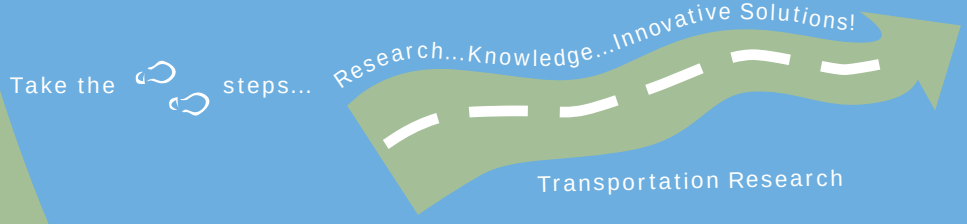
RESEARCH

2009-10

Implementation of Methodology for Weed Management Practices



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16. Abstract (Limit: 200 words)

A study initiated in 2004/2005 in District 4 of Mn/DOT compared the use of 100 1/4-mi long segments against seven 3-mi segments on sampling precision for the estimation of weed infestations in highway rights-of-way for Canada thistle (*Cirsium arvense* (L.)(Scop.), leafy spurge (*Euphorbia esula* L.), and poison ivy (*Toxicodendron radicans*). The comparison showed that the 3-mi and 1/4-mi plans yielded equivalent estimates of mean weed population density, although the results indicated that at the district level precision was greater with the 1/4-mi plan. Further investigations suggested that additional improvements in precision and efficiency would likely occur if segment lengths were shortened to 125' or less. The project implementation phase reported here aimed to investigate efficiencies of two sampling plans, one with weed density measured over 100, 225-ft segments, and one with presence/absence of weeds measured over 150, 14-ft segments. Results showed that the presence-absence surveys almost consistently underestimated the area infestation derived from the 225-ft surveys. The 14-ft survey required substantially less time to conduct, but at this time they appear to be less precise than the 225-ft surveys with regard to quantifying infestation density. It is recommended that an additional season of survey data be analyzed to better quantify the precision of the 14-ft survey results.

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Implementation of Methodology for Weed Management Practices

Final Report

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- Jerry Miller, assistant district engineer, operations, Mn/DOT District 4 (Mn/DOT_D4)
- Paul Walvatne, roadside vegetation management unit supervisor, Mn/DOT Office of Environmental Services
- Tina Markeson, Mn/DOT biological control program coordinator, Office of Environmental Services
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Executive Summary

By law, Departments of Transportation are required to control noxious weeds along highway rights-of-way (ROWs). District 4 (D4) of Minnesota Department of Transportation (Mn/DOT) has been monitoring the rights-of-ways in highways under its management to quantify infestations of Canada thistle (*Cirsium arvense* (L.)(Scop.), leafy spurge (*Euphorbia esula* L.), and poison ivy (*Toxicodendron radicans*) in chosen regions of the district. From 2000 until 2004 the surveys employed samples comprising seven, 3-mile long segments. In 2004, a 2-year study was initiated in which the effect of use of greater numbers of smaller (1/4-mi long) segments on surveying precision was investigated. The sampling surveys using the 3-mile plan were also continued concurrently through 2005.

A comparison of matching sample statistics from the 3-mi and 1/4-mi plans in each year indicated the two plans yielded statistically equivalent estimates of mean acres per roadway mile of each weed ($\alpha = 0.05$). However, precision at the district level was much greater in all cases with the 1/4-mi plan. A combination of computer based mapping and re-sampling of the 1/4-mi segments data observed in the two years suggested that additional improvements in precision and efficiency would likely occur if segment lengths are shortened to 225 feet or less.

An implementation phase project, upon which this report is based, was initiated in 2007 and aimed to investigate the efficiencies of two sampling schemes, one based on 225-ft segments, and the other based on 14-ft segments. In the study, sampling was to be conducted at select 100 225-ft long, and 150 14-ft long-segments. One objective was to investigate the application of a presence-absence sampling plan (with 14-ft segments), and compare achievable precision and efficiency of this plan to the population density (area infested per unit length of highway) mapping sampling plan (the 225-ft segments).

To relate presence-absence data to population density, the model by Kono and Sugino (1958) was adopted and calibrated using the population density data recorded in surveys with the 225-ft segments. To apply this model, data recorded with 225-ft segments were sliced into 14-ft segments, then further analyzed to determine the proportion of the 14-ft segments infested with given weed species. The proportion of 14-ft segments infested with Canada thistle in the 9 categories (ecological zone + type of highway) in the survey area was related to the population density (acres-per-mile) in the corresponding 225-ft segment. These data were used in the calibration of the Kono and Sugino model. The independent 150 14-ft presence-absence data were then used in the calibrated Kono and Sugino model to determine how well the model predicted the measured population densities. Results showed that the presence-absence surveys almost consistently underestimated the area infestation when evaluated values were compared to those derived from the 225-ft surveys. Also, the predictions (acre-per-mile) based on the 14-ft presence-absence surveys appear to be less precise than the 225-ft surveys values.

In addition to quantifying the precision of weed population estimation, it was of interest to determine which sampling plan was the most time efficient for field surveyors, with regard to travel time to sampling sites and associated sampling time. The 14-ft surveys required

substantially less time to conduct. A balance between precision and effort will need to be considered when deciding which survey scheme to use in conducting regional surveys.

It is recommended that an additional season of data be collected in 2008 to further test the Kono and Sugino (1958) model, and also to refine the estimates of the comparative effort required to conduct the surveys with 225-ft and the 14-ft segments.

Chapter 1 - Introduction

State Departments of Transportation are required by law (for Minnesota, Minnesota State law, section 18.78) to control prohibited noxious weeds in the rights-of-way (ROWs) of highways under their management. This can be difficult and expensive, as the areas to be controlled are often large, and the necessary information on location and distribution of the species difficult to obtain. Traditionally, data on location of vegetation over landscapes is usually obtained by conducting inventories of the entire highway ROWs, which can be costly and time consuming.

Survey data acquired from inspection of a few carefully selected sites can be applied in estimating population distributions of vegetation species over larger areas. According to Haila & Margules (1996), surveys and associated analyses of vegetation and habitat types provide basic information for decision making in nature conservation, environmental management and landscape planning. However, correct estimates of biodiversity or natural resource quality of an area are dependent on the sampling design of such surveys (Knollová et al., 2005). Some of the current biological surveys of large areas are more inclined to use environmentally stratified sampling designs (Gimaret-Carpentier et al., 1998; Goedickemeier et al., 1997; Olsen et al., 1999; Yoccoz et al., 2001) or different kinds of adaptive sampling strategies (Stein and Ettema, 2003; Thompson and Seber, 1996). When stratified sampling designs are employed, the strata are defined, usually based on environmental variables which have been demonstrated in studies to influence species composition (Knollová et al., 2005).

The Minnesota Department of Transportation Management District 4 (Mn/DOT_D4) initiated surveys in the summer of 2000 to assess population distribution of three problem weed species in the District's highway ROWs. The surveys were conducted to determine location and distribution of Canada thistle (*Cirsium arvense (L.)(Scop.),* leafy spurge (*Euphorbia esula L.*), and poison ivy (*Toxicodendron radicans*). The preselected sampling sites consisted of seven, 3-mile long segments within the highway ROWs. Because of questions raised regarding validity of the data obtained using this sampling design, a new survey design was implemented in the summer seasons for 2004 and 2005. The new survey adopted a sample comprising of 100, 1/4-mile segments selected by complete stratified random selection methodologies. Strata were based on ecological zones and types (with or without median) of highways in the district.

The two sampling plans studied (3-mi and ¼-mi) were tested in field surveys conducted in 2004-2005. Analysis of the data from the surveys showed the sampling plans yielding comparable values of mean infested populations. Comparisons of the district level means acres-per-linear mile evaluated from data acquired in surveys using the 3-mi and ¼-mi sampling designs did not show consistent and significant differences ($\alpha = 0.05$) as can be observed from Tables 1.1 and 1.2. This was true for all species, and in all categories (ecological zone, type of highway) of the study area. However, significant differences ($\alpha = 0.05$) were observed among ¼-mi means for different ecological zones, as shown in Tables 1.3 and 1.4.

Table 1.1 Mean acres-per-mile of Mn/DOT_D4 highway rights-of-way infested by Canada thistle, leafy spurge and poison ivy as evaluated from 3-mile and ¼-mile surveys (2005 surveys**)**

Sampling Plan	N	Canada thistle		Leafy spurge		Poison ivy	
		acre/mile	C.I.[&]	acre/mile	C.I.	acre/mile	C.I.
3-mi	7	2.437a[#]	11.84	0.004a	0.018	0.114a	0.674
¼-mi	101	2.854a	0.64	0.009a	0.011	0.163a	0.143

[#]Acre/mile values with the same symbol within a **Column** are **not** significantly different ($\alpha = 0.05$)
[&]95% confidence interval

Table 1.2 Mean acres-per-mile of Mn/DOT_D4 highway rights-of-way infested by Canada thistle, leafy spurge and poison ivy as evaluated from 3-mile and ¼-mile surveys (2004 surveys)

Sampling Plan	N	Canada thistle		Leafy spurge		Poison ivy	
		acre/mile	C.I.	acre/mile	C.I.	acre/mile	C.I.
3-mi	7	1.057b[#]	0.758	0.046b	0.063	0.118a	0.231
¼-mi	100	2.079a	0.507	0.005a	0.006	0.039a	0.048

[#]Acres/mile values with the same symbol within a **Column** are **not** significantly different ($\alpha = 0.05$)

Table 1.3 A comparison of mean acres-per-mile of Canada thistle, leafy spurge and poison ivy in highways rights-of-way in ecological zones and entire Mn/DOT_D4, evaluated from data recorded in surveys with 3-mile and ¼-mile sampling plans (2005)

Species	**Region****	**1/4-mi (acres/mile)**	**1/4-mi C.I.**	**3-mi (acres/mile)**	**3-mi C.I.**
Canada thistle	Mn/DOT_D4	2.854b[#]	0.64	2.437	11.843
	Hardwood Hills	3.079b	1.751	-[@]	-
	Minnesota R. Prairie	2.610b	0.744	-	-
	Pine Moraines	0.307a	0.287	-	-
	Red River	3.592c	1.364	-	-
Leafy spurge	Mn/DOT_D4	0.009b	0.011	0.004	0.018
	Hardwood Hills	0.027c	0.052	-	-
	Minnesota R. Prairie	0.006b	0.005	-	-
	Pine Moraines	0.000a	0	-	-
	Red River	0.002b	0.003	-	-
Poison ivy	Mn/DOT_D4	0.163b	0.143	0.114	0.674
	Hardwood Hills	0.131a	0.121	-	-
	Minnesota R. Prairie	0.031a	0.04	-	-
	Pine Moraines	1.502b	2.877	-	-
	Red River	0.019a	0.039	-	-

[#]¼-mi acres/mile values with the same symbol within a **Column** for a species are **not** significantly different ($\alpha = 0.05$).
[@] Data not available
** Chippewa falls Ecological zone with only 2 data points, was not included in this analysis

Table 1.4 A comparison of mean acres-per-mile of Canada thistle, leafy spurge and poison ivy in highways rights-of-way in ecological zones and entire Mn/DOT_D4, evaluated from data recorded in surveys with 3-mile and ¼-mile sampling plans (2004)

Species	**Region**	**1/4-mi (acres/mile)**	**1/4-mi C.I.**	**3-mi (acres/mile)**	**3-mi C.I.**
Canada thistle	Mn/DOT_D4	2.079c[#]	0.507	1.057	0.758
	Hardwood Hills	1.419b	1.242	-[@]	-
	Minnesota R. Prairie	2.297c	0.813	-	-
	Pine Moraines	0.270a	0.271	-	-
	Red River	2.621d	0.890	-	-
Leafy spurge	Mn/DOT_D4	0.005b	0.006	0.046	0.063
	Hardwood Hills	0.000a	0.000	-	-
	Minnesota R. Prairie	0.010c	0.015	-	-
	Pine Moraines	0.000a	0.000	-	-
	Red River	0.003b	0.006	-	-
Poison ivy	Mn/DOT_D4	0.039b	0.0480	0.118	0.231
	Hardwood Hills	0.137c	0.2870	-	-
	Minnesota R. Prairie	0.009a	0.0190	-	-
	Pine Moraines	0.082b	0.1680	-	-
	Red River	0.0000	0.0000	-	-

[#] ¼-mi acres/mile values with the same symbol within a **Column** for a species are **not** significantly different (α = 0.05).
[@] "-" Data not available

The influence of size of sampling segments was further investigated by re-sampling data collected for the ¼-mi segments. The data was re-sampled in 14-ft sections to facilitate testing on whether further improvements in precision and sampling efficiency are possible with even shorter segments. The results of these tests suggested that additional improvements in precision and efficiency are likely to occur if segment lengths are shortened to 225 feet or less. Shorter segments should reduce inspection costs, increase sample sizes, hence improved precision. Further, the shorter segments could possibly allow conversion from an area-measurement approach to one based on presence or absence of chosen weeds in selected segments. Testing this hypothesis was among key tasks of this project implementation phase.

This report details work completed in the implementation phase of the project, "Management Practices for Weed Control in Roadway Rights-of-Way", Mn/DOT Contract No. 81655, Work Order No. 124, conducted in 2004-05. In this phase, we have applied the methods developed in the earlier project to quantify the spatial distribution of invasive weed species in highway rights-of-way, within Mn/DOT_D4. This phase was conducted to establish whether adoption of the former project's recommended sampling designs would result in reduced time for performing weed population surveys, while simultaneously enhancing the precision of population estimation.

1.1 Project Objectives and Activities

The main objectives of this phase of this project were to test the surveying efficiencies and costs achievable in the adoption of 225ft and 14ft segments. Specific tasks undertaken include:

- Processing of survey data recorded in surveys conducted by personnel of Mn/DOT_D4, and
- Through statistical analysis of the data, to address the project objectives:
    - Application of two sampling methodologies developed in a previous Mn/DOT sponsored research project in assessing weed population distribution in Mn/DOT_ D4
    - Through analysis of weed population data set collected by Mn/DOT_D4 in summer 2007, evaluate sampling efficiency of the two sampling methods
    - Through analysis of weed population data set collected by Mn/DOT_D4 using the two sampling methods in summer 2007, evaluate cost of surveying using each sampling plan

Specific tasks in the project included initial entry, cleaning and post-processing of the data recorded in surveys conducted in 2007 by personnel from Mn/DOT_D4. This data was to be further processed and analyzed in GIS, producing maps of population distribution for all subject invasive weed species in Mn/DOT_D4 investigated in the project. Statistical analyses of data were conducted aimed at assessing economic advantages realized by adopting the proposed small samples design for Presence-Absence surveying in Mn/DOT_D4, and elsewhere.

Chapter 2 - Materials and Methods

Field surveys were conducted in the same study area which had been the object of weed surveys conducted by Mn/DOT_D4 in 2004 and 2005. The location of the study area within Minnesota is shown in Figure 2.1. The sampling sites used in the surveys were selected following methods described in section 2.1.

Surveys were conducted in the summer of 2007 by personnel from Mn/DOT_D4. The surveys mapped population distribution of thirteen noxious weed species in rights-of-way (ROWs) of the highways managed by Mn/DOT_D4. Data were recorded for the eleven Minnesota Prohibited Noxious Weed species including Perennial Sowthistle (*Sonchus arvensis (L.)*), Canada thistle (*Cirsium arvense (L.) Scop.*), Bull Thistle (*Cirsium vulgare (Savi) Tenore),* Field bindweed (*Convolvulus arvensis* (*L.*)*),* Leafy Spurge *(Euphorbia esula (L.)),* Plumeless Thistle (*Carduus acanthoides (L.)*), , Poison Ivy (*Toxicodendron radicans*), Purple Loosestrife *(Lythrum salicaria*, *virgatum (L.)),* Musk Thistle (*Carduus nutans (L.)*), Garlic mustard (*Alliaria petiolata (Bieb.)*), Hemp *(Cannabis sativa (L.),* and two additional species, Wild Parsnip (*Pastinaca sativa*) and Spotted Knapweed. The Mn/DOT_D4 staff members participating in the project field work were trained on use of the GPS units, which were required in recording of data. The following members participated in the surveys: Kevin Meacham, Lenny Zimmel, Marty Ringquist, Paul Bakken, Bernie Koch, Jeff Reuss, Dave Staples, and Paul Christeson. Data files were forwarded to the University of Minnesota research team, and organized in electronic file folders bearing the names of the individual responsible for the recording of constituent data files.

Selection of the sampling sites for adoption in this study was based on criteria for optimizing sample distribution over the 9 categories into which the study area was subdivided. Table 2.1 (in page 9) shows the categories and optimum distribution of sampling sites based on the two sampling plans. Procedures for sample selection are described in the User Guide (Arika et al., 2007b). Selection of the 225ft and 14/ft segments was effected using the population of 1/10-mile segments for the entire Mn/DOT_D4 highway miles. The 1/10-mile segments were adopted (instead of 225ft and 14ft lengths for entire District) for simplification of selection, and also for the ease of locating the sites in the field. Table 2.1 shows a portion of the 1/10-mi highways segments from which all sampling sites were selected using the MS Excel® randomizing function, Rand(). The appropriate number of samples for each of the 9 categories were selected by running the Rand() function on the possible sample locations. A portion of the resulting sample site selection with the associated generated random number is given in Table 2.2. The generated random numbers column is copied, then pasted (Paste_Special_Values) on the same (Rand()) column to 'fix' the obtained random number values. The whole table is then sorted (Ascending order) by the random numbers column and categories. The optimum number (X) of sampling sites for each category (Table 2.1) was selected by adopting the first X rows of data within the sorted categories data (Table 2.2). Information in Table 2.1 was also used in calculations for weighted mean acres-per-mile for each category (see section 3.1).

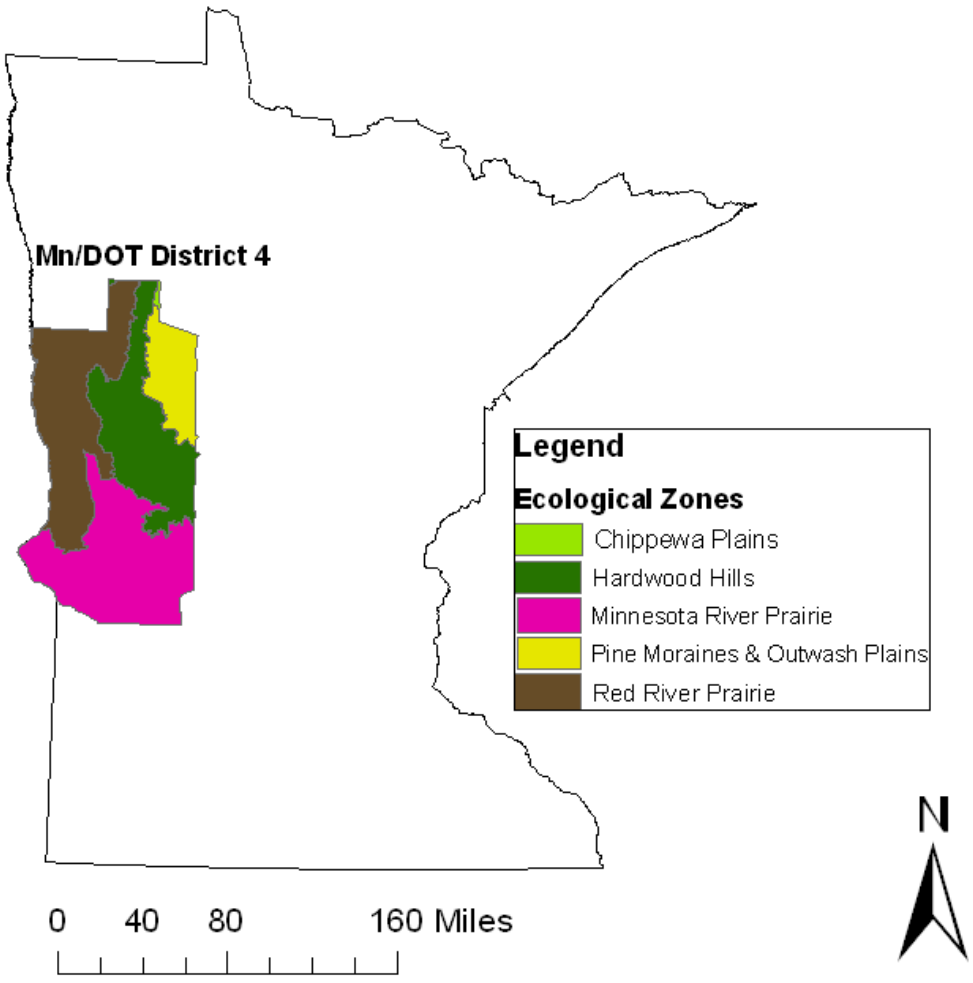


Figure 2.1 Location and ecological zone boundaries of Mn/DOT_D4 within Minnesota (Arika et al., 2007b).

