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Implementation of Methodology for Weed Management Practices - Phase II

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16. Abstract (Limit: 200 words)

In 2008 a Phase II implementation project was conducted to test whether presence/absence surveys could provide accurate and cost effective estimates of invasive weed species infestation in roadway rights-of-way within Mn/DOT District 4. A 225-ft survey, in which infested areas were mapped, was used as the standard for comparison to the presence/absence surveys which were conducted using 14-ft ‘stick walks’. A 2007 Phase I project had shown the presence/absence surveys to be more cost effective, but the infestation estimates were consistently lower than the standard. The 2008 study provided additional data to test the efficacy of the presence/absence surveys. The results of the 2008 study showed that the presence/absence surveys were significantly less costly than the standard, but the estimates of infestation themselves were not satisfactory relative to the standard scheme. From this study it is concluded that surveys should be conducted using the 225-ft sampling scheme for invasive species that form contiguous patches. The lower cost of the presence/absence surveying scheme might make it a good option for sampling of invasive weed species infestations for the case of rare species such as poison ivy which do not typically form contiguous patches.

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Implementation of Methodology for Weed Management Practices – Phase II

Final Report

Prepared by

Caleb N. Arika
John L. Nieber
Department of Bioproducts and Biosystems Engineering
University of Minnesota

Donald L .Wyse
Department of Agronomy and Plant Genetics
University of Minnesota

Roger D. Moon
Department of Entomology
University of Minnesota

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- 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
- Dean Olson, Mn/DOT_D4 South, maintenance superintendent
- Daniel Peterson, Mn/DOT_D4, maintenance supervisor, Alexandria
- Shirlee Sherkow, Mn/DOT research services and project administrative liaison

The Department of Bioproducts and Biosystems Engineering, University of Minnesota kindly placed at our disposal, facilities, equipment and administrative support for use in the project.

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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 of Minnesota Department of Transportation has been monitoring the ROWs in highways under its management (in chosen regions of the district) to quantify infestations of Canada thistle (*Cirsium arvense* (L.)(Scop.), leafy spurge (*Euphorbia esula* L.), and poison ivy (*Toxicodendron radicans*). From 2000 until 2004 the surveys employed samples comprising seven, 3-mile-long segments. In 2004, a study was initiated in which the effect of use of greater numbers of smaller (1/4-mile-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 were shortened to 225-ft or less.

Project implementation phases initiated in 2007 and continued in 2008, upon which this report is based, were aimed at investigating the efficiencies achievable in application 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 randomly selected 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, and 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 (the most abundant species) 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 from the 2007 data 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 efficient for field surveyors, with regard to travel time to sampling sites and associated sampling tasks. 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.

Based on further testing of the Kono and Sugino (1958) model using data collected in 2008 survey season, our conclusion is that it is not likely that presence-absence sampling can be used in similarly conducted surveys to estimate weed infestations. This is because when we fitted obtained data to the Kono and Sugino model, estimation variances were quite large. Since this equation is critical in estimating weed infestation densities based on the proportions infested values evaluated from data acquired in surveys with the 14-ft plan, highly inaccurate results would be achieved.

Analysis of survey time data revealed significant differences in costs associated with use of the 225-ft segments (1.06 man-hours per 6 segments) versus the 14-ft segments (0.5 man-hours per 6 segments). Among the three components to surveying time (traveling from office to first segment, and back from last segment, scouting individual segments, and finally transit between segments), the largest difference in cost of surveying the 14-ft and 225-ft segments was in scouting, averaging 3.7 minutes and 28 minutes, respectively. Transit time among 225-ft was 24 minutes compared to 15 minutes for the 14-ft; average time spent traveling to and from office was 41 minutes for both segments.

Whereas the obtained results do not support use of presence-absence surveys to estimate areas infested by individual species, the associated low surveying costs makes this an attractive alternative for detection of rare species in highway rights-of-way if sufficiently large number of sampling sites are adopted.

1.0 INTRODUCTION

Departments of Transportation are required by law 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 large and irregular, and the necessary information on location and distribution of the species difficult to obtain. Traditionally, data on location of vegetation over landscapes is obtained by conducting inventories of the entire highway ROWs, which can be costly and time consuming. This has necessitated instances where data acquired from inspection of few carefully selected sampling sites is applied to estimating population distribution 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 in an effort quantify population distribution of three problem weed species in the District's highway ROWs. The surveys were aimed at identifying the location and distribution characteristics 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 the validity of applying the data obtained using this sampling design to evaluate infestation over the entire District, new survey designs were tested in surveys conducted in 2004 and 2005. The surveys adopted samples comprising 100, 1/4-mile segments selected following different randomizing methods (complete random and stratified random selection). Strata were based on ecological zones and types of highways (with or without median) in the district. The 3-mi and 1/4-mi sampling plans were tested in surveys conducted in 2004 and 2005, with the results presented in tables 1.1 to 1.4. The analysis of these data sets showed the sampling plans yielding comparable values of mean infested acres-per-mile. Comparisons of the district level acres-per-mile values from surveys using the two sampling plans 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 areal density (acre/mile) infested by Canada thistle, leafy spurge and poison ivy in Mn/DOT_D4 highway rights-of-ways as evaluated from 3-mile and ¼-mile surveys for the 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 areal density (acre/mile) infested by Canada thistle, leafy spurge and poison ivy in Mn/DOT_D4 highway rights-of-way as evaluated from 3-mile and ¼-mile surveys for the 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

Table 1.3: A comparison of mean areal density (acre/mile) infested by Canada thistle, leafy spurge and poison ivy on highway rights-of-way in individual ecological zones and the entire Mn/DOT_D4, as evaluated from data recorded in surveys with 3-mile and ¼-mile sampling plans for the 2005 surveys.

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 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 areal density (acre/mile) infested by Canada thistle, leafy spurge and poison ivy in highways rights-of-way in ecological zones and the entire Mn/DOT_D4, as 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 same symbol within a **Column** for a species are **not** significantly different ($\alpha = 0.05$).
@ "-" Data not available.

These results appear to suggest that larger numbers of representative samples would achieve higher sensitivities in detection of differences among species infestation densities across larger study areas. These findings have inspired further investigations into use of a larger number of small size sampling units in more intensive surveys. In the proposed studies, data recorded in the 2004 and 2005 surveys using the ¼-mi and 3-mi sampling plans were sectioned into smaller units, re-sampled, and then analyzed.

Using GIS tools, data acquired on species infestation of Mn/DOT_D4 by surveys conducted using the 3-mi and ¼-mi sampling plans in 2004 and 2005 seasons, was sliced into shorter units. The 3-mi data sets were sectioned into 1/10th, 5/10th and 1-mile lengths then applied in analyses to estimate achievable precisions with their application in sampling surveys of Mn/DOT_D4. The obtained results seem to imply that improvements in precision (relative net precision, RNP) would be realized with use of subsequently shorter sampling units. The shortest unit (1/10th mile) yielded the highest RNP for all surveyed species (Table 1.5). Sectioning of the ¼-mi data within ecological zones into 0.05, 0.1, 0.15 and 0.2 unit length, also showed trends as obtained for the 3-mi sampling pan data. The shortest unit (0.05-mi) yielded the highest RNP among all weed species, and across all ecological zones as shown in Table 1.6. These findings have been further tested during the project implementation Phases I of 2007 and Phase II conducted in 2008. Based on the results, it could logically be deduced that further reductions in sampling unit length might result in improved sampling efficiencies.

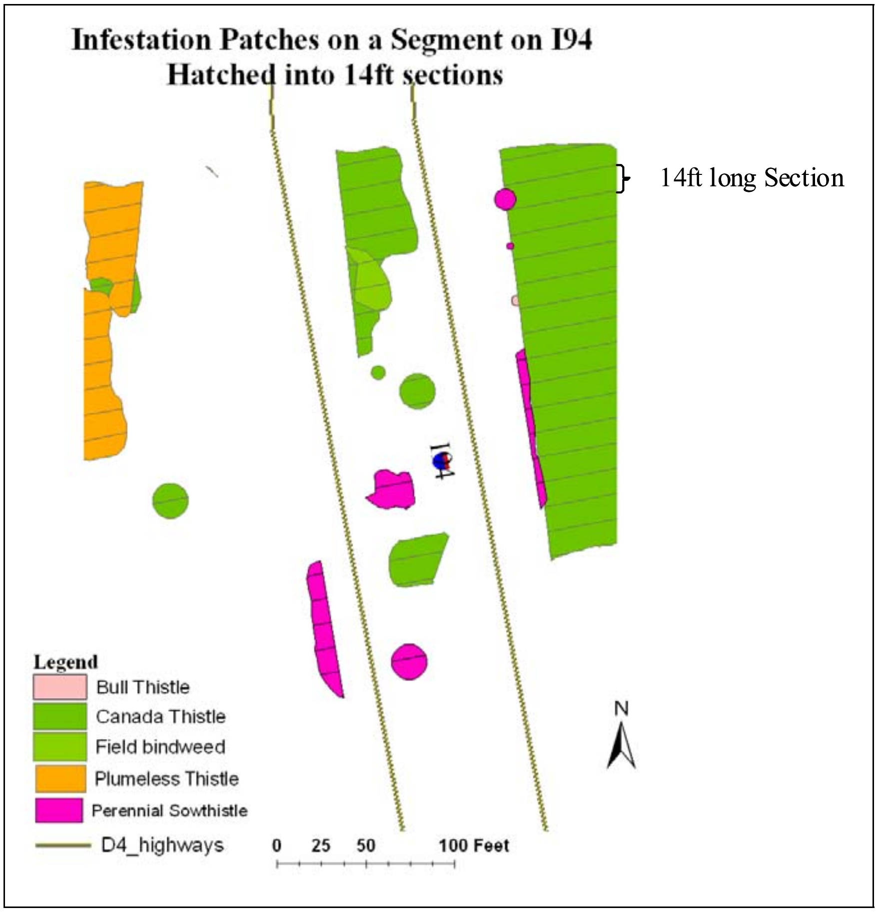


Figure 1.1: Illustration of the result of hatching mapped patches in a 225-ft segment located on US Highway I94, which are infested by indicated weed species (Bull thistle, Canada thistle, Field bindweed and Perennial sowthistle) into 14-ft lengths.

Table 1.5: Relative net precision (RNP) of different sub-segment lengths for estimating mean areal density (acres per road mile) infested by three noxious weeds, based on N = 4,999 re-sampling of 7 original 3 mi segments.

Sub-segment Length (mi)	Canada thistle		Poison ivy		Leafy spurge	
	2004	2005	2004	2005	2004	2005
1/10th	**0.39***	**0.21**	**4.71**	**7.10**	**13.96**	528
5/10th	0.14	0.09	2.17	3.11	8.25	630
1	0.13	0.07	1.72	3.22	9.21	**720**

Relative net precision for a given length is defined as RNP = (length/cost)*(length/variance).

*Key: * Within each column (species x year), the sub-segment length with the largest RNP (bold) was the most efficient sample unit.*

Table 1.6: Summary statistics and relative net precision (RNP) of different sub-segment lengths for estimating areal density (acres per mile) infested by Canada thistle, based on N = 4,999 re-samplings of ~100 original 1/4 mi segments, grouped by ecological regions in Mn/DOT_D4.

	Chippewa plains		Hardwood hills		MN River prairie		Pine moraines		Red River prairie	
Statistic	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
No. sampled:	0	1	16	23	35	42	13	6	34	31
No. infested:	–	1	14	20	32	38	11	6	32	31
Mean:	–	0.02	1.17	2.64	1.96	2.56	0.23	0.31	2.30	3.64
Variance:	–	–	3.73	13.25	3.27	5.46	0.15	0.07	5.55	14.64
Sub-segment length (mi)										
0.004	?	?	?	?	?	?	?	?	?	?
0.050	–	–	0.20	0.06	0.18	0.13	2.71	5.96	0.14	0.05
0.100	–	–	0.10	0.04	0.10	0.08	1.93	4.51	0.07	0.03
0.150	–	–	0.07	0.03	0.07	0.05	1.36	3.36	0.05	0.02
0.200	–	–	0.06	0.02	0.06	0.05	1.41	3.22	0.04	0.02

(? What is the expected RNP for 0.004 mi segment – Based on observed trend, RNP will be even higher)

Based on the prior results, Phase II of project implementation was carried out to further investigate sampling efficiencies of the short sampling units, i.e. the 225-ft (0.05 mile) and 14-ft (0.0026 mile) segments.

1.1 SUMMARY PHASE I AND PHASE II STUDIES

This report details work completed in the implementation Phase II 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 adopted the methods developed in the main project to quantify the spatial distribution of invasive weed species in highway rights-of-way spaces in Mn/DOT_D4. This phase was conducted to establish whether adoption of the main project's recommended sampling plan could lead to reduction in time expended in surveying the Mn/DOT_D4 ROW spaces, while simultaneously enhancing the precision of species population estimations.

In the two project phases, data sets recorded with the 225-ft sampling units were sectioned into 14-ft (0.0026-mi) units and subjected to statistical analyses. Project implementation Phases I and II have been carried out to continue with testing of the project findings that use of shorter sampling units would result in improved sampling precision.

1.2 PROJECT OBJECTIVES AND ACTIVITIES

The main objective of Phase II of the project implementation was to further the investigations initiated in Phase I investigating of verifying the key findings of the main project. Field surveys and data recording, data processing, and statistical analysis were conducted following the methodologies developed in the main research project. The following were the specific objectives:

- Investigate sampling efficiencies of 225-ft and 14-ft sampling plans
- Evaluate the costs associated with adoption of 225-ft and 14-ft sampling surveys.

To achieve these objectives, the following tasks were undertaken:

- Processing and preparation of survey data recorded in 2008 surveys conducted by personnel of Mn/DOT_D4, and
- Statistical analysis of the data to:
    - Evaluate potential for application of two sampling methodologies developed in the Mn/DOT sponsored research project in assessing weed population distribution in Mn/DOT_ D4
    - 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 2008, compare and contrast cost of using each of the two sampling plans in surveys of the district highways rights-of-way.

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 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, included evaluation processing, and analyzing the recorded time data spent by operators to inspect the surveyed segments (about 100 225-ft, and 150 14-ft), travelling between the sampling units, travelling from and to office, servicing equipment, and others, to assess the actual cost associated with the application of either sampling plan to map weed infestation of the study area. Further analyzes tested efficacy of application of the proposed small samples (14-ft) design for presence-absence, or ‘stickwalks’ surveying of Mn/DOT_D4, and elsewhere.

2.0 MATERIALS AND METHODS

Field surveys were conducted in Mn/DOT district 4 located in the western part of Minnesota, shown in Figure 2.1. The sample used in the surveys was selected following methods described in section 2.1.

Surveys were conducted in the summer of 2008 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 noxious species in the Minnesota Prohibited weeds list. These include 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 (*Centaurea maculosa*). 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: Marty Ringquist, Paul Bakken, Bernie Koch, Jeff Reuss, Dave Staples, Dan Peterson, Steve Nelson and Paul Christeson. Data files which were cleaned and differentially corrected by Mandy Uhrich of Mn/DOT were forwarded to the University of Minnesota research team.

Selection of the sampling sites for adoption in this study was based on procedures in which the study area was categorized based on ecological regions and types of highways (with or without median). The next step involved plugging data acquired in previous years' surveys in a tool (Figure 2.4 below) developed in MS Excel® to optimize distribution of number of sampling sites per category, with the number of sampling sites being proportional to the number of roadway miles in each category. Table 2.1 shows the categories and optimum distribution of sampling sites selected for adoption by the two sampling plans. The details on the procedures for sample selection are described in the User Guide (Arika et al., 2007b). Selection of the 225-ft and 14/ft segments was effected using the population of 1/10-mile segments for the entire Mn/DOT_D4 highway miles. To simplify the process of selection of sites and for ease of navigation to each site in the field, we substituted the 225ft and 14-ft mileposts with the $1/10^{th}$ -mile ones. 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 selected sampling sites, and associated generated random number, are 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).

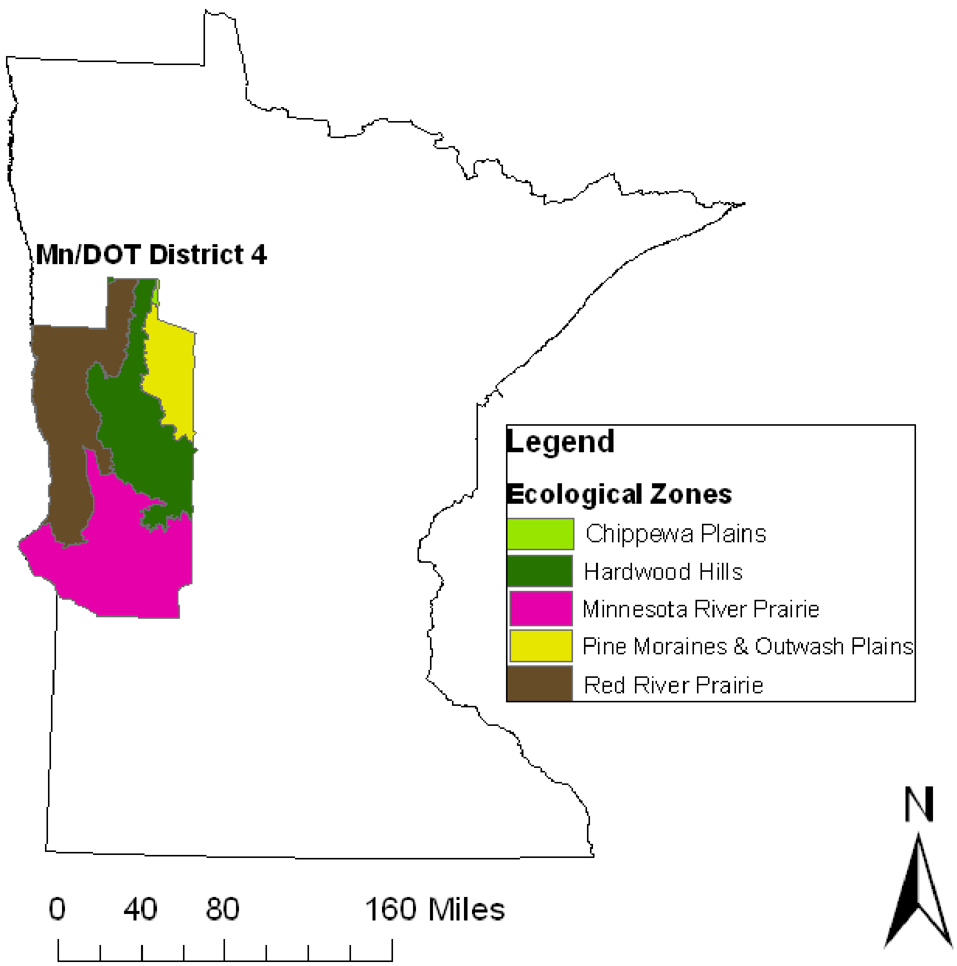


Figure 2.1: Location and ecological zone boundaries of Mn/DOT_D4 within Minnesota (Arika et al., 2007b).

2.1 SELECTION OF SAMPLING SITES

Selection of sampling sites was carried out by Mn/DOT personnel with consultations with the principal investigators. The selection followed the same procedures adopted during 2007 surveys, with the optimum number of sampling sites for each category selected with the aid of the spreadsheet in Figures 2.2 to 2.4. Selected sampling sites are shown in the same figures.

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	
										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	

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

Figure 2.2: Application of previous season Canada thistle infestation data to determine the optimal number of sampling sites (acceptable lowest measurement Standard Error, SE) for adoption in the next season's (2008) surveys.

Summary of previous sample	
whole district combined…	
Mean, acres per mile	3.50
SE:	0.38
Margin of error (ME):	0.75
ME/Mean (as %)	21.5
100(1-Alpha)% confidence limits	
Lower	**2.75**
Mean, acres per mile	**3.50**
Upper	**4.25**
Estimated district-wide total acres	
Lower confidence limit	**4,483**
Estimate	**5,710**
Upper confidence limit	**6,937**
Old total segments:	83
n(e)	58.8
df:	58
alpha:	**0.05**
Corresponding Student's t:	2.002

"alpha" is the chosen level of confidence (a probability of making a type-I error), set by user. 95% confidence, alpha = 0.05.

Figure 2.3: Application of previous season Canada thistle infestation data to determine the optimal number of sampling sites (acceptable lowest 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:		110.4
SegmentLength, mi:	0.042613636	
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 2.4: Application of previous season data to determine the optimal number of sampling sites (minimum accepted Mean Error, ME) and their optimal distribution in the study area for next season's surveys.

Selection of optimum samples was conducted with application of the previous season surveys data of the same study area. Figures 2.2, 2.3, and 2.4 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/mile) and the data further analyzed to determine mean infested, standard deviation, variance and mean errors for each of the nine categories within the study area, which can be observed in Figure 2.2. Figure 2.4 shows results of the application of data recorded in surveys with conducted in 2007 using the 225-ft segments plan, to evaluate 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.

Table 2.1: Population of possible sampling sites, and determined 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

For the chosen optimum sample size, the Mean /ME (%) Error (shaded in Figure 2.4), 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.

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.

Table 2.2: A portion of the potential sites from complete list of Mn/DOT_D4 highway reference posts which were applied in random selection of sites for adoption in 2008 surveys.

S/No.	Category	SubDistrict	Median	RoadNum	MP.10th	Easting	Northing	Rand()
5396	MNRP-0	Morris	0	MN114	5.10	303727.46	5062028.63	5.58E-05
3792	MNRP-0	Alex	0	MN79	11.00	287038.07	5097079.38	0.000114
12122	RRP-0	Fergus	0	MN9	123.10	226156.15	5136412.22	0.000122
5519	MNRP-0	Morris	0	MN7	7.30	210800.31	5040459.43	0.000205
1831	HH-0	Fergus	0	MN108	25.00	281830.31	5158299.44	0.000361
5097	MNRP-0	Fergus	0	US59	206.60	268338.41	5112280.48	0.000385
531	HH-0	Alex	0	MN108	51.50	307419.55	5144542.17	0.000404
8793	MNRP-0	Morris	0	US59	136.60	262799.59	5010732.63	0.000493
5540	MNRP-0	Morris	0	US12	7.70	240095.27	5021420.9	0.00059
7542	MNRP-0	Morris	0	MN28	44.50	266661.43	5050774.91	0.000664
11486	RRP-0	Fergus	0	MN108	7.10	256138.63	5161967.99	0.000969
7099	MNRP-0	Morris	0	MN104	36.80	313728.72	5050252.36	0.000982
11539	RRP-0	Fergus	0	MN34	8.10	251211.17	5172451.28	0.000996
2892	HH-0	Moorhead	0	US59	259.10	280152.13	5182484.91	0.001057
10357	PMOP-0	Moorhead	0	MN87	19.60	319344.65	5181168.35	0.001066
11372	RRP-0	Fergus	0	MN55	4.20	230484.58	5105115.28	0.001072
10899	PMOP-0	Moorhead	0	MN34	62.80	322678.84	5197721.5	0.001084
12975	RRP-0	Fergus	0	US59	225.70	259277.11	5138075.45	0.001133
2641	HH-0	Moorhead	0	MN200	57.00	292452.16	5244876.52	0.001365
14769	RRP-0	Morris	0	MN27	31.70	239843.37	5077584.13	0.001379
896	HH-0	Alex	0	MN27	71.70	302597.35	5079239.65	0.001399
5874	MNRP-0	Morris	0	MN7	14.60	218341.58	5035069.99	0.001603
6919	MNRP-0	Morris	0	MN9	33.50	299959.19	5022267.48	0.001772
15101	RRP-0	Morris	0	US75	169.90	230430.95	5074080.96	0.001817
4299	MNRP-0	Alex	0	MN29	66.90	314172.19	5062120.08	0.001828
1085	HH-0	Alex	0	MN27	81.20	316404.24	5084473.34	0.001832
15738	RRP-1	Fergus	1	I94	56.60	261037.82	5128482.08	0.001841
5339	MNRP-0	Morris	0	MN7	3.90	211011.79	5046859.89	0.001845
6090	MNRP-0	Morris	0	MN7	18.60	223793.38	5032519.43	0.001891
16185	RRP-1	Moorhead	1	US10	24.30	250954.27	5196715.81	0.001949
1960	HH-0	Fergus	0	MN78	31.40	295951.78	5138874.92	0.001983
1840	HH-0	Fergus	0	MN78	25.40	290740.70	5133651.7	0.002042
4421	MNRP-0	Alex	0	MN55	71.60	315389.49	5057583.06	0.002113

Table 2.3: Selected 100 225-ft sampling sites adopted in surveys conducted in 2008.

S/No.	SubDistrict	Category	Hwy-RefSpot	S/No.	SubDistrict	Category	Hwy-RefSpot	S/No.	SubDistrict	Category	Hwy-RefSpot
1	Alexandria	MNRP-1	I94-079.9	35	Fergus Falls	RRP-0	MN9-103.9	69	Moorhead	RRP-0	US75-233.4
2	Alexandria	MNRP-1	I94-082.8	36	Fergus Falls	RRP-0	MN9-127.5	70	Morris	MNRP-0	MN104-026.9
3	Alexandria	MNRP-1	I94-091.6	37	Fergus Falls	RRP-0	MN9-135.7	71	Morris	MNRP-0	MN104-032.6
4	Alexandria	HH-1	I94-098.2	38	Fergus Falls	RRP-0	MN9-138.9	72	Morris	MNRP-0	MN119-014.1
5	Alexandria	HH-1	I94-0102.4	39	Fergus Falls	RRP-0	MN9-160.0	73	Morris	RRP-0	MN27-025.0
6	Alexandria	HH-1	I94-0106.7	40	Fergus Falls	PMOP-1	US10-073.9	74	Morris	RRP-0	MN27-026.5
7	Alexandria	PMOP-0	MN106-07.3	41	Fergus Falls	PMOP-1	US10-082.5	75	Morris	MNRP-0	MN27-042.5
8	Alexandria	HH-0	MN108-058.7	42	Fergus Falls	RRP-0	US59-207.2	76	Morris	MNRP-0	MN27-052.2
9	Alexandria	HH-0	MN108-059.1	43	Fergus Falls	RRP-0	US59-207.9	77	Morris	MNRP-0	MN28-006.7
10	Alexandria	MNRP-0	MN27-065.8	44	Fergus Falls	HH-0	US59-237.1	78	Morris	MNRP-0	MN28-045.8
11	Alexandria	HH-0	MN27-084.5	45	Fergus Falls	RRP-0	US75-214.1	79	Morris	MNRP-0	MN28-051.7
12	Alexandria	MNRP-0	MN29-067.1	46	Moorhead	HH-0	MN113-022.0	80	Morris	MNRP-0	MN28-057.2
13	Alexandria	HH-0	MN29-098.4	47	Moorhead	RRP-0	MN200-047.4	81	Morris	MNRP-0	MN28-064.0
14	Alexandria	HH-0	MN29-104.6	48	Moorhead	CP-0	MN200-066.0	82	Morris	MNRP-0	MN29-030.4
15	Alexandria	HH-0	MN29-109.9	49	Moorhead	CP-0	MN200-066.1	83	Morris	MNRP-0	MN29-045.6
16	Fergus	RRP-1	I94-012.8	50	Moorhead	RRP-0	MN32-018.8	84	Morris	MNRP-0	MN7-013.1
17	Fergus	RRP-1	I94-014.1	51	Moorhead	RRP-0	MN32-026.6	85	Morris	MNRP-0	MN7-013.8
18	Fergus	RRP-1	I94-021.1	52	Moorhead	HH-0	MN34-037.9	86	Morris	MNRP-0	MN7-038.7
19	Fergus	RRP-1	I94-021.6	53	Moorhead	PMOP-0	MN34-058.4	87	Morris	MNRP-0	MN9-032.3
20	Fergus	RRP-1	I94-023.4	54	Moorhead	RRP-0	MN9-172.7	88	Morris	MNRP-0	MN9-034.9
21	Fergus	RRP-1	I94-023.5	55	Moorhead	RRP-0	MN9-179.4	89	Morris	MNRP-0	MN9-054.3
22	Fergus	RRP-1	I94-037.5	56	Moorhead	RRP-1	US10-012.0	90	Morris	MNRP-0	MN9-073.5
23	Fergus	RRP-1	I94-047.1	57	Moorhead	RRP-1	US10-024.1	91	Morris	MNRP-0	MN9-076.7
24	Fergus	RRP-1	I94-052.4	58	Moorhead	RRP-1	US10-025.5	92	Morris	MNRP-0	US12-040.3
25	Fergus	HH-1	I94-067.7	59	Moorhead	RRP-1	US10-026.8	93	Morris	MNRP-0	US59-172.8
26	Fergus	HH-0	MN108-035.2	60	Moorhead	HH-1	US10-027.8	94	Morris	MNRP-0	US59-172.8
27	Fergus	RRP-0	MN210-015.5	61	Moorhead	HH-1	US10-029.7	95	Morris	MNRP-0	US59-173.4
28	Fergus	RRP-0	MN210-018.2	62	Moorhead	HH-0	US59-250.6	96	Morris	MNRP-0	US59-181.7
29	Fergus	HH-0	MN32-004.4	63	Moorhead	HH-0	US59-260.6	97	Morris	MNRP-0	US75-140.2
30	Fergus	HH-0	MN32-005.6	64	Moorhead	HH-0	US59-265.2	98	Morris	MNRP-0	US75-156.4
31	Fergus	RRP-0	MN32-009.2	65	Moorhead	RRP-0	US59-278.1	99	Morris	RRP-0	US75-165.4
32	Fergus	MNRP-0	MN55-021.5	66	Moorhead	RRP-0	US59-281.9	100	Morris	RRP-0	US75-174.5
33	Fergus	MNRP-0	MN55-023.8	67	Moorhead	RRP-0	US59-294.8				
34	Fergus	HH-0	MN78-033.1	68	Moorhead	RRP-0	US59-307.3				

Table 2.4: Selected 150 14-ft sampling sites adopted in surveys conducted in 2008.

