% (19) |
| 1996 | 100 | 791 | [7.91] | 79% (628) | 11% (84) | 3.5% (29) | 3.5% (28) | 3% (22) |
| 1997 | 100 | 728 | [7.28] | 71% (515) | 13% (98) | 3% (24) | 10% (71) | 3% (20) |
| 1998 | 100 | 1246 | [12.46] | 84% (1041) | 4% (51) | 3% (42) | 6% (72) | 3% (40) |
| 1999 | 100 | 1627 | [16.27] | 85% (1376) | 7% (108) | 3% (46) | 4% (63) | 1% (9) |
| 2000 | 100 | 1173 | [11.73] | 83% (968) | 7% (86) | 5% (55) | 2% (28) | 3% (36) |

*Other includes *Microtus pennsylvanicus, Spermophilus tridecemlineatus, Zapus hudsonius, Mustela erminea, Tamiasciurus hudsonicus, Glaucomys volans, Sorex articus,* and several ground-feeding bird species.

## Table 3. Numbers and Percentages of Tick Species Collected by Stage and Year

| Year | No. sites | Total ticks collected | *Dermacentor variabilis* L[2] percent (n) | *Dermacentor variabilis* N[3] percent (n) | *Ixodes scapularis* L[2] percent (n) | *Ixodes scapularis* N[3] percent (n) | Other species[4] percent (n) |
|---|---|---|---|---|---|---|---|
| [1] 1990 | 250 | 9957 | 83% (8289) | 10% (994) | 6% (573) | 1% (74) | 0% (27) |
| 1991 | 270 | 8452 | 81% (6807) | 13% (1094) | 5% (441) | 1% (73) | 0% (37) |
| 1992 | 200 | 4130 | 79% (3259) | 17% (703) | 3% (114) | 1% (34) | 0% (20) |
| 1993 | 100 | 1785 | 64% (1136) | 12% (221) | 22% (388) | 1% (21) | 1% (19) |
| 1994 | 100 | 1514 | 53% (797) | 11% (163) | 31% (476) | 4% (67) | 1% (11) |
| 1995 | 100 | 1196 | 54% (650) | 19% (232) | 22% (258) | 4% (48) | 1% (8) |
| 1996 | 100 | 724 | 64% (466) | 20% (146) | 11% (82) | 3% (20) | 1% (10) |
| 1997 | 100 | 693 | 73% (506) | 10% (66) | 14% (96) | 3% (22) | 0% (3) |
| 1998 | 100 | 1389 | 56% (779) | 7% (100) | 32% (439) | 5% (67) | 0% (4) |
| 1999 | 100 | 1594 | 51% (820) | 8% (128) | 36% (570) | 4% (64) | 1% (12) |
| 2000 | 100 | 2207 | 47% (1030) | 10% (228) | 31% (688) | 12% (257) | 0% (4) |

[1] 1990 data exludes one *Tamias striatus* with 102 larval & 31 nymphal *I. scapularis*

[2] L = larvae

[3] N = nymphs

[4] Other species mostly *Ixodes muris.* 1999-2nd adult *I. muris* collected