2.1 Selection of Sampling Sites

In this project, it is recommended that selection of optimum samples be conducted with application of the previous season surveys data of the same study area. Figures 2.2a, 2.2b, and

Canada Thistle: analysis of 2007 data, by roadway category (ecozone x median type)

Aspect of plan used last time										
Segment length (mi):	0.042613636									
Intersegmental distance, mi:	**0.1**									
Median?	0	1	1	1	1	0	0	0	0	
Roadway category:	CP-0	PMOP-1	MNRP-1	HH-1	RRP-1	PMOP-0	HH-0	RRP-0	MNRP-0	Total
No. miles in category:	1.0	18.0	36.0	51.0	100.0	108.0	300.0	411.1	607.0	1,632
No. of segments possible:	10	180	360	510	1,000	1,080	3,000	4,111	6,070	16,321
No. examined last time:	2	3	3	6	9	3	12	19	26	83
No. infested:	1	3	3	5	9	3	10	17	26	77
Percent infested:	50%	100%	100%	83%	100%	100%	83%	89%	100%	93%
Percent examined:	20.0%	1.7%	0.8%	1.2%	0.9%	0.3%	0.4%	0.5%	0.4%	0.5%
Proportional allocation:	0.1%	1.1%	2.2%	3.1%	6.1%	6.6%	18.4%	25.2%	37.2%	100%
Optimal allocation:	0.014%	0.416%	1.246%	5.696%	5.129%	2.757%	14.364%	26.740%	43.637%	100%

Segment no. — **Raw data from each segment observed, converted to acres per mile of roadway…**

1	0	6.36149825	10.16037079	0	0.5324404	0.0420968	0	0	0.084193
2	1.047829979	7.04722585	12.84125002	0.0420964	1.4009987	0.0420969	0	0	0.084193
3		8.69478758	13.57048265	0.2757096	1.6005622	2.3365367	0.0420966	0.084193695	0.084193
4				3.7207636	1.7265124		1.3844661	0.168386158	0.194182
5				8.847345	2.2023309		2.0728162	0.191234098	0.556334
6				14.011023	3.5695912		2.1854401	0.478837186	1.036552
7					3.719173		3.0829219	0.662211144	1.65392
8					7.262947		3.3953515	1.128945858	1.826338
9					8.083891		3.782052	1.2021995	2.029858
10							3.9805991	1.234395397	2.90232
11							4.3988968	2.214292241	3.0692
12							8.8295887	2.652544586	3.118051
13								2.897255846	3.148338
14								3.46855242	3.223425
15								3.645416588	3.690683
16								4.662986121	4.313652
17								6.347384761	4.364821
18								9.878232951	4.737943
19								11.89942388	4.800135

Arbitrary segment number, substituted for original Hwy-RefSpot label.

This is the %age of all past segments that were actually observed in zone.

Grand Weighted Mean

										GWM
n	2	3	3	6	9	3	12	19	26	83
Mean	0.524	7.368	12.191	4.483	3.344	0.807	2.763	2.780	4.146	**3.50**
Variance	0.5490	1.4382	3.2246	33.5864	7.0820	1.7548	6.1713	11.3903	13.9135	**10.86**
SD	0.741	1.199	1.796	5.795	2.6612	1.3247	2.4842	3.3749	3.7301	**3.18**
SE	0.524	0.692	1.037	2.366	0.887	0.765	0.717	0.774	0.732	**0.81**
Student's t	12.706	4.303	4.303	2.571	2.306	4.303	2.201	2.101	2.060	2.35
ME/Mean, as %	1271	40	37	136	61	408	57	59	36	74.98
Adjusted optimal:		0.42%	1.25%	5.70%	5.13%	2.76%	14.37%	26.74%	43.64%	100.00%
Adjusted again:			1.25%	5.72%	5.15%	2.77%	14.43%	26.86%	43.83%	100.00%
New n:	2	2	2	5	5	3	14	26	42	
New SE:	0.524	0.848	1.270	2.483	1.202	0.816	0.670	0.667	0.578	
New Student's t:	4.303	4.303	4.303	2.776	3.182	4.303	2.179	2.064	2.021	
New ME as % of mean:	430.3	49.5	44.8	153.8	114.4	435.1	52.9	49.6	28.2	

Figure 2.2a Application of previous season data to determine the optimal number of sampling sites (with lower measurement Standard Error, SE) for adoption in the next season's (2008) surveys.

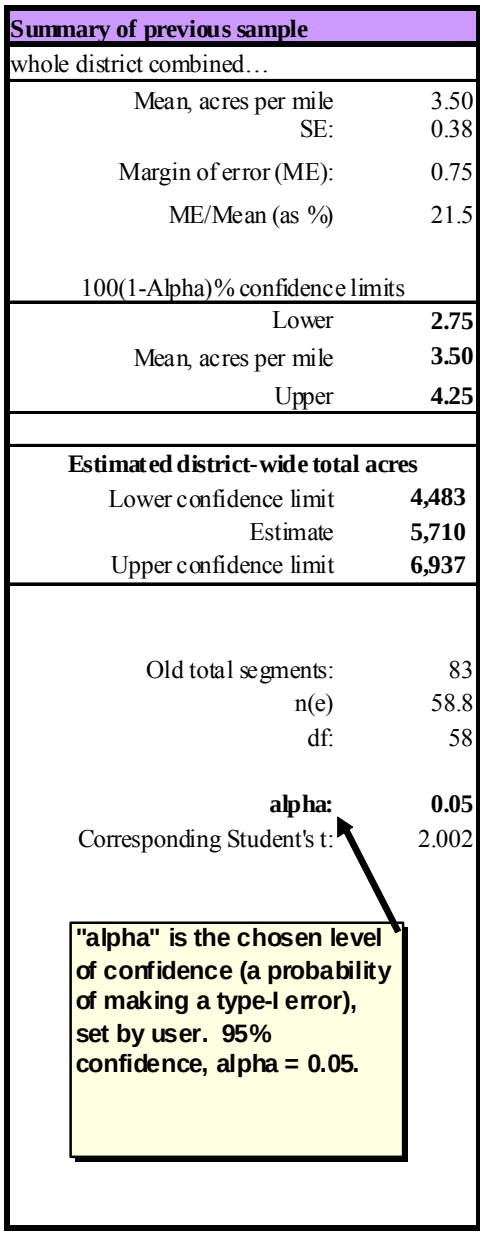


Figure 2.2b Application of previous season data to determine the optimal number of sampling sites (with lower measurement Standard Error, SE) for adoption in the next season's (2008) surveys.

Tools for planning next season

This is a trial-and-error value, to be set by the planner, for the TOTAL number of new segments to be observed in the next sampling season.

Projected precision, district-wide
using the OPTIMAL distribution of segments among zones, in next sampling season…

New total segments (75 paces ea):	**100**
Corresponding Student's t:	1.995
New SE:	0.32
Resulting new ME:	0.63
New ME/Mean (%):	**18.0**

Cost figures

Component	Minutes
Time to measure one mile: (SegmentLength, mi: 0.042613636)	110.4
Time to measure one segment:	4.7
Time to measure all segments:	470.5
Time to travel to average segment:	52.2
Total time to survey new segments:	**5,690**

Optimal distribution

Zone	No. segments possible (N)	Observe n	(ignore this column)
CP-0	10	2	
PMOP-1	180	2	
MNRP-1	360	2	
HH-1	510	5	
RRP-1	1,000	5	
PMOP-0	1,080	3	
HH-0	3,000	14	
RRP-0	4,111	26	
MNRP-0	6,070	42	
Total	16,321	100	

Projected precision as totals by zone

Zone	Total acres	± ME, acres	± % of total
CP0	0.52	2.3	430.3
PMOP1	132.6	66	49.5
MNRP1	439	197	44.8
HH1	229	352	153.8
RRP1	334	382	114.4
PMOP0	87	379	435.1
HH0	829	438	52.9
RRP0	1,143	566	49.6
MNRP0	2,517	708	28.2
District-wide total:	5,710		

Figure 2.3 Application of previous season data to determine the optimal number of sampling sites (minimum Mean Error, ME) and their optimal distribution in the study area for next season's surveys.

2.3 are part of an MS Excel® Worksheet developed for use in this selection. In this worksheet, the raw data on species infestations (acres) recorded for each sampling site (segment) is used to compute infested density (acres-per-mile), and the data then further analyzed to determine mean infested, standard deviation; variance and mean errors for each of the nine categories within the study area. Table 2.3 illustrates the application of data recorded in surveys conducted in 2007 using the 225ft segments plan, to determine the optimum sample number for use in the next season's surveys. With a 'tolerable' sampling error margin (mean standard error of less than 20%) in mind, the planner, through trial and error, has obtained an optimum sample number of 100, 225-ft segments for use in the following season surveys. The table also shows the projected acres of Canada thistle (predicted from last season's data) in different categories when the selected optimum sample is correctly applied in the following season surveys (see the lower right section of the table, with a of total 5,710 acres from the 100 segments in the 9 categories). With the knowledge of total miles of rights-of-way within each of the 9 categories in Mn/DOT_D4, or the entire Minnesota State, these values may be applied in computing predicted total acres in respective regions.

For the chosen optimum sample size, the Mean /ME (%) Error (shaded grey in Figure 2.3), which is based on a chosen level of confidence (95%) is an important criteria for establishing

measurement precision associated with adoption of the sampling plan and selected optimum sample size.

The results of the selection of sample size, and its allocation over the study area are as presented in Table 2.1.

Table 2.1 Predetermined optimal number and distribution of sampling sites in the 9-categories of the study area (Mn/DOT_D4)

Category (Zone, type highway)	**Total Possible number of 1/10-mile segments in D4 (N)**	**Number of 225-ft to be selected (N1)**	**Number of 14-ft to be selected (N2)**
CP-0	10	2	2
PM-1	180	2	2
MNRP-1	360	3	4
HH-1	510	6	10
RRP-1	1000	13	19
PM-0	1080	2	2
HH-0	3000	16	24
RRP-0	4111	25	39
MNRP-0	6070	31	48
Total	16321	100	150

Key:

CP-0 = Chippewa Plains; on highways without median
PMOP-0 = Pine Moraines & Outwash Plains, No median
PMOP-1 = Pine Moraines & Outwash Plains, with median
MNRP-0 = Minnesota River Prairie, No median
MNRP-1 = Minnesota River Prairie, with median
HH-0 = Hardwood Hills, No median
HH-1 = Hardwood Hills, with median
RRP-0 = Red River Prairie, No median
RRP-1 = Red River Prairie, with median

Results of the process of selection of sampling sites are as presented in Tables 2.3 and 2.4 showing the 100, 225-ft and 150, 14-ft segments implemented in each of the two sampling plans. Spatial distribution of the selected segments is as shown in maps, Figures 2.1 and 2.2.

Table 2.2 Example portion of sampling results which illustrate the method of random selection of sampling sites from Mn/DOT_D4 highway mile marker points (reference posts)

SubDistrict	Category	Median	RoadNum	RefPost 0.1.mi	Easting	Northing	Rand()
Morris	MNRP-0	0	MN29	33.2	296065.51	5021551.29	0.005205
Morris	MNRP-0	0	US12	10.2	244925.42	5021190.63	0.005363
Alex	HH-0	0	MN29	92.9	321061.89	5100478.26	0.005820
Morris	MNRP-0	0	MN104	22.9	323706.55	5036994.88	0.005827
Alex	HH-0	0	MN78	7.2	286083.28	5108960.00	0.005973
Alex	HH-0	0	MN235	2.2	309157.16	5110655.86	0.006070
Alex	HH-0	0	MN29	73.1	314398.54	5073148.88	0.006178
Fergus	HH-0	0	MN210	41.4	283690.55	5127555.11	0.006532
Alex	HH-0	0	MN29	86.6	320753.61	5090819.90	0.006823
Fergus	HH-0	0	MN78	34.2	299510.86	5141805.01	0.006925
Alex	HH-0	0	MN108	52.4	309031.46	5144497.25	0.007166
..	..	..	..	..	..	..	..
Moorhead	HH-0	0	US59	251.8	273491.49	5173526.51	0.010044
Fergus	HH-0	0	MN78	38.1	302340.69	5147111.98	0.010485
Alex	HH-0	0	MN29	103.1	320628.94	5117801.25	0.010613
Alex	HH-0	0	MN210	54.4	303882.15	5126093.18	0.011478
Moorhead	HH-0	0	MN87	2.4	293714.35	5178551.76	0.013388
Moorhead	HH-1	1	US10	46.2	284271.53	5188064.06	0.016102
..	..	..	..	..	..	..	..
Fergus	HH-1	1	US10	72.9	310668.29	5158641.07	0.020746
Alex	HH-1	1	I94	102.7	312959.49	5080244.10	0.022292
Fergus	HH-1	1	US10	69.4	306516.30	5160537.09	0.022480
Moorhead	HH-1	1	US10	61.7	297868.37	5168964.02	0.023533
..	..	..	..	..	..	..	..
Moorhead	CP-0	0	MN200	66.3	306891.99	5244502.40	0.127167
Moorhead	CP-0	0	MN200	66.2	306891.99	5244502.40	0.205485
..	..	..	..	..	..	..	..

Table 2.3 Sampling sites selected for surveys with the 225-ft sampling plan

S/No.	Category	RefP.10th	Hwy-RefSpot	Easting	Northing
1	CP-0	66	MN200-66	306891.99	5244502.4
2	CP-0	66.5	MN200-66.5	306891.99	5244502.4
3	HH-0	252.8	US59-252.8	274860.75	5174362.48
4	HH-0	21.5	MN108-21.5	275602.69	5158792.89
5	HH-0	72.1	MN210-72.1	329864.11	5132616.39
6	HH-0	106.2	MN29-106.2	320917.41	5122662.79
7	HH-0	12.4	MN78-12.4	290814.84	5112879.46
8	HH-0	18.6	MN34-18.6	267028.49	5171797.5
9	HH-0	10.3	MN78-10.3	290640.51	5109707.45
10	HH-0	268.9	US59-268.9	279419.71	5194972.65
11	HH-0	31.5	MN78-31.5	295951.78	5138874.92
12	HH-0	3.1	MN78-3.1	281338.25	5106176.78
13	HH-0	56.6	MN200-56.6	290847.66	5244970.34
14	HH-0	2	MN87-2	293714.35	5178551.76
15	HH-0	53.1	MN108-53.1	310193.53	5143907.38
16	HH-0	62.3	MN210-62.3	314184.66	5133089.13
17	HH-0	19.6	MN114-19.6	306633.42	5082488.23
18	HH-0	34.2	MN210-34.2	272925.86	5129642.54
19	HH-1	60.6	US10-60.6	297018.68	5170326.97
20	HH-1	93.4	I94-93.4	301583.8	5088350.81
21	HH-1	29.1	US10-29.1	259009.59	5196385.15
22	HH-1	106.5	I94-106.5	318996.41	5078433.81
23	HH-1	60.1	US10-60.1	297018.68	5170326.97
24	HH-1	69.1	US10-69.1	306516.3	5160537.09
25	MNRP-0	57.5	MN9-57.5	275976.14	5047773.61
26	MNRP-0	5.8	MN114-5.8	303727.46	5062028.63
27	MNRP-0	5.3	US12-5.3	236875.77	5021528.5
28	MNRP-0	0.3	MN54-0.3	268091.34	5079717.5
29	MNRP-0	154.1	US59-154.1	272176.75	5033849.43
30	MNRP-0	6.8	MN114-6.8	303776.61	5063623.2
31	MNRP-0	56.4	US12-56.4	313470.38	5009618.66
32	MNRP-0	30.4	MN29-30.4	295809.31	5016847.69
33	MNRP-0	58.8	MN27-58.8	282306.37	5079244.05
34	MNRP-0	43.1	MN29-43.1	299674.07	5036120.81
35	MNRP-0	15.5	MN27-15.5	217279.77	5071332.21
36	MNRP-0	63.2	MN9-63.2	270421.12	5055630.77
37	MNRP-0	21.1	MN104-21.1	323750.52	5035396.88
38	MNRP-0	50.5	MN29-50.5	300522.9	5047130.42
39	MNRP-0	44.4	MN55-44.4	281278.81	5081558.31
40	MNRP-0	42.9	US12-42.9	294921.46	5020819.56
41	MNRP-0	42.5	MN27-42.5	257274.66	5078225.83
42	MNRP-0	176.8	US59-176.8	275728.43	5067204.56
43	MNRP-0	67.6	MN29-67.6	314204.36	5063729.92
44	MNRP-0	199.4	US59-199.4	267996.11	5100984.98
45	MNRP-0	77.5	MN9-77.5	258154.4	5074279.96
46	MNRP-0	40.7	MN29-40.7	299500.28	5031306.39
47	MNRP-0	75.6	MN29-75.6	314500.06	5076367.64
48	MNRP-0	141.4	US75-141.4	231333.69	5029999.06
49	MNRP-0	17.3	MN104-17.3	323480.95	5028974.26
50	MNRP-0	42.5	MN28-42.5	263430.52	5050890.42

Table 2.3: Sampling sites selected for surveys with the 225-ft sampling plan (cont.)

S/No.	Category	RefP.10th	Hwy-RefSpot	Easting	Northing
51	MNRP-0	0.8	MN7-0.8	211227.19	5051681.5
52	MNRP-0	26.9	US12-26.9	269869.75	5018563.08
53	MNRP-0	47.5	MN27-47.5	265295.48	5078198.09
54	MNRP-0	13.2	MN27-13.2	214911.14	5069220.9
55	MNRP-0	9.5	MN7-9.5	211078.9	5037339.47
56	MNRP-1	69.4	I94-69.4	274249.11	5112686.19
57	MNRP-1	81.7	I94-81.7	286257.8	5098927.63
58	MNRP-1	69.7	I94-69.7	274249.11	5112686.19
59	PMOP-0	52.9	MN34-52.9	307240.63	5195337.6
60	PMOP-0	118.3	MN29-118.3	323305.49	5141004.95
61	PMOP-1	90.5	US10-90.5	335932.11	5145402.26
62	PMOP-1	73.6	US10-73.6	311912.45	5157733.36
63	RRP-0	285.1	US59-285.1	277950.77	5221972.4
64	RRP-0	50.4	MN200-50.4	281289.77	5245358.16
65	RRP-0	281.2	US59-281.2	278351.36	5215591.54
66	RRP-0	210.6	US75-210.6	223476.01	5136599.1
67	RRP-0	94.8	MN9-94.8	244278.93	5097847.18
68	RRP-0	188.2	US75-188.2	229663.41	5104331.05
69	RRP-0	98.3	MN9-98.3	241114.39	5103437.24
70	RRP-0	278.6	US59-278.6	278646.49	5210816.04
71	RRP-0	255.8	US75-255.8	214819.18	5203864.35
72	RRP-0	250.7	US75-250.7	212866.42	5197709.09
73	RRP-0	98.2	MN9-98.2	241114.39	5103437.24
74	RRP-0	282.8	US59-282.8	278040.34	5217151.97
75	RRP-0	217.1	US75-217.1	218060.39	5146344.23
76	RRP-0	33.2	MN210-33.2	271477.56	5130328.54
77	RRP-0	87.7	MN9-87.7	249835.86	5088004.42
78	RRP-0	179.2	MN9-179.2	234384.37	5221891
79	RRP-0	285.6	US59-285.6	277950.77	5221972.4
80	RRP-0	4.9	MN210-4.9	227139.41	5131525.22
81	RRP-0	16.4	MN32-16.4	251701.97	5197498.27
82	RRP-0	8.3	MN108-8.3	257289.21	5162601.71
83	RRP-0	84.1	MN9-84.1	252207.76	5083831.27
84	RRP-0	138.4	MN9-138.4	233489.23	5159365.78
85	RRP-0	272.8	US59-272.8	278457.37	5201202.61
86	RRP-0	144.1	MN9-144.1	235973.37	5168737.76
87	RRP-0	228.9	US59-228.9	259435.42	5142916.95
88	RRP-1	15.8	I94-15.8	231067.51	5184401.41
89	RRP-1	11.9	I94-11.9	226934.77	5189144.41
90	RRP-1	6.4	I94-6.4	221383.65	5194580.59
91	RRP-1	13.8	US10-13.8	233281.71	5197460.17
92	RRP-1	4	US10-4	218801.71	5198047.04
93	RRP-1	15.2	I94-15.2	231067.51	5184401.41
94	RRP-1	26.3	I94-26.3	241467.16	5170967.12
95	RRP-1	35.4	US10-35.4	268583.55	5195726.7
96	RRP-1	30	I94-30	244379.75	5165260.61
97	RRP-1	4	I94-4	218183.35	5194822.71
98	RRP-1	32.2	I94-32.2	245468.79	5162231.87
99	RRP-1	7.7	US10-7.7	223596.98	5197861.06
100	RRP-1	12.1	US10-12.1	231641.58	5197546.91

Maps presented in Figures 2.4 and 2.5 show the spatial distribution of selected sampling sites within Mn/DOT_D4.

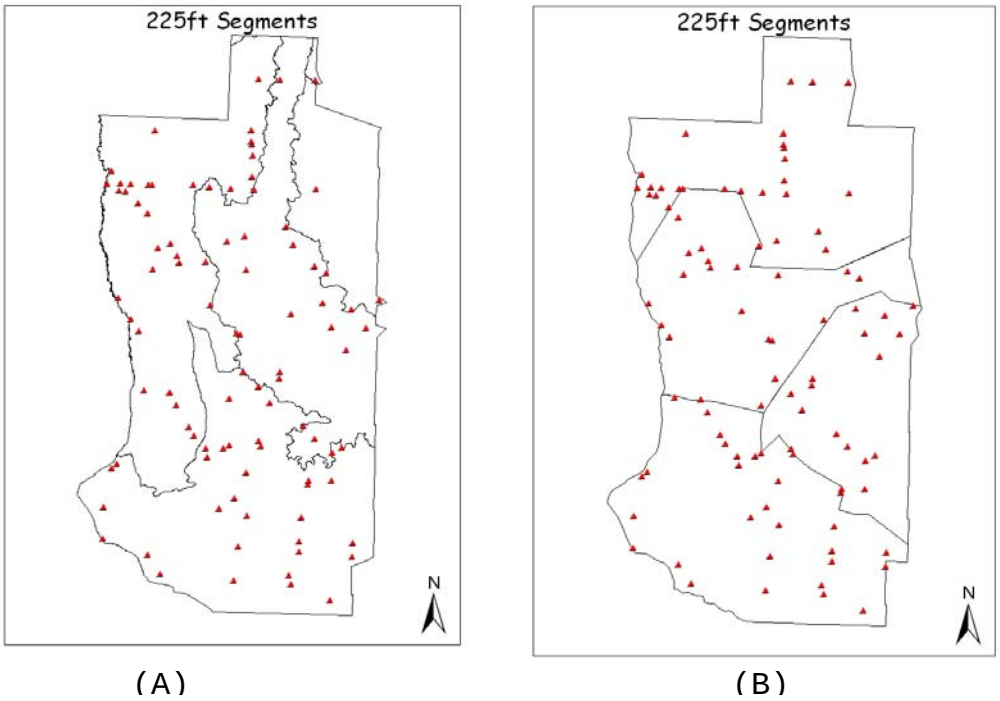


Figure 2.4 Distribution of the selected 100 sampling sites for surveys with the 225-ft sampling plan in (A) ecological zones and (B) management sub-districts of Mn/DOT_D4.