S/No.	SubDistrict	Category	Hwy-RefSpot	S/No.	SubDistrict	Category	Hwy-RefSpot	S/No.	SubDistrict	Category	Hwy-RefSpot
1	Alexandria	MNRP-1	I94-108.7	35	Fergus Falls	RRP-1	I94-048.1	69	Moorhead	RRP-1	I94-010.0
2	Alexandria	MNRP-1	I94-074.8	36	Fergus Falls	RRP-1	I94-054.7	70	Moorhead	RRP-1	I94-03.5
3	Alexandria	MNRP-1	I94-085.8	37	Fergus Falls	RRP-1	I94-065.5	71	Moorhead	RRP-1	I94-05.6
4	Alexandria	MNRP-1	I94-090.0	38	Fergus Falls	HH-1	I94-068.3	72	Moorhead	RRP-0	MN9-167.1
5	Alexandria	HH-1	I94-094.9	39	Fergus Falls	RRP-0	MN9-102.2	73	Moorhead	RRP-0	MN32-019.8
6	Alexandria	HH-1	I94-096.4	40	Fergus Falls	RRP-0	MN9-107.1	74	Moorhead	RRP-0	MN32-025.7
7	Alexandria	HH-0	MN27-067.2	41	Fergus Falls	RRP-0	MN9-134.3	75	Moorhead	RRP-0	MN32-028.0
8	Alexandria	HH-0	MN27-091.1	42	Fergus Falls	RRP-0	MN9-134.5	76	Moorhead	RRP-0	MN113-017.8
9	Alexandria	MNRP-0	MN28-085.1	43	Fergus Falls	RRP-0	MN9-135.4	77	Moorhead	HH-0	MN113-025.2
10	Alexandria	HH-0	MN29-104.7	44	Fergus Falls	RRP-0	MN9-141.0	78	Moorhead	PMOP-0	MN113-045.2
11	Alexandria	HH-0	MN29-084.9	45	Fergus Falls	RRP-0	MN9-144.8	79	Moorhead	CP-0	MN200-065.5
12	Alexandria	HH-0	MN29-095.0	46	Fergus Falls	RRP-0	MN9-148.4	80	Moorhead	CP-0	MN200-065.8
13	Alexandria	MNRP-0	MN54-010.4	47	Fergus Falls	RRP-0	MN32-02.1	81	Moorhead	PMOP-0	MN225-0.0
14	Alexandria	MNRP-0	MN55-032.8	48	Fergus Falls	RRP-0	MN34-07.1	82	Moorhead	RRP-1	US10-012.2
15	Alexandria	MNRP-0	MN55-053.4	49	Fergus Falls	RRP-0	MN55-01.7	83	Moorhead	RRP-1	US10-017.9
16	Alexandria	MNRP-0	MN55-065.6	50	Fergus Falls	RRP-0	MN55-017.5	84	Moorhead	HH-1	US10-032.1
17	Alexandria	HH-0	MN78-015.8	51	Fergus Falls	RRP-0	MN55-02.4	85	Moorhead	RRP-1	US10-033.8
18	Alexandria	HH-0	MN78-016.3	52	Fergus Falls	HH-0	MN78-038.5	86	Moorhead	RRP-1	US10-036.1
19	Alexandria	HH-0	MN78-019.6	53	Fergus Falls	HH-0	MN78-039.1	87	Moorhead	RRP-1	US10-036.5
20	Alexandria	MNRP-0	MN78-02.3	54	Fergus Falls	HH-0	MN108-010.8	88	Moorhead	HH-1	US10-051.1
21	Alexandria	HH-0	MN78-09.4	55	Fergus Falls	HH-0	MN108-019.2	89	Moorhead	HH-1	US10-051.9
22	Alexandria	HH-0	MN114-017.1	56	Fergus Falls	HH-0	MN108-034.3	90	Moorhead	RRP-1	US10-06.1
23	Alexandria	HH-0	MN210-066.4	57	Fergus Falls	RRP-0	MN210-029.8	91	Moorhead	HH-1	US10-061.8
24	Alexandria	HH-0	MN210-070.4	58	Fergus Falls	HH-0	MN210-043.2	92	Moorhead	HH-1	US10-062.4
25	Alexandria	HH-0	MN235-02.2	59	Fergus Falls	HH-0	MN210-045.1	93	Moorhead	HH-0	US59-256.4
26	Alexandria	MNRP-0	MN28-081.7	60	Fergus Falls	RRP-0	MN9-101.7	94	Moorhead	HH-0	US59-266.1
27	Alexandria	HH-0	MN29-097.4	61	Fergus Falls	HH-1	US10-072.1	95	Moorhead	RRP-0	US59-281.3
28	Fergus Falls	RRP-1	I94-014.8	62	Fergus Falls	HH-1	US10-072.3	96	Moorhead	RRP-0	US59-293.6
29	Fergus Falls	RRP-1	I94-022.4	63	Fergus Falls	PMOP-1	US10-087.4	97	Moorhead	RRP-0	US59-301.2
30	Fergus Falls	RRP-1	I94-028.2	64	Fergus Falls	PMOP-1	US10-088.3	98	Moorhead	RRP-0	US59-309.4
31	Fergus Falls	RRP-1	I94-030.0	65	Fergus Falls	RRP-0	US59-234.4	99	Moorhead	RRP-0	US59-310.0
32	Fergus Falls	RRP-1	I94-036.1	66	Fergus Falls	RRP-0	US75-210.0	100	Moorhead	RRP-0	US75-242.6
33	Fergus Falls	RRP-1	I94-040.2	67	Fergus Falls	RRP-0	US75-224.7	101	Moorhead	RRP-0	US75-247.3
34	Fergus Falls	RRP-1	I94-041.3	68	Fergus Falls	RRP-0	US75-230.7	102	Moorhead	RRP-0	US75-254.1

Table 2.4: Selected 150 14-ft sampling sites adopted in surveys conducted in 2008. (cont…)

S/No.	SubDistrict	Category	Hwy-RefSpot	S/No.	SubDistrict	Category	Hwy-RefSpot
103	Morris	MNRP-0	MN7-0.0	137	Morris	MNRP-0	US12-047.4
104	Morris	MNRP-0	MN7-036.2	138	Morris	MNRP-0	US59-144.9
105	Morris	MNRP-0	MN7-039.0	139	Morris	MNRP-0	US59-169.3
106	Morris	MNRP-0	MN7-08.6	140	Morris	MNRP-0	US59-170.0
107	Morris	MNRP-0	MN7-09.8	141	Morris	MNRP-0	US59-173.8
108	Morris	MNRP-0	MN9-023.3	142	Morris	MNRP-0	US75-128.0
109	Morris	MNRP-0	MN9-080.3	143	Morris	MNRP-0	US75-134.4
110	Morris	RRP-0	MN9-082.8	144	Morris	MNRP-0	US75-134.8
111	Morris	MNRP-0	MN27-018.8	145	Morris	MNRP-0	US75-151.9
112	Morris	RRP-0	MN27-028.4	146	Morris	MNRP-0	US75-159.2
113	Morris	RRP-0	MN27-032.7	147	Morris	MNRP-0	US75-159.5
114	Morris	MNRP-0	MN27-043.8	148	Morris	RRP-0	US75-161.8
115	Morris	MNRP-0	MN27-044.7	149	Morris	RRP-0	US75-168.1
116	Morris	MNRP-0	MN27-08.8	150	Morris	RRP-0	US75-178.6
117	Morris	MNRP-0	MN28-017.7				
118	Morris	MNRP-0	MN28-023.2				
119	Morris	MNRP-0	MN28-034.7				
120	Morris	MNRP-0	MN28-048.5				
121	Morris	MNRP-0	MN28-054.2				
122	Morris	MNRP-0	MN28-058.4				
123	Morris	MNRP-0	MN28-065.8				
124	Morris	MNRP-0	MN29-024.0				
125	Morris	MNRP-0	MN29-039.6				
126	Morris	MNRP-0	MN29-041.1				
127	Morris	MNRP-0	MN29-042.3				
128	Morris	MNRP-0	MN29-047.5				
129	Morris	MNRP-0	MN104-026.4				
130	Morris	MNRP-0	MN104-027.7				
131	Morris	MNRP-0	MN119-014.7				
132	Morris	RRP-0	MN27-033.3				
133	Morris	MNRP-0	MN29-050.6				
134	Morris	MNRP-0	MN54-0.8				
135	Morris	MNRP-0	MN7-039.5				
136	Morris	MNRP-0	US12-037.2				

The distribution of sites which were surveyed from among the selected 100 225-ft and 150 14-ft segments are as shown in maps, Figures 2.5, 2.6 and 2.7.

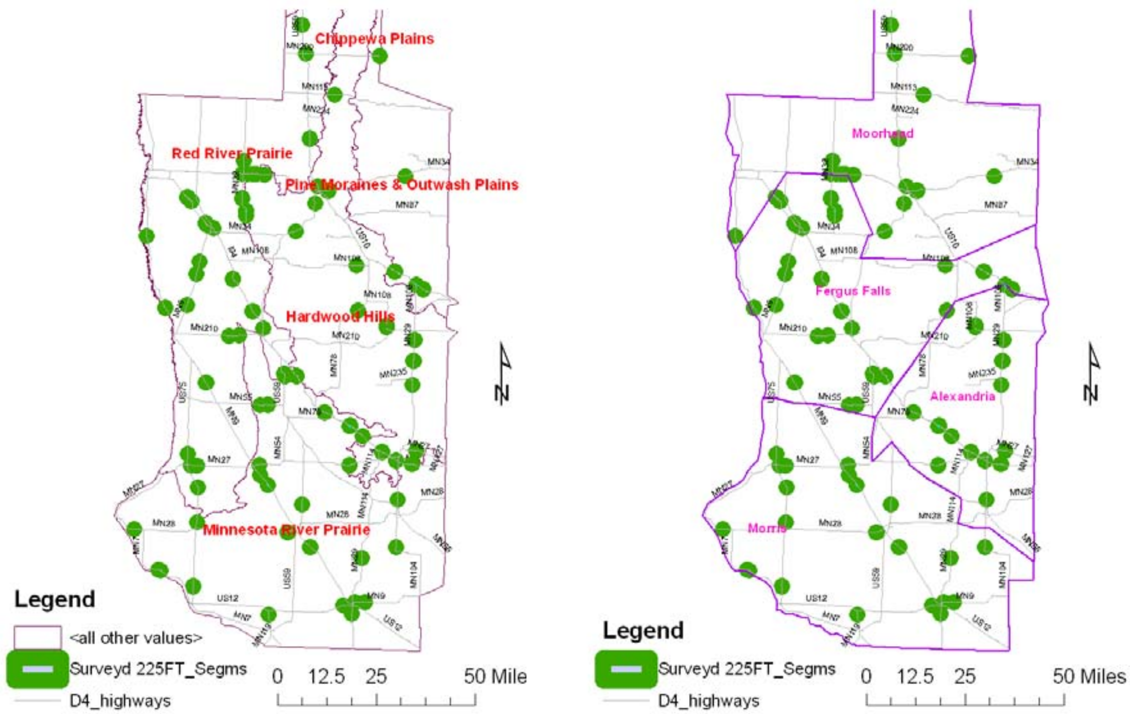
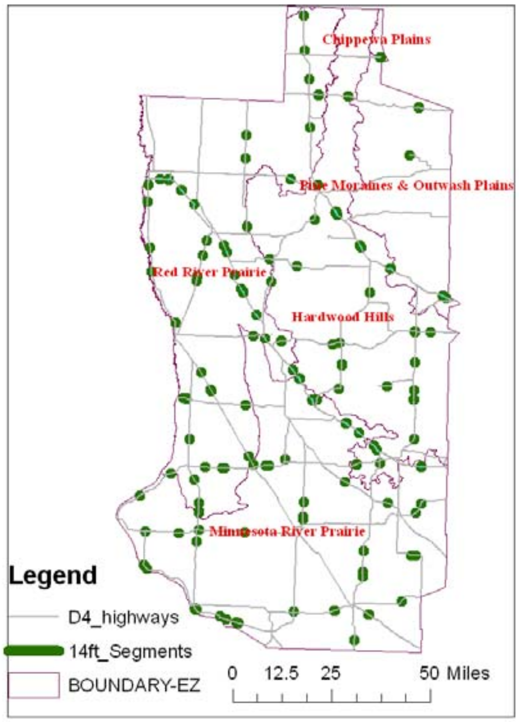


Figure 2.5: Distribution of the surveyed 225-ft sampling sites in (A) ecological zones and (B) management sub-districts of Mn/DOT_D4 (for the 2008 surveys).



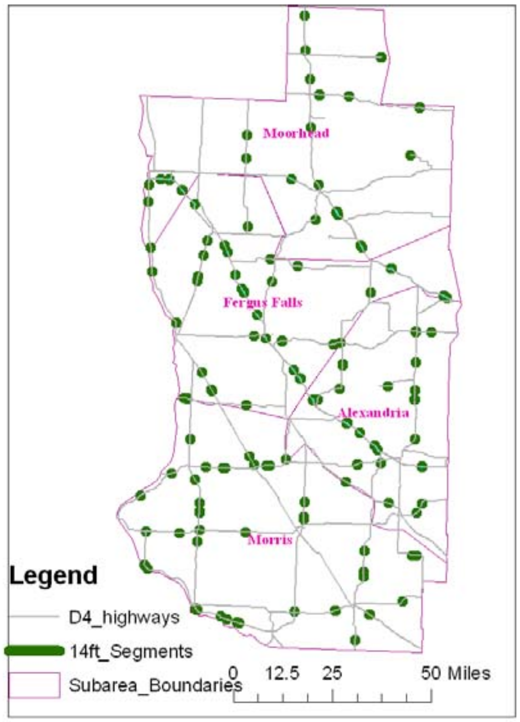


Figure 2.6: Distribution of the surveyed 14-ft sampling sites in (A) ecological zones and (B) management sub-districts of Mn/DOT_D4 (for the 2008 surveys).

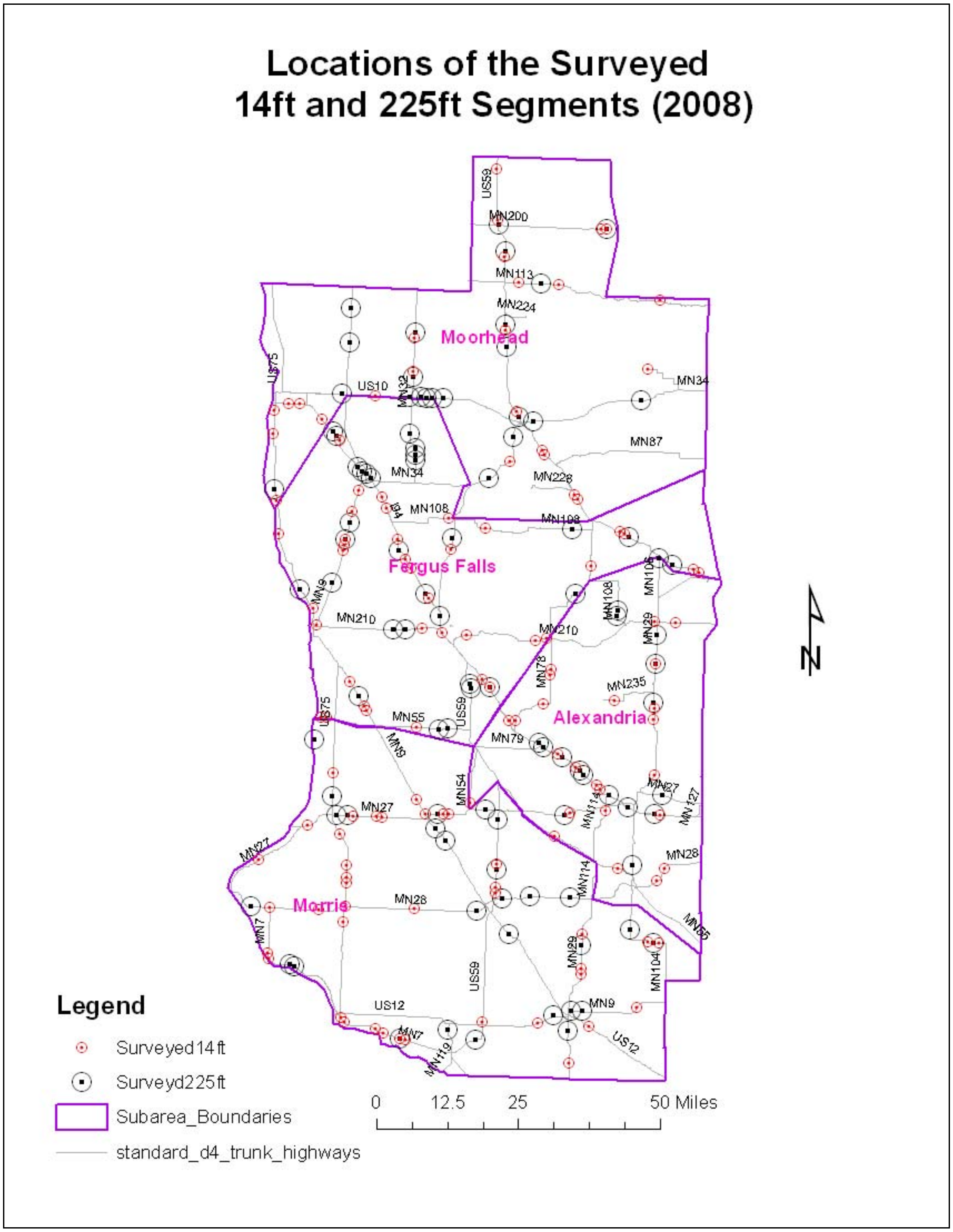


Figure 2.7: Spatial distribution of the 14-ft and 225-ft segments which were surveyed in Mn/DOT_D4's management sub-district (for the 2008 surveys).

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), and as further explained below. The surveys targeted the noxious species identified in section 2.0.

Surveys with the 225-ft segments was organized into runs, and then conducted by one or multiple number of scouts. The 14-ft-ers were covered in 26 runs by scouts working singly. The data recorded in these surveys have been analyzed and presented in various tables and figures.

Staff from the four sub-districts of Mn/DOT_D4 sampled roadside rights-of-ways independently with 225-ft roadway segments to measure areas covered by each of 13 noxious weeds, and with 14-ft segments ("stick walks") to determine presence-absence of the same species. Surveying and data recording at the 100 225-ft, and 150 14-ft 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 2.8 is a section of US 10, illustrating the distribution of species infested patches as observed during surveys with the 225-ft sampling plan.

Surveyors were required to keep complete records of time spent conducting the surveys. Time records included the following:

- Traveling time from office to first sampling site for each surveying day
- Inspecting individual sampling sites (100 225-ft and 150 14-ft segments)
- Traveling between sampling sites visited on each day for all days surveys were conducted
- Time traveling from last sampling site back to office for each surveying day
- Time spent on other activities, including breaks, time to service vehicles, etc.

Figure 2.8 is a section map showing the data recorded with the 225-ft plan surveys containing 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 with the 14-ft plan contained basic information identifying individual weed species, identifying information (highway and mile-post), and the spatial information (X and Y coordinates) on their location. The latter data, though lacking information on weed population density, was to be processed and applied to available empirical models to estimate population density of given weed species. Conducting surveys with the larger number of smaller sampling units in the 14-ft (presence-absence) sampling plan would be not only faster and cheaper than with the 225-ft or larger sampling plan, but would potentially provide higher precision of population estimations.

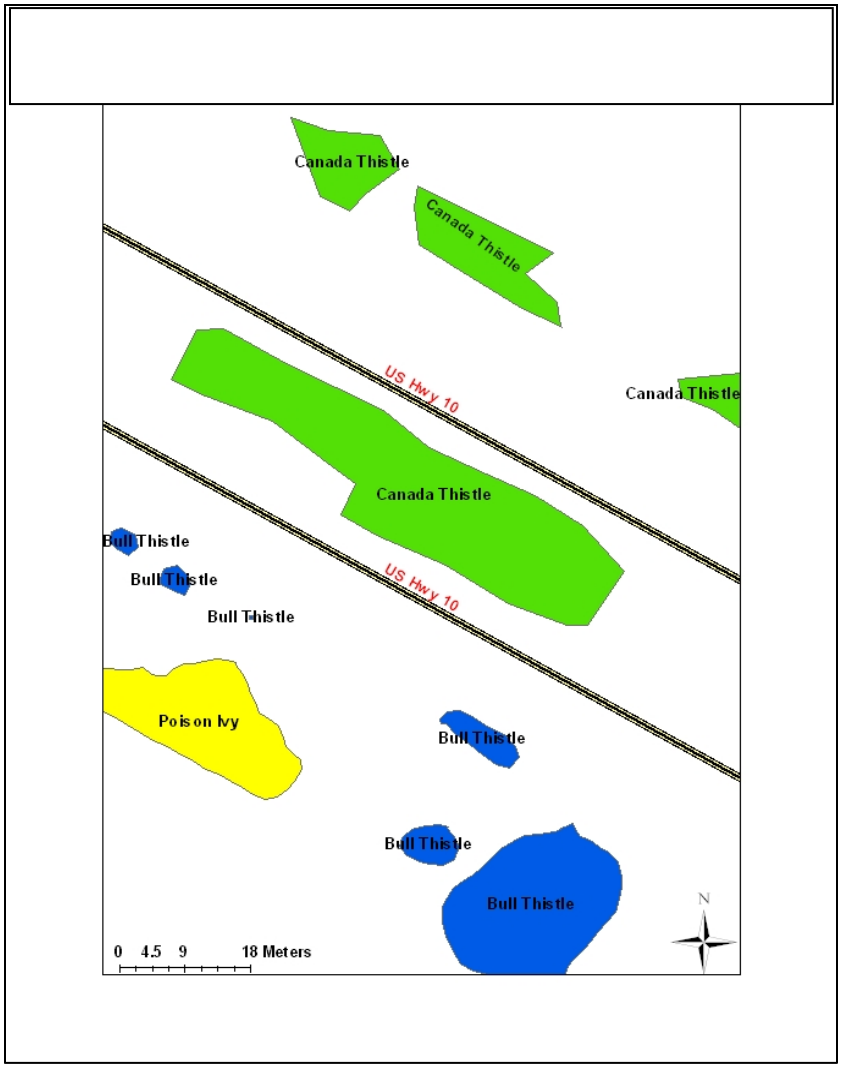


Figure 2.8: Map illustrating the distribution of species infestation patches in a segment of the ROW for US 10; the patches were mapped using the 225-ft sampling approach.

2.3 DATA PROCESSING

Data received from Mn/DOT was organized into 2 groupings based on sampling plan employed in its acquisition. The data files were uploaded and opened in the Trimble® GPS Pathfinder Office software, software employed in processing of the data. 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.

The 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.

Recorded data was processed and presented in formats which would facilitate planned evaluations and statistical analyzes. Summary tables providing information including the outcome of surveys with 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) have been created, samples of which are seen in Tables 2.5 and 2.6).

Table 2.5: Sample data showing the fate of the 100 225-ft sampling sites selected for sampling surveys of Mn/DOT_D4 for the 2008 surveys.

Sub District	Highway	Mile post	File Name/ Comment	Data Present
Moorhead	200	47.4	NONE	NONE
Moorhead	200	66	200MR071408WEED.SSF	ALL
Moorhead	200	66.1	200MR071408WEED.SSF	ALL
Moorhead	75	233.4	SKIPPED	SKIPPED
Moorhead	59	271.8	225PB071508WEED.SSF	All
Moorhead	59	265.2	225PB071508WEED.SSF used alternate milepost # 265.4	All
Moorhead	59	307.3	NONE	NONE
Moorhead	59	294.8	NONE	NONE
Moorhead	59	250.6	225MR072108WEAD.SSF	All
Moorhead	59	260.6	225MR072108WEAD.SSF	All
Moorhead	59	281.9	200MR071408WEED.SSF	ALL
Moorhead	59	265.2	SKIPPED	SKIPPED
Moorhead	59	278.1	SKIPPED	SKIPPED
Moorhead	34	58.4	225PB071508WEED.SSF	All
Moorhead	34	37.9	225PB071508WEED.SSF	All
Moorhead	32	18.8	NONE	NONE
Moorhead	32	26.6	NONE	NONE
Moorhead	10	25.5	R072310A.SSF	All
Moorhead	10	26.8	R072310A.SSF	All
Moorhead	10	27.8	R072310A.SSF & 225MR072308WEED.SSF	All
Moorhead	10	29.7	R072310A.SSF & 225MR072308WEED.SSF	All
Moorhead	10	24.1	225PB072308WEED.SSF & R072310A.SSF	All
Moorhead	10	12	NONE	NONE
Moorhead	9	179.4	NONE	NONE
Moorhead	9	172.7	NONE	NONE
Fergus Falls	210	15.5	071608PC225WS.SSF	All
Fergus Falls	113	22	NONE	NONE
Fergus Falls	108	35.2	225PB071508WEED.SSF	All

Table 2.6: Sample data showing the fate of the 150 14-ft sampling sites selected for sampling surveys of Mn/DOT_D4 for the 2008 surveys.

Sub District	Highway	Mile Post	File Name/Comment	Data Present
Moorhead	94	10	014PB072508WEEDS.SSF	All
Alexandria	94	108.7	14DP071808WEEDS.SSF	All
Fergus Falls	94	14.8	014PB072508WEEDS.SSF	All
Fergus Falls	94	22.4	014PB072508WEEDS.SSF	All
Fergus Falls	94	28.2	014PB072508WEEDS.SSF	None
Moorhead	94	3.5	014PB072508WEEDS.SSF	All
Fergus Falls	94	30	014PB072508WEEDS.SSF	All
Fergus Falls	94	36.1	014PB072408WEEDS.SSF	All
Fergus Falls	94	40.2	014PB072408WEEDS.SSF	All
Fergus Falls	94	41.3	014PB072408WEEDS.SSF	All
Fergus Falls	94	48.1	014PB072408WEEDS.SSF 014MR072408WEED.SSF	All
Moorhead	94	5.6	014PB072508WEEDS.SSF	All
Fergus Falls	94	54.7	014PB072408WEEDS.SSF	All
Fergus Falls	94	65.5	014PB072408WEEDS.SSF 014MR072408WEED.SSF	All
Fergus Falls	94	68.3	014PB072408WEEDS.SSF 014MR072408WEED.SSF	All
Alexandria	94	74.8	14DS071708WEEDS.SSF	All
Alexandria	94	85.8	14DS071708WEEDS.SSF	All
Alexandria	94	90	14DP071808WEEDS.SSF	None
Alexandria	94	94.9	14DP071808WEEDS.SSF	All
Alexandria	94	96.4	14DP071808WEEDS.SSF	All
Morris	104	26.4	071608JR14.SSF	All
Morris	104	26.9	D071407A.SSF	All
Morris	104	27.7	071608JR14.SSF	All
Morris	104	32.6	D071407A.SSF North freshly hayed	All
Fergus Falls	108	10.8	014MR072108WEED.SSF	None
Fergus Falls	108	19.2	014MR072108WEED.SSF	All
Fergus Falls	108	34.3	None	All
Morris	28	45.8	009JR08.SSF	Skipped
Morris	28	54.2	Skipped	All
Morris	28	58.4	Skipped	Skipped
Morris	28	65.8	Skipped	Skipped
Alexandria	28	81.7	D14DP072108WEEDS.SSF	All

2.4 ANALYSIS OF DATA

The data which has been processed is presented in tables to show infestation of sampled sites by the 13 noxious invasive weed species. Beginning with Table 2.7 upwards, and, and Figure 2.9 and others in the current chapter, summaries of the data on presence of various noxious species mapped in surveys with the 225-ft sampling plan, as well as the presence-absence survey with the 14-ft plan, are presented. Further descriptions of the obtained data on these noxious invasive species are provided in the following sections.