Table 2.4 Selected sites for the 14-ft sampling plan

S/No.	Category	RefP.10th	Hwy-RefSpot	Easting	Northing
1	CP-0	66.3	MN200-66.3	306891.99	5244502.4
2	CP-0	66.2	MN200-66.2	306891.99	5244502.4
3	HH-0	92.9	MN29-92.9	321061.89	5100478.26
4	HH-0	7.2	MN78-7.2	286083.28	5108960
5	HH-0	2.2	MN235-2.2	309157.16	5110655.86
6	HH-0	73.1	MN29-73.1	314398.54	5073148.88
7	HH-0	41.4	MN210-41.4	283690.55	5127555.11
8	HH-0	86.6	MN29-86.6	320753.61	5090819.9
9	HH-0	34.2	MN78-34.2	299510.86	5141805.01
10	HH-0	52.4	MN108-52.4	309031.46	5144497.25
11	HH-0	90.1	MN29-90.1	320958.38	5097259.96
12	HH-0	4.1	MN78-4.1	282171.52	5107392.92
13	HH-0	66.5	MN210-66.5	320620.07	5132889.95
14	HH-0	81.5	MN27-81.5	316404.24	5084473.34
15	HH-0	268.2	US59-268.2	279419.71	5194972.65
16	HH-0	34.6	MN210-34.6	272925.86	5129642.54
17	HH-0	53.8	MN108-53.8	310193.53	5143907.38
18	HH-0	83.6	MN29-83.6	318691.62	5086661.07
19	HH-0	36.8	MN78-36.8	301578.67	5144172.69
20	HH-0	36.7	MN78-36.7	301578.67	5144172.69
21	HH-0	33	MN108-33	293976.42	5159406.06
22	HH-0	251.8	US59-251.8	273491.49	5173526.51
23	HH-0	38.1	MN78-38.1	302340.69	5147111.98
24	HH-0	103.1	MN29-103.1	320628.94	5117801.25
25	HH-0	54.4	MN210-54.4	303882.15	5126093.18
26	HH-0	2.4	MN87-2.4	293714.35	5178551.76
27	HH-1	46.2	US10-46.2	284271.53	5188064.06
28	HH-1	41.1	US10-41.1	277175.07	5191447.43
29	HH-1	70.7	US10-70.7	307920.43	5159750.24
30	HH-1	72.9	US10-72.9	310668.29	5158641.07
31	HH-1	102.7	I94-102.7	312959.49	5080244.1
32	HH-1	69.4	US10-69.4	306516.3	5160537.09
33	HH-1	61.7	US10-61.7	297868.37	5168964.02
34	HH-1	42.3	US10-42.3	278587.04	5190683.28
35	HH-1	31.6	US10-31.6	262216.48	5196233.42
36	HH-1	43.1	US10-43.1	280123.02	5190259.04
37	MNRP-0	33.2	MN29-33.2	296065.51	5021551.29
38	MNRP-0	10.2	US12-10.2	244925.42	5021190.63
39	MNRP-0	22.9	MN104-22.9	323706.55	5036994.88
40	MNRP-0	28.3	MN28-28.3	240929.74	5051749.51
41	MNRP-0	9.6	MN27-9.6	209251.77	5066297.99
42	MNRP-0	29.4	MN29-29.4	295748.48	5015252.53
43	MNRP-0	26.3	MN9-26.3	311220.39	5021941.27
44	MNRP-0	35.7	MN55-35.7	272504.9	5092644.94
45	MNRP-0	52.3	MN55-52.3	290539.73	5072823.65
46	MNRP-0	165.2	US59-165.2	274053.25	5050592.54

Table 2.4 Selected sites for the 14-ft sampling plan (cont.)

S/No.	Category	RefP.10th	Hwy-RefSpot	Easting	Northing
47	MNRP-0	48.2	MN9-48.2	285155.53	5036971.44
48	MNRP-0	204.4	US59-204.4	268227.72	5109067.28
49	MNRP-0	46.4	MN7-46.4	259011.53	5011254.57
50	MNRP-0	44.8	MN7-44.8	255912.02	5012213.9
51	MNRP-0	90.5	MN27-90.5	330382.29	5081636.22
52	MNRP-0	13.2	MN7-13.2	216836.4	5035538.34
53	MNRP-0	20.8	US12-20.8	260460.59	5019428
54	MNRP-0	79.5	MN55-79.5	324683.45	5048986.36
55	MNRP-0	159.4	US59-159.4	272465.18	5041917.52
56	MNRP-0	56.9	MN9-56.9	276992.59	5046540.33
57	MNRP-0	137.3	US59-137.3	264278.01	5011036.79
58	MNRP-0	41.6	MN27-41.6	255813.84	5077617.71
59	MNRP-0	47	MN28-47	271284.7	5051274.07
60	MNRP-0	65.8	MN9-65.8	268711.04	5058334.17
61	MNRP-0	5.8	MN79-5.8	277471.81	5097176.65
62	MNRP-0	26.5	MN9-26.5	311220.39	5021941.27
63	MNRP-0	21.2	MN9-21.2	317942.76	5024949.14
64	MNRP-0	3.9	MN54-3.9	268200.85	5084546.85
65	MNRP-0	3.2	MN27-3.2	201313.47	5061114.45
66	MNRP-0	25.2	MN55-25.2	263479.79	5102580.96
67	MNRP-0	54	MN55-54	293389.38	5071330.5
68	MNRP-0	13.6	MN28-13.6	217247.25	5051415.38
69	MNRP-0	63.8	MN28-63.8	294950.78	5054581.47
70	MNRP-0	181	US59-181	276015.88	5075250.99
71	MNRP-0	87.5	MN28-87.5	325460.37	5064071.34
72	MNRP-0	21.7	MN28-21.7	229890.33	5051581.03
73	MNRP-0	141.2	US59-141.2	269662.49	5014265.04
74	MNRP-0	21.3	MN210-21.3	254473.63	5131139.62
75	MNRP-0	28.9	MN104-28.9	318703.4	5041919.61
76	MNRP-0	27.6	MN7-27.6	230985.92	5021029.98
77	MNRP-0	50.7	US12-50.7	305811.79	5015395.6
78	MNRP-0	46.4	MN29-46.4	299820.52	5040934.87
79	MNRP-0	42.7	MN27-42.7	257274.66	5078225.83
80	MNRP-0	4.7	MN7-4.7	210965.16	5045264.72
81	MNRP-0	15.5	MN28-15.5	220454.83	5051227.7
82	MNRP-0	50	MN28-50	274323.25	5053935.2
83	MNRP-0	131.8	US75-131.8	236746.83	5018323.24
84	MNRP-0	43.9	MN9-43.9	289324.35	5030065.71
85	MNRP-1	79.2	I94-79.2	283326.97	5100227.17
86	MNRP-1	104.1	I94-104.1	315864.9	5078901.53
86	MNRP-1	104.1	I94-104.1	315864.9	5078901.53
87	MNRP-1	88.9	I94-88.9	295751.22	5093664.7
88	MNRP-1	73.1	I94-73.1	277147.8	5107241.11
89	PMOP-0	18.9	MN87-18.9	317733.59	5181212.51
90	PMOP-0	47.3	MN113-47.3	325122.15	5223377.45
91	PMOP-1	80.4	US10-80.4	321470.61	5151844.29
92	PMOP-1	79.3	US10-79.3	319981.44	5152857.34

Table 2.4 Selected sites for the 14-ft sampling plan (cont.)

S/No.	Category	RefP.10th	Hwy-RefSpot	Easting	Northing
93	RRP-0	4.7	MN224-4.7	283792.77	5219505.84
94	RRP-0	32.2	MN210-32.2	270305.09	5129376.6
95	RRP-0	164.4	MN9-164.4	232920.56	5197850.85
96	RRP-0	259.1	US75-259.1	214921.38	5210358.74
97	RRP-0	24.8	MN210-24.8	259197.28	5130957.15
98	RRP-0	0	MN55-0	224104.38	5105918.42
99	RRP-0	0.1	MN297-0.1	262962.43	5131611.08
100	RRP-0	37.9	MN27-37.9	249516.9	5077253.18
101	RRP-0	0.9	MN224-0.9	277893.97	5220742.5
102	RRP-0	269.3	US75-269.3	212024.49	5226003.46
103	RRP-0	3.7	MN108-3.7	250480.4	5161274.9
104	RRP-0	250.3	US75-250.3	212866.42	5197709.09
105	RRP-0	232.5	US59-232.5	260177.34	5149308.03
106	RRP-0	182.6	US75-182.6	229223.73	5094656.28
107	RRP-0	256.3	US75-256.3	214899.2	5205529.96
108	RRP-0	28.7	MN210-28.7	264104.42	5128390.38
109	RRP-0	227.9	US75-227.9	214039.44	5161050.97
110	RRP-0	258.2	US75-258.2	215049.44	5208750.62
111	RRP-0	236.5	US75-236.5	212530	5175380.05
112	RRP-0	130	MN9-130	230211.11	5146950.92
113	RRP-0	158.3	MN9-158.3	232510.82	5188237.42
114	RRP-0	90.3	MN9-90.3	247452.99	5092214.59
115	RRP-0	266.9	US75-266.9	212107.72	5221210.2
116	RRP-0	288.9	US59-288.9	278110.11	5226789.59
117	RRP-0	232	US75-232	212932.62	5169030.44
118	RRP-0	147.3	MN9-147.3	238163.31	5172341.34
119	RRP-0	169.9	US75-169.9	230430.95	5074080.96
120	RRP-0	230.1	US59-230.1	259857.65	5146118.79
121	RRP-0	187	US75-187	229611.09	5102712.63
122	RRP-0	214.9	US75-214.9	219918.85	5141939.78
123	RRP-0	155.8	MN9-155.8	233885.45	5183691.83
124	RRP-0	98.5	MN9-98.5	241114.39	5103437.24
125	RRP-0	34.3	MN27-34.3	244677.48	5077437.4
126	RRP-0	181.4	MN9-181.4	234479.71	5225092.38
127	RRP-0	142.6	MN9-142.6	235039.98	5165646.12
128	RRP-0	192.8	US75-192.8	229983.65	5110761.43
129	RRP-0	9.6	MN55-9.6	238355.91	5103595.75
130	RRP-0	136.3	MN9-136.3	232744.17	5156238.14
131	RRP-0	172.9	US75-172.9	228801.11	5078618.32
132	RRP-1	45.9	I94-45.9	253882.98	5143781.86
133	RRP-1	8.5	I94-8.5	223967.69	5192961.9
134	RRP-1	48.6	I94-48.6	256323.47	5139667.49
135	RRP-1	9.8	US10-9.8	226830.34	5197750.92
136	RRP-1	10.1	I94-10.1	225946.4	5190416.06
137	RRP-1	18	US10-18	241287.74	5196990.28

Table 2.4 Selected sites for the 14-ft sampling plan (cont.)

S/No.	Category	RefP.10th	Hwy-RefSpot	Easting	Northing
138	RRP-1	6.9	US10-6.9	221984.45	5197919.85
139	RRP-1	36.9	I94-36.9	247555.77	5156236.59
140	RRP-1	9.8	I94-9.8	224959.02	5191686.44
141	RRP-1	12.7	I94-12.7	227954.15	5187902.18
142	RRP-1	32.3	I94-32.3	245468.79	5162231.87
143	RRP-1	33.9	US10-33.9	265451.69	5196129.82
144	RRP-1	35	I94-35	247430.74	5157817.11
145	RRP-1	18.2	US10-18.2	241287.74	5196990.28
146	RRP-1	30.1	I94-30.1	244379.75	5165260.61
147	RRP-1	39.2	I94-39.2	249131.88	5152167.47
148	RRP-1	7.9	US10-7.9	223596.98	5197861.06
149	RRP-1	15.5	I94-15.5	231067.51	5184401.41
150	RRP-1	51.6	I94-51.6	259332.76	5136074.79

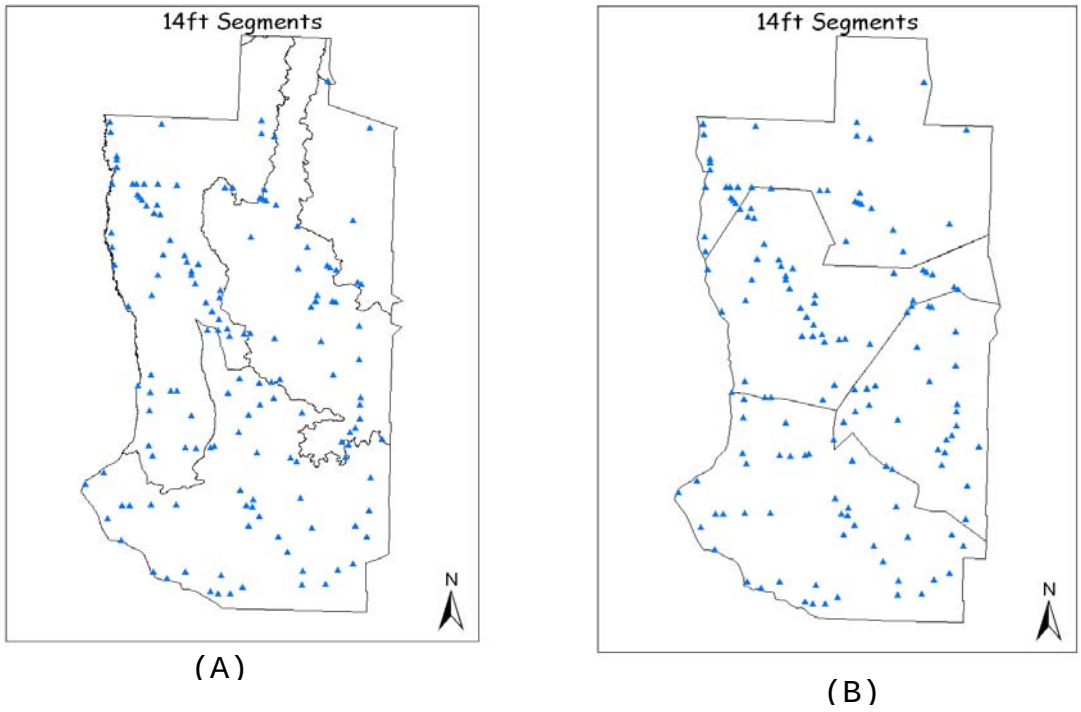


Figure 2.5 Distribution of the selected 150 sampling sites for surveys with the 14-ft sampling plan in (A) ecological zones and (B) management sub-districts of Mn/DOT_D4.

2.2 Field Work and Data Collection

This phase of the project was conducted following the procedures described in the report by Arika et al. (2007b). The surveys targeted the noxious species enumerated in section 2.0.

Surveying and data recording at the 100 and 150 sampling sites were conducted aided by GPS units. Data dictionaries loaded in the units provided templates for recording the data. Two distinct data dictionaries designed to facilitate data recording following the two sampling plans were initially constructed and loaded in the GPS units providing for:

- Mapping infestation patches of the 13 invasive species at 100, 225 feet long segments along highway ROWs.
- Recording presence-absence of the 13 invasive species at 150, 14 feet long segments along highway ROWs; these required limited data containing the species names.

Figure 2.6 is a section of US 10, illustrating the distribution of species infested patches as observed during surveys with the 225-ft sampling plan.

2.3 Descriptions of Recorded Data Sets

Surveys conducted following the two sampling plans (14-ft and 225-ft segments) yielded distinct data sets. Data recorded with the 225-ft plan surveys contain information on patch area, patch location (highway name, milepost, and coordinates), and landscape position for all the 13 weed species studied. Data recorded in the surveys conducted with the 150, 14-ft segments contain names of invasive weed species and their spatial information (X and Y coordinates) on location in the landscape. The 14-ft sampling plan was intended to provide information on population distribution, which in turn is to be applied both in estimating the magnitude of the problem posed by a given species, and for planning control measures. The advantages of using the 14-ft (presence-absence) sampling plan is that the data collection can be carried out faster and more cheaply compared to use of the 225-ft or larger segment size sampling plan.

Upon observation of the data acquired in the study, it was noted that many of initially selected sampling sites were not successfully surveyed. The data recorded from the surveys is summarized in Tables 2.5 and 2.6 providing details on the outcome for each of the selected sampling sites; those successfully surveyed, not surveyed, or those replaced by other newly selected sites (following previously provided guidelines for replacing site which cannot be surveyed). Attempts have been made to detail in these tables the reasons for the missing data in some sites.

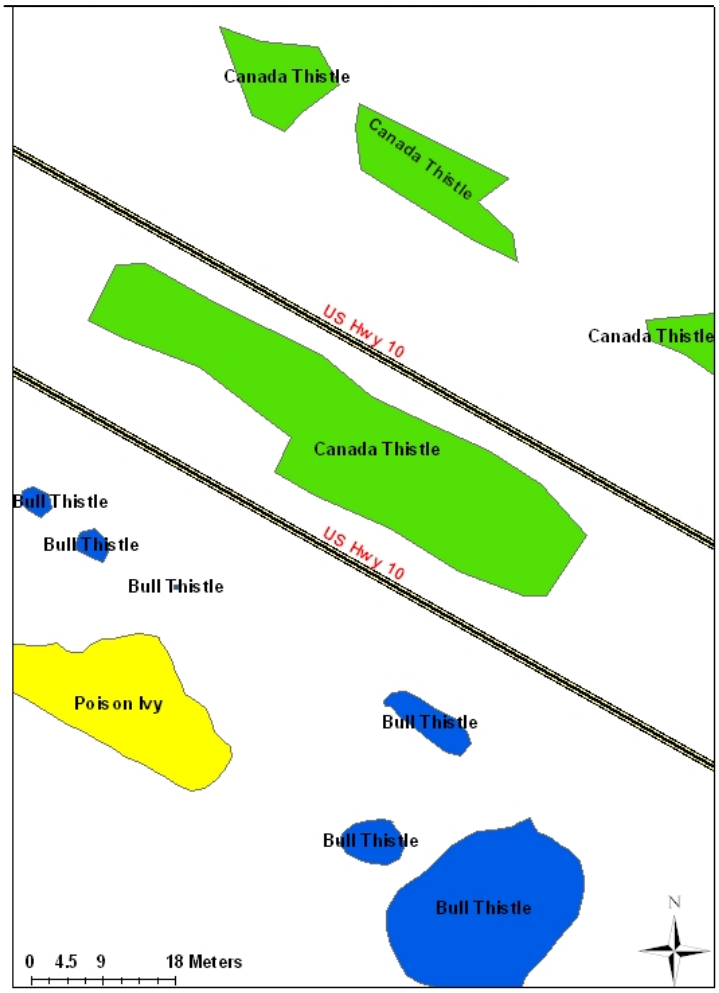


Figure 2.6 Map illustrating the distribution of species infestation patches in a segment of the ROW for US 10; the patches were mapped using the 225-ft sampling approach.

Table 2.5 Summary on time spent inspecting the 150, 14-ft sampling sites surveyed in Mn/DOT_D4

S/No.	SegmID	Median	Survey Time (hh/mm/ss)	Remarks
1	I94_10.1	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
2	I94_102.7	Y	0:00:57	
3	I94_104.1	Y	0:00:20	
4	I94_12.7	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
5	I94_15.5	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
6	I94_30.1	Y	0:02:30	
7	I94_32.3	Y	0:01:09	
8	I94_35	Y	0:01:11	
9	I94_36.9	Y	0:01:29	
10	I94_38.1	Y	0:01:06	
11	I94_39.2	Y	0:00:25	
12	I94_45.9	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
13	I94_48.9	Y	0:01:01	
14	I94_51.6	Y	0:00:35	
15	I94_73.1	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
16	I94_79.2	Y	0:00:57	
17	I94_8.5	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
18	I94_88.9	Y	0:00:16	
19	I94_9.8	Y	-	Missing Data (Not surveyed, replaced, or no weeds found?)
20	MN104_22.9	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
21	MN104_28.9	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
22	MN108_3.7	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
23	MN108_33	N	0:00:44	
24	MN108_52.4	N	0:02:23	
25	MN108_53.8	N	0:01:48	
26	MN113_47.3	N	0:03:12	
27	MN200_66.2	N	0:01:21	
28	MN200_66.3	N	0:03:30	
29	MN210_21.3	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
30	MN210_24.8	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
31	MN210_28.7	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
32	MN210_32.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
33	MN210_34.6	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
34	MN210_41.4	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
35	MN210_54.4	N	-	Replacement - MN210_55
36	MN210_55	N	0:02:04	
37	MN210_66.5	N	-	Replacement - MN210_68
38	MN210_68	N	0:04:45	Replacement for MN210_66.5
39	MN224_0.9	N	0:04:05	
40	MN224_4	N	0:03:07	Replacement for MN224_4.7
41	MN235_2.2	N	0:02:13	
42	MN26_41.6	N	0:01:39	

Table 2.5 Summary on time spent inspecting the 150, 14-ft sampling sites surveyed in Mn/DOT_D4 (cont.)

S/No.	SegmID	Median	Survey Time (hh/mm/ss)	Remarks
43	MN26_42.7	N	0:03:24	
44	MN27_3.2	N	0:08:10	
45	MN27_34.3	N	0:08:13	
46	MN27_37.9	N	0:06:02	
47	MN27_41.6	N	0:01:49	
48	MN27_42.7	N	0:02:31	
49	MN27_82.7	N	0:06:34	Replacement for MN27_81.5 – mowed
50	MN27_9.6	N	0:12:37	
51	MN27_90.7	N	0:05:57	Replacement for MN27_90.5 – mowed
52	MN28_13.6	N	0:18:28	
53	MN28_15.5	N	0:07:56	
54	MN28_22.4	N	0:11:25	Replacement for MN28_21.7 - mowed/Town
55	MN28_28.3	N	0:15:47	
56	MN28_47	N	0:08:44	
57	MN28_50	N	0:05:58	
58	MN28_63.8	N	0:56:27	
59	MN28_87.5	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
60	MN29_103.1	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
61	MN29_29.4	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
62	MN29_33.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
63	MN29_46.4	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
64	MN29_73.1	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
65	MN29_83.9	N	0:03:36	Replacement for MN29_83.6 – mowed
66	MN29_87.2	N	0:04:43	Replacement for MN29_86.6 – mowed
67	MN29_90.2	N	0:04:42	Replacement for MN29_90.1 – Swamp
68	MN29_93.1	N	0:04:28	Replacement for MN29_92.9 – mowed
69	MN297_0.1	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
70	MN54_3.4	N	0:05:10	Replacement for MN54_3.9
71	MN55_0	N	0:06:05	
72	MN55_25.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
73	MN55_35.7	N	0:04:14	
74	MN55_52.3	N	0:01:38	
75	MN55_54	N	0:04:49	
76	MN55_79.6	N	1:59:18	Replacement for MN55_79.5
77	MN55_9.6	N	0:06:03	
78	MN7_13.2	N	0:07:19	
79	MN7_27.6	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
80	MN7_4.7	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
81	MN7_44.8	N	0:02:59	
82	MN7_46.4	N	0:02:56	
83	MN78_34.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
84	MN78_37.9	N	0:01:46	Replacement for MN78_36.7

Table 2.5 Summary on time spent inspecting the 150, 14-ft sampling sites surveyed in Mn/DOT_D4 (cont.)

S/No.	SegmID	Median	Survey Time (hh/mm/ss)	Remarks
85	MN78_38.1	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
86	MN78_38.2	N	0:02:00	Replacement for MN78_36.8
87	MN78_4.7	N	0:03:13	Replacement for MN78_4.1
88	MN78_7.2	N	0:02:37	
89	MN79_6	N	0:04:57	Replacement for MN79_5.8
90	MN87_18.9	N	0:04:03	
91	MN87_3.6	N	0:04:10	Replacement for MN87_2.4
92	MN9_130	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
93	MN9_136.3	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
94	MN9_142.6	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
95	MN9_147.3	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
96	MN9_155.8	N	0:03:02	
97	MN9_158.3	N	0:06:29	
98	MN9_164.4	N	0:06:09	
99	MN9_181.4	N	1:51:17	
100	MN9_21.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
101	MN9_26.3	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
102	MN9_26.5	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
103	MN9_43.9	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
104	MN9_48.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
105	MN9_56.9	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
106	MN9_65.8	N	0:16:43	
107	MN9_90.3	N	0:04:56	
108	MN9_98.5	N	0:08:45	
109	MN94_102.7	Y	0:01:26	
110	MN94_104.1	Y	0:01:56	
111	MN94_51.6	Y	0:04:55	
112	MN94_73.1	Y	0:03:30	
113	MN94_79.2	Y	0:01:15	
114	MN94_88.9	Y	0:01:00	
115	MNI94_102.7	Y	0:00:35	

Table 2.5 Summary on time spent inspecting the 150, 14-ft sampling sites surveyed in Mn/DOT_D4 (cont.)

S/No.	SegmID	Median	Survey Time (hh/mm/ss)	Remarks
116	MNI94_79.2	Y	0:00:30	
117	MNI94_88.9	Y	0:00:29	
118	US10_18	Y	0:00:03	
119	US10_18.2	Y	0:00:32	
120	US10_31.6	Y	0:00:30	
121	US10_33.9	Y	0:10:56	
122	US10_41.1	Y	0:06:41	
123	US10_42.3	Y	0:03:46	
124	US10_43.1	Y	0:03:11	
125	US10_47.7	Y	0:02:47	Replacement for US10_46.2
126	US10_6.9	Y	0:01:21	
127	US10_60.7	Y	0:00:16	
128	US10_61.7	Y	0:00:13	
129	US10_69.4	Y	0:01:01	
130	US10_7.9	Y	0:01:16	
131	US10_70.7	Y	0:00:55	
132	US10_72.9	Y	0:04:03	
133	US10_80.4	Y	0:11:40	Replacement for US10_79.3
134	US10_9.8	Y	0:04:38	
135	US12_10.2	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
136	US12_20.8	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
137	US12_50.7	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
138	US59_137.3	N	0:05:04	Hayed
139	US59_141.2	N	0:05:39	Hayed
140	US59_159.4	N	0:06:30	
141	US59_165.2	N	0:10:07	
142	US59_181	N	0:06:57	hayed - some regrowth
143	US59_204.4	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
144	US59_230.1	N	0:01:38	
145	US59_232.5	N	0:00:56	
146	US59_251.8	N	0:01:04	
147	US59_268.3	N	0:10:59	Replacement for US59_268.2 (cattails?)
148	US59_289	N	0:04:45	

Table 2.5 Summary on time spent inspecting the 150, 14-ft sampling sites surveyed in Mn/DOT_D4 (cont.)

S/No.	SegmID	Median	Survey Time (hh/mm/ss	Remarks
149	US75_131.8	N	0:02:04	
150	US75_158.2	N	0:02:16	
151	US75_169.9	N	0:07:18	hayed recently
152	US75_173	N	0:08:18	Replaced US75_172.9 at river in ditch bottom
153	US75_182.6	N	0:11:11	hayed, regrowth
154	US75_187	N	0:21:30	Hayed
155	US75_192.8	N	0:06:15	Hayed
156	US75_214.9	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
157	US75_227.9	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
158	US75_232	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
159	US75_236.5	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
160	US75_250.3	N	-	Missing Data (Not surveyed, replaced, or no weeds found?)
161	US75_256.3	N	0:05:24	
162	US75_258.2	N	0:04:35	
163	US75_259.1	N	0:05:22	
164	US75_266.9	N	0:06:42	
165	US75_269.3	N	0:18:06	
166	US75_31.8	N	0:03:29	

Tables 2.5 and 2.6 also provide information on time spent surveying each of the pre-selected segments for the surveys with the 14-ft and 225-ft sampling plans. There were problems noted with the recorded time data. These were:

- Incomplete time data, missing record of time spent traveling between office and survey sites, and between survey sites
- Records showed cases of unreasonably long periods (more than 2 hours), or too short (less than 2 minutes) time spent inspecting some of the sampling sites.

Accurate data on time spent collecting and processing data on species infestation within segments was a critical component for determination of surveying cost.

Table 2.6 Summary on time spent inspecting the 100, 225-ft sampling sites surveyed in Mn/DOT_D4

S/No	SegmID	Median	Acres	Survey Time	Comment
1	I94_106.5	Y	0.002	0:10:45	-
2	I94_11.9	Y	0	-	-
3	I94_15.2	Y	0	-	-
4	I94_15.8	Y	0.012	0:08:05	-
5	I94_15.9	Y	0.007	0:06:45	
6	I94_26.3	Y	0.015	0:17:50	
7	I94_30	Y	0.310	0:04:09	
8	I94_30	Y	0	-	
9	I94_32.2	Y	0.027	0:08:54	
10	I94_4	Y	0	-	
11	I94_6.4	Y	0	-	
12	I94_69.7	Y	0.095	14:40:40	
13	I94_81.7	Y	0.005	0:10:59	
14	I94_93.4	Y	0.051	0:12:11	
15	MN104_17.3	N	0	-	
16	MN104_21.1	N	0	-	
17	MN108_21.5	N	0	-	
18	MN108_53.1	N	0.002	0:01:02	-
19	MN108_53.1	N	0	-	-
20	MN108_8.3	N	0.003	0:04:23	-
21	MN114_19.4	N	0.009	0:10:54	Replacement for mowed I94_19.6
22	MN114_5.8	N	0.008	0:02:26	Mowed
23	MN114_5.8	N	0	-	Mowed
24	MN114_6.8	N	0	-	
25	MN200_50.4	N	0.002	0:05:28	-
26	MN200_56.6	N	0.004	0:05:42	
27	MN200_66	N	0	-	
28	MN200_66.5	N	0	-	
29	MN200_67	N	0.001	0:09:16	
30	MN200_67.8	N	0.005	0:12:22	
31	MN210_33.2	N	0	-	33.2 was mowed res. lawn
32	MN210_33.4	N	0.121	0:30:04	33.2 was mowed res. lawn
33	MN210_34.2	N	0	-	-
34	MN210_4.9	N	0	-	-
35	MN210_62.3	N	0	-	62.3 hayed
36	MN210_66.5	N	0.002	0:06:33	-
37	MN210_72.1	N	0	-	72.1 swamp
38	MN210_72.2	N	0.048	0:03:29	72.1 swamp
39	MN27_13.2	N	0.099	0:14:52	-
40	MN27_15.5	N	0	-	moved from 15.5 - hayed fresh
41	MN27_16.2	N	0	0:16:16	moved from 15.5 - hayed fresh
42	MN27_42.5	N	0.038	0:11:59	
43	MN27_47.5	N	0.007	0:23:53	moved .1, mowed yard

Table 2.6 Summary on time spent inspecting the 100, 225-ft sampling sites surveyed in Mn/DOT_D4 (cont.)

S/No	SegmID	Median	Acres	Survey Time	Comment
44	MN27_58.8	N	0	-	58.5 was in town
45	MN27_59.5	N	0.006	0:11:56	58.5 was in town
46	MN28_42.5	N	0.018	0:59:20	
47	MN29_106.2	N	0	-	
48	MN29_107.4	N	0.003	0:01:17	106.2 mowed
49	MN29_107.4	N	0.003	-	106.2 mowed
50	MN29_118.3	N	0	-	118.3 swamp
51	MN29_119.3	N	0.036	0:03:42	118.3 swamp
52	MN29_30.4	N	0.002	0:00:00	Mowed
53	MN29_40.7	N	0	-	-
54	MN29_43.1	N	0.002	0:07:00	Mowed
55	MN29_50.5	N	0.079	0:02:23	mowed/had some weeds
56	MN29_67.6	N	0	-	67.6 mowed for hay
57	MN29_69.3	N	0	0:13:23	67.6 mowed for hay
58	MN29_75.6	N	0	-	75.6 construction in ditch
59	MN29_75.7	N	0.002	0:07:34	75.6 construction in ditch
60	MN32_16.4	N	0.015	0:05:48	
61	MN34_18.6	N	0	0:04:11	
62	MN34_52.9	N	0.004	0:08:22	
63	MN54_0.3	N	0.002	0:19:08	Mowed
64	MN55_44.4	N	0.079	0:07:36	
65	MN55_52.3	N	0.011	-	
66	MN55_79.6	N	0.003	-	cattails @ 75.5
67	MN7_0.8	N	0.002	0:06:02	Hayed
68	MN7_9.5	N	0.043	0:42:37	Hayed
69	MN78_10.3	N	0	-	-
70	MN78_11.1	N	0.002	0:07:16	10.3 swamp
71	MN78_12.4	N	0	-	12.4 swamp
72	MN78_12.9	N	0.008	0:07:57	12.4 swamp
73	MN78_3.1	N	0.006	0:11:13	-
74	MN78_31.5	N	0	-	-
75	MN87_2	N	0	-	-
76	MN87_3.1	N	0.002	0:09:08	
77	MN9_138.4	N	0	-	-
78	MN9_144.1	N	0	-	-
79	MN9_179.2	N	0	-	179.2 was mowed
80	MN9_179.35	N	0.039	5:27:04	179.2 was mowed
81	MN9_50.5	N	0.002	0:06:06	Mowed
82	MN9_57.5	N	0	0:06:45	Mowed
83	MN9_63.2	N	0.039	0:47:31	-
84	MN9_77.5	N	0.015	0:16:08	-
85	MN9_84.1	N	0.007	0:13:54	
86	MN9_87.7	N	0.111	0:09:57	-

Table 2.6 Summary on time spent inspecting the 100, 225-ft sampling sites surveyed in Mn/DOT_D4 (cont.)

S/No	SegmID	Median	Acres	Survey Time	Comment
87	MN9_94.8	N	0.002	0:09:57	deep ditch-mowed
88	MN9_98.2	N	0.006	0:09:12	water in deep ditch
89	MN9_98.3	N	0.063	0:09:54	water in deep ditch
90	US10_12.1	Y	0	-	
91	US10_13.8	Y	0.002	0:11:24	
92	US10_29.1	Y	0.013	0:23:02	
93	US10_35.4	Y	0.014	0:19:00	
94	US10_4	Y	0	-	
95	US10_4.1	Y	0.049	0:08:57	Replacement for mowed US10_4.0
96	US10_60.1	Y	0.027	0:00:47	-
97	US10_60.6	Y	0	0:02:55	
98	US10_69.1	Y	0.001793881	0:01:37	-
99	US10_7.7	Y	0.003	0:06:45	
100	US10_73.6	Y	0.196	12:30:45	
101	US10_79.3	Y	0.002	0:13:53	
102	US10_91.8	Y	0.003	0:10:32	Replacement for mowed US10_90.5
103	US12_26.9	N	0.027	0:03:46	Mowed
104	US12_42.9	N	0	-	-
105	US12_5.3	N	0	0:05:35	
106	US12_56.4	N	0.036	0:03:32	Mowed
107	US59_154.1	N	0.029	0:19:08	hayed area
108	US59_176.8	N	0.051	0:09:35	farmer mowed area
109	US59_199.4	N	0	-	-
110	US59_228.9	N	0.015	0:09:50	
111	US59_252.8	N	0	-	-
112	US59_268.9	N	0.025	1:29:40	
113	US59_272.8	N	0.082	0:30:28	
114	US59_278.6	N	0.002	0:23:23	
115	US59_281.2	N	0	-	-
116	US59_281.5	N	0.005	0:07:43	
117	US59_282.8	N	0	-	-
118	US59_282.9	N	0.013	0:46:50	
119	US59_283.6	N	0.002	0:00:00	
120	US59_285.1	N	0	-	-
121	US59_285.3	N	0.002	0:08:39	
122	US59_285.6	N	0	-	-
123	US59_285.8	N	0.002	0:06:58	
124	US59_63	N	0	0:04:18	
125	US75_141.4	N	0.027	0:18:17	Hayed
126	US75_188.2	N	0.019	0:03:18	Mowed
127	US75_210.6	N	0	-	-
128	US75_217.1	N	0	-	-
129	US75_250.7	N	0	-	-
130	US75_255.8	N	0	-	-

2.4 Evaluating Precision of the 14-ft and 225-ft Sampling Plans

In this project we have assumed the definition of sampling precision to be the measure of how close the estimator is expected to be in compared to the true value (complete survey inventory) parameter. In this part of the project we attempted to compare the sampling precisions of the two plans (14-ft or 225-ft) adopted in the study. A useful measure of sampling precision is the measurement variance.

2.4.1 Estimating infested area from presence-absence data

The presence-absence (14-ft sampling plan) has potential to improve the techniques for estimating area (acres/mile) of highway ROW infested by given weed species, cheaply and at a pre-specified precision level. The presence-absence data is first processed to determine the proportion of sampling sites infested (p^+) by each of the subject species in the nine (ecological zone-highway type) categories of the study area. The p^+ data was applied to the empirical equation by Kono and Sugino (1958), to estimate the acres-per-mile of roadway right-of-way infested by the weed species studied. The empirical equation is given by:

$$\mu = \exp^{\alpha}\left[-\ln(1-p^{+})\right]^{\beta} \quad \text{.....(2.1)}$$

or

$$\ln(\mu) = \alpha + \beta \ln\left[-\ln\left(1-p^{+}\right)\right] = \alpha + \beta \ln\left[-\ln p^{o}\right] \quad \text{.....(2.2)}$$

where μ is acres-per-mile of area infested, p^+, and p^0 (=1- p^+) are respectively the proportion of segments with and without presence of the subject weed species; and α and β are the intercept, and the line slope respectively, evaluated from equation 2.2. An illustrative plot of equation 2.1 is given in Figure 2.7.

To calibrate equation 2.1 for a given area of interest would requires use of measured infested areas along reasonably long stretches (225-ft) of ROW, re-sampling (slicing) the data for the 225-ft segments into 14-ft sections, and then determining the proportion of the sections with species present (p^+), or absent (p^0). This data can then be transformed by logarithm, from which the values α and β can be determined (equation 2.2). The acres-per-mile infested, and proportion infested (p^+) are determined for all the 14-ft sections.

For comparisons of sampling precision of the two plans to be conducted, it is necessary to estimate for the data recorded with the 14-ft sampling plan, the acres-per-mile for each weed specie. This estimate can be derived by processing the data recorded with the 14-ft plan to yield p^+ values, and then applying equation 2.1.

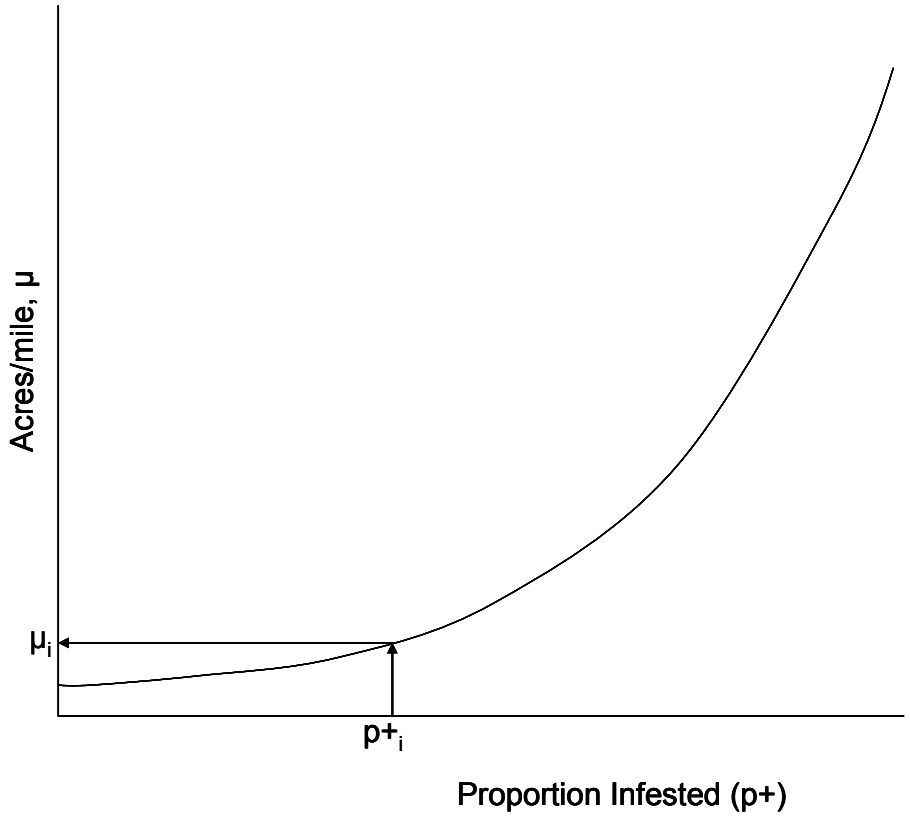


Figure 2.7 Proportion and acres-per-mile of 14-ft sections (sliced from 225-ft sampling plan data) infested with given weed species.

2.4.2 Variance – 14-ft sampling plan

Kuno (1986) recommended calculating estimated variance (c1) for the Kono and Sugino model using the approximation relation:

$$c1 = \frac{p^{+}\beta^{2}}{n(1-p^{+})\ln[1-p^{+}]^{2}} \quad \text{.....(2.3)}$$

where n is the number of sampling units selected.

Equation 2.3 is considered only an estimate (Pedigo and Buntin, 1993) of the sampling variance. Binns and Bostianian (1990) have pointed out that the total variance should be the sum of c1 and the variance of predicting the (ln *m*) from the estimations of α and β using the standard regression formulas for predicting the confidence intervals for an individual case.

$$Var(\ln m)_{p} = mse + \frac{mse}{N} + \left\{\ln\left[-\ln(1-p^{+}) - \overline{p}^{+}\right]\right\}^{2} s_{b}{}^{2} \quad \text{.....(2.4)}$$

The equation is partitioned into two components as:

$$c2 = \frac{mse}{N} + \{ln[-\ln(1-p^{+})] - \overline{p}\}^{2} s_b{}^{2} \quad \text{.....(2.5)}$$

and

$$c4 = mse \quad \text{.....(2.6)}$$

where *mse* is the mean square error from the regression of equation 2.3, N is the number of data points in the regression used to estimate α and β, $\overline{p}$ is the mean of the independent variable (i.e., $\ln[-\ln(1-p^{+})]$) in the data sets used to estimate α and β, $s_b{}^2$ is the sample estimate of the variance of β. The term *mse* is generally the dominant term (Pedigo and Buntin, 1993) in equation 2.4. Binns and Bostanian (1990) estimate the total variance as:

$$Var(\ln m)_{Total} = c1 + c2 + c4 \quad \text{.....(2.7)}$$

The estimate of the variance for the infested area/mile derived from absence-presence data may therefore be evaluated from the equation 2.7.

2.4.3 Variance – 225-ft sampling plan

Statistical analysis of the data recorded with the 225-ft sampling plan was completed and presented in Table 3.4. Other statistical values evaluated included the mean error of estimates (Standard error, SE).