2.4.1. Summary of results 225-ft surveys

Table 2.7 is a portion of the results obtained in surveys with the 100 225-ft sampling segments; with the indicated quantities being amounts (acres) of each species found within individual surveyed segments. The 225-ft sampling plan data was processed and applied in evaluating infestation densities for different categories, ecological zones, or management sub-districts. The obtained values have been presented in various figures and tables to follow.

Table 2.8 is a section of the data recorded in surveys conducted using the 14-ft sampling plan. Presence of species in any of the surveyed segments is indicated by a value ‘1’, while segments with a ‘blank’ signify that none of the species being inventoried were found in sufficient area and densities to warrant recording. This information was processed and applied in determining the proportion of the surveyed segments infested by given species.

Maps in Figure 2.9 show the presence and distribution of the surveyed for 13 noxious species in the study area. Two species, Canada thistle and perennial sowthistle, are significant problems in the study area. The figure on the species infestation shows its occurrence in almost all parts of the district. Sowthistle infestation tapers off towards the south and southwestern parts of the district. The rest of the species (11) were less common, with some of the ‘minor’ problem species, such as hemp and purple loosestrife, being encountered at the southern and northern regions, respectively, of the study area. Figure 2.10 provides spatial view as well as means acres/mile of infested areas in the management sub-districts of Mn/DOT_D4

Table 2.7: A section of data set showing quantities (acres) of weed infestation mapped at the surveyed 225-ft sampling sites.

				Acres Infested by Species												
Management sub-district	Ecolo-gical zone	MED-IAN	SegmID	Canada Thistle	Leafy Spurge	Poison Ivy	Bull Thistle	Spotted Knapweed	Musk Thistle	Plume-less Thistle	Perennial Sowthistle	Purple Loose-strife	Field bind-weed	Wild Parsnip	Hemp	Garlic Mustard
Moorhead	CP	0	MN200_66	-	-	-	-	-	-	-	-	-	-	-	-	-
Moorhead	CP	0	MN200_66.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Moorhead	CP	0	MN200_67	0	0	0	0	0.19111	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67	0	0	0	0	0.02239	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67	0	0	0	0	0.11952	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67	0	0	0.005836	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67	0	0	0.001385	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00496	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00893	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00998	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0	0	0	0	0	0	0	0.00698	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00749	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0	0	0	0	0.00397	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00179	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0	0	0	0	0.003397	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00179	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00202	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0	0	0	0	0.00725	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00179	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00179	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0.00411	0	0	0	0	0	0	0	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0	0	0	0	0	0	0	0.00179	0	0	0	0	0
Moorhead	CP	0	MN200_67.8	0	0	0	0	0.00460	0	0	0	0	0	0	0	0
Alexandria	HH	0	MN108_53.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Alexandria	HH	0	MN114_19.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Alexandria	HH	0	MN210_62.3	-	-	-	-	-	-	-	-	-	-	-	-	-
Alexandria	HH	0	MN210_72.1	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2.8: A section of the data recorded in surveys with 14-ft plan showing species presence (1) at segments in different ecological zones (for the 2008 surveys).

Catergory	SEGMID	Field bindweed	Bull Thistle	Canada Thistle	Leafy Spurge	Musk Thistle	Perennial Sowthistle	Plumeless Thistle	Poison Ivy	Purple Loosestrife	Spotted Knapweed	Wild Parsnip
CP-0	MN200_65.8			1								
	MN200_66.1						1					
HH-0	MN108_10.8			1								
	MN108_19.2			1								
	MN113_25.2						1					
	MN114_17.1						1					
	MN210_43.2							1				
	MN210_45.1							1				
	MN210_66.4											
	MN210_70.4											
	MN235_2.2											
	MN27_67.2								1			
	MN29_104.7											
	MN29_84.9						1					
	MN29_95								1			
	MN29_97.4											
	MN78_15.8											
	MN78_16.3						1					
	MN78_39.1							1				
	MN78_9.4											
	US59_256.4						1					
	US59_266.1											
HH-1	I94_68.3						1					
	I94_94.9						1					
	I94_96.4	1										
	US10_51.1											
	US10_51.9								1			
	US10_61.8							1				
	US10_62.4							1				
	US10_72.1											
	US10_72.3							1				
MNRP-0	MN104_26.4											
	MN104_27.7				1					1		
	MN210_21.4						1					
	MN27_18.8											
	MN27_43.8											
	MN27_44.7	1					1					
	MN27_8.8		1									
	MN28_17.7						1					
	MN28_23.2											
	MN28_34.7											
	MN28_81.7											
	MN28_85.1											
	MN29_24											
	MN29_41.1											
	MN29_42.3						1					
	MN29_47.5		1									
	MN54_0.8											
	MN55_53.4											
	MN55_65.6								1			
	MN7_0	1										
	MN7_36.2											
	MN7_39											
	MN7_39.5						1					
	MN7_8.6											
	MN7_9.8											
	MN78_2.3											1
	MN9_23.3											1
	MN9_80.3											
	US12_37.2											
	US12_47.2											
	US59_144.9	1										
	US59_169.3		1									
	US59_170											
	US59_173.8											
	US75_128	1		1								
	US75_134.4											
	US75_134.8	1										
	US75_151.9	1		1								
	US75_159.2		1									
	US75_159.5			1								

Table 2.8: A section of the data recorded in surveys with 14-ft plan showing species presence (1) at segments in different ecological zones (for the 2008 surveys). (cont…)

Catergory	SEGMID	Field bindweed	Bull Thistle	Canada Thistle	Leafy Spurge	Musk Thistle	Perennial Sowthistle	Plumeless Thistle	Poison Ivy	Purple Loosestrife	Spotted Knapweed	Wild Parsnip
MNRP-1	I94_108.7	1										
	I94_74.8										1	
	I94_85.8											1
	I94_90	1										1
PMOP-0	MN113_45.2						1		1			
	MN225_0											
PMOP-1	US10_87.4			1								
	US10_88.3			1								
RRP-0	MN113_17.8										1	
	MN210_29.8					1						
	MN27_28.4											
	MN27_32.7			1			1					
	MN27_33.3											
	MN32_19.8						1					
	MN32_25.7			1								
	MN55_1.7	1										
	MN55_17.5					1	1					
	MN55_2.4						1					
	MN9_101.7											
	MN9_102.2	1										
	MN9_107.1		1									
	MN9_120.2						1					
	MN9_134.3						1					
	MN9_134.5						1					
	MN9_135.4											
	MN9_141											
	MN9_144.8			1								
	MN9_82.8											
	US59_234.9						1	1				
	US59_281.3						1					
	US59_293.6											
	US59_301.2						1					
	US59_310											
	US75_161.8											
	US75_168.1						1					
	US75_178.6	1										
	US75_210	1										
	US75_224.7						1					
	US75_230.7											
	US75_242.6	1		1								
	US75_247.3						1					
RRP-1	I94_10						1					
	I94_14.8						1					
	I94_28.2						1					
	I94_3.5						1					
	I94_30						1					
	I94_36.1							1				
	I94_40.2											
	I94_41.7					1						
	I94_48.1											
	I94_5.6			1								
	I94_54.7						1					
	I94_65.5						1					
	US10_17.9						1					

2.4.2. Characterization of species infestation in Mn/DOT D4

Data from surveys with the 225-ft plan were applied in characterizing infestation by different weed species, and results presented in the following Figures and Tables.

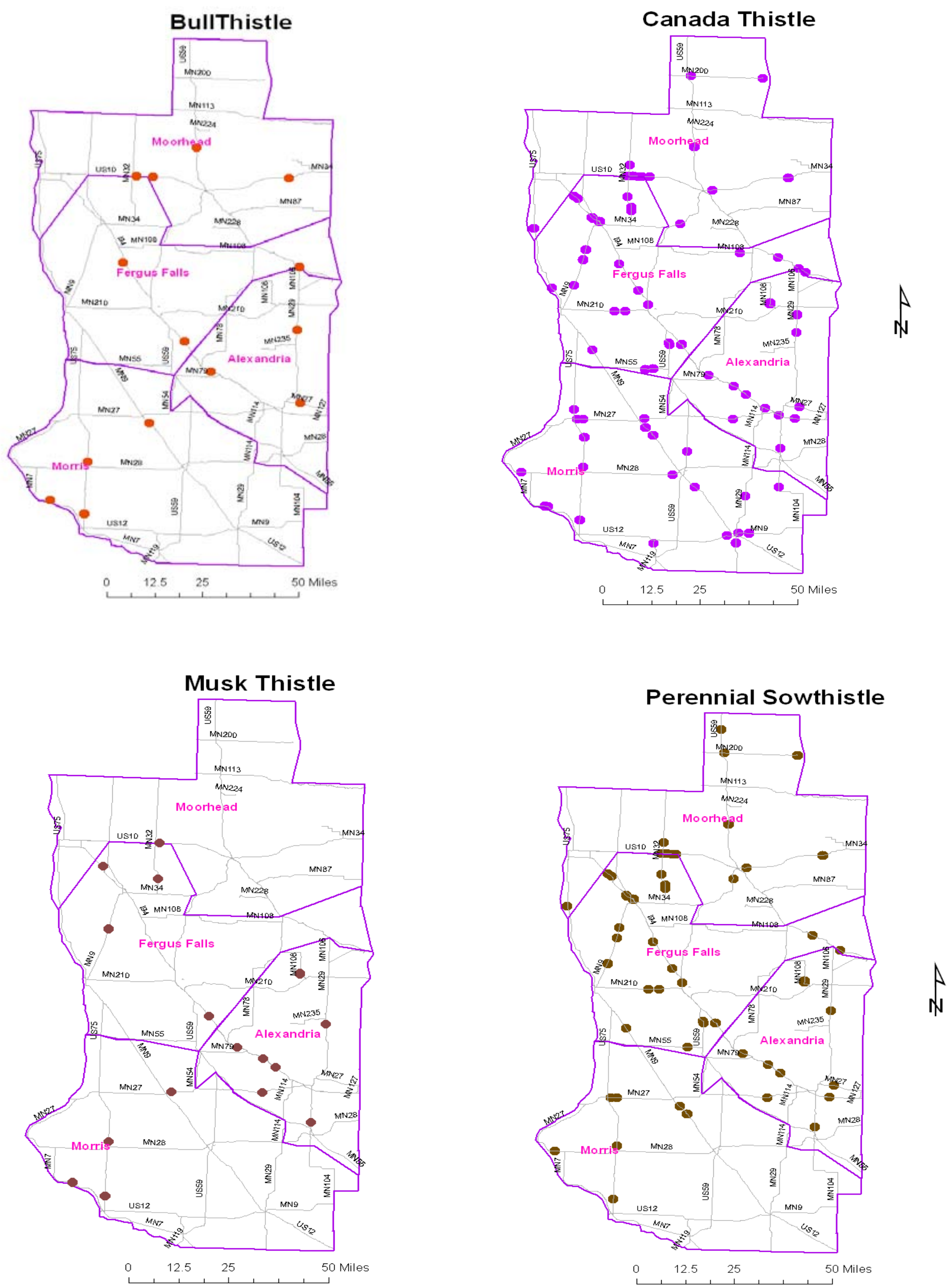


Figure 2.9: Spatial distribution of (12 of the 13) weed species surveyed for in the Mn/DOT_D4 using the 225-ft sampling plan (for the 2008 surveys).

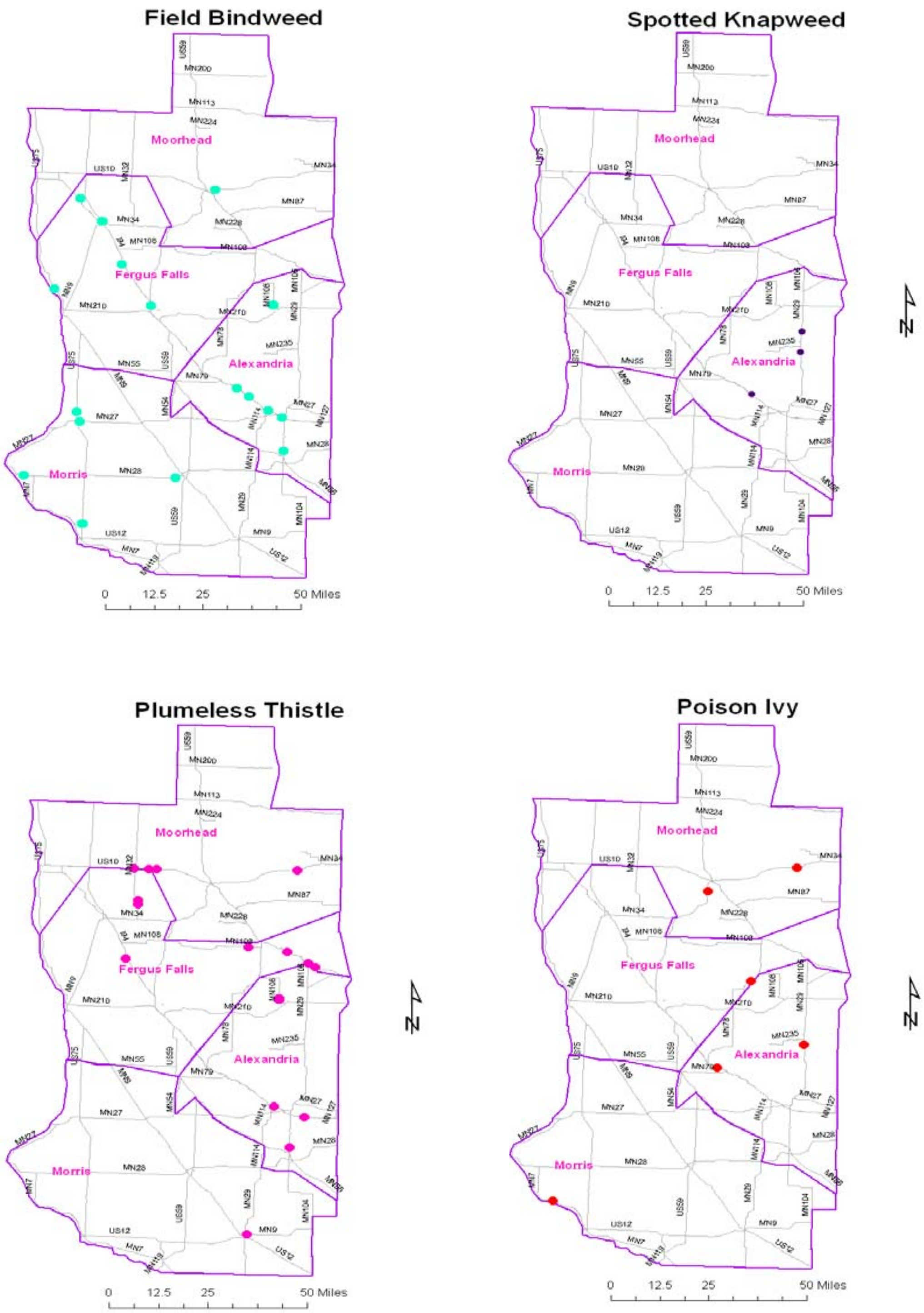


Figure 2.9: Spatial distribution of (12 of the 13) weeds species surveyed for in the Mn/DOT_D4 using 225-ft sampling plan (for the 2008 surveys). (cont…)

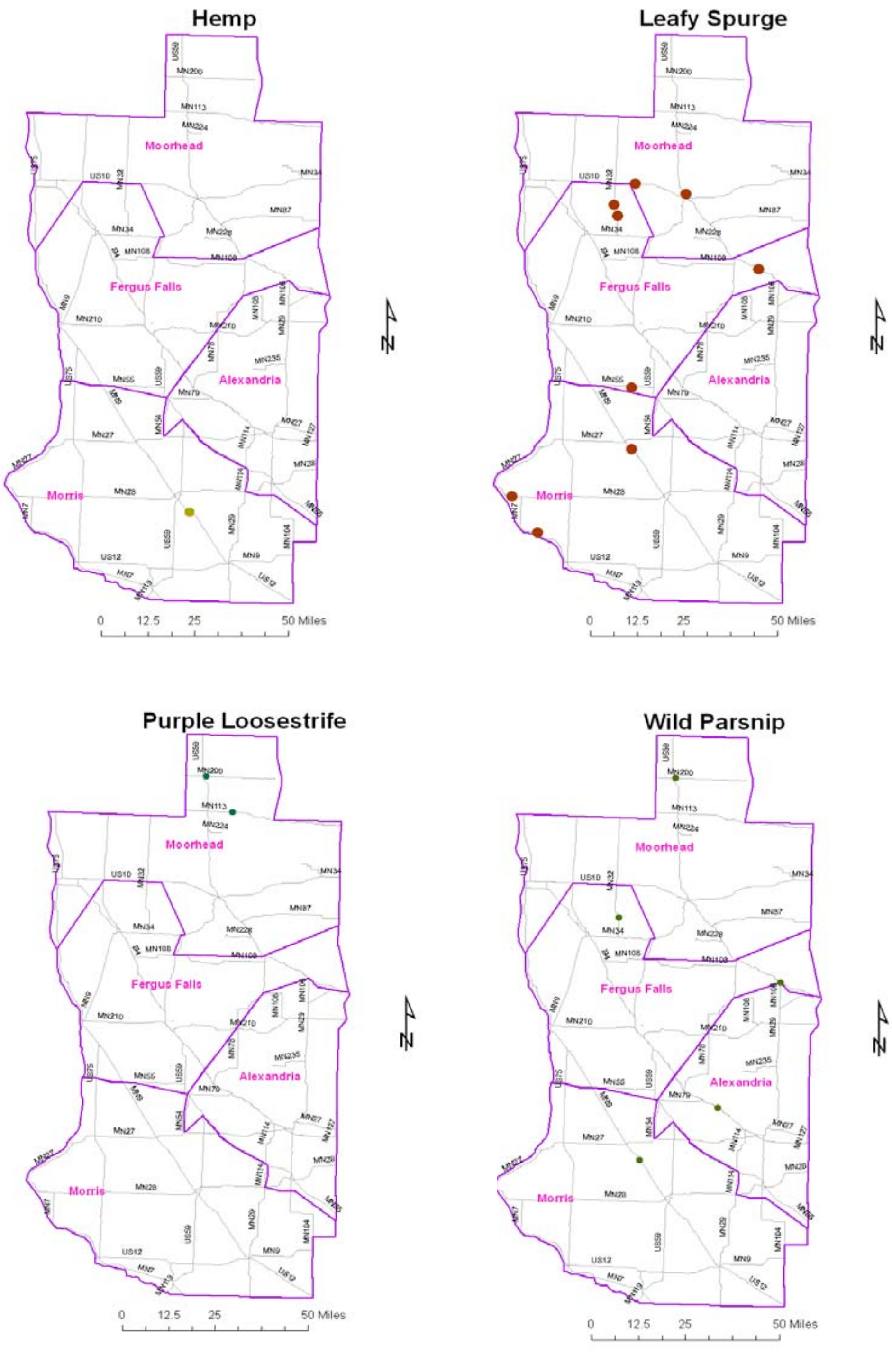
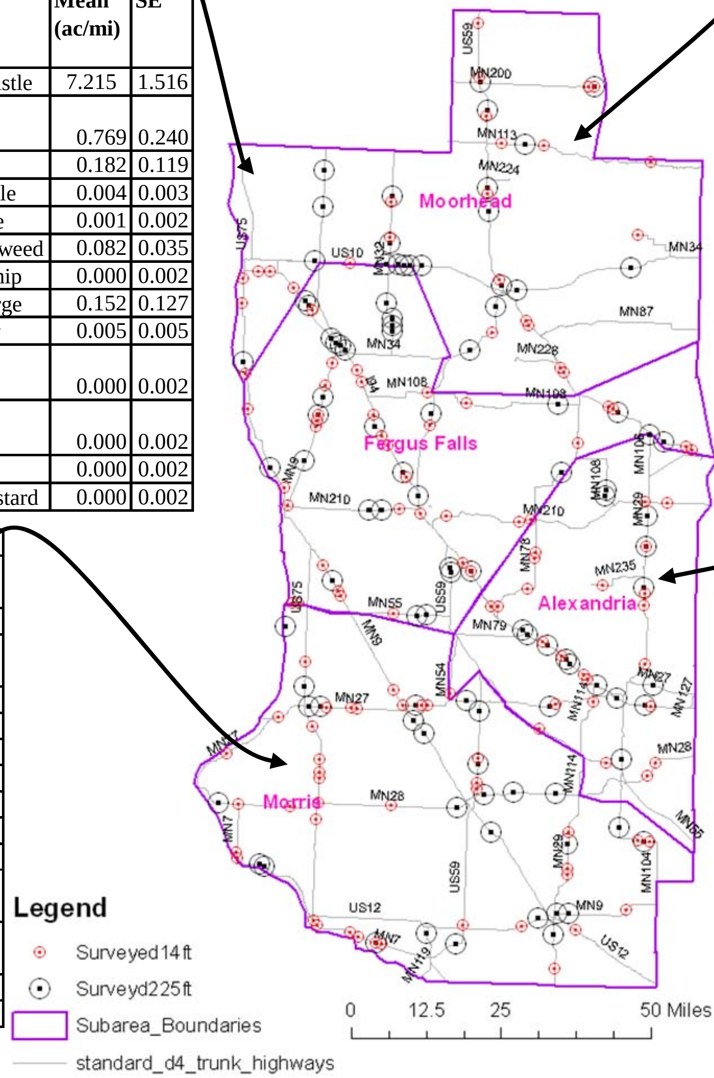


Figure 2.9: Spatial distribution of (12 of the 13) weed species surveyed for in the Mn/DOT_D4 using 225-ft sampling plan (for the 2008 surveys). (cont…)

Fergus Falls		
Species	Mean (ac/mi)	SE
Canada thistle	7.215	1.516
Perennial sowthistle	0.769	0.240
Plumeless	0.182	0.119
Musk thistle	0.004	0.003
Bull thistle	0.001	0.002
Field bindweed	0.082	0.035
Wild parsnip	0.000	0.002
Leafy spurge	0.152	0.127
Poison ivy	0.005	0.005
Spotted knapweed	0.000	0.002
Purple loosestrife	0.000	0.002
Hemp	0.000	0.002
Garlic mustard	0.000	0.002

Moorhead		
Species	Mean (ac/mi)	SE
Canada thistle	3.486	1.140
Perennial sowthistle	0.656	0.229
Plumeless	0.414	0.401
Musk thistle	0.004	0.004
Bull thistle	0.008	0.006
Field bindweed	0.003	0.003
Wild parsnip	0.000	0.002
Leafy spurge	0.000	0.002
Poison ivy	0.112	0.093
Spotted knapweed	0.000	0.002
Purple loosestrife	0.010	0.009
Hemp	0.000	0.002
Garlic mustard	0.000	0.002



Morris		
Species	Mean (ac/mi)	SE
Canada thistle	4.633	0.674
Perennial sowthistle	0.209	0.161
Plumeless thistle	0.004	0.004
Musk thistle	0.038	0.032
Bull thistle	0.010	0.005
Field bindweed	0.559	0.427
Wild parsnip	0.019	0.019
Leafy spurge	0.011	0.007
Poison ivy	0.007	0.007
Spotted knapweed	0.000	0.002
Purple loosestrife	0.000	0.002
Hemp	0.002	0.002
Garlic mustard	0.000	0.002

Alexandria		
Species	Mean (ac/mi)	SE
Canada thistle	4.652	1.044
Perennial sowthistle	0.440	0.149
Plumeless thistle	0.073	0.046
Musk thistle	0.028	0.009
Bull thistle	0.021	0.012
Field bindweed	0.219	0.141
Wild parsnip	0.381	0.376
Leafy spurge	0.000	0.002
Poison ivy	0.095	0.093
Spotted knapweed	0.011	0.007
Purple loosestrife	0.000	0.002
Hemp	0.000	0.002
Garlic mustard	0.000	0.002

Figure 2.10: Distribution of 14-ft and 225-ft sampling sites in Mn/DOT D4 management sub-districts, and evaluated infestation densities by the 13 weed species from surveys with 225-ft sampling plan (for the 2008 surveys).

2.4.3. Evaluation of mean infested density

The weighted means for each weed species were evaluated using the relation:

Weighted mean = the product of Category mean acres/mile and 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 each of the 13 noxious weed species in Mn/DOT_D4. Results are presented below.

Table 2.9: Weed infestation densities (acres/mile) by the 13 weed species as evaluated from data recorded in surveys of Mn/DOT_D4 using 225-ft sampling plan for the 2008 surveys.

Species	**Acres/mi**	**t*SE**	**Total acres**
Canada Thistle	4.77	0.97	7,776
Perennial Sowthistle	0.42	0.51	688
Field bindweed	0.22	0.27	365
Plumeless Thistle	0.11	0.11	185
Leafy Spurge	0.06	0.10	96
Poison Ivy	0.06	0.07	93
Wild Parsnip	0.03	0.07	55
Musk Thistle	0.02	0.03	35
Bull Thistle	0.02	0.05	26
Purple Loosestrife	0.00	0.01	4
Spotted Knapweed	0.00	0.00	3
Hemp	0.00	0.00	1
Garlic Mustard	0.00	0.00	0
There is a total of 1,629.1 miles of roadway in the district			

The data sets were applied to determine the acres/mile of Mn/DOT_D4 infested by each of the 13 noxious species being studied. The results of analysis of data from surveys conduced in 2008 with the 225-ft sampling plan are presented in Tables 2.9, 2.12 and 2.13, as well as in Figures 2.11 and 2.12.

Table 2.10: 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)

When values for the 2007 and 2008 surveys are viewed together (Table 2.11), observable variations in species infestations over the two years are not significantly large.

Table 2.11: Grand weighted mean area of species infestation of highway ROWs in Mn/DOT_D4 based on surveys with the 225-ft sampling segments in 2007 and 2008.

Species	**Weighted Mean, acres per mile**		**Standard Error (SE):**		**Estimated Infested Area (acres)**	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**
Bull thistle	0.11	0.02	0.05	0.05	179.2	26.0
Canada thistle	3.50	4.77	0.38	0.97	5701.9	7776.0
Field bindweed	0.08	0.22	0.04	0.27	130.3	365.0
Garlic mustard	0.00	0.00	0.00	0.00	0.0	0.0
Hemp	0.00	0.00	0.00	0.00	0.0	1.0
Leafy spurge	0.10	0.06	0.05	0.10	162.9	96.0
Musk thistle	0.04	0.02	0.03	0.03	65.2	35.0
Perennial Sowthistle	0.34	0.42	0.08	0.51	553.9	688.0
Plumeless thistle	0.08	0.11	0.04	0.11	130.3	185.0
Poison ivy	0.17	0.06	0.06	0.07	276.9	93.0
Purple loosestrife	0.01	0.00	0.01	0.01	16.3	4.0
Spotted knapweed	0.03	0.00	0.03	0.00	48.9	3.0
Wild parsnip	0.01	0.03	0.01	0.07	16.3	55.0

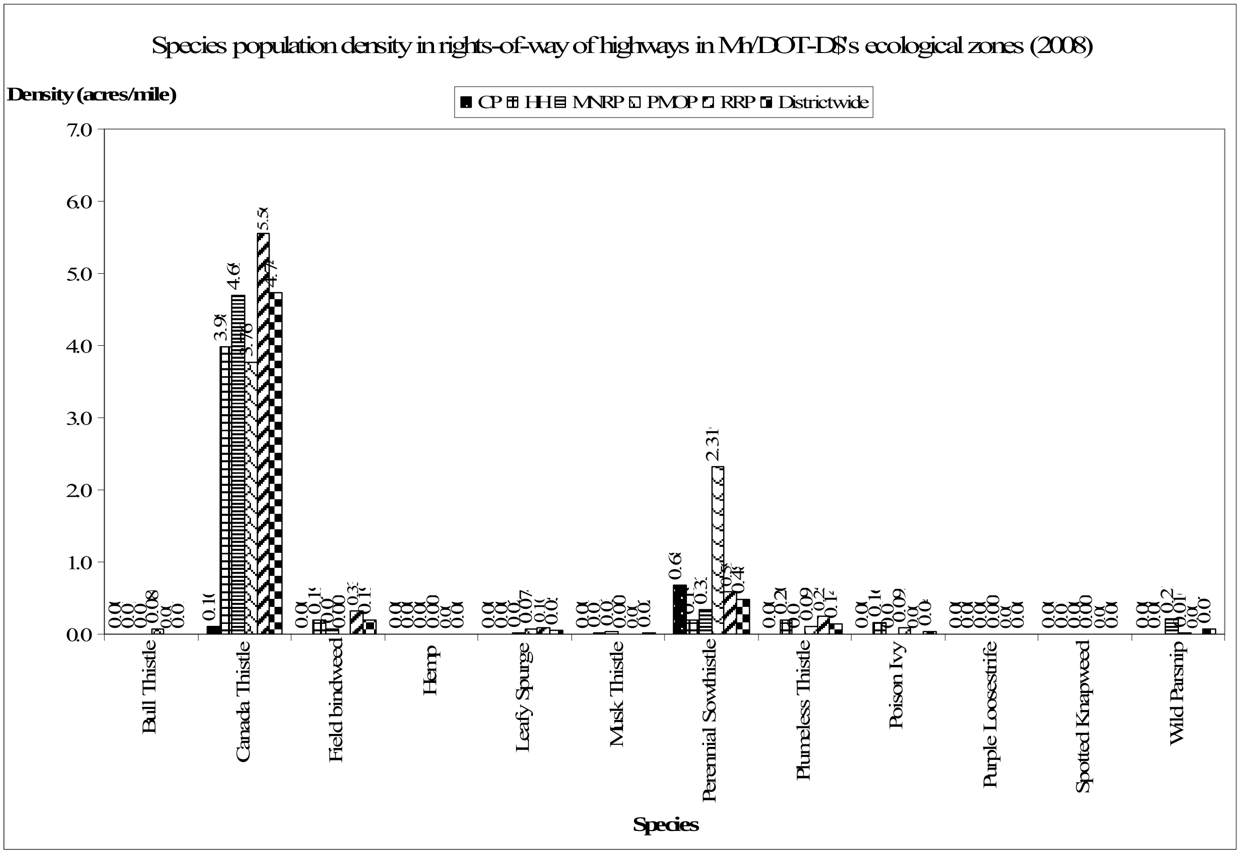


Figure 2.11: Infestation densities (acres-per-mile) within highway ROWs in ecological zones of Mn/DOT_D4 based on surveys with the 225-ft sampling segments (2008).