2.5 Determining Sampling Efficiency

The main aim of sampling design is to obtain the maximum amount of quantitative information for a given large area at a given total cost or effort. In this project a hypothesis stating that, "using 14-ft long segments for absence-presence surveys, and survey mapping with 225-ft long segments would yield weed population distribution estimates for a large area such as Mn/DOT_D4, with comparable accuracies.

In the scope of this project, sampling efficiency is defined as ***"how closely the weed population density and distribution values evaluated from data recorded in sampling surveys using a small sample (and at a specified minimum cost) selected to represent a larger area, compares to the actual values obtainable in an inventory of the entire area***". To evaluate efficiencies of the sampling plans, time data (time spent conducting survey of a given region, which included traveling between office and sampling sites, time traveling between sites, and total time spent inspecting each site) was subjected to series of analyses.

To facilitate determination of sampling efficiency, the **relative net precision (RNP)** was evaluated from the data and applied as a 'reasonable' measure of sampling efficiency. RNP was determined using the expression (Cochran, 1977):

$$RNP = \frac{Length}{Cost} x \frac{Length}{Variance} \quad \text{.....(2.8)}$$

where ***length*** is the size of the sampling unit (in this case 14-ft or 225-ft segments), ***cost*** is the time in human minutes or hours, spent to collect and process one sampling unit , and ***variance*** (variance in this equation refer to the Standard Error of mean estimations, SE) is evaluated for the acres-per-mile infested by each weed species. Obtained values are presented in Table 3.4.

The data recorded in surveys with the 14-ft sampling plan does not include area infested by subject species.It is therefore not possible to evaluate variance for this data set (of presence-absence surveys) using similar procedures applied in evaluation of variance for the 225-ft sampling plan data. Alternative methods are employed, in which the variance for different species is evaluated using the relations in equations 2.3 to 2.7.

Chapter 3 - Data Processing, Analysis, Results and Discussion, and Conclusions

At the beginning of fall 2007, Mn/DOT_D4 supplied the University of Minnesota research team with the raw electronic data from the 2007 season survey. The provided data consisted of 91 .SSF files, organized in electronic file folders, each folder bearing the identity of the surveyor whom recorded the data.

The data was first organized into 2 groupings, with data files separated according to the sampling plan under which the data was recorded. The data files were uploaded and opened in the Trimble® GPS Pathfinder Office software for further processing. The raw data sets were first subjected to manual cleaning, following methodologies and purposes as described in section 3.1 of the User Guide (Arika et al., 2007a). The edited data was subjected to differential correction to improve spatial positional accuracy. The data (.COR) files were next exported as *Shapefiles* (ArcMap GIS compatible) for further processing and analysis in the GIS environment, as described in the User Guide.

These files were opened in ArcView 9.0, and further processed producing weed distribution maps for the study area. Further processing and analysis included:

- Sectioning 225-ft segments data into 14-ft long sections. This facilitated re-sampling for further investigations on use of 14-ft segments for presence-absence surveys
- Overlaying weed infestation maps with Mn/DOT_D4 ecological zones and management sub-areas maps
- Inventorying of data to assess the success of surveys at the initially selected sampling sites for both the 225-ft and 14-ft survey segments (find out how many of the initially selected segments were surveyed, not surveyed but were replaced by others, etc.)

The final output for the GIS analysis was exported as ***.DBF*** data files, for further processing, and analysis in MS EXCEL. The final output data was subjected to statistical analyses.

The data processing and analysis conducted was aimed at evaluating sampling precision of the two sampling plans adopted in the study, and also to determine the cost of conducting surveys using the same plans.

3.1 Weed Population Distribution

Table 3.1 is a record of data obtained in surveys with the 14-ft sampling plan. The data shows presence-absence of different weed species in ecological zones and management sub-districts of Mn/DOT_D4. Further processing yielded summaries (Tables 3.2 and 3.3) showing the proportions (and number of segments within) categories infested by each problem specie. The magnitude of the infestation problem posed by individual specie, and locales preferred by individual specie may be inferred form these data tables.

Table 3.1 Absence-presence of weed species as recorded in surveys with 14-ft segments in highway ROWs of Mn/DOT_D4

S/No.	Category	Subarea	SegmID	Canada Thistle	Plumeless thistle	Spotted Knapweed	Leafy Spurge	Bull Thisttle	Perennial sowthistle	Purple Loosestrife	Poison Ivy	Wild Parsnip	Musk Thistle	Hemp	Garlic Mustard	Field Bindweed
1	CP-0	Moorhead	MN200_66.2	0	0	1	0	0	0	0	0	0	0	0	0	0
2			MN200_66.3	1	0	0	0	0	1	0	0	0	0	0	0	0
						1	0	0	1	0	0	0	0	0	0	0
4	HH-0	Alexandria	MN108_52.4	0	0	0	0	0	0	0	0	0	0	0	0	0
5			MN108_53.8	0	0	0	0	0	0	0	0	0	0	0	0	0
6			MN210_55	1	0	0	0	0	0	0	0	0	0	0	0	0
7			MN210_68	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	1	0	0	0	0	0	0	0	0	0	0	0
8			MN235_2.2	0	0	0	0	0	0	0	0	0	0	0	0	0
											1	0	0	0	0	0
9			MN27_82.7	0	0	0	0	0	1	0	1	0	0	0	0	0
								1	0	0	1	0	0	0	0	0
10			MN27_90.7	1	0	0	0	0	1	0	0	1	0	0	0	0
					1	0	0	0	1	0	0	0	0	0	0	0
11			MN29_83.9	1	0	0	0	0	0	0	0	0	0	0	0	0
											1	0	0	0	0	0
12			MN29_87.2	0	0	0	0	1	0	0	0	1	0	0	0	0
				1	0	0	1	0	0	0	0	0	0	0	0	0
13			MN29_90.2	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
14			MN29_93.1	1	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	1	0	1	0	0	0	0	0
15			MN78_4.7	1	0	0	0	0	0	0	0	1	0	0	0	0
								1	0	0	0	1	0	0	0	0
16			MN78_7.2	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	1	0	0	0	0	0
17		Fergus Falls	MN108_33	0	0	0	0	0	0	0	0	0	0	0	0	0
18			MN78_37.9	0	0	0	0	0	0	0	0	0	0	0	0	0
19			MN78_38.2	0	0	0	0	0	0	0	0	0	0	0	0	0
20		Moorhead	US59_251.8	1	0	0	0	0	0	0	1	0	0	0	0	0
21			US59_268.3	1	0	0	0	0	0	0	0	0	0	0	0	0
22	HH-1	Fergus Falls	US10_69.4	0	0	0	0	0	0	1	0	0	0	0	0	0
										0	0	0	0	0	0	0
23			US10_70.7	0	0	0	0	1	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
24		Moorhead	US10_31.6	0	0	0	0	0	1	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
25			US10_41.1	1	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	0	0	1	0	0	0	0	0
26			US10_42.3	0	0	0	0	0	0	0	1	0	0	0	0	0
					1	0	0	0	0	0	0	0	0	0	0	0
27			US10_43.1	1	1	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
28			US10_47.7	1	0	0	0	0	0	0	1	0	0	0	0	0
29			US10_60.7	0	0	0	1	0	0	0	0	0	0	0	0	0
30			US10_61.7	1	1	0	0	1	0	0	0	0	0	0	0	0
31	MNRP-0	Alexandria	MN54_3.4	1	0	0	0	0	0	0	0	0	0	0	0	0
													1	0	0	0
32			MN55_35.7	1	0	0	0	0	0	0	0	0	0	0	0	0
33			MN55_52.3	1	0	0	0	0	0	0	0	0	0	0	0	0
34			MN55_54	1	0	0	0	0	0	0	0	0	0	0	0	0
35			MN55_79.6	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	1	0	0	0	0
36			MN79_6	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
37		Morris	MN26_41.6	1	0	0	0	0	0	0	0	0	0	0	0	0
38			MN26_42.7	0	0	0	0	0	0	0	0	0	0	0	0	0
39			MN27_3.2	1	0	0	0	0	0	0	0	0	0	0	0	0
40			MN27_41.6	1	0	0	0	0	0	0	0	0	0	0	0	0
41			MN27_42.7	1	0	0	0	0	0	0	0	0	0	0	0	0
42			MN27_9.6	0	0	0	0	0	0	0	0	0	0	0	0	0
43			MN28_13.6	0	0	0	0	0	0	0	0	0	0	0	0	1
				1	0	0	0	0	0	0	0	0	0	0	0	1
44			MN28_15.5	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	1
45			MN28_22.4	0	0	0	1	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
46			MN28_28.3	1	0	0	0	0	1	0	0	0	0	0	0	0
																1
47			MN28_47	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0

Key: For all species, 1 = species present, 0 = species absent.

Table 3.1 Absence-presence of weed species as recorded in surveys with 14-ft segments in highway ROWs of Mn/DOT_D4 (cont.)

S/No.	Category	Subarea	SegmID	Canada Thistle	Plumeless thistle	Spotted Knapweed	Leafy Spurge	Bull Thisttle	Perennial sowthistle	Purple Loosestrife	Poison Ivy	Wild Parsnip	Musk Thistle	Hemp	Garlic Mustard	Field Bindweed
48	MNRP-0	Morris	MN28_50	1	0	0	0	0	0	0	0	0	0	0	0	0
49			MN28_63.8	1	0	0	0	0	0	0	0	0	0	0	0	0
50			MN7_13.2	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
51			MN7_44.8	1	0	0	0	0	0	0	0	0	0	0	0	0
52			MN7_46.4	1	0	0	0	0	0	0	0	0	0	0	0	0
53			MN9_65.8	0	0	0	0	0	0	0	0	0	0	0	0	1
					1	0	0	0	1	0	0	0	0	0	0	0
54			US59_137.3	0	0	0	1	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
55			US59_141.2	1	0	0	0	0	1	0	0	0	0	0	0	0
								1	0	0	0	0	0	0	0	0
56			US59_159.4	0	0	0	0	1	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
57			US59_165.2	1	0	0	0	0	1	0	0	0	0	0	0	0
					1	0	0	0	1	0	0	0	0	0	0	0
58			US59_181	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
59			US75_131.8	0	0	0	0	0	0	0	0	0	0	0	0	0
60			US75_31.8	1	0	0	0	0	0	0	0	0	0	0	0	1
61	MNRP-1	Alexandria	I94_102.7	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
62			I94_104.1	1	0	0	0	0	0	0	0	0	0	0	0	0
63			I94_73.1	1	0	0	0	1	1	0	0	0	0	0	0	0
						1	0	0	0	0	0	0	0	0	0	0
64			I94_79.2	1	0	0	0	0	0	0	0	0	0	0	0	0
								1	0	0	0	0	0	0	0	0
							1	1	0	0	0	0	0	0	0	0
65			I94_88.9	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
66	PMOP-0	Moorhead	MN113_47.3	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
67			MN87_18.9	0	0	0	0	1	0	0	0	0	0	0	0	0
				1	0	0	0	1	0	0	0	0	0	0	0	0
68			MN87_3.6	0	0	0	0	0	0	0	1	0	0	0	0	0
				1	1	0	0	0	0	0	0	0	0	0	0	0
69	PMOP-1	Fergus Falls	US10_72.9	1	0	0	0	0	1	0	0	0	0	0	0	0
					1	0	0	0	1	0	0	0	0	0	0	0
70			US10_80.4	1	0	0	0	1	0	0	0	0	0	0	0	0
													1	0	0	0
71	RRP-0	Fergus Falls	MN55_0	1	0	0	0	0	0	0	0	0	0	0	0	0
																1
72			MN55_9.6	0	0	0	0	1	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
73			MN9_158.3	1	0	0	0	0	1	0	0	0	0	0	0	0
74			MN9_98.5	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
75			US59_230.1	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
76			US59_232.5	0	0	0	0	0	1	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
77			US75_192.8	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
78		Moorhead	MN224_0.9	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
79			MN224_4	1	0	0	0	0	0	0	0	0	0	0	0	0
					1	0	0	0	1	0	0	0	0	0	0	0
80			MN9_164.4	0	0	0	0	0	1	0	0	0	0	0	0	0
81			MN9_181.4	1	0	0	0	1	0	0	0	0	1	0	0	0
82			US59_289	1	0	0	0	0	0	0	1	0	0	0	0	0
									1	0	0	0	0	0	0	0
83			US75_158.2	1	0	0	0	0	0	0	0	0	0	0	0	0
84			US75_256.3	1	0	0	0	0	0	0	0	0	0	0	0	0
85			US75_258.2	1	0	0	0	0	0	0	0	0	0	0	0	0
86			US75_266.9	1	0	0	0	0	1	0	0	0	0	0	0	0
87			US75_269.3	1	0	0	0	0	0	1	0	0	0	0	0	0
									1	0	0	0	0	0	0	0

Key: For all species, 1 = species present, 0 = species absent.

Table 3.1 Absence-presence of weed species as recorded in surveys with 14-ft segments in highway ROWs of Mn/DOT_D4 (cont.)

S/No.	Category	Subarea	SegmID	Canada Thistle	Plumeless thistle	Spotted Knapweed	Leafy Spurge	Bull Thisttle	Perennial sowthistle	Purple Loosestrife	Poison Ivy	Wild Parsnip	Musk Thistle	Hemp	Garlic Mustard	Field Bindweed
88	RRP-0	Morris	MN27_34.3	1	0	0	0	0	0	0	0	0	0	0	0	1
									1	0	0	0	0	0	0	0
89			MN27_37.9	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
90			MN9_90.3	1	0	0	0	0	0	0	0	0	0	0	0	0
91			US75_169.9	1	0	0	0	0	0	0	0	0	0	0	0	0
92			US75_173	1	0	0	0	0	1	0	0	0	0	0	0	0
							1	0	1	0	0	0	0	0	0	0
93			US75_182.6	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
94			US75_187	0	0	0	0	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	0	0	0	0	0	0	0	0
95	RRP-1	Fergus Falls	I94_30.1	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
96			I94_32.3	1	0	0	0	0	1	0	0	0	0	0	0	0
97			I94_35	1	0	0	0	0	0	0	0	0	0	0	0	0
98			I94_36.9	1	0	0	0	1	0	0	0	0	0	0	0	0
99			I94_38.1	1	0	0	0	0	0	0	0	0	0	0	0	0
100			I94_39.2	1	0	0	0	0	1	0	0	0	0	0	0	0
101			I94_48.9	1	0	0	0	0	0	0	0	0	0	0	0	0
102			I94_51.6	1	0	0	0	0	0	0	1	0	0	0	0	0
									1	0	1	0	0	0	0	1
103		Moorhead	US10_18	1	0	0	0	0	1	0	1	0	0	0	0	0
104			US10_18.2	1	0	0	0	0	1	0	0	1	0	0	0	0
105			US10_33.9	1	0	0	0	0	0	0	0	0	0	0	0	0
									1	0	0	0	0	0	0	0
106			US10_6.9	1	0	0	0	0	1	0	0	0	0	0	0	0
											1	0	0	0	0	0
107			US10_7.9	0	0	0	1	0	0	0	0	0	0	0	0	0
				1	0	0	0	0	1	0	0	0	0	0	0	0
108			US10_9.8	1	0	0	0	0	0	0	0	0	0	0	0	0

Key: For all species, 1 = species present, 0 = species absent.

Table 3.2 Proportion of sampling sites in the different study area categories infested by weed species based on survey data with the 14-ft sampling plan for the 2007 survey

Species	Category								
	CP-0	HH-0	HH-1	MNRP-0	MNRP-1	PMOP-0	PMOP-1	RRP-0	RRP-1
Canada thistle	0.500	0.458	0.600	0.771	1.000	1.000	1.000	0.590	0.737
Plumeless thistle	0.000	0.125	0.400	0.042	0.000	0.500	0.500	0.026	0.000
Spotted knapweed	1.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000
Leafy spurge	0.000	0.042	0.100	0.042	0.250	0.000	0.000	0.026	0.053
Bull thistle	0.000	0.125	0.200	0.042	0.750	1.000	0.500	0.051	0.053
Perennial sowthistle	1.000	0.250	0.400	0.208	0.750	0.000	1.000	0.410	0.474
Purple loosestrife	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.026	0.000
Poison ivy	0.000	0.292	0.300	0.000	0.000	0.500	0.000	0.026	0.211
Wild parsnip	0.000	0.167	0.000	0.021	0.000	0.000	0.000	0.000	0.053
Musk thistle	0.000	0.000	0.000	0.021	0.000	0.000	0.500	0.026	0.000
Hemp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garlic mustard	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field bindweed	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.051	0.053

Table 3.3 Population distribution of species among surveyed segments based on data recorded with14-ft sampling plan for the 2007 survey. The total number of segments surveyed was 108 (150 were selected to be surveyed)

Species	**Number of Segments with Specie Present**
Canada thistle	91
Plumeless thistle	13
Spotted knapweed	3
Leafy Spurge	8
Bull Thistle	17
Perennial sowthistle	52
Purple loosestrife	3
Poison ivy	17
Wild parsnip	7
Musk thistle	4
Hemp	1
Garlic mustard	1
Field bindweed	10

Table 3.3 is an attempt to quantify the magnitude of the problem each species presents in Mn/DOT_D4. Column 2 shows the number of segments from all those inspected and species found which are infested by the respective species. This shows that Canada thistle is the most serious problem, infesting 91 out of 108 segments inspected. This is followed by perennial sowthistle as the next most common species, being found in 52 out of 108 segments. Based on this data, the species which pose the least problem (based on extent of infestation in the district) are plumeless thistle, purple loosestrife, spotted knapweed, hemp and garlic mustard.

Data from surveys with the 225-ft plan was processed, with the results tabulated to show presence and distribution of the different species. Mean acres-per-mile infested by the different species are presented in Tables 3.4 and 3.5, and Figures 3.1 to 3.4. The weighted means for each weed species presented in Table 3.5 were evaluated using the relation:

Weighted mean = Category mean acres-per-mile x *f*

where f *is a proportionality factor evaluated:*

$$f = \frac{\text{Total number of possible segments in a category}}{\text{Total number of segments in the study area (Mn/DOT\_D4)}}$$

$$categorymean = \left(\sum_{1}^{n} \frac{A_s .5280\, ft/mi}{225\, ft} \right) acres/mile$$

A_s = area (acres) infested by a species within a segment
n = total number of segments selected for survey in a category

Grand means have also been evaluated, showing the magnitude of infestation problems by the 13 noxious weed species in Mn/DOT_D4. Results are presented in Tables 3.5 and 3.6. Means were calculated for the two scenarios.

Table 3.4 Summary statistics of species infestation in the 9 ecological zone categories of Mn/DOT_D4 based on 225-ft sampling plan for the 2007 survey

	CP-0	PMOP-1	MNRP-1	HH-1	RRP-1	PMOP-0	HH-0	RRP-0	MNRP-0	Weighted Means
n	2	3	3	6	9	3	12	19	26	
Canada thistle										
Mean (acres/mile)	0.524	7.368	12.191	4.483	3.344	0.807	2.763	2.780	4.146	3.498
Variance	0.5490	1.4382	3.2246	33.5864	7.0820	1.7548	6.1713	11.3903	13.9135	10.865
SD	0.741	1.199	1.796	5.795	2.661	1.325	2.484	3.375	3.730	3.179
SE	0.524	0.692	1.037	2.366	0.887	0.765	0.717	0.774	0.732	0.808
Sow thistle										
Mean (acres/mile)	0.103	0.028	0.988	0.197	0.894	0.218	0.186	0.131	0.465	0.338
Variance	0.0212	0.0006	1.7828	0.2147	1.1254	0.0289	0.1492	0.0258	0.9743	0.513
SD	0.146	0.024	1.335	0.463	1.061	0.170	0.386	0.161	0.987	0.599
SE	0.103	0.014	0.771	0.189	0.354	0.098	0.112	0.037	0.194	0.153
Poison ivy										
Mean (acres/mile)	0.085	1.315	0.000	0.231	0.000	1.745	0.110	0.038	0.005	0.169
Variance	0.0144	1.3047	0.0000	0.3205	0.0000	2.2588	0.0537	0.0272	0.0007	0.191
SD	0.120	1.142	0.000	0.566	0.000	1.503	0.232	0.165	0.026	0.223
SE	0.085	0.659	0.000	0.231	0.000	0.868	0.067	0.038	0.005	0.096
Bull thistle										
Mean (acres/mile)	0.000	1.423	2.263	0.192	0.002	0.042	0.135	0.022	0.021	0.112
Variance	0.0000	1.9464	14.5166	0.0817	0.0000	0.0018	0.1013	0.0051	0.0048	0.366
SD	0.000	1.395	3.810	0.286	0.005	0.042	0.318	0.071	0.069	0.214
SE	0.000	0.805	2.200	0.117	0.002	0.024	0.092	0.016	0.014	0.089
Leafy spurge										
Mean (acres/mile)	0.000	0.498	0.078	0.000	0.001	0.000	0.237	0.060	0.088	0.099
Variance	0.0000	0.7436	0.0184	0.0000	0.0000	0.0000	0.6761	0.0684	0.1401	0.202
SD	0.000	0.862	0.136	0.000	0.002	0.000	0.822	0.262	0.374	0.369
SE	0.000	0.498	0.078	0.000	0.001	0.000	0.237	0.060	0.073	0.093
Plumeless thistle										
Mean (acres/mile)	0.000	0.091	0.000	0.009	0.035	0.264	0.018	0.060	0.098	0.076
Variance	0.0000	0.0250	0.0000	0.0004	0.0113	0.1769	0.0037	0.0222	0.2491	0.112
SD	0.000	0.158	0.000	0.020	0.106	0.421	0.061	0.149	0.499	0.271
SE	0.000	0.091	0.000	0.008	0.035	0.243	0.018	0.034	0.098	0.068
Spotted knapweed										
Mean (acres/mile)	4.133	0.000	0.000	0.000	0.000	0.508	0.004	0.002	0.000	0.035
Variance	27.1137	0.0000	0.0000	0.0000	0.0000	0.7747	0.0001	0.0001	0.0000	0.051
SD	5.207	0.000	0.000	0.000	0.000	0.880	0.012	0.010	0.000	0.063
SE	3.682	0.000	0.000	0.000	0.000	0.508	0.004	0.002	0.000	0.035
Musk thistle										
Mean (acres/mile)	0.000	0.000	1.470	0.021	0.000	0.000	0.012	0.000	0.012	0.040
Variance	0.0000	0.0000	6.4870	0.0027	0.0000	0.0000	0.0016	0.0000	0.0021	0.144
SD	0.000	0.000	2.547	0.052	0.000	0.000	0.041	0.000	0.045	0.082
SE	0.000	0.000	1.470	0.021	0.000	0.000	0.012	0.000	0.009	0.039
Purple loosestrife										
Mean (acres/mile)	0.000	0.000	0.000	0.007	0.155	0.000	0.000	0.000	0.000	0.010
Variance	0.0000	0.0000	0.0000	0.0003	0.2172	0.0000	0.0000	0.0000	0.0000	0.013
SD	0.000	0.000	0.000	0.018	0.466	0.000	0.000	0.000	0.000	0.029
SE	0.000	0.000	0.000	0.007	0.155	0.000	0.000	0.000	0.000	0.010
Field bindweed										
Mean (acres/mile)	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.011	0.195	0.076
Variance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0014	0.3083	0.115
SD	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.038	0.555	0.218
SE	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.009	0.109	0.043
Wild parsnip										
Mean (acres/mile)	0.000	0.000	0.000	0.152	0.004	0.000	0.011	0.002	0.015	0.013
Variance	0.0000	0.0000	0.0000	0.1388	0.0001	0.0000	0.0007	0.0001	0.0060	0.007
SD	0.000	0.000	0.000	0.373	0.012	0.000	0.026	0.010	0.078	0.048
SE	0.000	0.000	0.000	0.152	0.004	0.000	0.008	0.002	0.015	0.013
Hemp										
Mean (acres/mile)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
Variance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
SD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
SE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
Garlic mustard										
Mean (acres/mile)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
Variance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
SD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
SE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0

Table 3.5 Mean acres-per-mile infested by Canada thistle in different survey location categories of Mn/DOT_D4 based on 225-ft samples for the 2007 survey

Roadway category:	CP-0	PMOP-1	MNRP-1	HH-1	RRP-1	PMOP-0	HH-0	RRP-0	MNRP-0	Grand Weighted Means
Median? (1=Yes)	0	1	1	1	1	0	0	0	0	
No. of sites inspected	2	3	3	6	9	3	12	19	26	
Mean (acres/mile)	0.524	7.368	12.191	4.483	3.344	0.807	2.763	2.780	4.146	3.50
Variance	0.549	1.4382	3.225	33.586	7.082	1.755	6.171	11.390	13.9135	10.86
SD	0.741	1.199	1.796	5.795	2.661	1.325	2.484	3.375	3.730	3.18
SE	0.524	0.692	1.037	2.366	0.887	0.765	0.717	0.774	0.732	0.81
Student's t	12.706	4.303	4.303	2.571	2.306	4.303	2.201	2.101	2.060	2.35
ME/Mean, %	1271	40	37	136	61	408	57	59	36	74.98

Table 3.6 Grand weighted mean area of species infestation of highway ROWs in Mn/DOT_D4 based on surveys with the 225-ft sampling segments (2007)

Species	Weighted Mean, acres per mile	Standard Error (SE):	Margin of error (ME)*:
Canada thistle	3.50	0.38	0.75
Sow thistle	0.34	0.08	0.16
Poison ivy	0.17	0.06	0.77
Bull thistle	0.11	0.05	0.23
Leafy spurge	0.10	0.05	0.11
Field bindweed	0.08	0.04	0.08
Plumeless thistle	0.08	0.04	0.08
Musk thistle	0.04	0.03	0.42
Spotted knapweed	0.03	0.03	0.43
Wild parsnip	0.01	0.01	0.02
Purple loosestrife	0.01	0.01	0.02
Garlic mustard	0.00	0.00	--
Hemp	0.00	0.00	--

* This statistic expresses the amount of random sampling error in survey results (larger the ME, less the confidence in the survey results' being good measure of species population for the sampled larger area)

A review of the mean density evaluated from data recorded in the surveys conducted in 2004 and 2005 using ¼-mile and 3-mile sampling segments (Tables 3.7 to 3.10), reveal interesting trends. These are discussed below for the studied weed species.

Canada thistle

Mean infested acres-per-mile data recorded for this species in surveys conducted in years 2004 and 2005 using the ¼-mile segment length, and in 2007 using the 225-ft segments, are respectively 2.02, 2.86, and 3.50. Associated standard sampling errors were 0.2534, 0.323 and 0.38. It could logically be concluded that these values, though based on two different sampling

plans, are reasonable estimates of the species populations. According to this there appears to be a notable increase in population of the species over the years.

Mean acres-per mile evaluated from the data recorded in surveys using the 3-mile sampling plan from the 2004 and 2005 were respectively, 1.057 and 2.437, with respective standard errors of 0.3098 and 4.840. The mean values for the 2004 appear significantly different from those obtained in the surveys using ¼-mile sampling plan; however in 2005, the mean values were comparable, but the standard sampling errors were much larger for the 3-mile sampling plan.

Leafy spurge

Mean acre-per mile for 2004, 2005 and 2007 were 0.005, 0.009 and 0.10 respectively for the ¼-mile sampling plan. Standard errors of sampling were very low (less than 0.05) for all years. Values evaluated from the data recorded on this species with the 3-mile sampling plan in 2004 and 2005 were, respectively, 0.046 and 0.0039.

Poison ivy

Mean acres-per mile evaluated from data recorded for poison ivy in surveys carried in 2004, 2005 and 2007 using ¼-mile sampling plan were, respectively 0.039, 0.136 and 0.17. Sampling errors were 0.0241, 0.072, and 0.06. Values evaluated from data recorded in the surveys using 3-mile sampling plan in 2004 and 2005 were 0.1178 and 0.1144, with standard errors of 0.0945 and 0.2756 respectively.

Table 3.7 Grand weighted mean area of species infestation in highway ROWs of Mn/DOT_D4 based on the surveys of the ¼-mile sampling segments (2005)

Species	Mean (acres/mile)	Standard Error (SE)
Canada Thistle	2.854	0.323
Leafy spurge	0.009	0.006
Poison ivy	0.163	0.072

Table 3.8 Grand weighted mean area of species infestation of highway ROWs in Mn/DOT_D4 for the survey using 3-mile sampling segments (2005)

Species	Mean (acres/mile)	Standard Error (SE)
Canada Thistle	2.437	4.840
Leafy spurge	0.004	0.007
Poison ivy	0.114	0.276

Table 3.9 Grand weighted mean area of species infestation of highway ROWs in Mn/DOT_D4 for the survey using 1/4-mile sampling segments (2004)

Species	Mean (acres/mile)	Standard Error (SE)
Canada Thistle	2.079	0.253
Leafy spurge	0.005	0.003
Poison ivy	0.039	0.024

Table 3.10 Grand weighted mean area of species infestation of highway ROWs in Mn/DOT_D4 for the survey using 3-mile sampling segments (2004)

Species	Mean (acres/mile)	Standard Error (SE)
Canada Thistle	1.057	0.310
Leafy spurge	0.046	0.026
Poison ivy	0.118	0.094

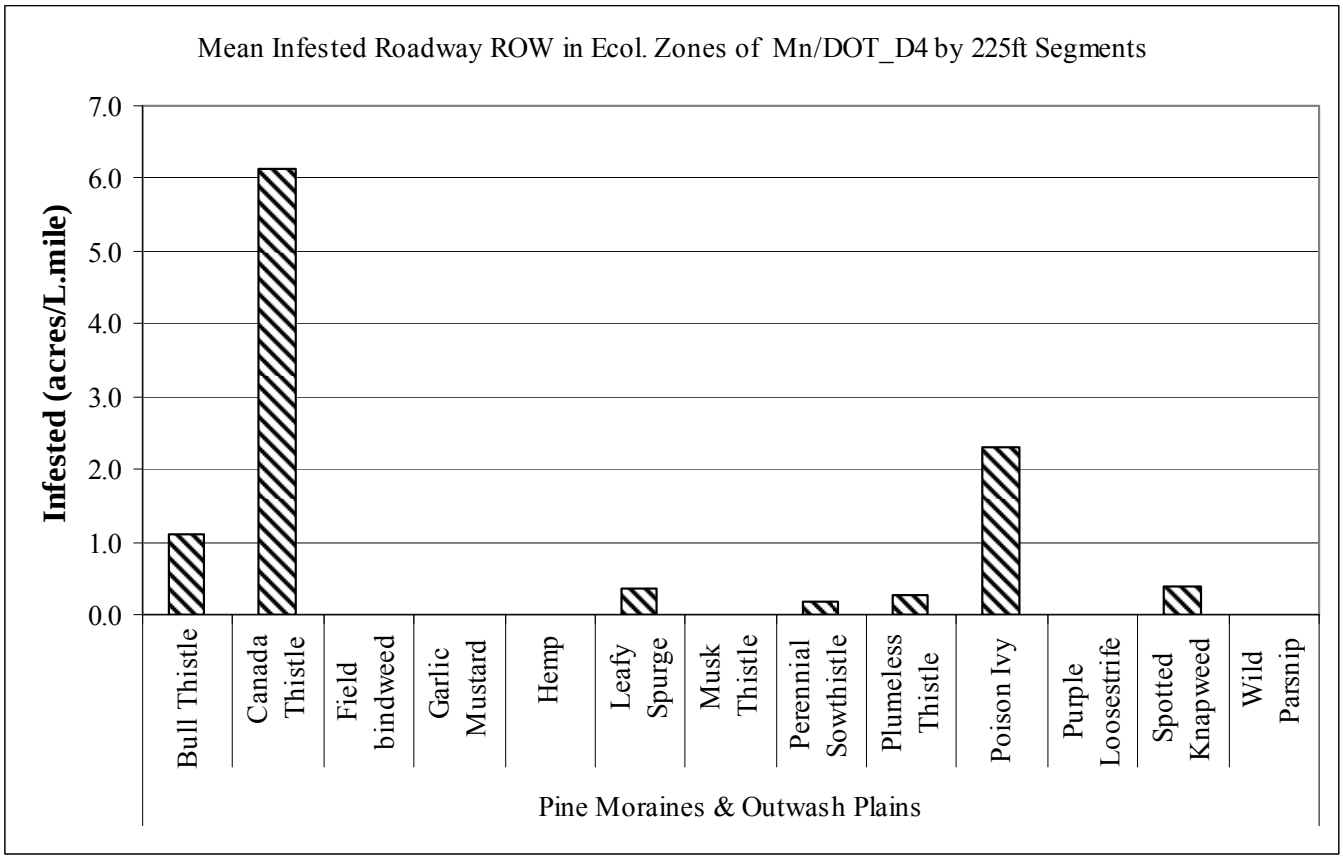


Figure 3.1 Acres-per-linear mile of highway ROWs (acres infested ÷ [number of selected segments x segment length]) infested with noxious species as recorded in surveys with 225-ft segments in Pine Moraines and Outwash Plains Ecological Zone of Mn/DOT_D4, 2007.

The plots presented in figures 3.1 – 3.5 show the weed population densities evaluated for different ecological zones of Mn/DOT_D4. These values were calculated by dividing the total area (acres) infested by given species, by total linear miles of highway rights-of-way (ROWs) sampled within each of the ecozone in Mn/DOT_D4. The total miles surveyed in an ecological zone were taken as the product of the segment length (225ft or 0.0426 miles) and the number of segments initially selected for sampling within each ecozone. It could be argued that the logical method for computing total miles surveyed in an ecological zone would be to multiply segment length by the total number of segments inspected per ecological zone; we could not apply this method because documentation was not complete, making it difficult to determine whether some of the segments selected for surveying and had no data were not surveyed (missing data), or were surveyed and no species found (0 acres). This happened so because the GPS units were not switched on to record data when a segment was not infested by any of the subject species. When data recorded in the units were downloaded and processed, all segments with no species infestations would not appear in the recorded data. By evaluating weed population density using the method described in this section would result in un-determined error of under-estimation, because there could be cases where some of the initially selected sampling sites may have been missed out in the surveys. The alternative would have been to evaluate the miles infested based

on the number of segments with recorded data. Since the GPS were not switched on to record data where no infestations were found, many more segments would be missing in the recorded data (especially for less prevalent species). In this situation, evaluated densities would again be of indeterminate error of over-estimation. Inspection of the data showed that the error of over-estimation would be much, much greater compared to under-estimation one.

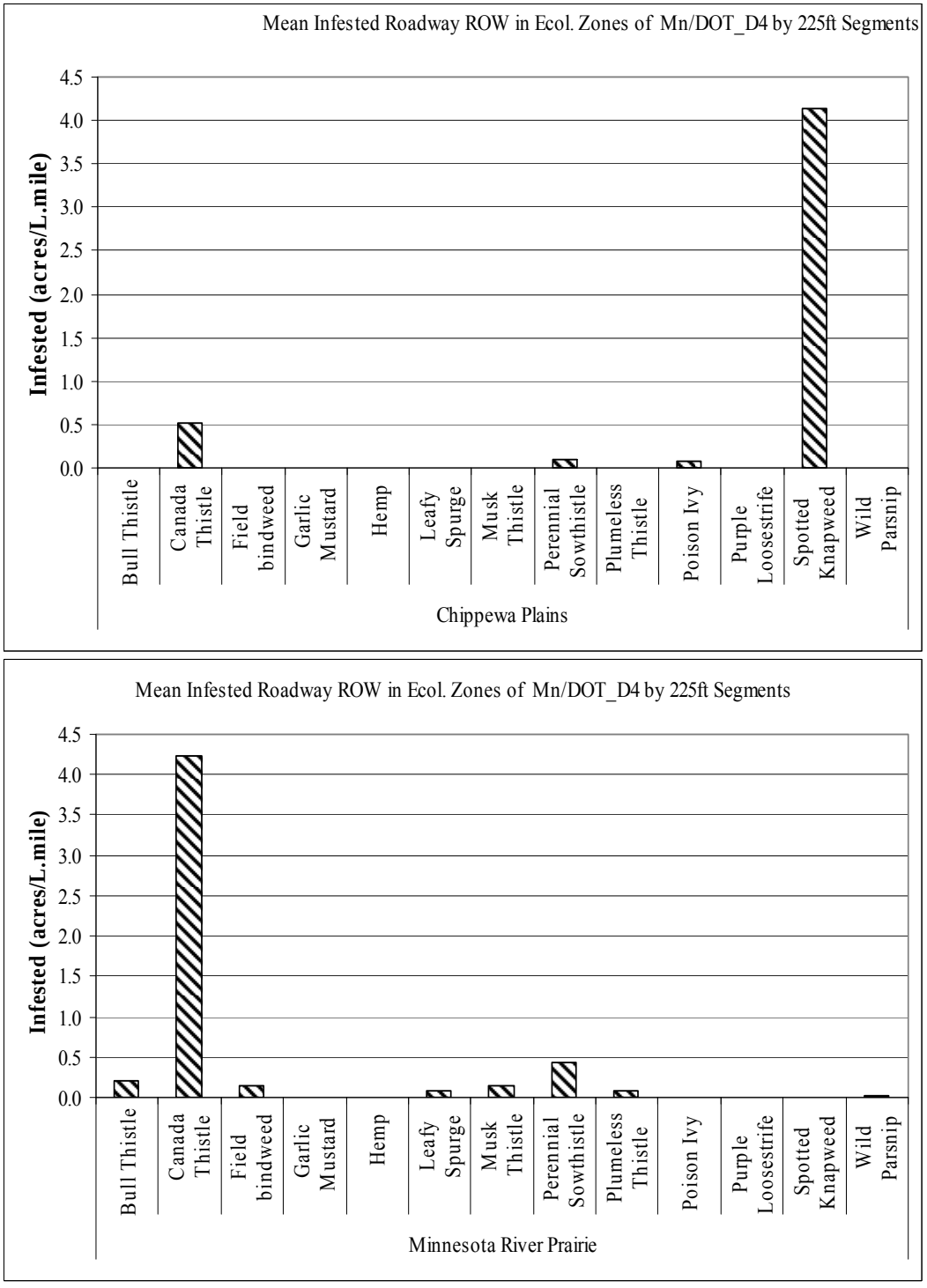
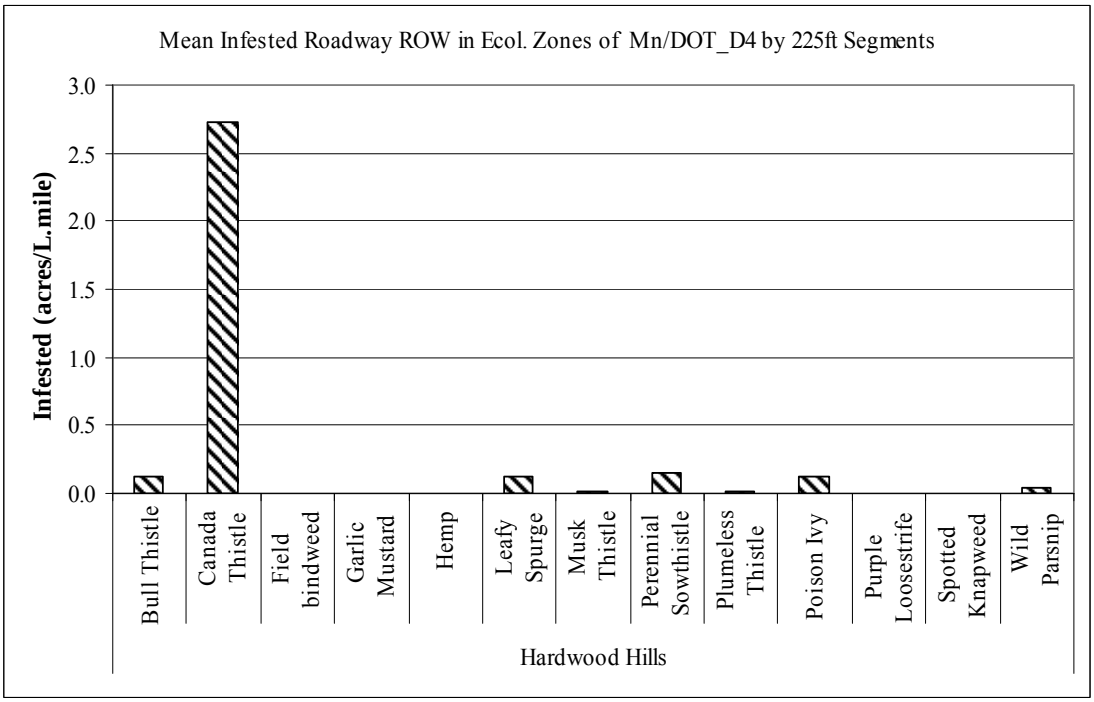


Figure 3.2 Acres-per-linear mile of highway ROWs (acres infested ÷ [number of selected segments x segment length]) infested with noxious species as recorded in surveys with 225-ft segments in Chippewa Plains and Minnesota River Prairie Ecological Zones of Mn/DOT_D4, 2007.



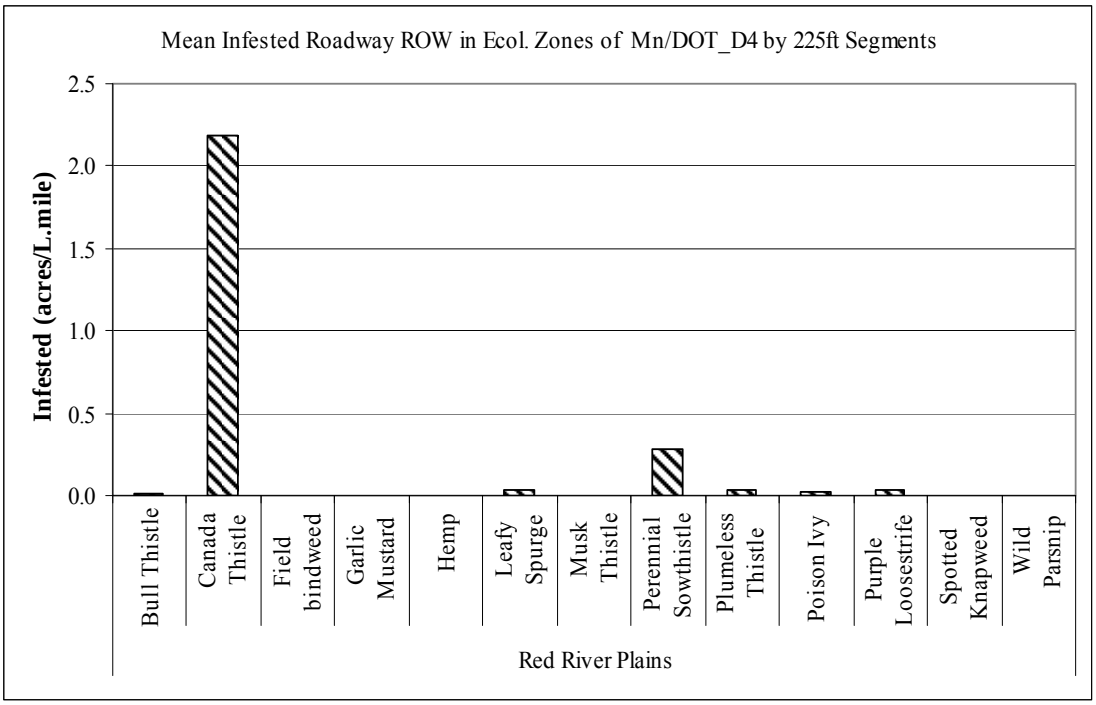


Figure 3.3 Acres-per-linear mile of highway ROWs (acres infested ÷ [number of selected segments x segment length]) infested with noxious species as recorded in surveys with 225-ft segments in Hardwood Hills and Red River Plains Ecological Zones of Mn/DOT_D4, 2007.