Table 2.12: Infestation densities (acres/mile) for sub-districts in Mn/DOT_D4, by 13 noxious weeds evaluated from survey data recorded with 225-ft sampling plan for the 2008 surveys.

Species	Alex	Fergus	Moorhead	Morris	Weighted Avg
Canada Thistle	4.65	7.22	3.49	4.63	4.77
Perennial Sowthistle	0.44	0.77	0.66	0.21	0.42
Field bindweed	0.22	0.08	0.00	0.56	0.22
Plumeless Thistle	0.07	0.18	0.41	0.00	0.11
Leafy Spurge	0.00	0.15	0.00	0.01	0.06
Poison Ivy	0.10	0.01	0.11	0.01	0.06
Wild Parsnip	0.38	0.00	0.00	0.02	0.03
Musk Thistle	0.03	0.00	0.00	0.04	0.02
Bull Thistle	0.02	0.00	0.01	0.01	0.02
Purple Loosestrife	0.00	0.00	0.01	0.00	0.00
Spotted Knapweed	0.01	0.00	0.00	0.00	0.00
Hemp	0.00	0.00	0.00	0.00	0.00
Garlic Mustard	0.00	0.00	0.00	0.00	0.00

Table 2.13: Infestation densities (acres per mile) of roadway right-of-ways in Mn/DOT_D4 and ecological zones, evaluated from survey data using 225-ft sampling plan, that were infested by 13 different noxious weeds, by roadway category and by management sub-district for the 2008 surveys.

Category / Sub-District	Garlic mustard	Hemp	Spotted knapweed	Purple loosestrife	Bull thistle	Musk thistle	Wild parsnip	Poison ivy	Leafy spurge	Plumeless thistle	Field bindweed	Perennial sowthistle	Canada thistle	Combined
RRP-1	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.75	0.17	1.23	8.05	10.21
RRP-0	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.19	0.00	0.54	0.34	5.45	6.54
MNRP-1	0.00	0.00	0.01	0.00	0.01	0.02	1.14	0.01	0.00	0.00	0.03	0.97	5.90	8.08
MNRP-0	0.00	0.00	0.00	0.00	0.01	0.04	0.02	0.01	0.02	0.01	0.10	0.22	5.22	5.66
HH-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.21	0.38	10.33	10.95
HH-0	0.00	0.00	0.01	0.00	0.01	0.02	0.00	0.23	0.01	0.28	0.17	0.14	1.56	2.43
PMOP-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.01	0.00	3.09	4.64	7.89
PMOP-0	0.00	0.00	0.00	0.00	0.16	0.00	0.02	0.18	0.00	0.19	0.00	1.28	2.59	4.43
CP-0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.05	0.45
Fergus Falls	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.18	0.08	0.77	7.22	8.41
Alexandria	0.00	0.00	0.01	0.00	0.02	0.03	0.38	0.10	0.00	0.07	0.22	0.44	4.65	5.92
Morris	0.00	0.002	0.00	0.00	0.01	0.04	0.02	0.01	0.01	0.00	0.56	0.21	4.63	5.49
Moorhead	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.11	0.00	0.41	0.00	0.66	3.49	4.69
D4 average	0.000	0.001	0.002	0.002	0.02	0.02	0.03	0.06	0.06	0.11	0.22	0.42	4.77	5.73

Key:

CP-0 = Chippewa Plains, in undivided highway
HH-0 = Hardwood Hills, in undivided highway; HH-1 = in a divided highway
MNRP-0 = Minnesota Prairie River, undivided highway; MNRP-1 = in a divided highway
PMOP-0 = Pine Moraines & Outwash Plains, undivided highway; PMOP-1 = in a divided highway
RRP-0 = Red River Prairie, undivided highway; RRP-1 = in a divided highway

A casual observation of the mean densities evaluated from data recorded in the surveys conducted in 2004 and 2005 using ¼-mile and 3-mile sampling segments (Tables 2.14 and 2.15), reveal certain trends. These are discussed for some of the species of concern in Mn/DOT_D4 below.

Canada thistle

Mean infestation density evaluated for this species from data recorded in surveys conducted in 2004 and 2005 using ¼-mile segment length, and in 2007 and 2008 using the 225-ft segments, are 2.02, 2.86, 3.50, and 4.77, respectively. Associated standard sampling errors were 0.2534, 0.323 0.38, and 0.97. 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 infestation density 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 errors for sampling were much larger for the 3-mile sampling plan.

It appears that Canada thistle presence increased consistently over the years.

Leafy spurge

Mean infestation densities (acres/mile) for 2004, 2005, 2007 and 2008 were 0.005, 0.009, 0.10 and 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 infestation densities (acres/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.

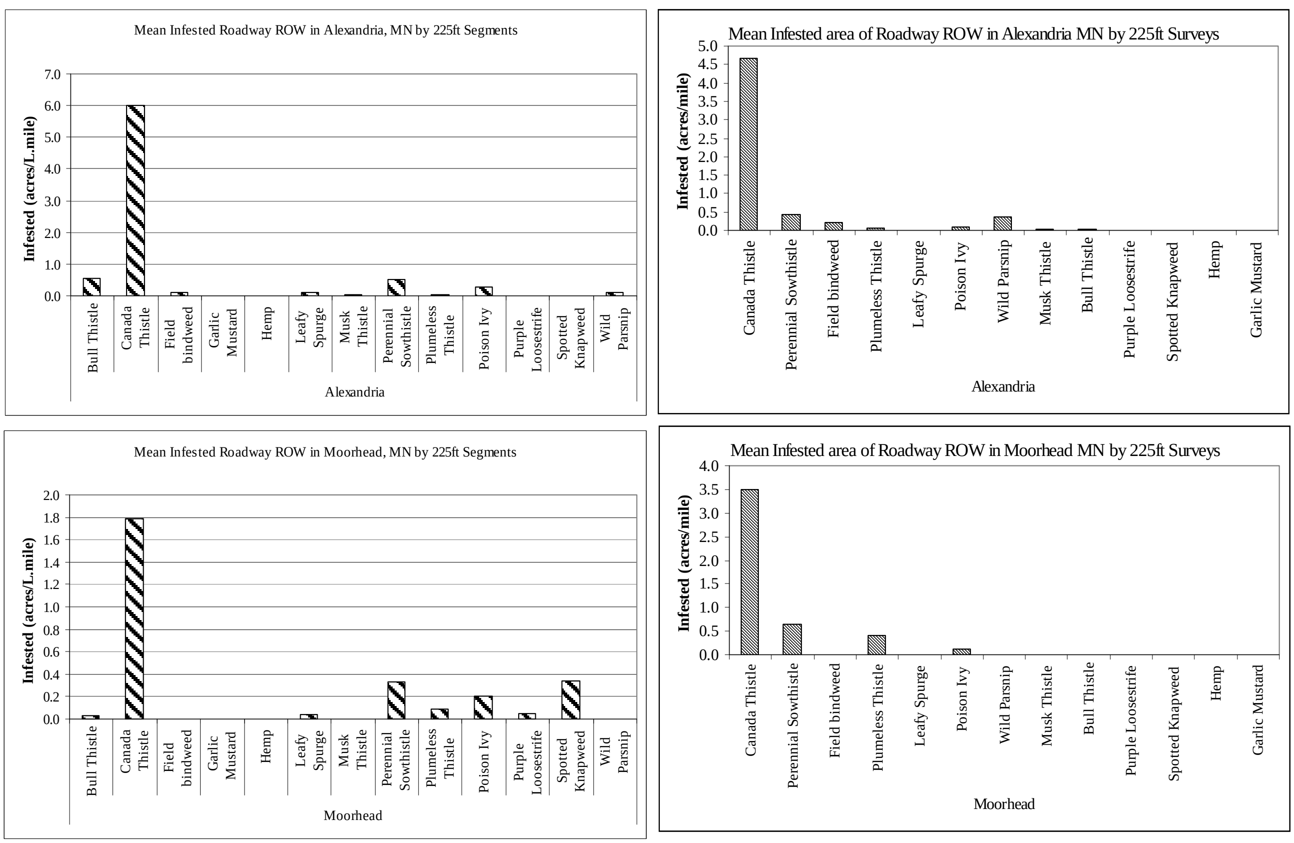
Table 2.14: Grand weighted mean area of species infestation in highway ROWs of Mn/DOT_D4 based on the surveys of the ¼-mile and 3-mile sampling plans (2005).

	Species	Mean (acres/mile)	Standard Error (SE)
¼-mile Surveys	Canada Thistle	2.854	0.323
	Leafy spurge	0.009	0.006
	Poison ivy	0.163	0.072
3-mile Surveys	Canada Thistle	2.437	4.840
	Leafy spurge	0.004	0.007
	Poison ivy	0.114	0.276

Table 2.15: Grand weighted mean area of species infestation of highway ROWs in Mn/DOT_D4 for the survey using ¼-mile and 3-mile sampling plans (2004).

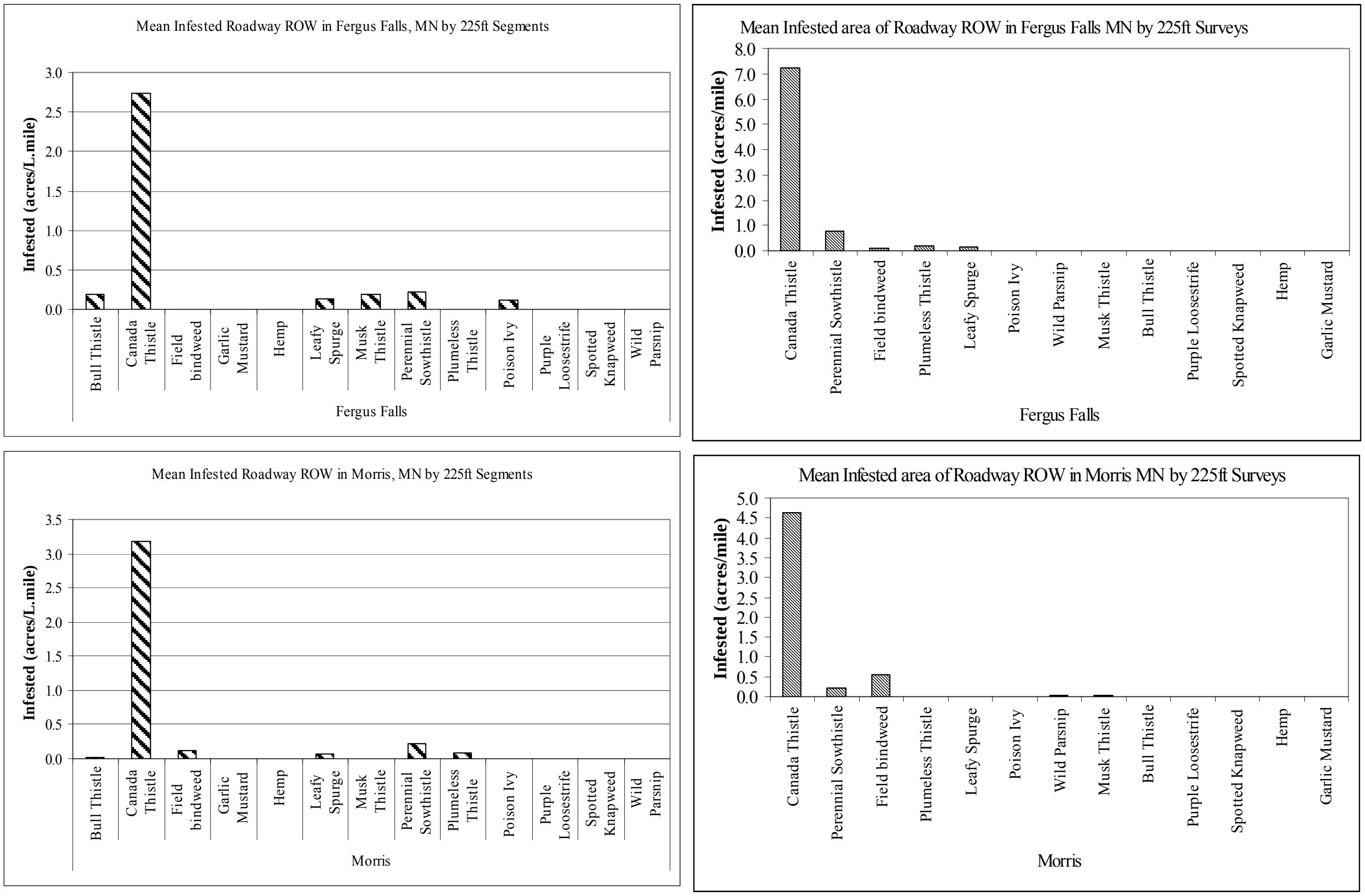
	Species	Mean (acres/mile)	Standard Error (SE)
¼-mile Surveys	Canada thistle	2.079	0.253
	Leafy spurge	0.005	0.003
	Poison ivy	0.039	0.024
3-mile Surveys	Canada thistle	1.057	0.310
	Leafy spurge	0.046	0.026
	Poison ivy	0.118	0.094

The plots presented in Figures 2.12 and 2.13 show weed population densities evaluated for different management sub-districts of Mn/DOT_D4. These values were evaluated by dividing the total area (acres) infested by given species, by total center-line miles of highway rights-of-way (ROWs) sampled within each of the Ecozones in Mn/DOT_D4. The total miles surveyed in an ecological zone were taken as the product of the segment length (225-ft or 0.0426 miles) and the number of segments initially selected for sampling within each Ecozone.



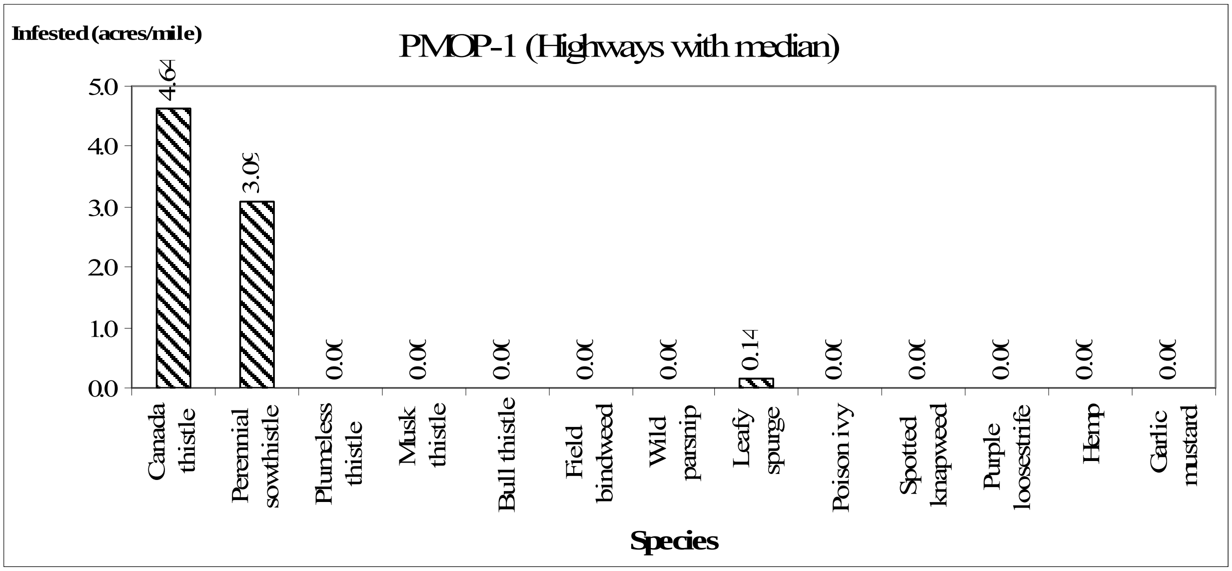
2007 **2008**

Figure 2.12a: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Moorhead and Alexandria Management Sub-districts of Mn/DOT_D4 for the 2007 and 2008 surveys.



2007 **2008**

Figure 2.12b: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Fergus Falls and Morris Management Sub-districts of Mn/DOT_D4 for the 2007 and 2008 surveys.



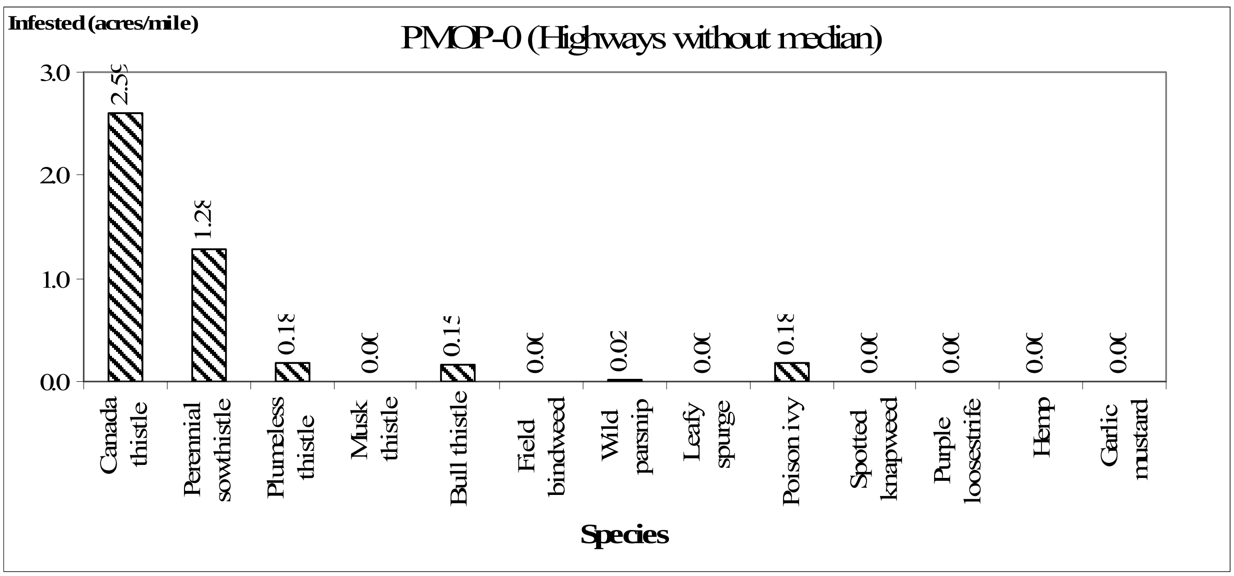


Figure 2.13a: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Pine Moraines Ecozone of Mn/DOT_D4 for the 2008 surveys.

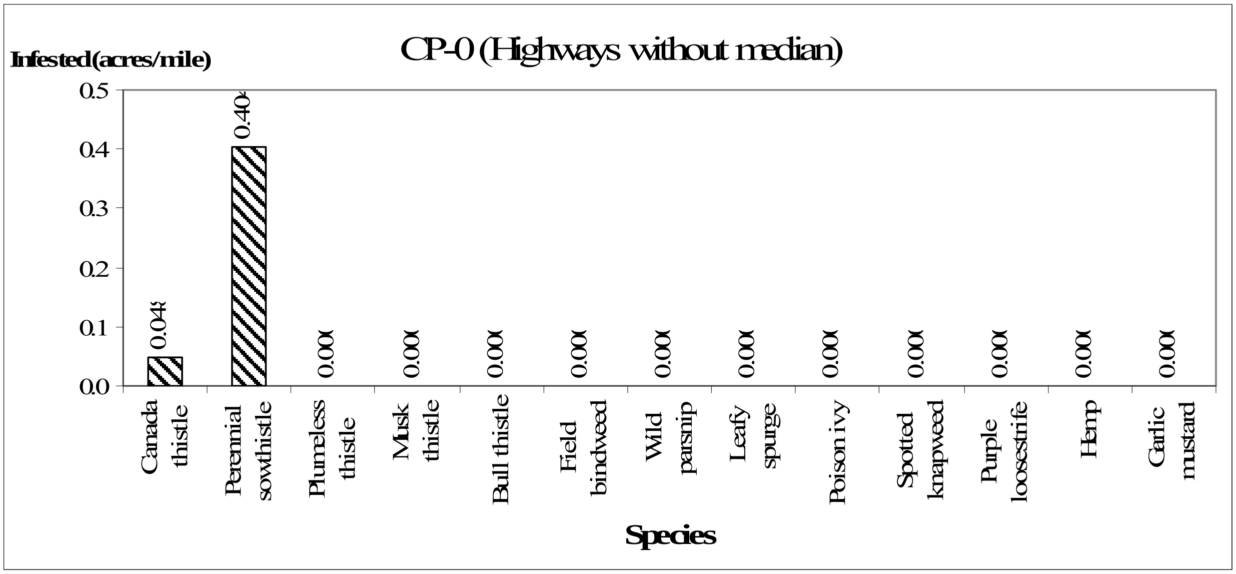
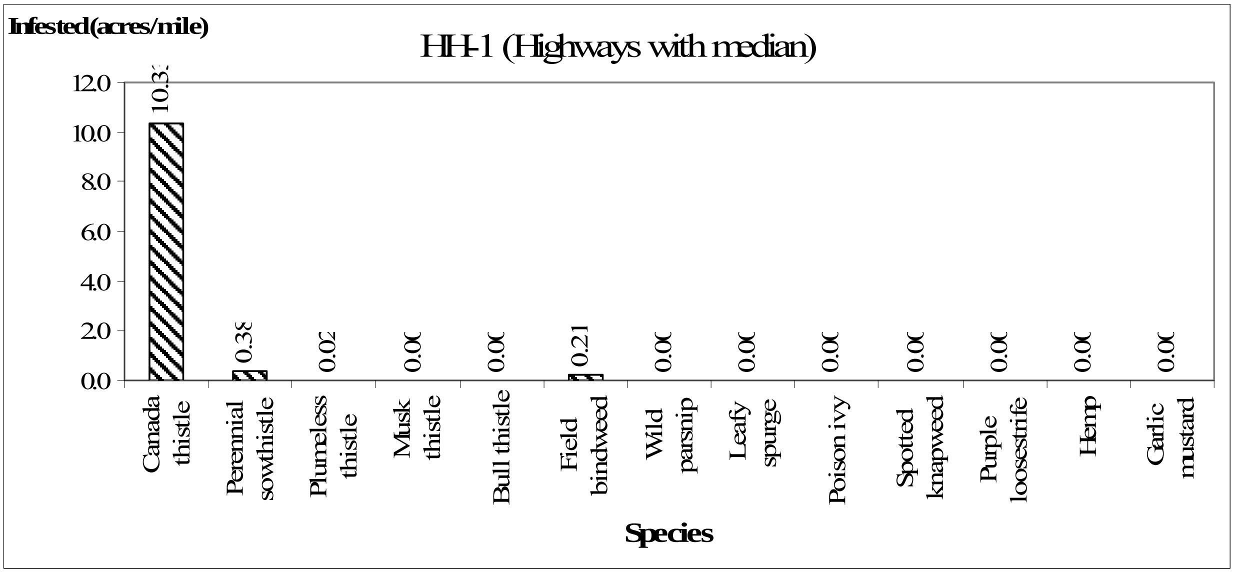


Figure 2.13b: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Chippewa Plains Ecozone of Mn/DOT_D4 for the 2008 surveys.

Note: There are no divided highways under Mn/DOT management traversing Chippewa Falls ecological zone in District 4.



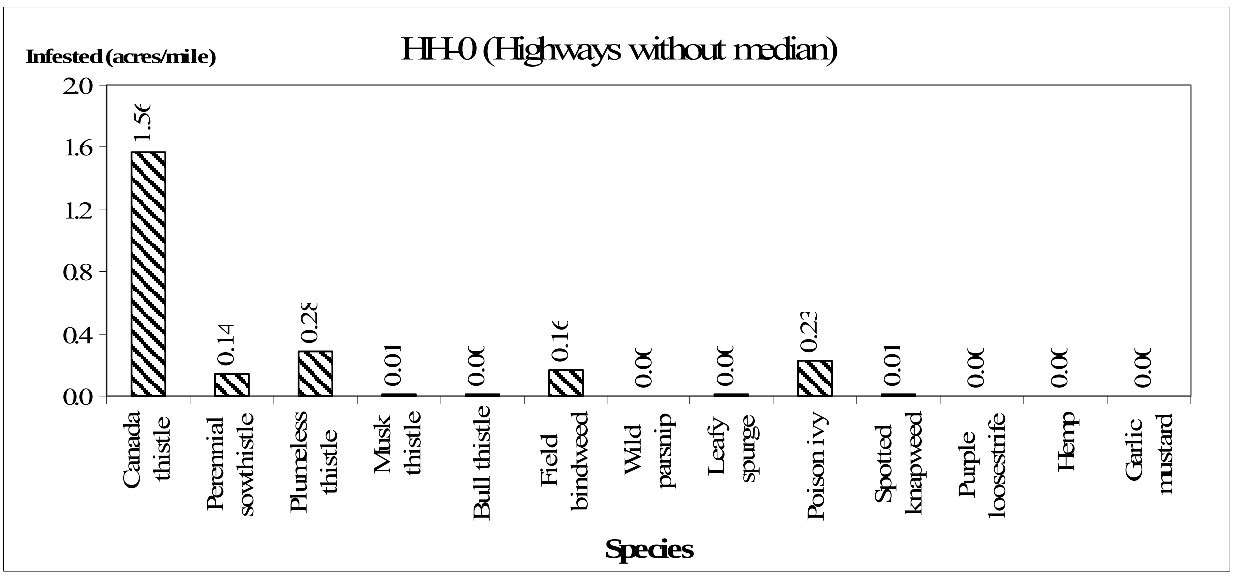
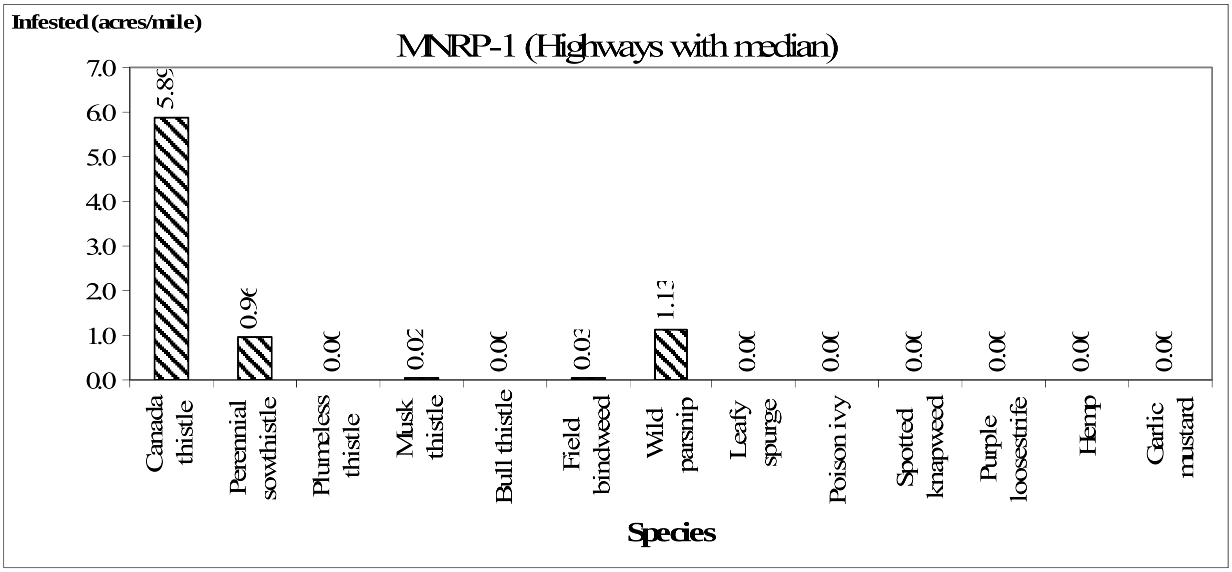


Figure 2.13c: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Hardwood Hills Ecozone of Mn/DOT_D4 for the 2008 surveys.