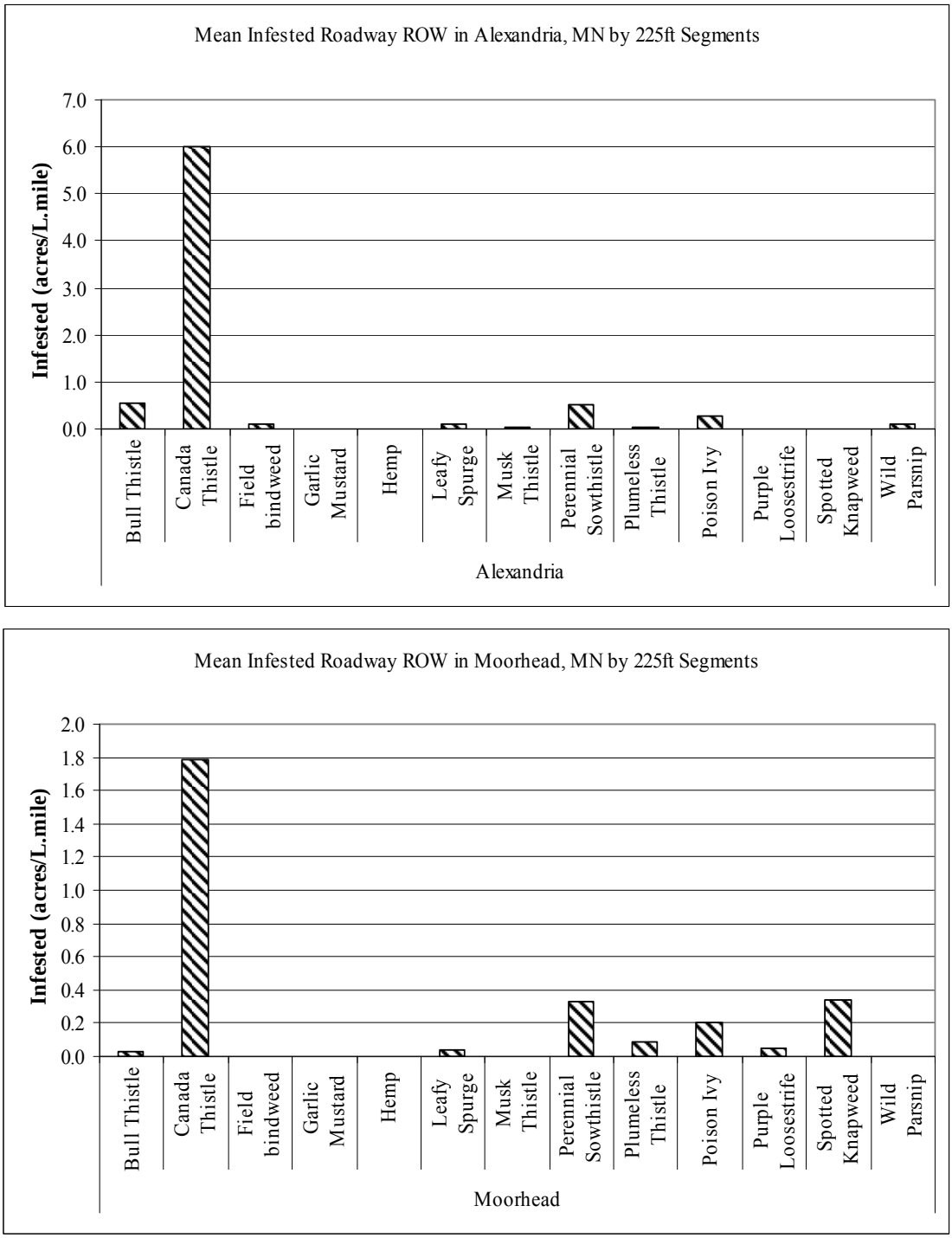


Figure 3.4 Acres-per-linear mile of highway ROWs (acres infested ÷ [number of selected segments x segment length]) infested with noxious species as recorded in surveys with 225-ft segments in Alexandria and Moorhead Management Subareas of Mn/DOT_D4, 2007.

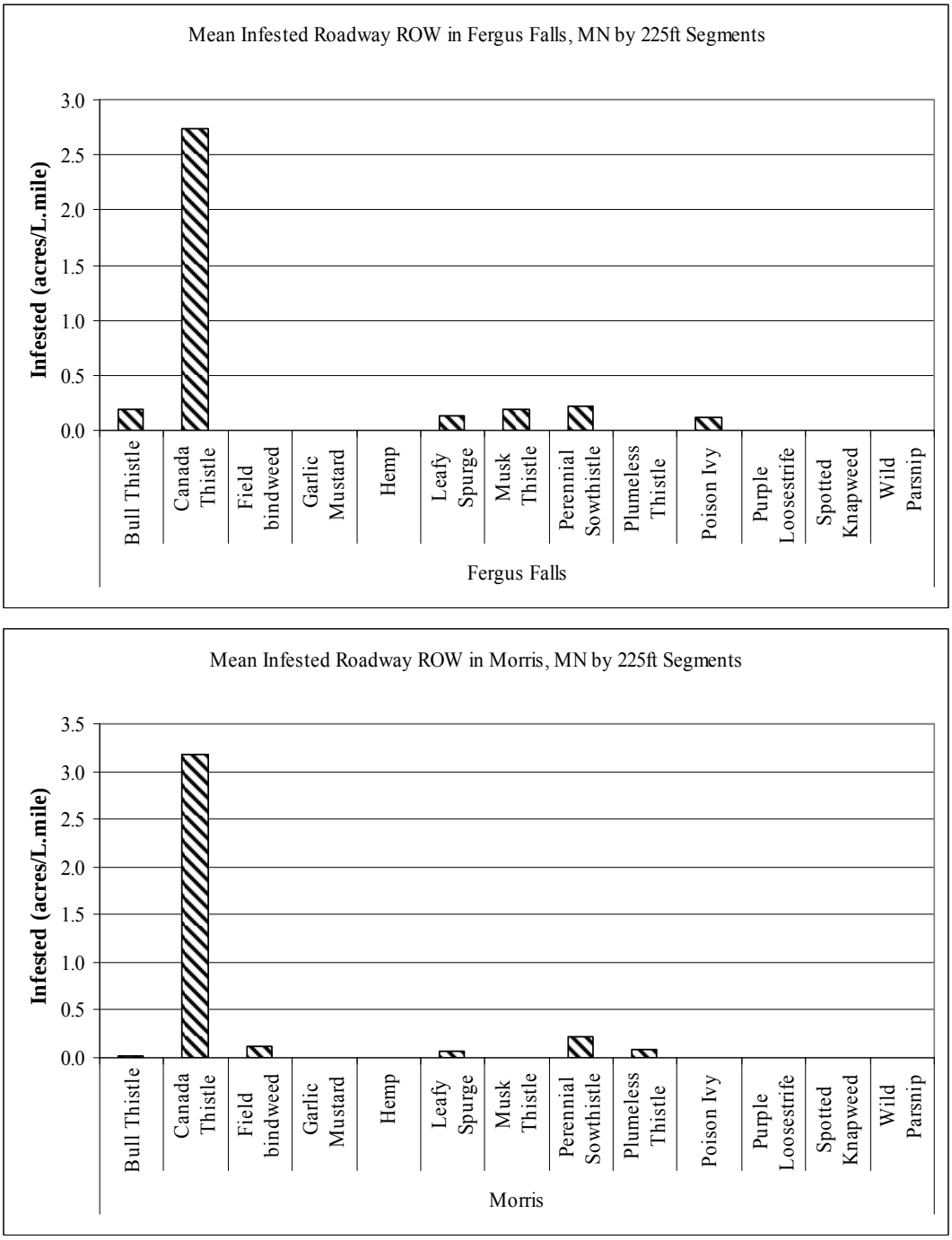


Figure 3.5 Acres-per-linear mile of highway ROWs (acres infested ÷ [number of selected segments x segment length]) infested with noxious species as recorded in surveys with 225-ft segments in Fergus Falls and Morris Management Subareas of Mn/DOT_D4, 2007.

3.2 Evaluating Area Infested Using Presence-Absence Data

The 225-ft segment surveys were re-sampled into 14-ft segment, and presence/absence of weeds in each of the 14-ft segments was determined. The proportion of 14-ft segments in a given 225-ft segment that were infested was then plotted against the acres/mile infestation for that 225-ft segment. The result of this is given in Figure 3.6.

The fit of the data to equation 2.1 is shown in Figure 3.6. When the data I subjected to a log-log transform, and fitted to equation 2.2, the result is presented in Figure 3.7. The parameters for the fit are $\alpha = -0.0633$ and $\beta = 1.2525$, with a coefficient of determination of 0.8403.

The fitted equation was then used with the 14-ft sampling plan data (the independent set of 14-ft stick walk data) for each ecological zone to estimate the population density for that zone. This was done by averaging the 14-ft sampling presence values acquired from a given ecological zone. The mean presence values for each of the ecological zones are presented in Table 3.11 along with the predicted population densities from the fitted equation 2.1. For Canada thistle this result corresponds to the top row of the table. The predicted mean population densities from the 225-ft surveys were determined for each of the ecological zones as well.

Figure 3.8 shows a comparison of Canada thistle infestation density (acres-per-mile) values obtained from two methods. The first method corresponds to the same data plotted in Figure 3.5. The second method is the application of the fitted equation 2.1 with the values for the proportion infested derived from the mean of the proportion infested values from the 14-ft stickwalks for each of the ecological zones. The plotted points from the second method gives are a total of nine points because there are nine ecological zones. The plot shows the nine predicted population density values fall well within the cloud of points derived from the sectioned data recorded in the surveys with 225-ft sampling plan. This by implication would indicate potential usefulness of the stickwalks sampling plan, and application of the data to the Kono and Sugino (1958) model in estimating species infestation density in highway rights-of-way.

The mean population density of Canada thistle for each ecological zone, determined by computing the means of the population density in the 225-ft segments in a given ecological zone, is presented in Table 3.12 along with the predicted mean population densities. The latter values are computed the fitted equation 2.1 and the proportion infested (p+) values evaluated form data recorded from the 14-ft stickwalks survey. Figure 3.8 shows graphical presentation of these mean acres-per-mile values evaluated from data obtained using the two (225-ft and 14-ft) sampling plans.

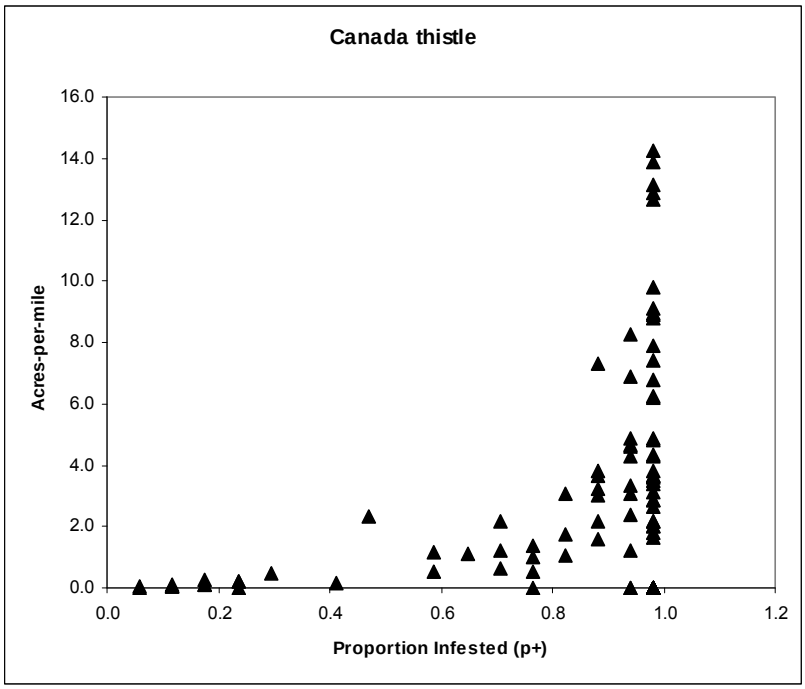


Figure 3.6 Proportion infested and the area (acres/mile) Canada thistle derived from data recorded in surveys using the 225-ft sampling plans, 2007.

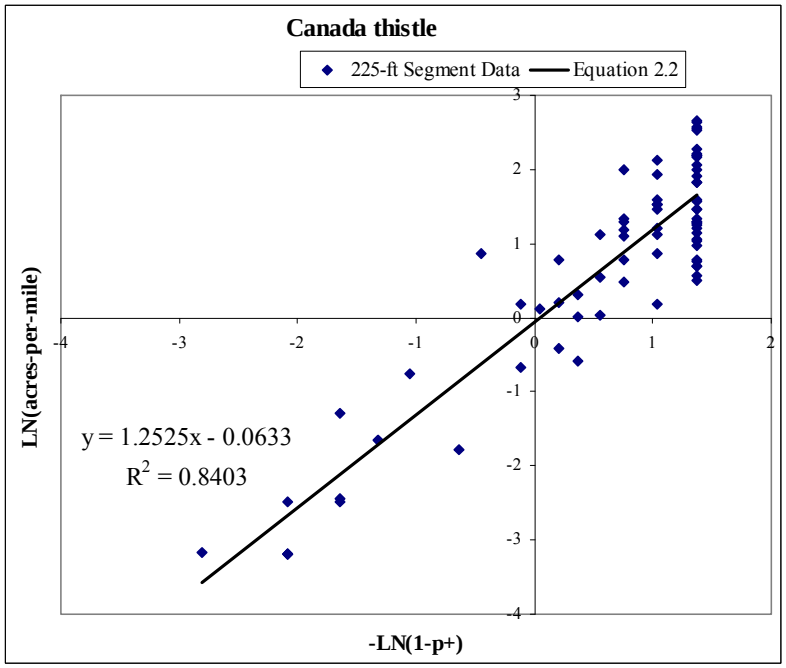


Figure 3.7 Log-log transformations of the data in Figure 3.5, and fitted trend line for the transformed Kono and Sugino model (equation 2.2).

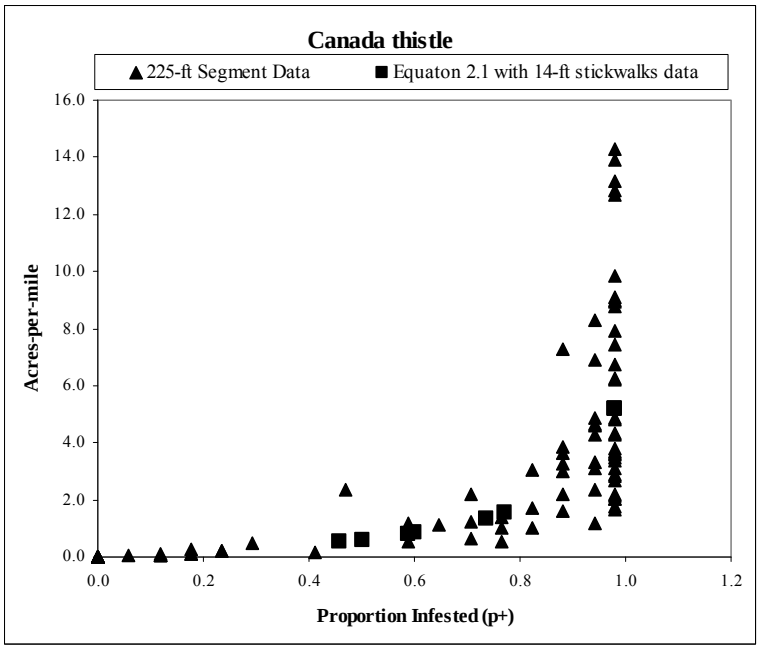


Figure 3.8 Relations of population density acres-per-mile for 14-ft stickwalks re-sampled from the 225-ft segments, and the proportion of the section infested by Canada thistle versus acres-per-mile evaluated from application of the 14ft-stick-walks data on the Kono and Sugino (1958) model. Note in Figure 3.8 that three points for the predictions with equation 2.1 have identical location in the plot (see Table 3.12 for data).

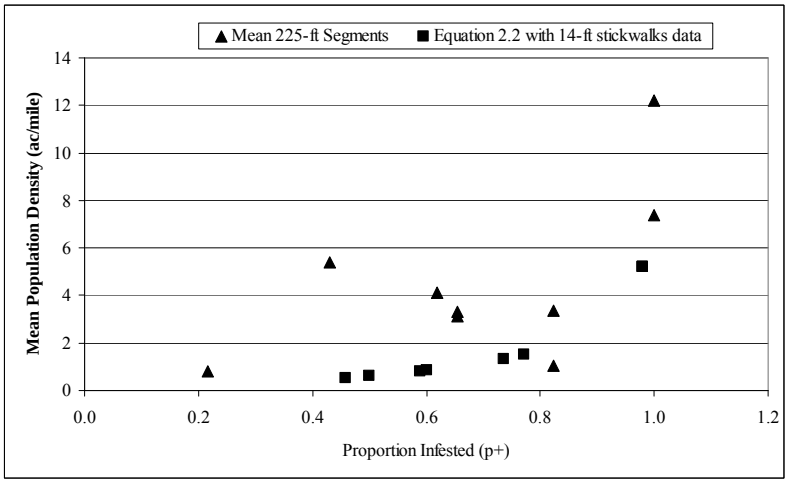


Figure 3.9. Mean population density by Canada thistle predicted for each ecological zone using equation 2.1 with the proportion infested in the respective zone determined from the 14-ft stickwalks survey values. Note in Figure 3.9, that three points for the prediction with equation 2.1 have identical locations in the plot (see Table 3.11 for data), hence the 7 instead of 9 points seen in the chart.

Table 3.11 Application of the Kono and Sugino (1958) model on the proportion infested data acquired with 14-ft sampling plan, to determine mean acres-per-mile of infested population intensity for the 2007 survey

	CP-0		HH-0		HH-1		MNRP-0		MNRP-1		PMOP-0		PMOP-1		RRP-0		RRP-1	
Species	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**	**Proportion**	**Acres/mile**
Canada thistle	0.500	0.593	0.458	0.509	0.600	0.841	0.771	1.525	0.980	5.182	0.980	5.182	0.980	5.182	0.590	0.812	0.737	1.348
Plumeless thistle	0.000	0.000	0.125	0.075	0.400	0.405	0.042	0.018	0.000	0.000	0.500	0.593	0.500	0.593	0.026	0.010	0.000	0.000
Spotted knapweed	0.980	5.182	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.197	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Leafy spurge	0.000	0.000	0.042	0.018	0.100	0.056	0.042	0.018	0.250	0.197	0.000	0.000	0.000	0.000	0.026	0.010	0.053	0.024
Bull thistle	0.000	0.000	0.125	0.075	0.200	0.143	0.042	0.018	0.750	1.413	0.980	5.182	0.500	0.593	0.051	0.023	0.053	0.024
Perennial sowthistle	0.980	5.182	0.250	0.197	0.400	0.405	0.208	0.152	0.750	1.413	0.000	0.000	0.980	5.182	0.410	0.422	0.474	0.539
Purple loosestrife	0.000	0.000	0.000	0.000	0.100	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.010	0.000	0.000
Poison ivy	0.000	0.000	0.292	0.247	0.300	0.258	0.000	0.000	0.000	0.000	0.500	0.593	0.000	0.000	0.026	0.010	0.211	0.154
Wild parsnip	0.000	0.000	0.167	0.111	0.000	0.000	0.021	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.024
Musk thistle	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.007	0.000	0.000	0.000	0.000	0.500	0.593	0.026	0.010	0.000	0.000
Hemp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garlic mustard	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field bindweed	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.075	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.023	0.053	0.024

Table 3.12 Mean acres-per-mile and Proportion (col. 2 and 3) of surveyed segments infested with Canada thistle evaluated from data recorded on 225-ft sampling plan, and acres-per-mile and proportion infested with Canada thistle (Col. 4 and 5) of the 14-ft surveys using the Kono and Sugino (1958) model for the 2007 survey

Category	**225-ft Survey data**		**14-ft Survey Data**	
	Acres/mile	**Proportion Infested**	**Proportion Infested**	**Acres/mile (predicted from fitted equation 2.2)**
CP0	1.048	0.824	0.500	0.593
HH0	3.315	0.655	0.458	0.509
HH1	5.379	0.431	0.600	0.841
MNRP0	4.121	0.618	0.542	1.525
MNRP1	12.191	1.000	0.980	5.182
PMOP0	0.807	0.216	0.980	5.182
PMOP1	7.368	1.000	0.980	5.182
RRP0	3.109	0.654	0.590	0.812
RRP1	3.344	0.824	0.737	1.348

Comparative analysis of the 3-mile, ¼-mil, 225-ft and 14-ft sampling plans

Table 3.12, 3.13, and 3.14 show the population densities and proportion infested amounts for Canada thistle in Mn/DOT_D4 highways' rights-of-way as evaluated from data recorded in surveys conducted in 2007, 2004 and 2005 using 225-ft, ¼-mile and 3-mile sampling plans, respectively. These data sets provide a means of comparing efficacies associated with application of each of the three sampling plans in assessing Canada thistle population distribution in these and other regions in the State. There are notable differences between infestation density values across the sampling methods. However, since the data has been recorded in each of the representative categories over three years' period, the changes may be attributable to other factors other than differences in sampling methods. Infestation dynamics may be influenced by other factors, including climate.

It is known that due to the limited number of sampling sites associated with the surveys using 3-mile sampling plan, the distribution of sampling sites was poor, within several ecological zones having no sampling sites, hence the missing data (-) in some Categories. This made it difficult to effectively compare weed population distribution in these regions using data recorded with these three sampling plans.

Figure 3.10 shows the proportion infested and Figure and 3.11 shows the population density for Canada thistle, across the categories, as acquired through surveys using the ¼-mile, 225-ft and the 14-ft stickwalks sampling plans. Although the differences between the mean acres-per-mile values across categories appear to be small, the values obtained with the 225-ft plan were higher in many (6 of 9) categories compared to those from the other sampling plans. On the other hand, there were observable clear trends observed in the proportion infested (p+) data (Figure 3.9), either among sampling plans or across sites categories.

It is not possible at this point to draw conclusions on the observed differences and/or similarities among data acquired in the surveys using the three sampling plans. Data recorded in surveys conducted in 2008 using the 225-ft and 14-ft stick walks may be useful in arriving at specific conclusions as to which sampling plan is better in surveys to assess weed population distribution in highways rights-of-way. Further, the questions on sampling efficiency and cost of sampling will be addressed in the analysis of the 2008 data.

Table 3.13 Mean acres-per-mile, and the proportion of surveyed segments infested with Canada thistle as evaluated from data recorded on ¼-mile and 3-mile sampling plans, 2004

Category	1/4-mile		3-mile	
	Acres/mile	Proportion Infested	Acres/mile	Proportion Infested
CP0	0.000	0.000	-	0.000
HH0	1.055	0.846	0.830	1.000
HH1	2.997	1.000	-	0.000
MNRP0	1.581	0.893	1.048	1.000
MNRP1	5.161	1.000	1.600	1.000
PMOP0	0.233	0.917	-	0.000
PMOP1	0.719	1.000	-	0.000
RRP0	1.969	0.964	1.131	1.000
RRP1	15.236	0.857	-	0.000

Table 3.14 Mean acres-per-mile, and the proportion of surveyed segments infested with Canada thistle as evaluated from data recorded on ¼-mile and 3-mile sampling plans, 2005

	1/4-mile		**3-mile**	
Category	**Acres/mile**	**Proportion Infested**	**Acres/mile**	**Proportion Infested**
CP0	0.000	0.000	-	0.000
HH0	2.040	0.941	3.033	1.000
HH1	6.186	0.800	-	0.000
MNRP0	2.665	0.947	0.178	1.000
MNRP1	1.433	0.333	11.398	1.000
PMOP0	0.307	0.833	-	0.000
PMOP1	0.000	0.000	-	0.000
RRP0	2.752	1.000	1.225	1.000
RRP1	9.203	1.000	-	0.000

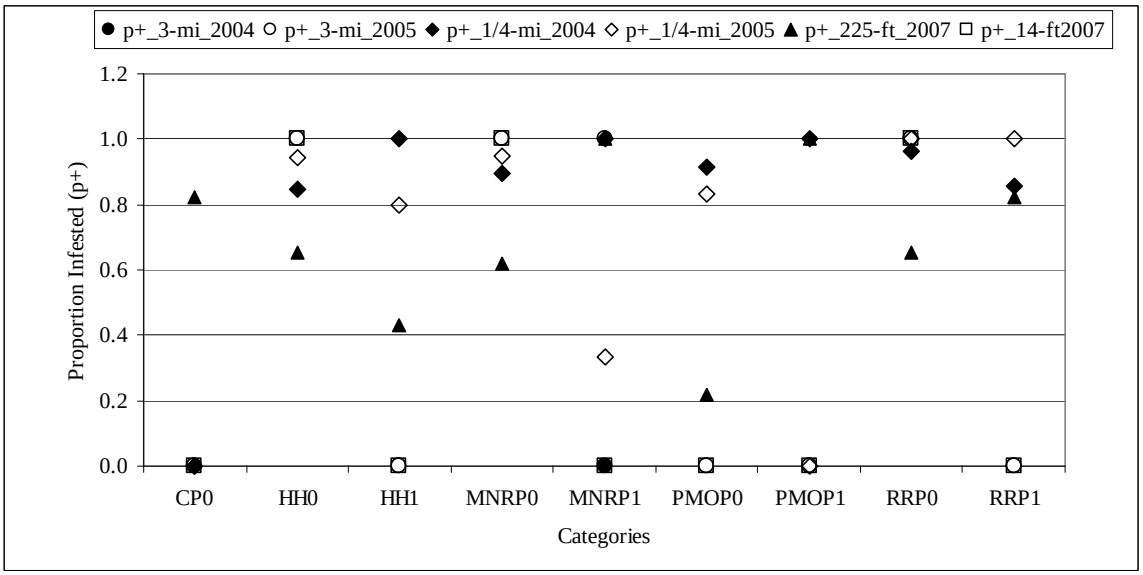


Figure 3.10 Proportion of surveyed segments infested with Canada thistle as evaluated from data recorded in surveys with ¼-mile sampling plans, in 2004 and 2005.

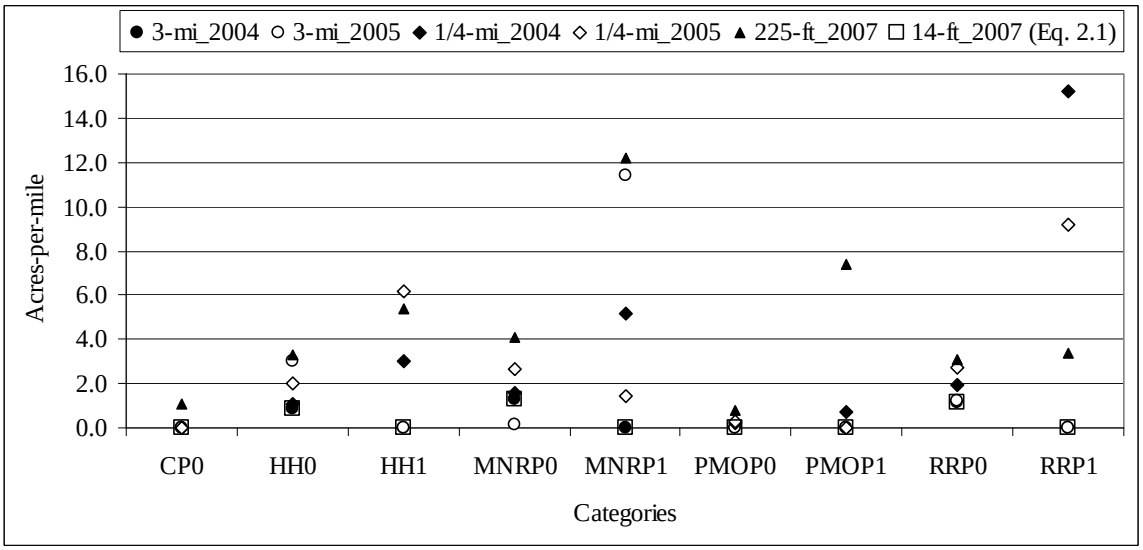


Figure 3.11 Acres-per-mile infested with Canada thistle as evaluated from data recorded in surveys with ¼-mile sampling plans, in 2004 and 2005.

3.3 Evaluation of Efficiency - 14-Ft and 225-Ft Sampling Plans

Because of the large differences in the character of species population distribution, it is necessary to evaluate sampling efficiency in application of the plans in surveying for individual weed species. Canada thistle, being the most prominent problem in Mn/DOT_D4, we shall determine the sampling efficiency in application of the plans in surveying for the species.

The first part of this determination is to evaluate the RNP (relative net precision), evaluated using equation 2.8 which is explained in section 2.5.

Data on the cost of conducting surveys was evaluated using available data of time spent inspecting sampling sites, as summarized in Table 2.5. It will be noted that many sampling sites lack data on time spent in their inspection. The remarks column attempts to explain the reasons for the missing information, with comments such as "Missing Data". However, there are many sampling sites for which data is lacking; explanations for the deficiencies have, however, not been provided.

Figure 3.12 is a graphical presentation of time spent, and personnel participation in surveying the 14-ft and 225-ft segments. This analysis facilitates computing of survey cost, based on man-hours expended in the various surveys and associated activities.

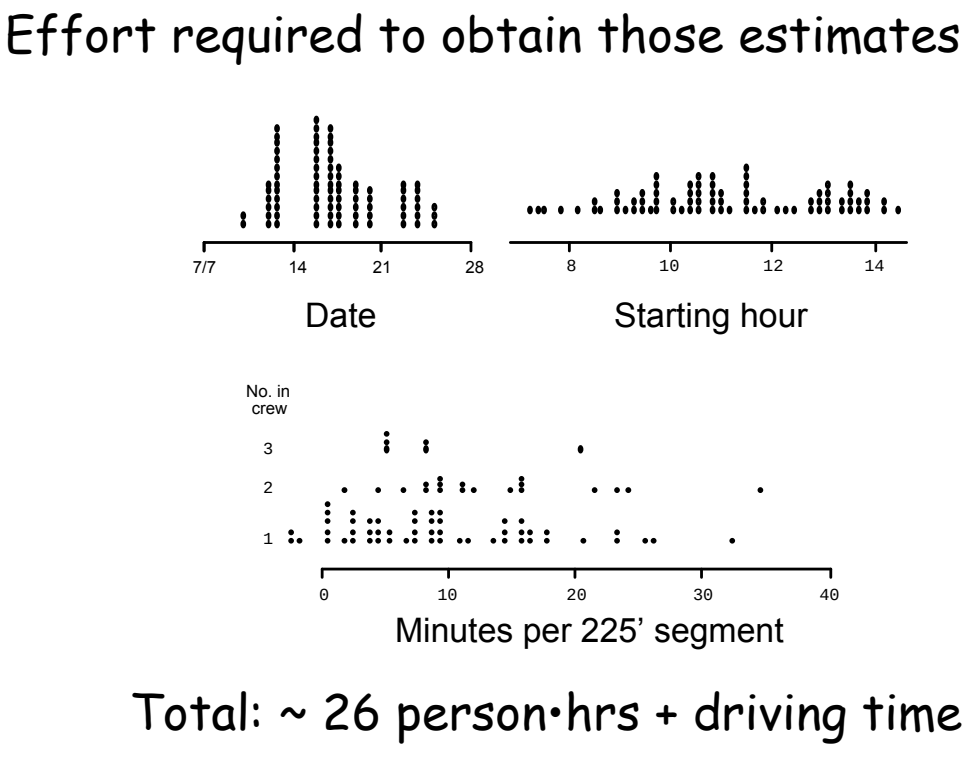


Figure 3.12 Distribution of cost in time to implement surveying procedures.

In the analysis of time data, we have adopted reasonable estimates of the maximum and minimum times within which inspection of a segment should be completed. It was estimated that inspection of a 225-ft segment could easily be completed within a time of not less that two (2) minutes, and no longer that 30 minutes. Likewise, 14-ft segments should reasonably be inspected within the range of 1 and 8 minutes. The data was edited, deleting all inspection time less than 2

minutes or greater than 30 minutes for the 225-ft sampling plans, and less than 1 minute or more than 8 minute in the 14-ft sampling plan data. Basic statistical analysis was performed on the modified data sets. Results of the analyses for the unmodified and the modified data are summarized in Tables 3.15 to 3.18.

Table 3.15 Analysis of time (hh/mm/ss) expended surveying the 14-ft sampling units

	Types of Highways (with or without median)		
	Median	**No Median**	**Combined**
Count	38	79	117
Max	0:11:40	1:59:18	1:59:18
Minimum	0:00:03	0:00:44	0:00:03
Mode	0:00:16	0:01:38	0:00:16
Median	0:01:07	0:05:07	0:03:36
Average	**0:02:08**	**0:09:11**	**0:06:54**
Std Dev.	0:02:40	0:18:37	0:15:42

Table 3.16 Analysis of time (hh/mm/ss) expended surveying the 14-ft sampling units (outliers deleted)

	Types of Highways (with or without median)		
	Median	**No Median**	**Combined**
Number of Segments	31	64	95
Max	0:04:55	0:08:45	0:07:56
Minimum	0:00:20	0:01:04	0:00:16
Median	0:01:09	0:04:43	0:03:02
Average	**0:01:39**	**0:04:31**	**0:03:14**
Std Dev.	0:01:19	0:02:05	0:02:06

Based on calculations in the analyses, the average time spent surveying a 14-ft segment in a divided highway was 2 minutes 08 seconds, while it took 9 minutes 11 seconds surveying an undivided highway. These results are unexpected. Logically, it should take longer to inspect the much larger area in segments within a divided highway, compared to those in the undivided ones. Editing the data by removing outliers did not change this trend.

Based on the overall average (3 minutes, 14 seconds derived from the edited data shown in Table 3.16) taken to inspect a 14-ft segment, the total time a surveyor would spend inspecting all 150, 14-ft segments would be 8.075 hours. This figure does not include travel time between surveyed segments, as this data was not available for application in this analysis.

Table 3.17 Analysis of time (hh/mm/ss) expended surveying the 225-ft sampling units

	Types of Highways (with or without median)		
	Median	**No Median**	**Combined**
Number of Segments	27	103	130
Max	14:40:40	5:27:04	14:40:40
Minimum	0:00:47	0:00:00	0:00:00
Median	0:10:39	0:08:54	0:09:10
Average	**1:30:30**	**0:18:25**	**0:36:00**
Std Dev.	4:08:58	0:42:43	2:09:56

Table 3.18 Analysis of time (hh/mm/ss) expended surveying the 225-ft sampling units (outliers deleted)

	Types of Highways (with or without median)		
	Median	**No Median**	**Combined**
Number of Segments	23	52	115
Max	0:23:02	0:30:28	0:30:04
Minimum	0:02:55	0:02:23	0:02:23
Median	0:10:39	0:08:31	0:08:57
Average	**0:11:00**	**0:10:08**	**0:10:02**
Std Dev.	0:05:22	0:06:32	0:05:47

In the analysis of data from surveys with 225-ft sampling plan, an average time of 1 hour, 30.5 minutes was required to complete survey of a segment in a divided highway, and 18 minutes 25 seconds to complete inspecting a segment in an undivided highway (Table 3.17). When data was edited (removing extreme values), the computed average time required to inspect a 225-ft segment in a divided highway was were 11 minutes, while it would take 10 minutes, 8 seconds to complete inspecting the same segment in an undivided highway (Table 3.18). Based on the overall average (10.02 minutes, derived from the edited data) taken to inspect segments, the total time a surveyor would spend inspecting all 100, 225-ft segments would be 16.72 hours.

Figure 3.13 below presents an accounting of time spent completing sampling inspection of a 14ft or 225ft segments. According to the graph, time spent in completing sampling survey of the 14-ft or 225-ft segment was approximately 7 minutes for the former, and 15 minutes for the latter segment. If these results are proved valid in the next study, it would appear then that there are no significant savings in costs associated with presence-absence sampling with the 'stick-walk' method compared to complete mapping of a larger (225-ft) sampling unit. However, it is recognized that there were serious problems noted, in the especially, accurate accounting of time spent in surveys with either of the two sampling plans.

3.3.1 Calculating RNP - 225-ft sampling plan

Length = 225ft = 0.042613636 miles

*C**ost***, from Table 3.18, was determined to be = 10.02 minutes
Variance = 0.81 acres-per-mile

RNP = length/cost x length/variance
= (0.0426136miles / 10.02minutes x (1hr/60minutes)) x (0.0426136miles /0.81 acres/mile)

= 8.81E-03 $miles^2$/acre-hr

3.3.2 Calculating RNP - 14-ft sampling plan

Length = 14ft = 0.00265 miles

Cost is evaluated as = 3.14 minutes (Table 3.16)
Variance = …analysis to be completed

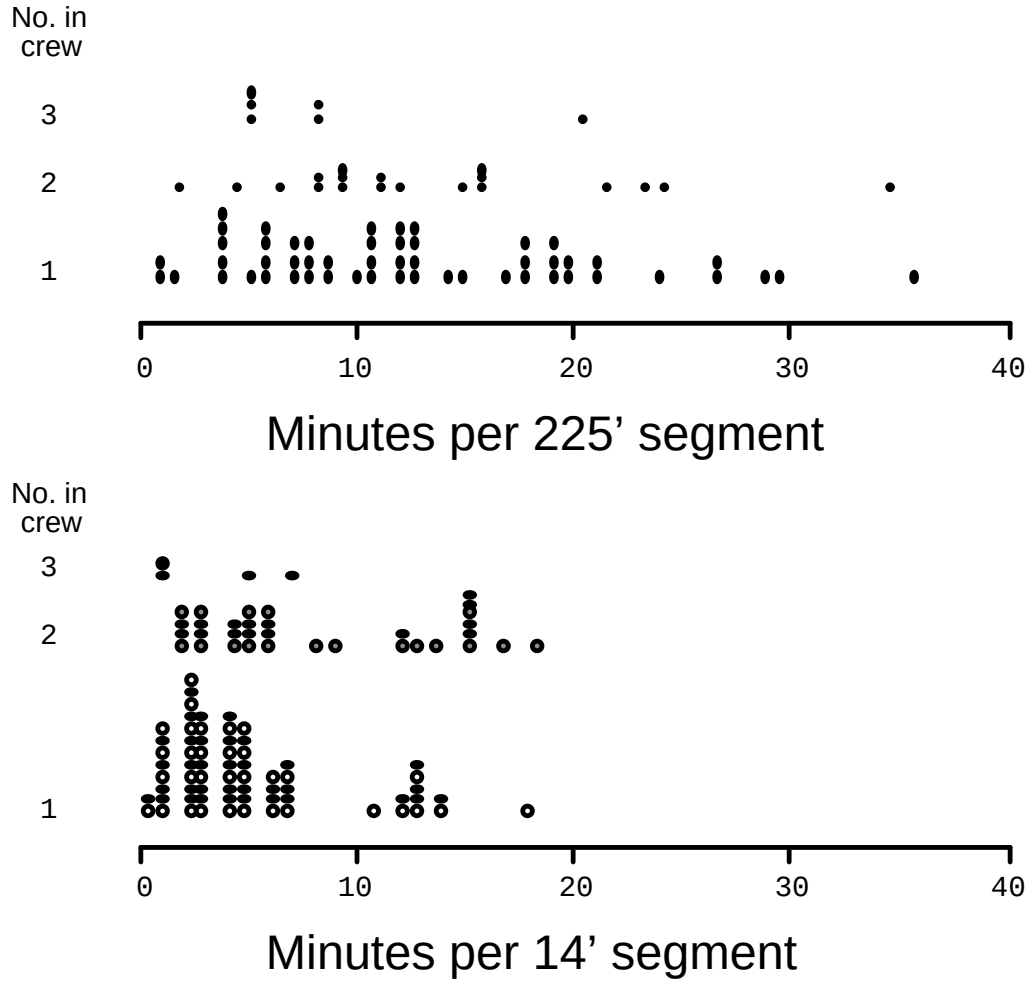


Figure 3.13 Distribution of personnel and time required to complete survey of 14-ft and 225-ft segments.

3.4 Discussion

To conduct an effective comparison of the precision possible with use of the two sampling designs (14-ft versus 225-ft segments), we need accurate data on acres-per-mile evaluated from the proportion infested by 14-ft sampling plan, to be used in the predictions with the equation by Kono and Sugino (1958). The data recorded in the 2007 surveys with the 14-ft plan (presence-absence data) could provide a maximum of nine (9) data points corresponding to weed absence/presence at the 9 categories (highway type - ecological zones classifications) within the survey area. We estimate that at least 20 data points would be necessary for a statistically valid application of the Kono and Sugino (1958) empirical model on the 14-ft sampling plan data to determine accurate acres-per-mile infested.

It is recommended that more surveys be conducted in the year 2008 using as many of both the 14-ft and 225-ft segments applied in sampling surveys at multiple study sites. Such data would aid in more precise estimations of specie infested acres-per-mile from the absence-presence data.

The surveys conducted on the original 14-ft and 225-ft sampling sites presented various challenges, including "missing data" for some sites. Tables 2.5 and 2.6 show the outcome of the surveys. This shows that, some of the selected segments were either not surveyed, were replaced by other new selected sites, or simply not surveyed and not replaced. Where the term replacement is provided in the comments column meant that the site could not be surveyed due some serious problem with it, hence was skipped and another, located within 1 mile or so, surveyed instead. The remarks column of Tables 2.5 and 2.6 provide descriptions of the reasons some of the sites could not be surveyed, was replaced by other more suitable sites, or not replaced at all.

3.5 Conclusions

The cost associated with surveys for species population is an important part of the decision on whether to apply a given survey method or not. In this phase of the project, data analysis was conducted aimed at assessing costs associated with the application of the sampling plans adopted in the 2007 surveys. The analysis evaluated time employed in surveying all sampling sites. Total time included the time spent travelling from office to the sampling sites and back, between sampling sites, and inspecting all the sampling sites.

Efforts to evaluate the relative cost of conducting surveys with the two sampling plans were partially successful, mainly because of an incomplete record of time spent in the surveys. A necessary complete record of time spent by surveyors travelling between sampling sites and the office was not maintained or available. Further, there were other problems noted in the time data, such as cases of excessively long (more than 5 hours), or too short (less than 1 minute) time having been spent inspecting some of the segments. When we deleted such time 'outliers' (the extremely large or extremely low time values), further data analysis showed that surveys with the 14-ft sampling plan generally required less than half the time taken to inspect the 225-ft segments. However, the difference in time was not reasonable and proportional to both the differences in the sizes of the sampling sites (14-ft versus 225-ft), as well as in the expected less effort required in conducting presence-absence sampling with the 14-ft segment versus complete walking mapping of an entire 225-ft segment. If these trends are repeated in the results of future implementation studies, then it would appear that savings in surveying costs expected from adopting the 14-ft 'stick-walk' (presence-absence) over mapping with 225-ft sampling plan may not be 'significantly' greater.

Application of the data being recorded in the ongoing 2008 surveys of Mn/DOT_D4 should help to refine the answer to the question of which of the two sampling plans would be more cost effective for specified sampling precision.

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