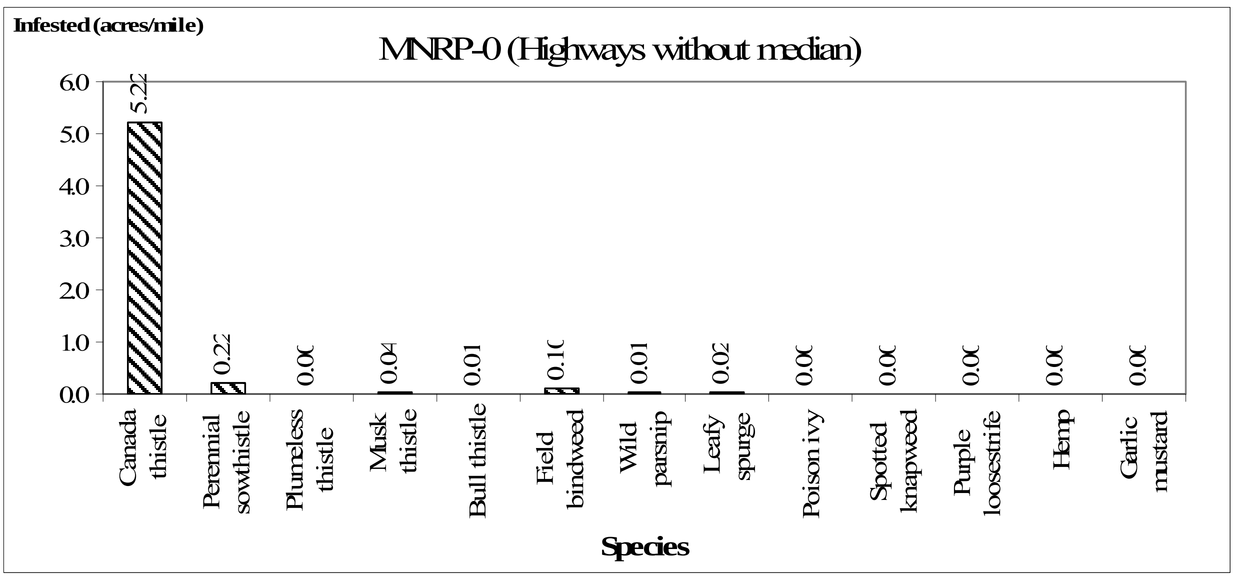
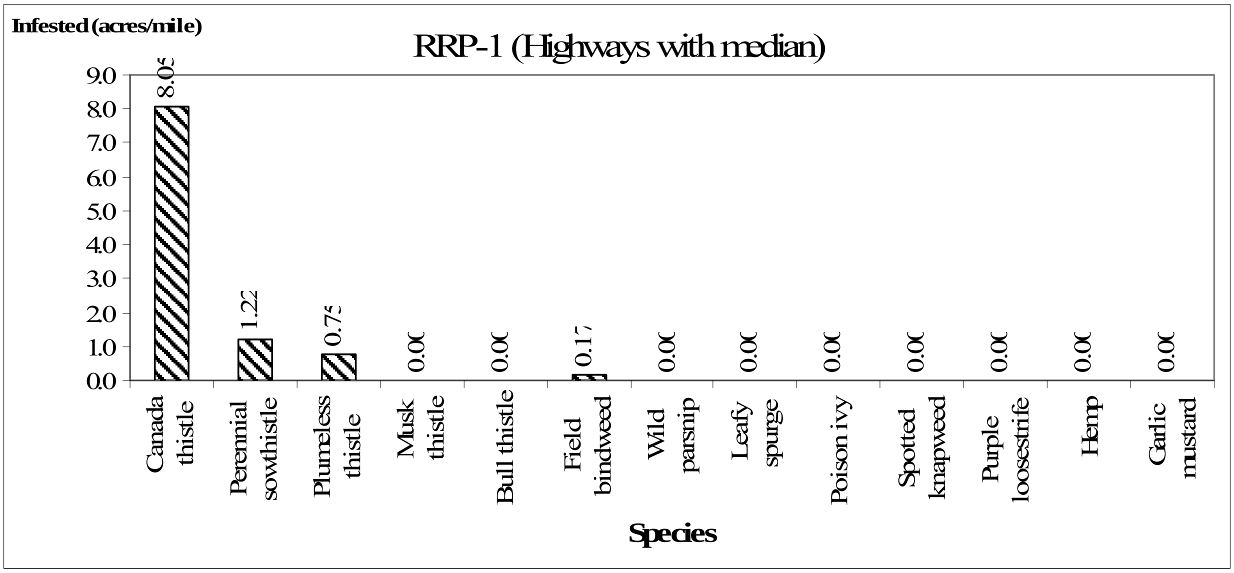


Figure 2.13d: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Minnesota River Prairie Ecozone of Mn/DOT_D4 for the 2008 surveys.



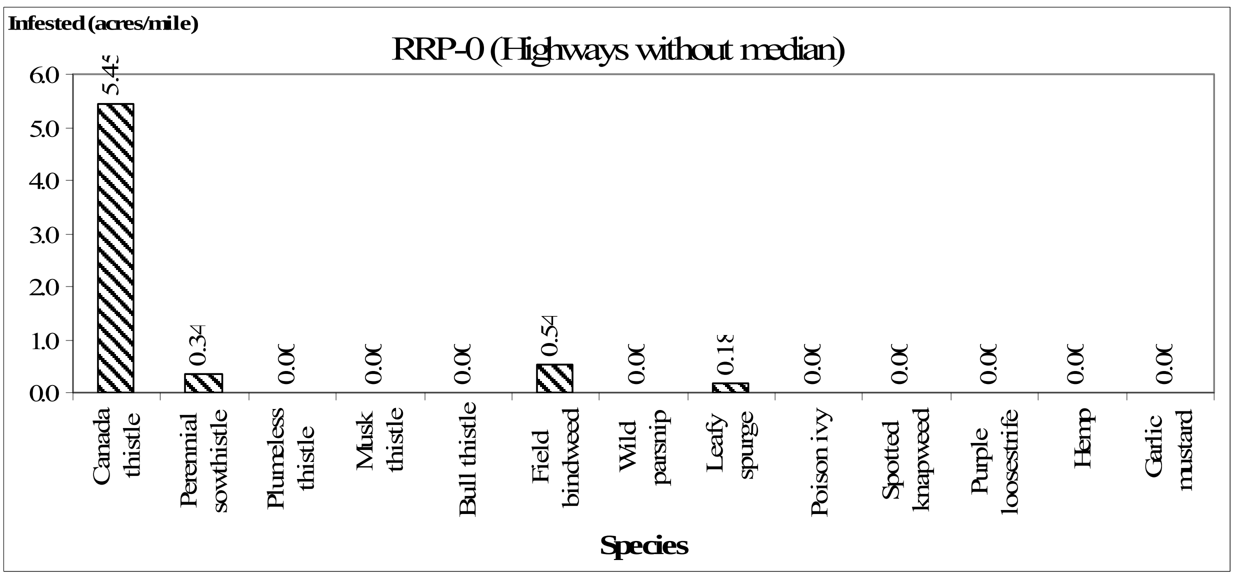


Figure 2.13e: Infestation density of highway ROWs by noxious species evaluated from data recorded in surveys with 225-ft segments in Red River Plains Ecozone of Mn/DOT_D4 for the 2008 surveys.

2.5 EVALUATING SAMPLING PRECISION FOR 14-ft AND 225-ft PLANS

In this project we have interpreted sampling precision as "the measure of how closely the mean value estimated from sample data matches the true large area (complete inventory) population mean". In this part of the project we have compared precisions of the two sampling plans (14-ft or 225-ft) which we applied in conducting surveys in the study. The sampling precision of the two plans were compared using evaluated measurement variance values. Variances were computed from infestation density data evaluated from recorded information on absence-presence of given species from surveys with the 14-ft sampling plan.

2.5.1. Evaluating infestation densities from presence-absence data

The presence-absence surveying method (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/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 the proportion infested (p^+) and equation 2.2. An illustrative plot of equation 2.1 is given in Figure 2.14.

To calibrate equation 2.1 for a given area of interest, we used data recorded in the 225-ft segments of ROW, which we re-sampled after slicing the same into 14-ft sections, then determining the proportion of the sections with species present (p^+), or absent (p^0), and the density (acres-per-mile) within each 14-ft section infested by a given weed species (Table 2.16). This data was then transformed into natural logarithm, plotted (Figure 2.15) and the values α and β (equation 2.2) determined. This shows a weak fit to the data, with an R^2 value of 0.083. These results are quite poor compared to those obtained in similar fit to the 2007 data, R^2 of 0.804

Table 2.18 shows the proportion of the sampled 14-ft segments which are infested by indicated species. Proportion infested values were evaluated as the ratio of the number of surveyed 14-ft segments infested by given species and the total number of segments which were surveyed.

Table 2.16: Proportion of 14-ft sections within categories, and density infested by each weed species based on re-sampling of data recorded in surveys using 225-ft sampling plan for the 2008 surveys.

	CP-0		**HH-0**		**HH-1**		**MNRP-0**		**MNRP-1**		**PMOP-0**		**PMOP-1**		**RRP-0**		**RRP-1**	
Species	Pinf	APM	Pinf	APM	Pinf	APM	Pinf	APM	Pinf	APM	Pinf	APM	Pinf	APM	Pinf	APM	Pinf	APM
Bull Thistle	0.000	0.000	0.000	0.008	0.000	0.001	0.125	0.010	0.000	0.007	0.000	0.159	0.000	0.000	0.000	0.001	0.000	0.003
Canada Thistle	0.000	0.049	0.450	1.563	0.333	10.331	0.700	5.223	0.250	5.896	0.000	2.595	0.500	4.641	0.727	5.450	0.231	8.052
Field bindweed	0.000	0.000	0.000	0.168	0.000	0.212	0.125	0.102	0.250	0.035	0.000	0.000	0.000	0.000	0.152	0.544	0.154	0.170
Leafy spurge	0.000	0.000	0.000	0.006	0.111	0.001	0.100	0.025	0.000	0.000	0.000	0.000	0.000	0.148	0.000	0.187	0.000	0.000
Musk thistle	0.000	0.000	0.000	0.017	0.000	0.002	0.025	0.044	0.000	0.021	0.000	0.000	0.000	0.000	0.091	0.004	0.000	0.006
Perennial Sowthistle	1.000	0.405	0.350	0.144	0.333	0.380	0.225	0.220	0.250	0.968	0.667	1.282	0.500	3.090	0.394	0.342	0.692	1.226
Plumeless Thistle	0.000	0.000	0.100	0.284	0.222	0.024	0.025	0.006	0.000	0.000	0.000	0.186	0.000	0.009	0.061	0.000	0.000	0.753
Poison Ivy	0.000	0.000	0.100	0.231	0.111	0.000	0.025	0.007	0.000	0.007	0.333	0.183	0.000	0.000	0.000	0.000	0.000	0.000
Purple Loosestrife	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000
Spotted knapweed	0.000	0.000	0.200	0.010	0.000	0.000	0.000	0.000	0.000	0.007	0.333	0.000	0.000	0.000	0.030	0.000	0.000	0.000
Wild Parsnip	0.000	0.000	0.000	0.000	0.111	0.000	0.050	0.019	0.500	1.135	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.000

** Pinf = Proportion of 14fters Infested; APM = Acres Per Mile (of 225ft in same category)*

Table 2.17: Proportion of 14-ft sections within categories which are infested by each weed species based on re-sampling of data recorded in surveys using 225-ft sampling plan, 2007 survey.

Species	**CP-0**		**HH-0**		**HH-1**		**MNRP-0**		**MNRP-1**		**PMOP-0**		**PMOP-1**		**RRP-0**		**RRP-1**	
	Pinf*	**APM****	**Pinf**	**APM**	**Pinf**	**APM**	**Pinf**	**APM**	**Pinf**	**APM**	**Pinf**	**APM**	**Pinf**	**APM**	**Pinf**	**APM**	**Pinf**	**APM**
Bull thistle	0.000	0.000	0.125	0.075	0.200	0.143	0.042	0.018	0.750	1.413	1.000	5.182	0.500	0.593	0.051	0.023	0.053	0.024
Canada thistle	0.500	0.593	0.458	0.509	0.600	0.841	0.771	1.525	1.000	5.182	1.000	5.182	1.000	5.182	0.590	0.812	0.737	1.348
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
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
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
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
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
Perennial sowthistle	1.000	5.182	0.250	0.197	0.400	0.405	0.208	0.152	0.750	1.413	0.000	0.000	1.000	5.182	0.410	0.422	0.474	0.539
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
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
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
Spotted knapweed	1.000	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
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

** Pinf = Proportion of 14-fters infested; ** APM = Acres/mile (of 225-ft in same category)*

The parameters obtained through curve fitting (Figure 2.14) are to be applied to evaluate Canada thistle infested density, and proportion infested (p^+) , which when plotted should yield a chart similar to theoretical illustrations in Figure 2.15 and 2.16 However, because of the poor fit to the data, we did not attempt to calculate infested densities using data recorded in 2008 surveys with the 14-ft.

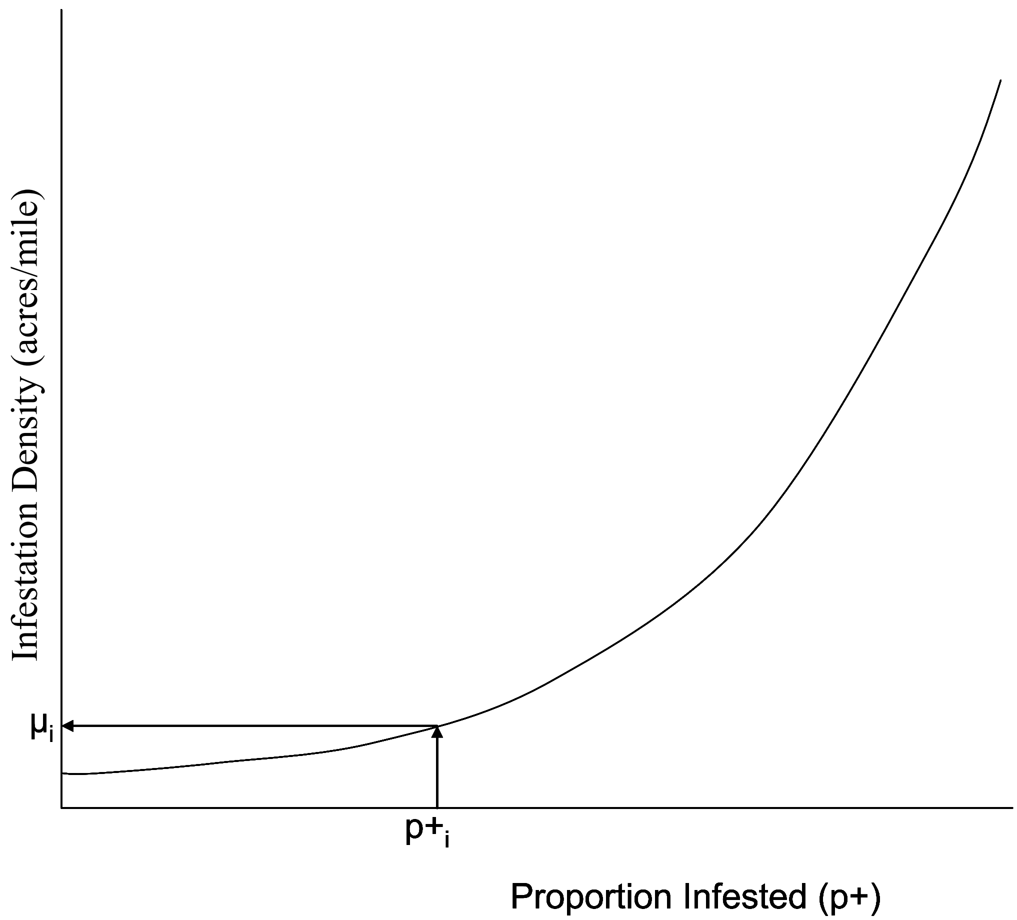


Figure 2.14: Theoretical plot of the proportion infested and corresponding infested density data of 14-ft sections (sliced from 225-ft sampling plan data) for given weed species.

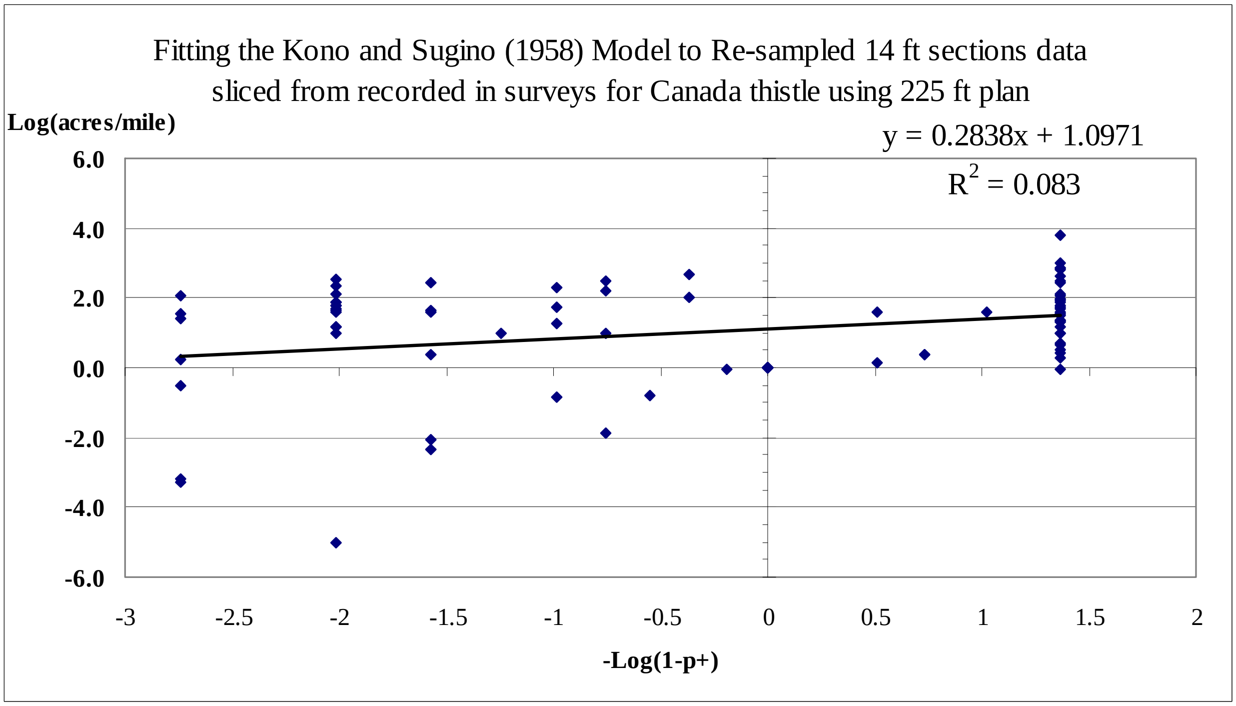
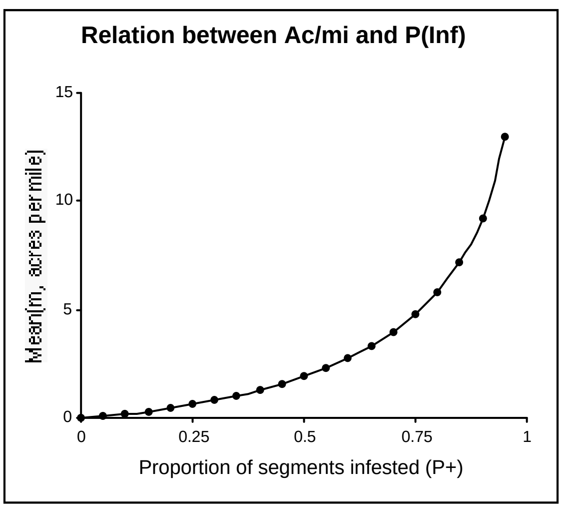


Figure 2.15: Evaluation of the Kono and Sugino model variables using 14-ft data re-sampled from sliced sections of the 225-ft plan data recorded in surveys for Canada thistle for the 2008 surveys.



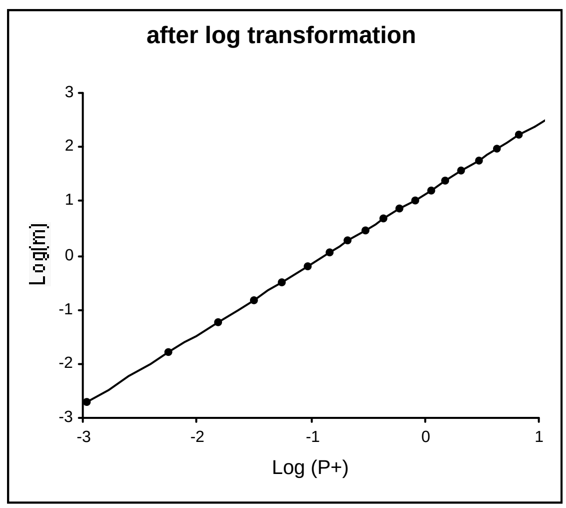


Figure 2.16: Generic plots showing expected relations between density infested and the proportion of surveyed segments which are infested (p+) by a weed species, based on data recorded in surveys using the 14-ft (x-axis) and 225-ft (y-axis) sampling plans.

Figures 2.18 and 2.20 show results of the plots with data recorded in surveys conducted in 2007 and 2008, respectively, using the 14-ft and 225-ft sampling plans. Figure 2.17 (2007 data) show closer similarity with Figure 2.15.

Table 2.18: Proportion of the 14-ft segments per roadway/ecological zones category infested (p+) by each of the 13 weed species surveyed for in Mn/DOT_D4 for the 2008 surveys.

Category	CP-0	HH-0	HH-1	MNRP-0	MNRP-1	PMOP-0	PMOP-1	RRP-0	RRP-1	Total
# Selected sites	**2**	**24**	**10**	**48**	**4**	**2**	**2**	**39**	**19**	150
# Surveyed sites	2	20	9	40	4	2	2	33	13	125
Canada Thistle	1.000	0.600	0.556	0.550	1.000	0.000	1.000	0.818	0.846	0.680
Poison Ivy	0.500	0.200	0.111	0.025	0.000	1.000	0.500	0.000	0.000	0.080
Perennial Sowthistle	1.000	0.500	0.333	0.250	0.500	0.500	1.000	0.606	0.846	0.488
Spotted Knapweed	0.000	0.200	0.000	0.000	0.250	0.500	0.000	0.030	0.000	0.056
Plumeless Thistle	0.000	0.250	0.333	0.000	0.000	0.000	0.000	0.030	0.077	0.080
Purple loosestrife	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.008
Musk Thistle	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.091	0.077	0.040
Field bindweed	0.000	0.000	0.111	0.175	0.750	0.000	0.000	0.242	0.154	0.168
Leafy Spurge	0.000	0.000	0.111	0.025	0.000	0.000	0.000	0.000	0.000	0.016
Wild Parsnip	0.000	0.000	0.111	0.050	0.750	0.000	0.000	0.000	0.000	0.048
Hemp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bull Thistle	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.091	0.000	0.064
Garlic Mustard	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Species	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.077	0.016

Table 2.19: 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

Tables 2.19 and 2.23 show the proportion of 14-ft segments which are infested by different species based on data recorded in surveys of Mn/DOT_D4 conducted in 2007 and 2008 seasons.

Table 2.20: Infested density of species, evaluated by applying the proportion infested data from 2008 surveys to the Kono and Sugino (1958) model.

Species Infestation density (acres/mile) per Category									
Category	**CP-0**	**HH-0**	**HH-1**	**MNRP-0**	**MNRP-1**	**PMOP-0**	**PMOP-1**	**RRP-0**	**RRP-1**
Canada Thistle	0.000	0.636	0.636	0.565	0.000	0.000	0.000!	1.060	0.787
Poison Ivy	0.636	0.176	0.104	0.022	0.000	0.000	0.636	0.000	0.000
Perennial Sowthistle	0.000	0.499	0.336	0.223	0.636	0.636	0.000	0.659	0.787
Spotted Knapweed	0.000	0.176	0.000	0.000	0.273	0.636	0.000	0.027	0.000
Plumeless Thistle	0.000	0.223	0.336	0.000	0.000	0.000	0.000	0.027	0.055
Purple loosestrife	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.000
Musk Thistle	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.080	0.055
Field bindweed	0.000	0.000	0.104	0.153	1.240	0.000	0.000	0.220	0.109
Leafy Spurge	0.000	0.000	0.104	0.022	0.000	0.000	0.000	0.000	0.000
Wild Parsnip	0.000	0.000	0.104	0.043	1.240	0.000	0.000	0.000	0.000
Hemp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bull Thistle	0.000	0.000	0.000	0.108	0.000	0.000	0.000	0.080	0.000
Garlic Mustard	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Species	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.055

To be able to conduct comparisons of sampling precision by the two plans data recorded in surveys with the 14-ft sampling plan were used to evaluate proportion infested (p^+) by individual species. This data was then applied to equation 2.1 to compute density infested by each weed species. Results are shown in Table 2.20.

2.5.2. Analysis of 14-ft sampling plan infestation data in Mn/DOT_D4

Use of 'stick-walks' sampling plan to conduct presence-absence surveys on Mn/DOT_D4 yielded result summarized in Table 2.21. Canada thistle, perennial sowthistle and field bindweed occur in greater numbers of sampled segments and roadway categories compared to the rest of the species. The data show Canada thistle infesting 8 out of the 9 roadway categories. Further, the same species was found to occur in all selected segments in 3 (p+ =1) roadway categories, and in 50% or more (p+ = 0.5) of the other 5 categories. Perennial sowthistle was again the second most abundant, showing presence in all 9 roadway categories, with a 50% or greater infestation in 6 out of the 9 categories. All cases of species presence in at least 1/10th of the surveyed segments are shown highlighted in grey. These show field bindweed as the third most common species, showing presence in 5 out of 9 categories.

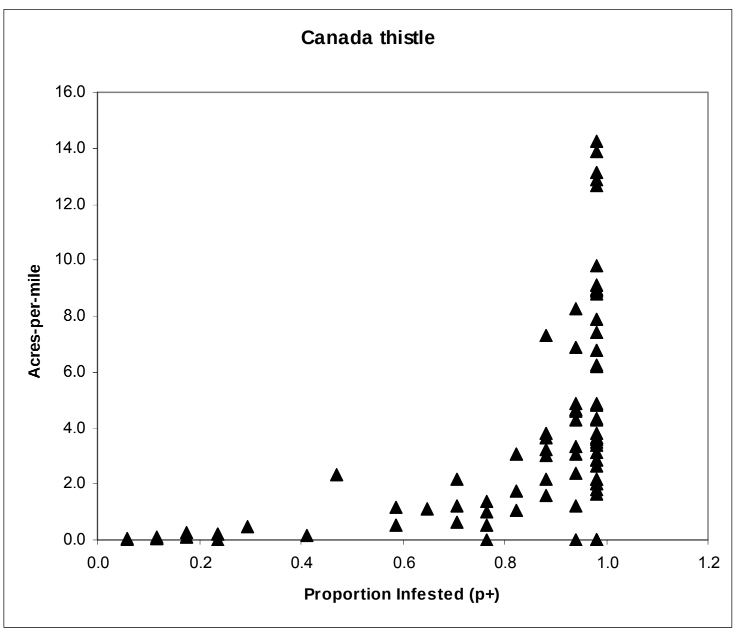


Figure 2.17: Proportion of 225-ft segments and the respective units' density (acres/mile) infested with Canada thistle as evaluated from data recorded in 2007 surveys.

Table 2.21: Population distribution of species among surveyed segments based on data recorded with14-ft sampling plan for the 2008 survey. The total number of segments surveyed was 125.

Catergory	CP-0	HH-0	HH-1	MNRP-0	MNRP-1	PMOP-0	PMOP-1	RRP-0	RRP-1	Total
# Selected sites	**2**	**24**	**10**	**48**	**4**	**2**	**2**	**39**	**19**	150
# Surveyed sites	2	20	9	40	4	2	2	33	13	125
Canada Thistle	2	12	5	22	4	0	2	27	11	85
Poison Ivy	1	4	1	1	0	2	1	0	0	10
Perennial Sowthistle	2	10	3	10	2	1	2	20	11	61
Spotted Knapweed	0	4	0	0	1	1	0	1	0	7
Plumeless Thistle	0	5	3	0	0	0	0	1	1	10
Purple loosestrife	0	0	0	1	0	0	0	0	0	1
Musk Thistle	0	0	0	1	0	0	0	3	1	5
Field bindweed	0	0	1	7	3	0	0	8	2	21
Leafy Spurge	0	0	1	1	0	0	0	0	0	2
Wild Parsnip	0	0	1	2	3	0	0	0	0	6
Hemp	0	0	0	0	0	0	0	0	0	0
Bull Thistle	0	0	0	5	0	0	0	3	0	8
Garlic Mustard	0	0	0	0	0	0	0	0	0	0
Other Species	0	0	0	0	0	0	0	1	1	2

Table 2.22: 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

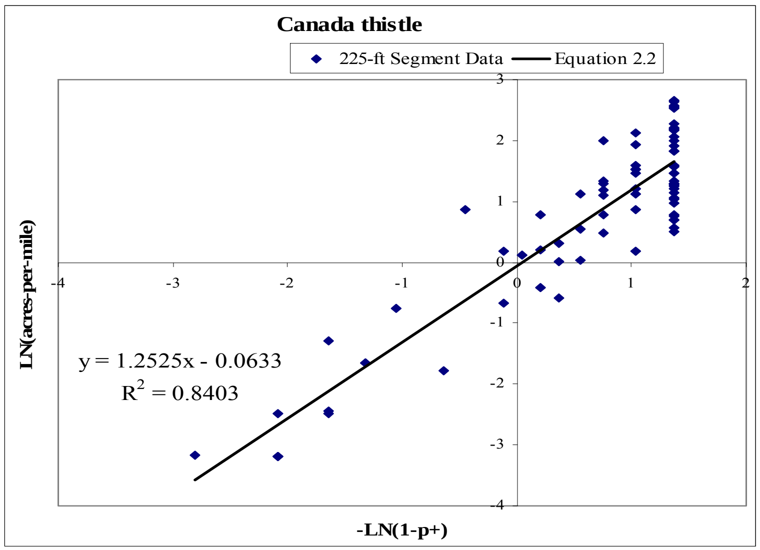


Figure 2.18: Log-log transformations of acres-per-mile and proportion infested data fitted trend line for the transformed Kono and Sugino model (equation 2.2) for the 2007 surveys.

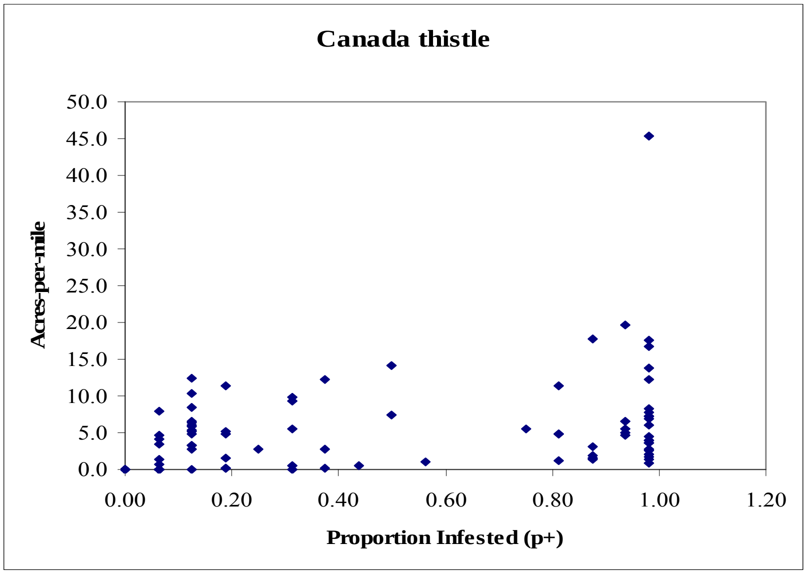


Figure 2.19: Proportion of 225-ft segments and the respective units' areas (acres/mile) infested with Canada thistle evaluated from data recorded in 2008 surveys.

When the proportion of 225-ft segment which are infested by a given species are plotted against infested densities (acres/mile), should yield curves shown in Figure 2.16. When the data sets are subjected to a log-log transform, these yield a straight line curve as shown in the same figure. Note that cases where m was zero, or p^+ was either zero or one become undefined in the transformed scale, so there may be fewer points in a log-log plot than an m-p^+ plot.

The fitted equation can then be applied in computations using the 14-ft sampling plan data (the independent set of 14 ft stick walk data) to estimate the population density per ecological zone.

Results are presented in graphs Figures 2.20 to 2.29. The variables are:

- APM = mean (*m*) acres per roadway mile in each roadway category
- PINF = proportion of "stick-walks" infested (*P*+), matched with APMs
- Open circles are from undivided roads, and filled ones are from divided ones (with medians)
- Y = $\log_e$(APM), X = $\log_e$(-loge(1–PINF))
- Lines are linear regressions, fitted separately.

Based on these results, the general conclusion is that it is not likely that presence-absence sampling can be used to estimate infestation density by any of the weed species. Variability is too great to provide reasonable accuracy of density estimation. An idea that improvements in the results from similar analyses may be achieved if data re-grouped by type of highways, with or without median, could not be tested due to time constraints (will be explored and reported in planned publications).

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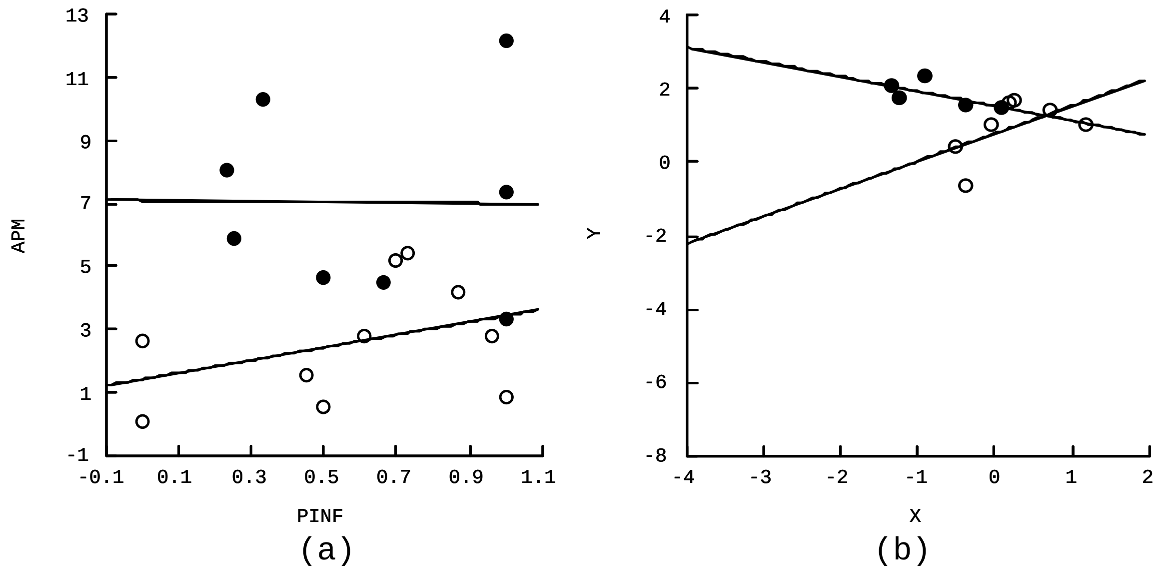


Figure 2.20: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Canada thistle as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).

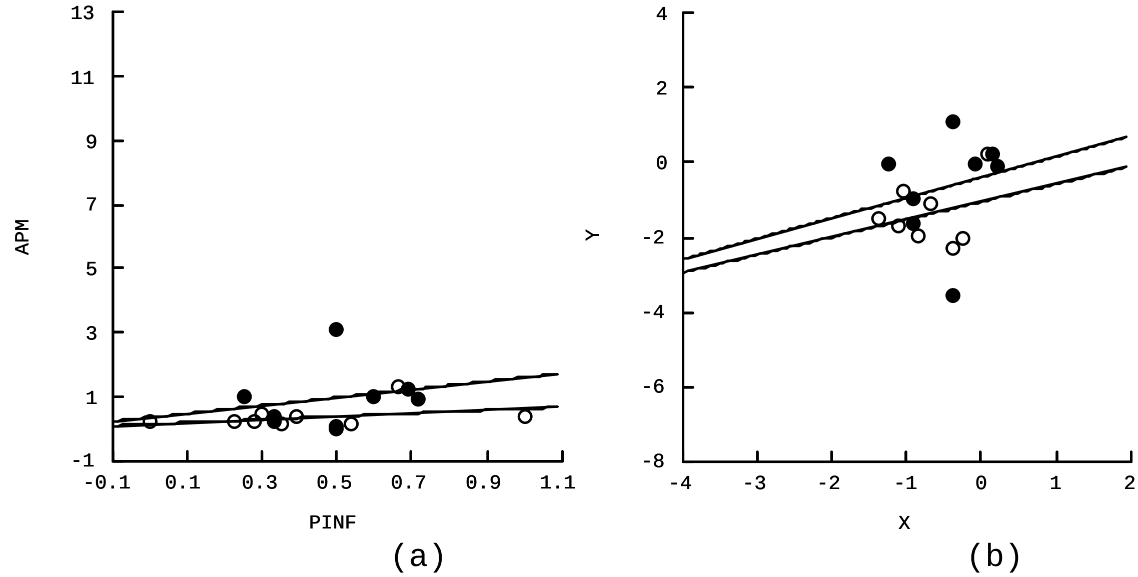


Figure 2.21: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Perennial sowthistle as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).

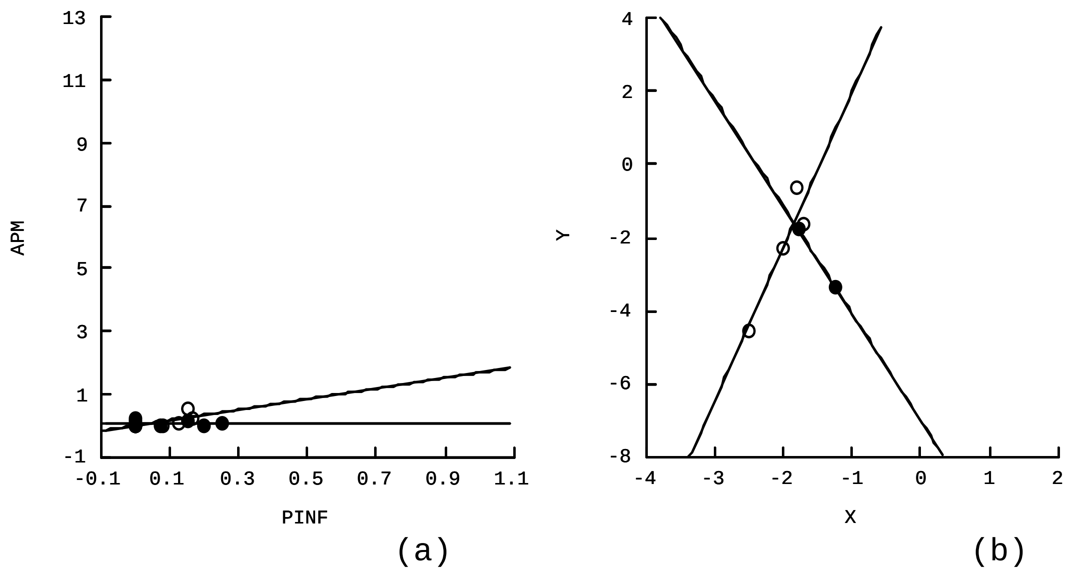
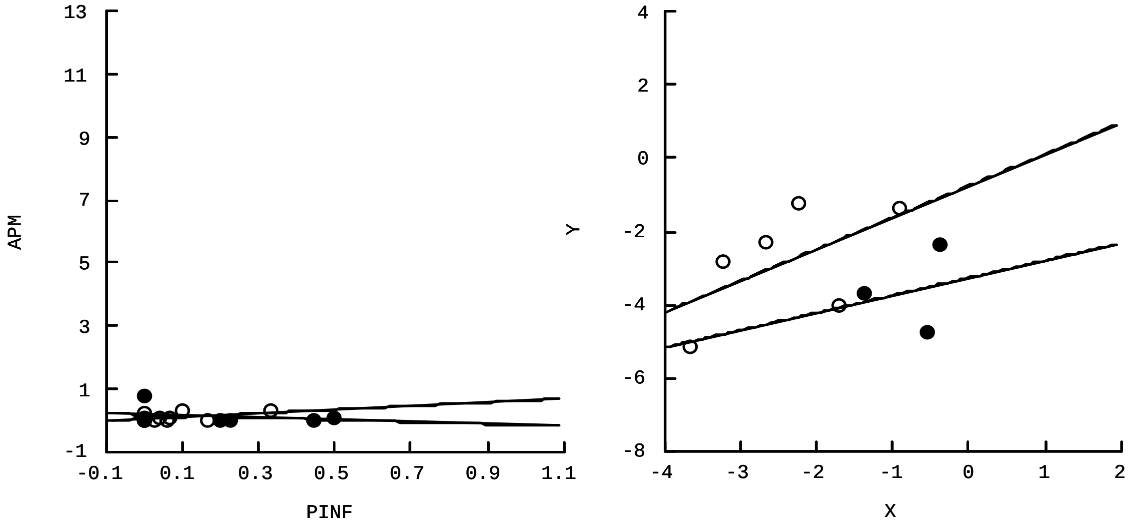
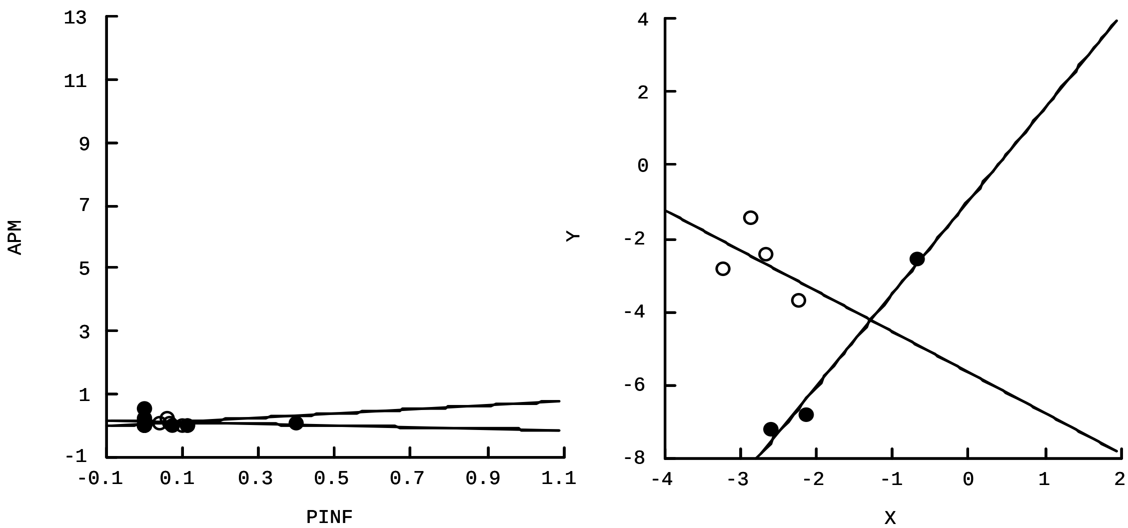


Figure 2.22: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Field bindweed as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).



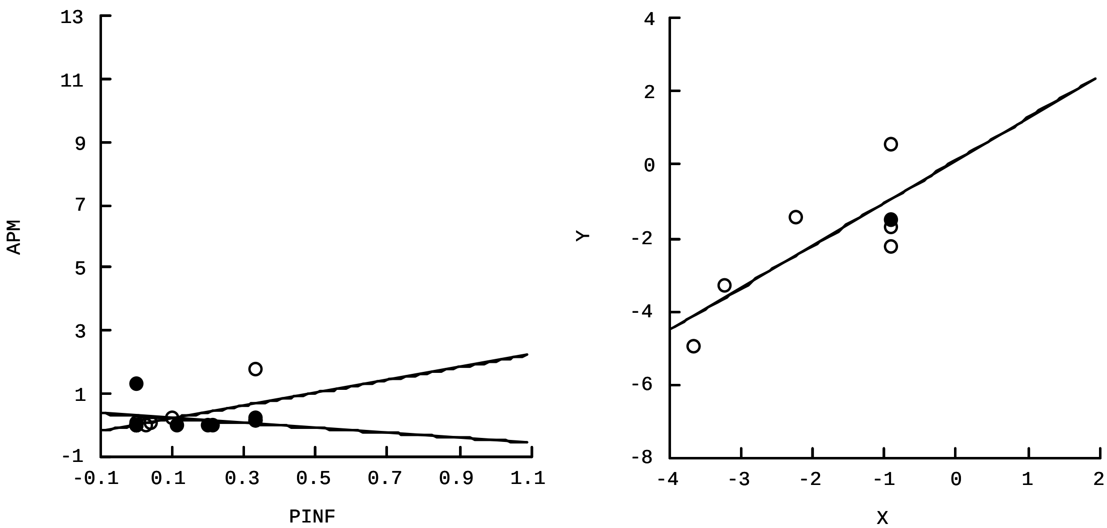
(a) (b)

Figure 2.23: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Plumeless thistle as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).



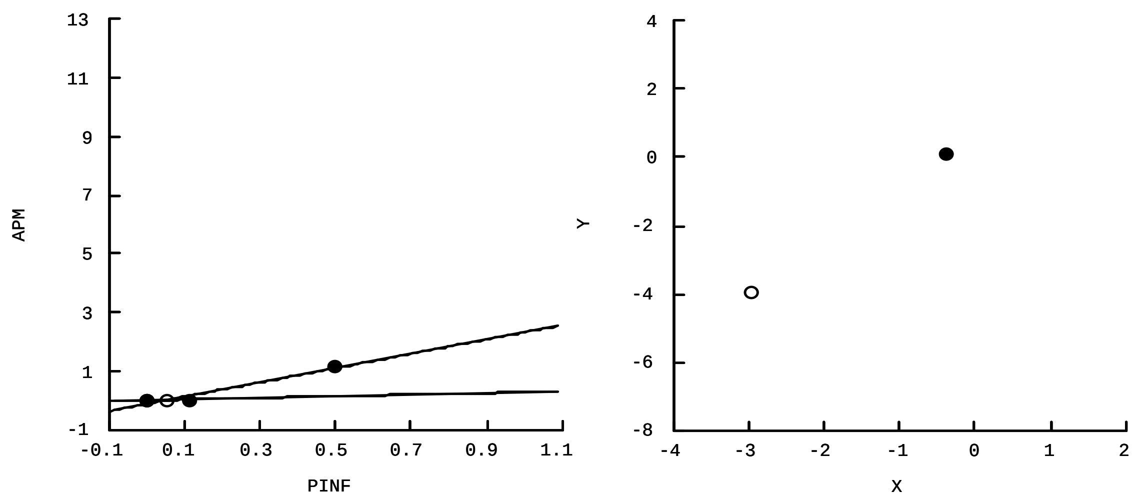
(a) (b)

Figure 2.24: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Leafy spurge as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).



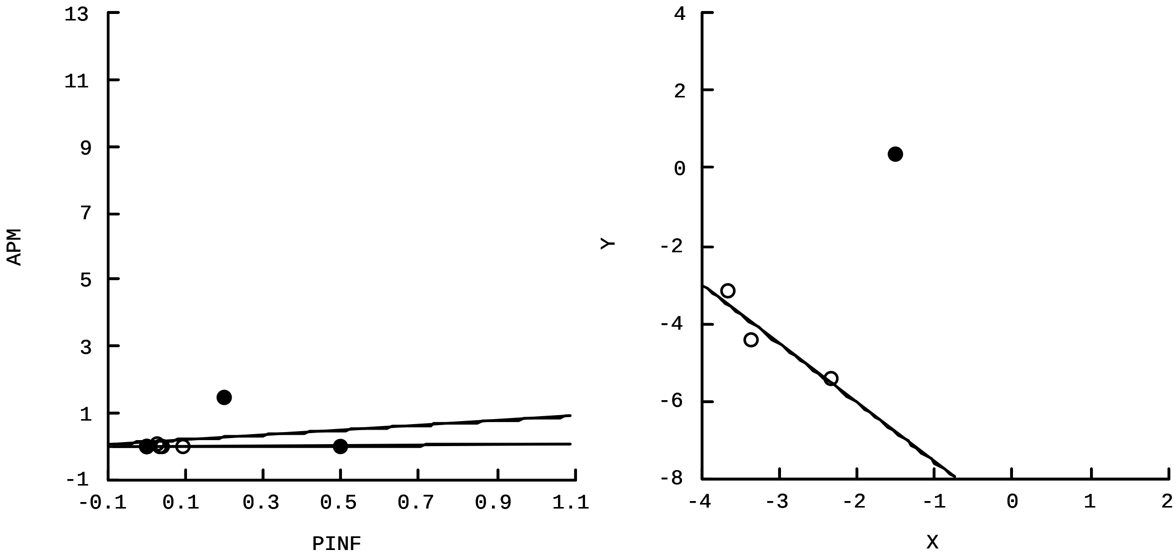
(a) (b)

Figure 2.25: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Poison ivy as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).



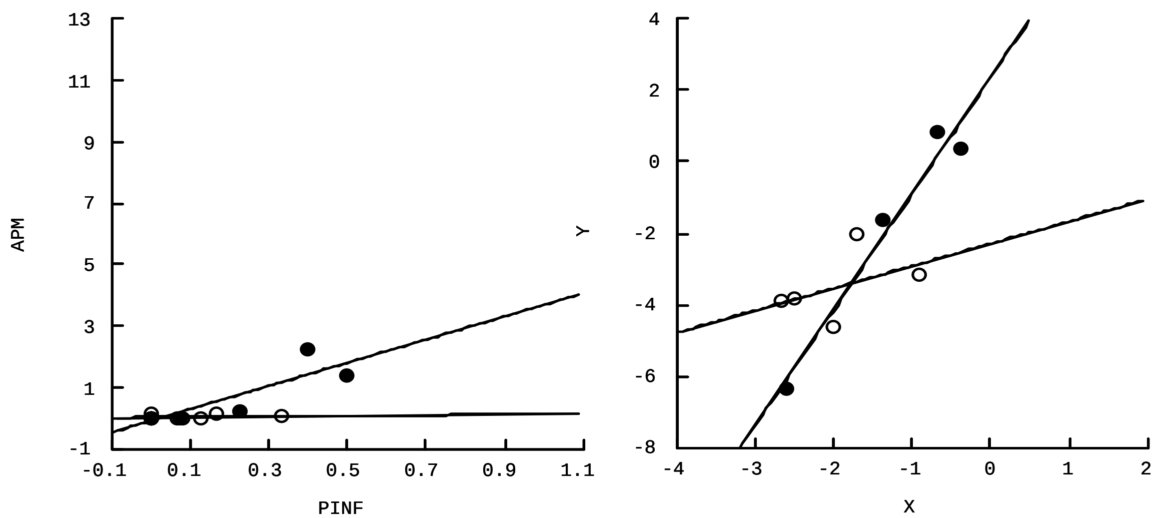
(a) (b)

Figure 2.26: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Wild parsnip as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).



(a) (b)

Figure 2.27: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Musk thistle as evaluated from data recorded in surveys conducted in Mn/DOT D4 highways in 2008 (filled circles are for highways with medians).



(a) (b)

Figure 2.28: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Bull thistle as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).

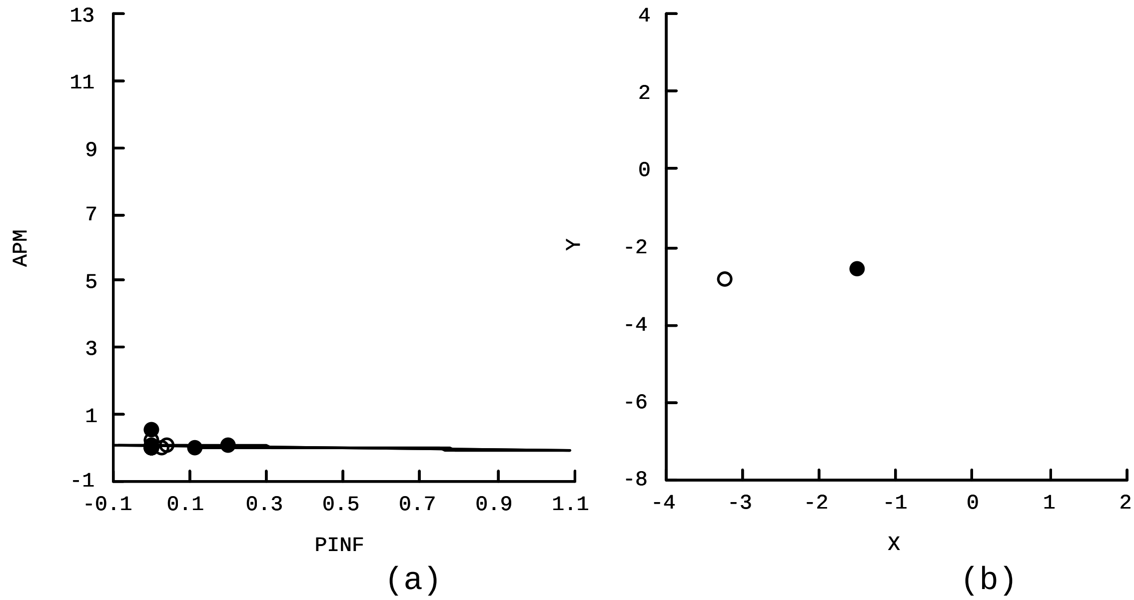


Figure 2.29: Normal (a) and log-log (b) plots of the proportion of 225-ft segments versus density (acres/mile) infested with Purple loosestrife as evaluated from data recorded in surveys conducted in highways in Mn/DOT D4 in 2008 (filled circles are for highways with medians).

*2.5.3. Variance – 14-*ft *sampling plan*

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

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

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.

$$Var(\ln m)_p = mse + \frac{mse}{N} + \left\{\ln\left[-\ln(1-p^{+}) - \overline{p}^{+}\right]\right\}^2 s_b^{\ 2} \quad (2.4)$$

The equation is partitioned into two components as:

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

and

$$c3 = mse \qquad (2.6)$$

where *mse* is the mean square error from the regression of equation 2.2, N is the number of data points in the regression used to estimate α and β, $\bar{p}$ is the mean of the independent variable (i.e., $\ln[-\ln(1-p^{+})]$) in the data sets used to estimate α and β, and 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:

$$Var(\ln m)_{Total} = c1 + c2 + c3 \qquad (2.7)$$

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

2.5.4. Variance – 225-ft sampling plan

Statistical analysis of the data recorded with the 225-ft sampling plan was completed and presented in Tables 2.23 and 2.25. Other statistical values evaluated included the mean error of estimates (Standard error, SE).

2.6 EVALUATING SAMPLING EFFICIENCIES FOR 14-ft AND 225-ft PLANS

In this project, we have defined sampling efficiency simply 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".**

The aim of conducting sampling is to obtain information on specific species populating a given area, at the highest level of accuracy possible, with minimal costs or effort applied. In this project a hypothesis, that **"absence-presence surveys conducted using 14-ft long segments, or, mapping surveys with 225-ft long segments, would yield weed population distribution estimates for a large area such as Mn/DOT_D4, with comparable accuracies".**

To evaluate efficiencies of the sampling plans, time data (time spent conducting survey of a given region, which includes traveling between office and sampling sites, traveling site-to-site, and total time spent inspecting each site) were subjected to series of analyses.

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

$$RNP = \frac{Length}{Cost} \, x \, \frac{Length}{Variance} \qquad (2.8)$$

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 in collecting and processing data for 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.

To calculate variances for data recorded in the presence-absence surveys (14ft plan), we computed the parameter by applying evaluated infestation density data (Table 2.20, page 54) for each weed species to equations 2.3 - 2.7.

Calculations and discussions on these evaluations are presented in section 3.2 in this report

2.7 STATISTICAL ANALYSIS

Processed data was applied to various analyses, including evaluating errors associated to obtained mean infested for each species in surveyed categories. Results of the analyses are as presented in tables 2.23 to 2.26.

Table 2.23: Summary statistics of species infestation densities (acres/mile) in the management sub-districts in Mn/DOT_D4 based on 225-ft sampling plan for the 2008 survey.

Canada thistle	**Alexandria Canada thistle**	**Fergus Falls Canada thistle**	**Moorhead Canada thistle**	**Morris Canada thistle**	**District-Wide Totals/means**
n	18	28	18	22	86
Mean	4.652	7.215	3.486	4.633	4.770
Variance	19.612	64.348	23.380	10.002	
SD	4.429	8.022	4.835	3.163	
SE	1.044	1.516	1.140	0.674	0.544
Perennial sowthistle	**Perennial sowthistle**	**Perennial sowthistle**	**Perennial sowthistle**	**Perennial sowthistle**	
n	18	28	18	22	86
Mean	0.440	0.769	0.656	0.209	0.420
Variance	0.401	1.611	0.946	0.570	
SD	0.633	1.269	0.973	0.755	
SE	0.149	0.240	0.229	0.161	0.099
Plumeless thistle	**Plumeless thistle**	**Plumeless thistle**	**Plumeless thistle**	**Plumeless thistle**	
n	18	28	18	22	86
Mean	0.073	0.182	0.414	0.004	0.110
Variance	0.039	0.398	2.891	0.000	
SD	0.197	0.631	1.700	0.018	
SE	0.046	0.119	0.401	0.004	0.099
Musk thistle	**Musk thistle**	**Musk thistle**	**Musk thistle**	**Musk thistle**	
n	18	28	18	22	86
Mean	0.028	0.004	0.004	0.038	0.020
Variance	0.001	0.000	0.000	0.023	
SD	0.038	0.016	0.016	0.151	
SE	0.009	0.003	0.004	0.032	0.010
Bull thistle	**Bull thistle**	**Bull thistle**	**Bull thistle**	**Bull thistle**	
n	18	28	18	22	86
Mean	0.021	0.001	0.008	0.010	0.020
Variance	0.003	0.000	0.001	0.000	
SD	0.053	0.010	0.025	0.022	
SE	0.012	0.002	0.006	0.005	0.003
Field bindweed	**Field bindweed**	**Field bindweed**	**Field bindweed**	**Field bindweed**	
n	18	28	18	22	86
Mean	0.219	0.082	0.003	0.559	0.220
Variance	0.358	0.034	0.000	4.003	
SD	0.598	0.184	0.014	2.001	
SE	0.141	0.035	0.003	0.427	0.137
Wild parsnip	**Wild parsnip**	**Wild parsnip**	**Wild parsnip**	**Wild parsnip**	
n	18	28	18	22	86
Mean	0.381	0.000	0.000	0.019	0.030
Variance	2.544	0.000	0.000	0.008	
SD	1.595	0.010	0.010	0.090	
SE	0.376	0.002	0.002	0.019	0.081

Table 2.23: Summary statistics of species infestation densities (acres/mile) in the management sub-districts in Mn/DOT_D4 based on 225-ft sampling plan for the 2008 survey. (cont…)

Leafy spurge	Alexandria Leafy spurge	Fergus Falls Leafy spurge	Moorhead Leafy spurge	Morris Leafy spurge	District-Wide Totals/means
n	18	28	18	22	86
Mean	0.000	0.152	0.000	0.011	0.060
Variance	0.000	0.450	0.000	0.001	
SD	0.010	0.671	0.010	0.034	
SE	0.002	0.127	0.002	0.007	0.030
Poison ivy	**Poison ivy**	**Poison ivy**	**Poison ivy**	**Poison ivy**	
n	18	28	18	22	86
Mean	0.095	0.005	0.112	0.007	0.060
Variance	0.155	0.001	0.154	0.001	
SD	0.394	0.028	0.393	0.033	
SE	0.093	0.005	0.093	0.007	0.030
Spotted knapweed	**Spotted knapweed**	**Spotted knapweed**	**Spotted knapweed**	**Spotted knapweed**	
n	18	28	18	22	86
Mean	0.011	0.000	0.000	0.000	0.002
Variance	0.001	0.000	0.000	0.000	
SD	0.029	0.010	0.010	0.010	
SE	0.007	0.002	0.002	0.002	0.002
Purple loosestrife	**Purple loosestrife**	**Purple loosestrife**	**Purple loosestrife**	**Purple loosestrife**	
n	18	28	18	22	86
Mean	0.000	0.000	0.010	0.000	0.002
Variance	0.000	0.000	0.002	0.000	
SD	0.010	0.010	0.039	0.010	
SE	0.002	0.002	0.009	0.002	0.002
Hemp	**Hemp**	**Hemp**	**Hemp**	**Hemp**	
n	18	28	18	22	86
Mean	0.000	0.000	0.000	0.002	0.001
Variance	0.000	0.000	0.000	0.000	
SD	0.010	0.010	0.010	0.012	
SE	0.002	0.002	0.002	0.002	0.001
Garlic mustard	**Garlic mustard**	**Garlic mustard**	**Garlic mustard**	**Garlic mustard**	
n	18	28	18	22	86
Mean	0.000	0.000	0.000	0.000	0.000
Variance	0.000	0.000	0.000	0.000	
SD	0.010	0.010	0.010	0.010	
SE	0.002	0.002	0.002	0.002	0.001

Table 2.24: Population distribution of different weed species in the 9 ecological zones/highway types categories of Mn/DOT District evaluated from 225-ft sampling plan data for the 2008 survey.

	CP-0	PMOP-1	MNRP-1	HH-1	RRP-1	PMOP-0	HH-0	RRP-0	MNRP-0
n	**2**	**2**	**6**	**6**	**12**	**2**	**15**	**19**	**22**
					Canada thistle				
Mean (ac/mi)	0.049	4.641	5.896	10.331	8.052	2.595	1.563	5.450	5.223
Variance	0.005	20.059	23.992	217.311	26.330	2.680	2.913	29.422	11.558
SD	0.069	4.479	4.898	14.741	5.131	1.637	1.707	5.424	3.400
SE	0.049	3.167	2.000	6.018	1.481	1.158	0.441	1.244	0.725
					Perennial sowthistle				
Mean (ac/mi)	0.405	3.090	0.968	0.380	1.226	1.282	0.144	0.342	0.220
Variance	0.000	18.172	0.702	0.326	0.723	3.289	0.061	0.495	0.569
SD	0.020	4.263	0.838	0.571	0.851	1.814	0.248	0.704	0.754
SE	0.014	3.014	0.342	0.233	0.246	1.282	0.064	0.161	0.161
					Plumeless thistle				
Mean (ac/mi)	0.000	0.009	0.000	0.024	0.753	0.186	0.284	0.000	0.006
Variance	0.000	0.000	0.000	0.001	4.425	0.002	0.564	0.000	0.000
SD	0.010	0.010	0.010	0.033	2.103	0.040	0.751	0.010	0.020
SE	0.007	0.007	0.004	0.014	0.607	0.028	0.194	0.002	0.004
					Musk thistle				
Mean (ac/mi)	0.000	0.000	0.021	0.002	0.006	0.000	0.017	0.004	0.044
Variance	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.023
SD	0.010	0.010	0.023	0.010	0.019	0.010	0.038	0.019	0.151
SE	0.007	0.007	0.009	0.004	0.006	0.007	0.010	0.004	0.032
					Bull thistle				
Mean (ac/mi)	0.000	0.000	0.007	0.001	0.003	0.159	0.008	0.001	0.010
Variance	0.000	0.000	0.000	0.000	0.000	0.005	0.001	0.000	0.000
SD	0.010	0.010	0.017	0.010	0.010	0.073	0.023	0.010	0.022
SE	0.007	0.007	0.007	0.004	0.003	0.052	0.006	0.002	0.005
					Field bindweed				
Mean (ac/mi)	0.000	0.000	0.035	0.212	0.170	0.000	0.168	0.544	0.102
Variance	0.000	0.000	0.004	0.113	0.062	0.000	0.404	4.628	0.089
SD	0.010	0.010	0.066	0.336	0.249	0.010	0.636	2.151	0.299
SE	0.007	0.007	0.027	0.137	0.072	0.007	0.164	0.494	0.064

Table 2.24: Population distribution of different weed species in the 9 ecological zones/highway types categories of Mn/DOT District evaluated from 225-ft sampling plan data for the 2008 survey. (cont…)

	CP-0	PMOP-1	MNRP-1	HH-1	RRP-1	PMOP-0	HH-0	RRP-0	MNRP-0
n	**2**	**2**	**6**	**6**	**12**	**2**	**15**	**19**	**22**
					Wild parsnip				
Mean (ac/mi)	0.000	0.000	1.135	0.000	0.000	0.021	0.000	0.000	0.019
Variance	0.000	0.000	7.623	0.000	0.000	0.001	0.000	0.000	0.008
SD	0.010	0.010	2.761	0.010	0.010	0.030	0.010	0.010	0.090
SE	0.007	0.007	1.127	0.004	0.003	0.021	0.003	0.002	0.019
					Leafy spurge				
Mean (ac/mi)	0.000	0.148	0.000	0.001	0.000	0.000	0.006	0.187	0.025
Variance	0.000	0.044	0.000	0.000	0.000	0.000	0.001	0.664	0.005
SD	0.010	0.209	0.010	0.010	0.010	0.010	0.023	0.815	0.072
SE	0.007	0.148	0.004	0.004	0.003	0.007	0.006	0.187	0.015
					Poison ivy				
Mean (ac/mi)	0.000	0.000	0.007	0.000	0.000	0.183	0.231	0.000	0.007
Variance	0.000	0.000	0.000	0.000	0.000	0.067	0.338	0.000	0.001
SD	0.010	0.010	0.017	0.010	0.010	0.259	0.581	0.010	0.033
SE	0.007	0.007	0.007	0.004	0.003	0.183	0.150	0.002	0.007
					Spotted knapweed				
Mean (ac/mi)	0.000	0.000	0.007	0.000	0.000	0.000	0.010	0.000	0.000
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
SD	0.010	0.010	0.017	0.010	0.010	0.010	0.030	0.010	0.010
SE	0.007	0.007	0.007	0.004	0.003	0.007	0.008	0.002	0.002
					Purple loosestrife				
Mean (ac/mi)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
SD	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.038	0.010
SE	0.007	0.007	0.004	0.004	0.003	0.007	0.003	0.009	0.002
					Hemp				
Mean (ac/mi)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SD	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.012
SE	0.007	0.007	0.004	0.004	0.003	0.007	0.003	0.002	0.002
					Garlic mustard				
Mean (ac/mi)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SD	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
SE	0.007	0.007	0.004	0.004	0.003	0.007	0.003	0.002	0.002

Table 2.25: Population distribution of species among surveyed segments based on data recorded with 225-ft sampling plan for the 2008 survey. The total number of segments surveyed was 87.

Species	Number of Segments with species presence from among the surveyed (100) in D4
Canada thistle	77
Plumeless thistle	17
Spotted knapweed	3
Leafy Spurge	9
Bull Thistle	13
Perennial sowthistle	58
Purple loosestrife	2
Poison ivy	6
Wild parsnip	6
Musk thistle	17
Hemp	1
Garlic mustard	0
Field bindweed	18

Table 2.25 shows the magnitude of the problem each species presents in Mn/DOT_D4. The values against each species/road category are the number of segments from those inspected which have species presence. This shows Canada thistle being the most serious problem species, with 77 out of 87 inspected sites having species presence. Perennial sowthistle is the next most common species, with a presence in 58 out of the 87 inspected segments. Based on this data, the species which pose the least problem (based on extent of infestation in the district) are purple loosestrife, spotted knapweed, hemp and garlic mustard.

Table 2.26: Mean acres/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

2.8 PROPORTION INFESTED IN THE COMBINED 2007, 2008 DATA

Analysis of data recorded in surveys for Canada thistle infestation using 14-ft and 225-ft sampling plans show consistent trends across the years (2007 – 2008). Figure 2.30 is a plot showing relationship between infestation density and proportion of the 225-ft segments surveyed for species presence in 2007 and 2008. The figure shows a more uniform distribution of points across the whole range of proportions infested (0 – 1), compared to similar analysis results for the 2007 data (Figure 2.17) which show increased populations in the higher proportion range (greater than 0.5). Curve fitting density infested and proportion infested data to the Kono and Sugino (1958) model showed poorer fit (R^2=0.237, Figure 2.31) compared to obtained with the 2007 (R^2=0.8403, Figure 2.18) data. The results were however, better than obtained in the fit with 2008 data ($R^{2=}$ 0.083, Figure 2.14).

The data was further processed to obtain density and proportion infested values for the 9 categories (Ecozone-type of highway, divided or undivided). This was applied to a plot with proportion infested values for the same 9 categories which are evaluated from data recorded from surveys with the 14-ft sampling plan. These were plotted in attempt to establish how well data recorded with the 14-ft plan would fit the Kono and Sugino model. The results are shown in Figure 2.32, with an R^2 value of 0.3837. The results argue against application of the data obtained in surveys with the 14-ft plan to compute infested densities using the Kono and Sugino model.

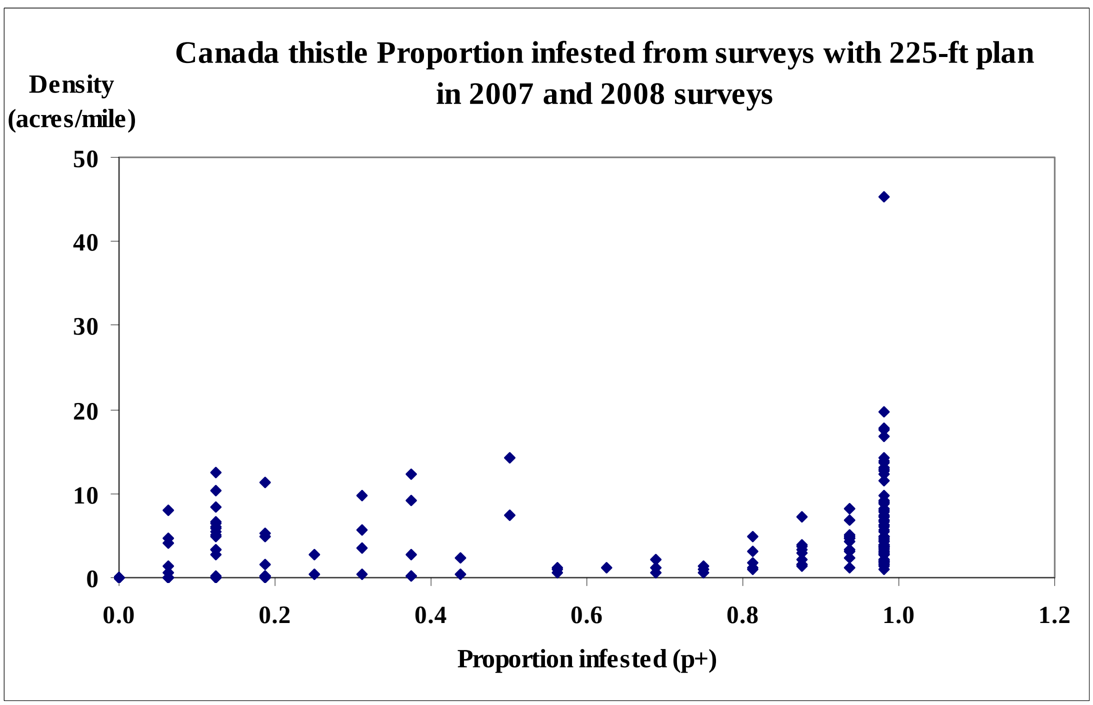


Figure 2.30: Proportion of 225-ft segments and the respective units' areas (acres/mile) infested with Canada thistle evaluated from data recorded in 2007 and 2008 surveys.

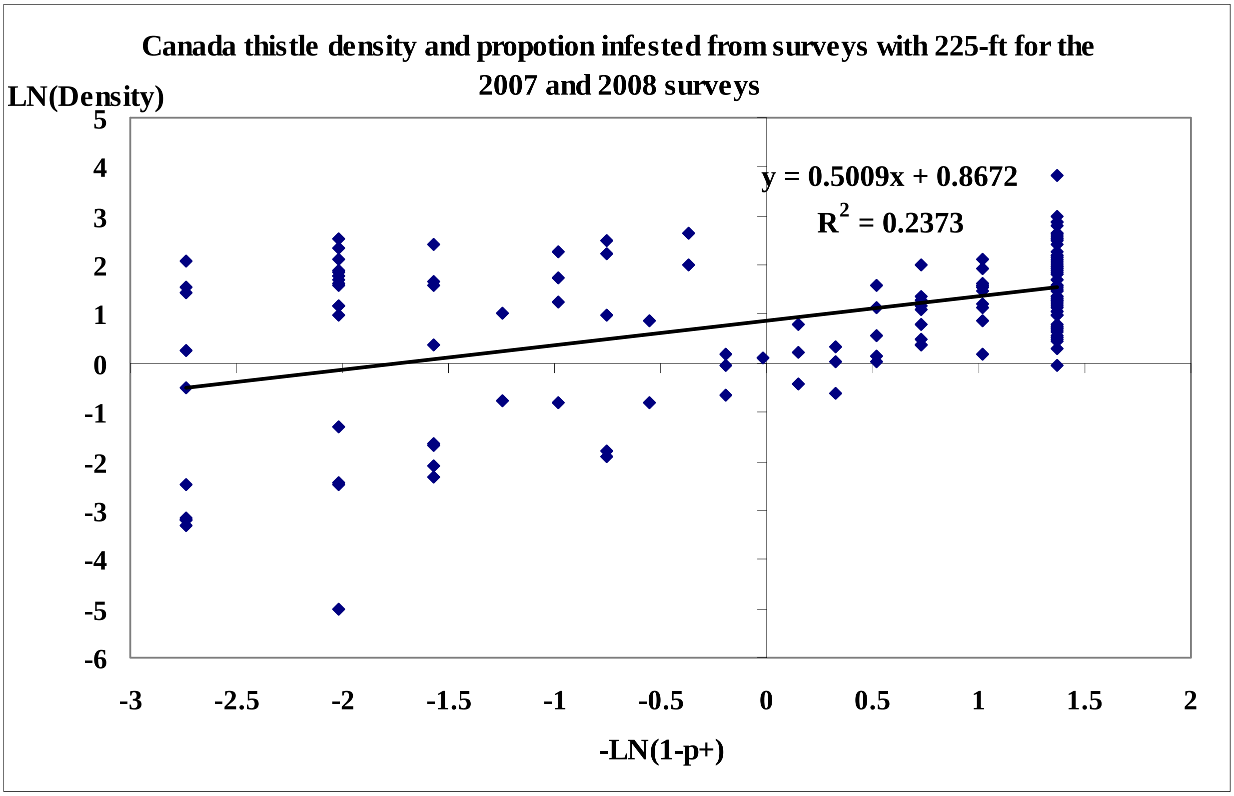
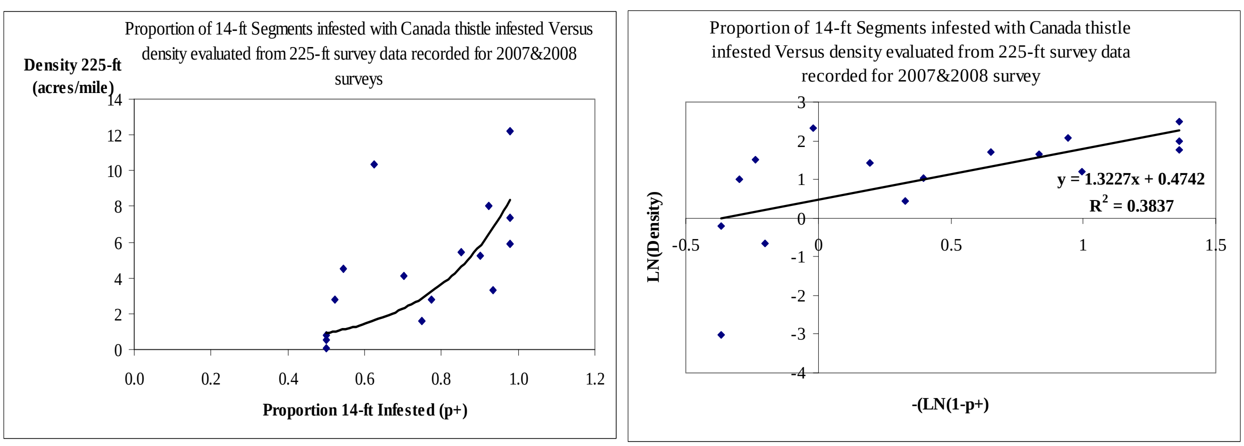


Figure 2.31: Plot of the log-log transformed density and proportion infested data and evaluation of the Kono and Sugino model parameters from data recorded with 225-ft sampling plan from surveys conducted in 2007 and 2008.



(a). LN(Density) vs (p+) (b) Log(Density) vs _LN (p+)

Figure 2.32: Relationship between density and the proportion of segments infested (p+) by Canada thistle, based on data recorded in surveys conducted in 2007 and 2008 using the 14-ft (x-axis) and 225-ft (y-axis) sampling plans; (b) is the log transformation for (a).

In view of the foregoing findings, it was not necessary to attempt comparisons of the performance of the 14-ft and 225-ft sampling plans in evaluating acres infested in the study area by any given weed species.

2.9 COMPARATIVE ANALYSIS OF THE 3-MILE, ¼-MILE, 225-FT AND 14-FT SAMPLING PLANS

Tables 2.27 and 2.28 show the population densities and proportion infested for Canada thistle in Mn/DOT_D4 highways' rights-of-way as evaluated from data recorded in surveys conducted in 2004 and 2005 using ¼-mile and 3-mile sampling plans, respectively. These data sets and their analyses provide a means for comparing efficacies associated with application of the two 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 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 the three sampling plans.

To evaluate the unknown parameters of the Kono and Sugino (1958) model, a plot of the tow data sets acquired in surveys using the 225-ft and 14-ft sampling plans is necessary. This is achieved by first re-sampling the 225-ft sampling plan data into 14-ft segments as earlier explained, and obtaining both the proportion of these 14-ft sections infested and infested density for each section. These are plotted together with the proportion infested values obtained from data recorded in surveys with the 14-ft sampling plan. The results for Canada thistle 2007 and 2008 surveys are shown in Figure 2.32.

Figures 2.33 and 2.34 show comparative infested densities (acres/mile) of Canada thistle in the surveyed categories evaluated from data recorded in surveys with the three sampling plans. Although the differences between the mean acres-per-mile values across categories appear to be small, values obtained with the 225-ft plan were higher in many (6 of 9) categories compared to those from the other sampling plans.

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. Part of the reason for the difficulty is because of incomplete data across surveyed categories.

Table 2.27: Mean acres/mile, and the proportion of surveyed segments infested by Canada thistle evaluated from data recorded on ¼-mile and 3-mile sampling plans for the 2004 survey.

Category	¼-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 2.28: Mean acres/mile, and the proportion of surveyed segments infested by Canada thistle evaluated from data recorded on ¼-mile and 3-mile sampling plans for the 2005 survey.

	¼-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

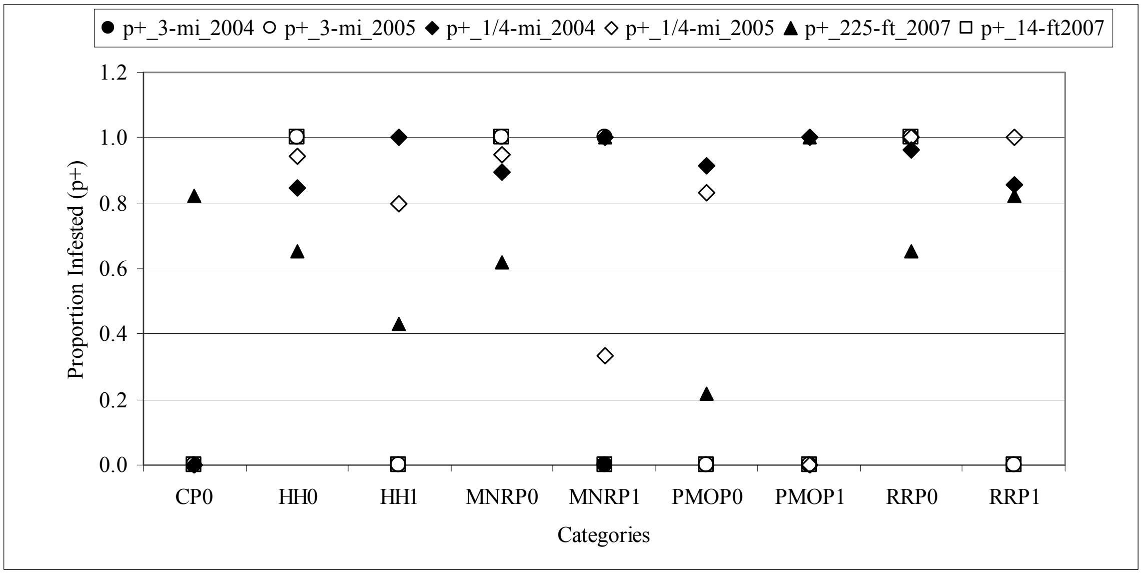


Figure 2.33: Proportion of surveyed segments infested with Canada thistle for the nine categories as evaluated from data recorded in surveys with 3-mile and ¼-mile sampling plans, in 2004 and 2005 surveys.

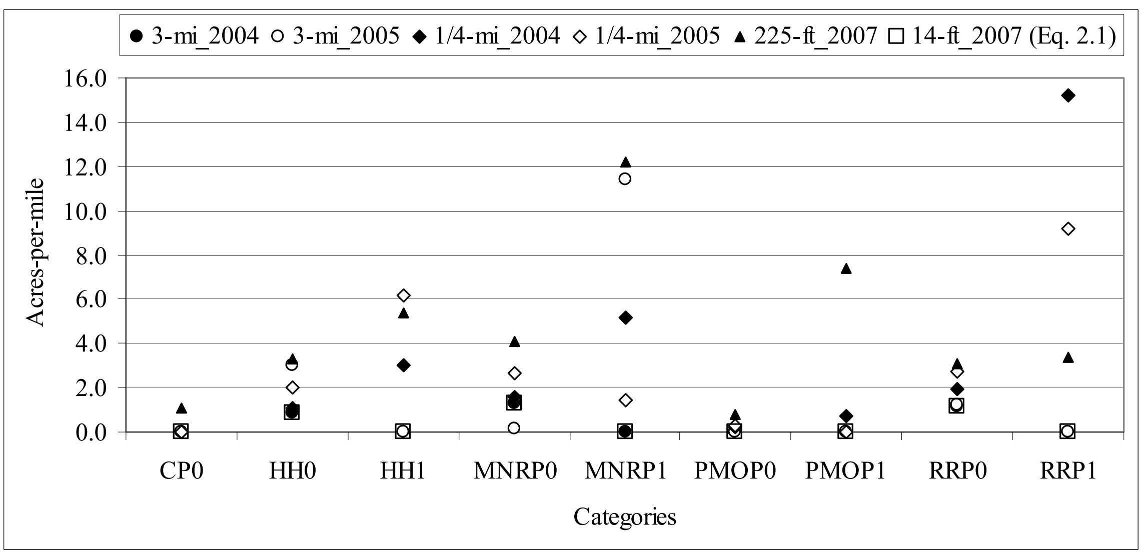


Figure 2.34: Acres/mile infested with Canada thistle for the nine categories as evaluated from data recorded in surveys with 3-mile and ¼-mile sampling plans, in 2004 and 2005 surveys.

3.0 WEED SCOUTING TIMES WITH 225-ft SEGMENTS AND 14-ft TRANSECTS

Surveying was carried out by operators who inspected sites individually or in groups of 2 or more people working together (Tables 3.1 and 3.2). Scouting accomplished by these operators in a given day was considered a 'run'. Surveyors maintained a record of time spent on a run, which constituted time traveling from office to the first sampling site or from last sampling site to office (leg), traveling between sampling units (transit), and inspecting the site (scout). Time record for both the 225-ft and 14-ft sampling plans were processed and presented in tables (Tables 3.3 and 3.3) and figures (Figures 3.1 to 3.5). The data was applied to produce a summary of unit cost (time) to survey one sampling site, either in a divided or undivided highway.

Table 3.1: Summary of sampling runs, by date and sub-district, which have been applied in estimating acres of weeds per roadway mile using data from the 225-ft segments sample units in Mn/DOT_D4 for the 2008 survey.

Roadway segments per sampling run							
Run	Scout(s)	Date	Alex	Fergus	Moorhead	Morris	Combined
1	JR	7/11/08	.	.	.	3	3
2	DS, SN	7/14/08	5	.	.	.	5
3	JR	7/14/08	.	.	.	6	6
4	MR, PB	7/14/08	.	.	8	.	8
5	PC	7/14/08	.	.	.	6	6
6	DS, SN	7/15/08	4	.	.	.	4
7	JR	7/15/08	.	.	.	4	4
8	MR, PB	7/15/08	.	.	8	.	8
9	PC	7/15/08	.	.	.	3	3
10	SN	7/15/08	3	.	.	.	3
11	DS	7/16/08	2	.	.	.	2
12	PC, BK	7/16/08	.	5	.	.	5
13	MR	7/21/08	.	3	.	.	3
14	PC, BK	7/21/08	.	.	.	8	8
15	MR, PB	7/22/08	.	.	6	.	6
16	MR, PB	7/23/08	.	8	.	.	8
17	MR, PB	7/24/08	.	8	.	.	8
18	PB	7/25/08	.	2	.	.	2
		No runs:	4	5	3	6	18
		No. segments:	14	26	22	30	92
		Segments/run:	6.6	5.2	7.3	5.0	5.8

Table 3.2: Summary of sampling runs, by date and sub-district, used for presence-absence (14-ft) sampling of weeds in Mn/DOT_D4 for the 2008 survey.

Roadway segments per sampling run							
Run	Date	Scout	Alex	Fergus	Moorhead	Morris	Combined
1	7/10/08	PB	.	1	.	.	1
2	7/16/08	JR	.	.	.	8	8
3	7/16/08	MR	.	.	2	.	2
4	7/16/08	PB	.	.	5	.	5
5	7/17/08	DS	3	.	.	.	3
6	7/17/08	JR	.	.	.	4	4
7	7/17/08	MR	.	15	.	.	15
8	7/18/08	DP	2	.	.	.	2
9	7/18/08	DS	15	.	.	.	15
10	7/21/08	DP	2	.	.	.	2
11	7/21/08	DS	5	.	.	.	5
12	7/21/08	MR	8	.	.	.	8
13	7/22/08	BK	10	.	.	.	10
14	7/22/08	MR	8	.	.	.	8
15	7/22/08	PB	4	.	.	.	4
16	7/22/08	PC	4	.	.	.	4
17	7/23/08	BK	.	.	.	11	11
18	7/23/08	MR	.	.	5	.	5
19	7/23/08	PB	.	1	.	.	1
20	7/23/08	PC	.	.	.	3	3
21	7/24/08	BK	.	.	.	8	8
22	7/24/08	MR	.	2	.	.	2
23	7/24/08	PB	.	5	.	.	5
24	7/24/08	PC	.	.	.	6	6
25	7/25/08	BK	.	.	.	3	3
26	7/25/08	PB	.	.	7	.	7
		No. runs:	10	5	4	7	26
		No. segments:	61	24	19	43	147
		Segments/run:	6.1	4.8	4.8	6.1	5.7

Time spent surveying each of the selected segments in surveys with the 14-ft and 225-ft sampling plans were recorded and used to evaluate cost of surveys. Maintained time data included traveling (office to first site, then last site to office), scouting each site, and traveling between sites. Tables 3.3 and 3.4 provide a portion of the recorded times.

.

Table 3.3: A section of the data recorded showing time spent surveying each of the 100, 225-ft segments adopted in mapping noxious weed species in Mn/DOT_D4 for the 2008 survey.

Run	Scout	Sub-District	SegmID	Category	EZ	Median	Scouting (mins.)	Transit (mins.)	#Leg
1	JR	Morris	Home	.	.	.	.	.	4
1	JR	Morris	MN29-030.4	MNRP-0	MNRP	0	20	20	.
1	JR	Morris	MN29-045.6	MNRP-0	MNRP	0	13	25	.
1	JR	Morris	US12-040.3	MNRP-0	MNRP	0	15	.	.
2	DS, SN	Alex	Home	.	.	.	.	.	.
2	DS, SN	Alex	Home	.	.	.	.	.	12
2	DS, SN	Alex	I94-102.4	HH-1	HH	1	50	.	.
2	DS, SN	Alex	I94-106.7	HH-1	HH	1	56	25	.
2	DS, SN	Alex	MN27-065.8	MNRP-0	MNRP	0	86	.	.
2	DS, SN	Alex	MN27-084.5	HH-0	HH	0	60	.	.
2	DS, SN	Alex	MN29-067.1	MNRP-0	MNRP	0	88	105	.
2	SN	Alex	Home	.	.	.	.	.	15
3	JR	Morris	Home	.	.	.	.	.	15
3	JR	Morris	MN104-026.9	MNRP-0	MNRP	0	15	6	.
3	JR	Morris	MN104-032.6	MNRP-0	MNRP	0	5	.	.
3	JR	Morris	MN9-032.3	MNRP-0	MNRP	0	23	3	.
3	JR	Morris	MN9-034.9	MNRP-0	MNRP	0	15	32	.
3	JR	Morris	US59-172.3	MNRP-0	MNRP	0	15	15	.
3	JR	Morris	US59-181.7	MNRP-0	MNRP	0	10	.	.
4	MR	Moorhead	Home	.	.	.	.	.	70
4	MR	Moorhead	US59-281.9	RRP-0	RRP	0	65	.	.
4	MR, PB	Moorhead	MN113-022.1	HH-0	HH	0	20	20	.
4	MR, PB	Moorhead	MN200-047.4	RRP-0	RRP	0	50	25	.
4	MR, PB	Moorhead	MN200-066.0	CP-0	CP	0	20	1	.
4	MR, PB	Moorhead	MN200-066.1	CP-0	CP	0	28	22	.
4	MR, PB	Moorhead	US59-294.8	RRP-0	RRP	0	30	15	.
4	MR, PB	Moorhead	US59-307.3	RRP-0	RRP	0	26	55	.
4	PB	Moorhead	US59-281.9	RRP-0	RRP	0	20	.	.
5	PC	Morris	Home	.	.	.	.	.	56

Table 3.4: A section of the data recorded showing the sequence and time in which surveys were conducted on each of the 150, 14-ft segments inspected for noxious weed species during 2008 surveys.

Run	Date	Scout	SubD	Start	End	Leave	Arrive	Spot	Category	EZ	Median	Scout mins	Transit mins	Leg mins
1	7/10/2008	PB	Fergus	2:24 PM	2:26 PM	.	.	MN210-021.4	MNRP-0	MNRP	0	2	.	.
2	7/16/2008	JR	Morris	8:29 AM	8:31 AM	8:33 AM	9:12 AM	MN29-024.0	MNRP-0	MNRP	0	3	39	.
2	7/16/2008	JR	Morris	9:24 AM	9:26 AM	9:28 AM	9:30 AM	MN29-041.1	MNRP-0	MNRP	0	1	2	.
2	7/16/2008	JR	Morris	9:31 AM	9:33 AM	9:36 AM	9:46 AM	MN29-042.3	MNRP-0	MNRP	0	2	10	.
2	7/16/2008	JR	Morris	9:49 AM	9:50 AM	9:55 AM	10:25 AM	MN29-047.5	MNRP-0	MNRP	0	1	30	.
2	7/16/2008	JR	Morris	10:28 AM	10:30 AM	10:32 AM	10:35 AM	MN104-027.7	MNRP-0	MNRP	0	2	3	.
2	7/16/2008	JR	Morris	10:36 AM	10:38 AM	10:40 AM	11:04 AM	MN104-026.4	MNRP-0	MNRP	0	1	24	.
2	7/16/2008	JR	Morris	11:04 AM	11:06 AM	1:33 PM	2:14 PM	MN9-023.3	MNRP-0	MNRP	0	2	41	.
2	7/16/2008	JR	Morris	2:18 PM	2:20 PM	.	.	US59-144.9	MNRP-0	MNRP	0	3	.	.
3	7/16/2008	MR	Moorhead	10:13 AM	10:15 AM	10:15 AM	10:20 AM	MN113-025.2	HH-0	HH	0	2	5	.
3	7/16/2008	MR	Moorhead	1:31 PM	1:32 PM	.	.	US59-310.0	RRP-0	RRP	0	1	.	.
4	7/16/2008	PB	Moorhead	9:31 AM	9:34 AM	.	.	MN113-017.8	RRP-0	RRP	0	3	.	.
4	7/16/2008	PB	Moorhead	10:49 AM	10:50 AM	10:50 AM	11:00 AM	MN113-045.2	PMOP-0	PMOP	0	2	10	.
4	7/16/2008	PB	Moorhead	11:49 AM	11:51 AM	11:51 AM	11:55 AM	MN200-065.8	PMOP-0	PMOP	0	2	3	.
4	7/16/2008	PB	Moorhead	11:58 AM	12:00 PM	12:05 PM	1:20 PM	MN200-066.1	CP-0	CP	1	2	.	.
4	7/16/2008	PB	Moorhead	.	.	1:20 PM	1:30 PM	US59-309.4	RRP-0	RRP	0	.	10	.
5	7/17/2008	DS	.	.	.	9:20 AM	9:25 AM	.	.	.	.	.	5	.
5	7/17/2008	DS	Alex	12:22 PM	12:25 PM	12:25 PM	12:34 PM	I94-090.0	MNRP-1	MNRP	1	3	9	.
5	7/17/2008	DS	Alex	12:34 PM	12:38 PM	.	.	I94-085.8	MNRP-1	MNRP	1	4	.	.
5	7/17/2008	DS	.	.	.	1:44 PM	2:13 PM	.	.	.	.	.	29	.
5	7/17/2008	DS	Alex	1:10 PM	1:17 PM	.	.	I94-074.8	MNRP-1	MNRP	1	6	.	.
5	7/17/2008	DS	.	.	.	2:20 PM	3:05 PM	.	.	.	.	.	45	.
5	7/17/2008	DS	Alex	.	.	3:10 PM	3:30 PM	Home	.	.	.	.	.	20
6	7/17/2008	JR	Morris	10:28 AM	10:30 AM	10:33 AM	10:34 AM	US59-169.3	MNRP-0	MNRP	0	1	1	.

For analysis, consider that sampling time consists of 3 time components:

L = time driving out to the first segment in a run, or back from the last;
S = time surveying each segment within a run,
T = transit time from one segment to the next within a run

Assuming future runs would be done by scouts working singly, and that they would organize chosen segments in runs of n segments, then total time for a run (C_r, in minutes) would be

$\boldsymbol{C_r = 2L + n(S) + (n\text{-}1)(T)}$

As analyzed below, we estimate the following:

For L, driving times (± SE) out to the first destination or back from the last, whether to 225-ft segments or 14-ft segments, averaged 41 ± 5.2 minutes.

For S, times to measure weed areas in a 225-ft segment depended on presence of median:

without medians,	***S0 = 24.6 ± 1.4 minutes per segment,***
with a median,	***S1 = 42.7 ± 2.5 minutes per segment.***

In 2008, the optimal allocation of 100 segments called for 76 from roadways without medians, and 24 with medians. Thus, a weighted estimate of S for future budgeting would be

S.= (0.74)24.6 + (0.24)42.7 = 28 ± 1.7 minutes per 225-ft segment.

Presence-absence scouting with 14-ft segments required ***MUCH LESS TIME***:

without medians,	***S0 = 3.0 ± 1.3 minutes;***
with a median,	***S1 = 6.0 ± 2.4 minutes,***

If 74% of future segments are to be from roadways without medians,

S.= 3.7 ± 1.6 minutes per segment.

For T, transit times driving among consecutive segments in a run were the same in all sub-districts, but seemed to depend on numbers of destinations to be covered. Transit times in runs of 225-ft-ers averaged
T = 24.0 ± 3.2 minutes, whereas runs with 14-ft segments averaged T = 15 ± 1.4 minutes.

Based on these estimates of L, S, and T, future cost per run (***Cr***) of arbitrary length n would be as follows:

Using 225-ft segments**,**

Cr = 82 + n(28) + (n-1)(24) minutes. ***With n = 6, cost in hours would be:*** ***Cr = 6.36 (± 0.15) hrs per run, or 1.06 person-hrs per segment.***

Using 14-ft segments**,**

Cr = 82 + n(3.7) + (n-1)(15) minutes, and with n = 6,
Cr = 3 (± 0.2) hrs per run, and 0.5 person-hrs per segment.

Costs per segment with both kinds of sample units would decline further if **runs were longer than 6 segments**.

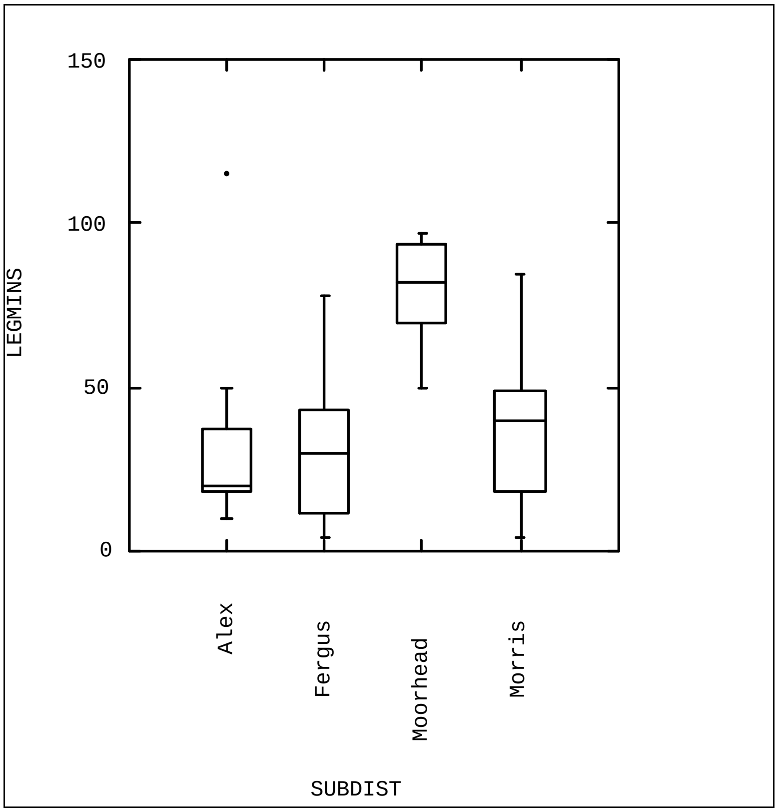


Figure 3.1: Time (Leg times L, minutes) spent surveying segments in different management sub-districts – combined for 14-ft and 225-ft segments.

DEP VAR: LEGMINS
N: 34
MULTIPLER: 0.628
SQUARED MULTIPLE R: 0.394

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
SUBDIST	8504.498376	3	2834.832792	4.008864	**0.018013**
UNITSIZE	116.729305	1	116.729305	0.165072	0.687854
SUBDIST$*UNITSIZE	1034.269734	3	344.756578	0.487536	0.693914
ERROR	0.183857E+05	26	707.141239		

{omit interaction and unitsize, because both were insignificant…}

DEP VAR:	LEGMINS
N:	34
MULTIPLE R:	0.600
SQUARED MULTIPLE R:	0.360

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
SUBDIST	.109134E+05	3	3637.803536	5.619225	**0.003521**
ERROR	0.194216E+05	30	647.385333		

SUBDIST$	LS MEAN	SE	N
Alex	31.076923	7.056832	13
Fergus	31.375000	8.995730	8
Morris	37.714286	9.616840	7
Moorhead	79.333333	10.387375	6

WARNING: Case 197 is an outlier (Studentized residual = 4.332)

Using model MSE of 647.385, with 30.0 DF, Fisher's least-significant-difference, pairwise comparison probabilities:

		Alex	Fergus	Moorhead	Morris
Alex	1	1.000000			
Fergus	2	0.979374	1.000000		
Morris	4	0.582036	0.633724	0.006263	1.000000
Moorhead	3	0.000587	0.001516	1.000000	

For simplicity, disregard differences among sub-districts:

LEGMINS	
No. OF CASES:	34
MINIMUM:	4.000000
MAXIMUM:	115.000000
MEAN:	41.029412
STANDARD DEV:	30.318996
STD. ERROR:	5.199665

3.1 DO SCOUTING TIMES (S) VARY AMONG SUB-DISTRICTS, ROADWAY TYPES AND UNIT SIZES?

DEP VAR:	SCOUTMIN
N:	234
MULTIPLE R:	0.749
SQUARED MULTIPLE R:	0.561

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
SUBDIST$	1513.084699	3	504.361566	3.240442	0.022912
MEDIAN	2825.5672	1	2825.5672	18.153817	0.000030
UNITSIZE	.347778E+05	1	.347778E+05	223.441633	0.000000
MEDIAN*UNITSIZE	2609.203422	1	2609.203422	16.763715	0.000059
ERROR	.353316E+05	227	155.645897		

WARNING: NINE outliers noted

Disregard differences among sub-districts:

DEP VAR:	SCOUTMIN
N:	234
MULTIPLE R:	0.736
SQUARED MULTIPLE R:	0.542

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
MEDIAN	4678.558658	1	4678.558658	29.205514	0.000000
UNITSIZE	.355209E+05	1	.355209E+05	221.736439	0.000000
UNITSIZE*MEDIAN	2389.921763	1	2389.921763	14.918888	0.000146
ERROR	.368447E+05	230	160.194362		

WARNING: NINE residuals

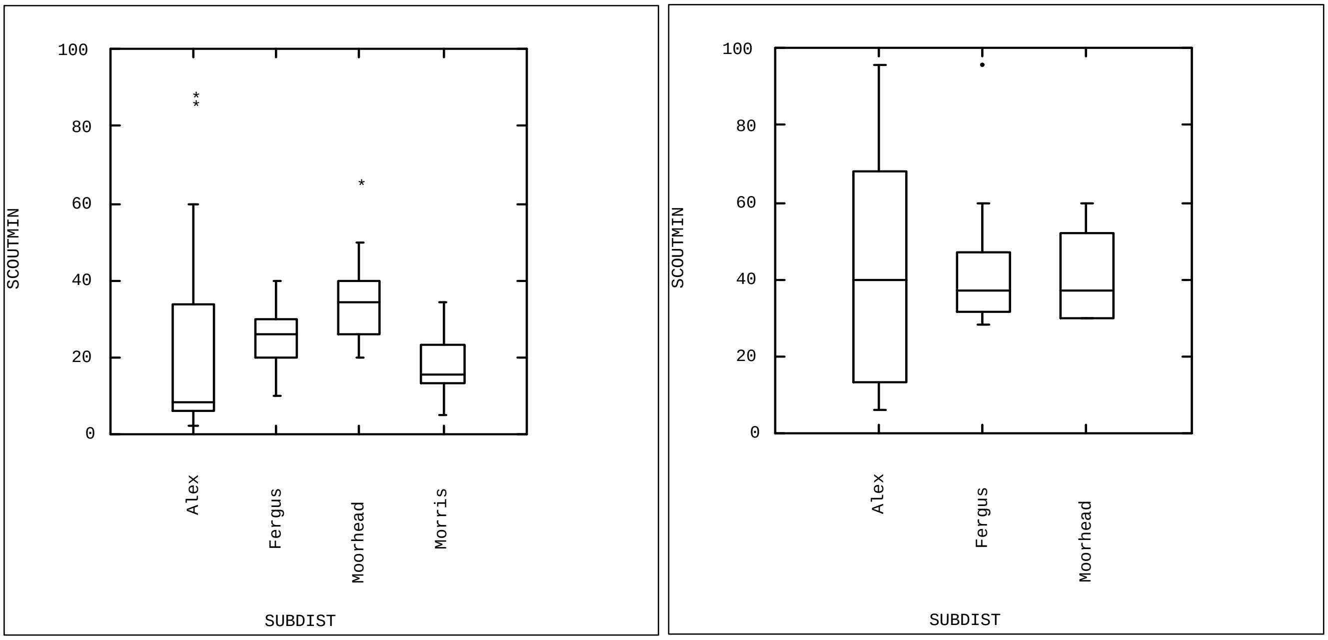


Figure 3.2: Time (SCOUTMIN, minutes) spent surveying 225-ft segments in highways without median in different management sub-districts for the 2008 survey.

225-ft, without median
Mean = 24.6 ± SE = 1.3, *n* =83

225-ft segments, with median
Mean = 42.7 ± 2.5, *n* = 26

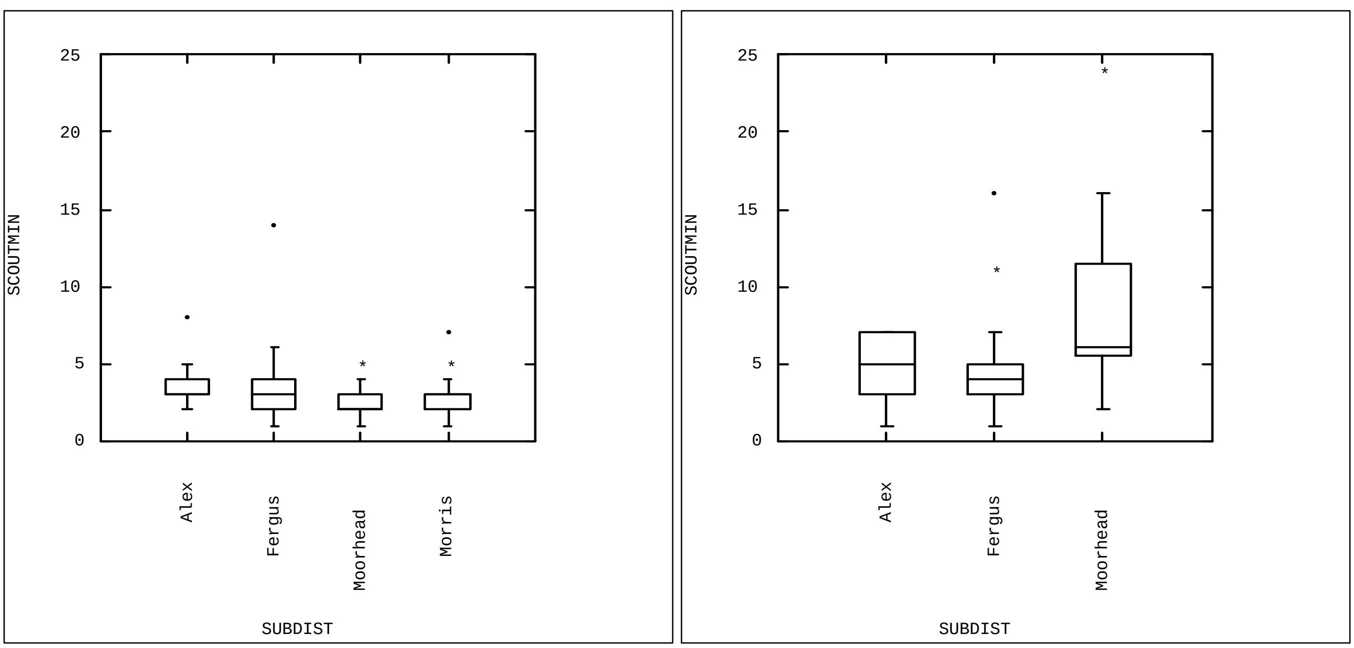


Figure 3.3: Time (SCOUTMIN, minutes) spent surveying 14-ft segments in highways without median in different management sub-districts for the 2008 survey.

14-ft segments, without median
Mean = 3.0 ± 1.3, n = 96

14-ft segments, with median
Mean = 6.0 ± 2.4, *n* = 29

<u>Times (T) to travel between segments</u>

DEP VAR:	Transit
N:	205
MULTIPLE R:	0.272
SQUARED MULTIPLE R:	0.074

SOURCE	SUM-OF-SQUARES	**DF**	MEAN-SQUARE	F-RATIO	**P**
SUBDIST$	2485.438067	3	828.479356	1.525995	0.209028
MEDIAN	966.842044	1	966.842044	1.780849	0.183593
UNITSIZE	4280.302304	1	4280.302304	7.883988	0.005492
SUBDIST$*UNITSIZE	1599.789056	3	533.263019	0.982230	0.402198
ERROR	.106411E+06	196	542.910779		

{omit interaction, subdistrict and median, because none were significant…}

DEP VAR: Transit
N: 210
MULTIPLE R: 0.196
SQUARED MULTIPLE R: 0.039

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
UNITSIZE	4476.661967	1	4476.661967	8.33834	0.004292
ERROR	.111670E+06	208	536.876602		

UNITSIZE	LS MEAN	SE	N
14	14.959677	2.080781	124
225	24.348837	2.498550	86

<u>WARNING</u>: NINE outliers

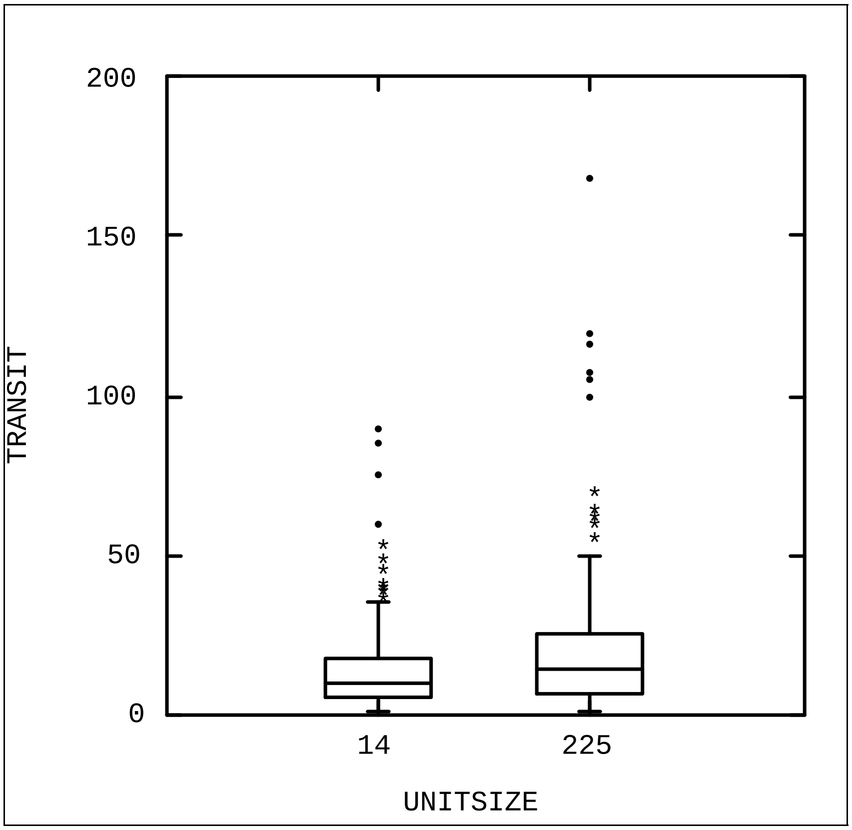


Figure 3.4: Time (TRANSIT, minutes) spent travelling between 14-ft segments and 225-ft segments in Mn/DOT_D4 for the 2008 survey.

3.2 EVALUATION OF SAMPLING EFFICIENCIES FOR 14-FT AND 225-FT PLANS

There are a large number of problem noxious species infesting highways rights-of-way in any parts of Minnesota. The quantities and distribution of each species varies drastically from those by others. Surveys to quantify infestation by individual species (most rare to the most abundant) should apply tools which are designed to account for infestation character of all species. In this study, we understand the need for conducting separate analysis of the data recorded for each weed species in surveys using 14-ft and 225-ft sampling plans. We have however focused our attention on the most abundant species (Canada thistle) in assessing efficiencies attainable in surveys using these two sampling plans.

The first part of this determination was to evaluate the RNP (relative net precision), evaluated using equation 2.8. Data on the cost of conducting surveys was evaluated using the available record of time spent inspecting sampling sites. .

3.2.1. Calculating RNP - 225-ft sampling plan using data on Canada thistle infestations

Length = 225-ft = 0.042613636 miles

Cost (Cr):
This has been previously presented as consisting of components:
L = time driving out to the first segment in a run, or back from the last;
S = time surveying each segment within a run,
T = transit time from one segment to the next within a run

In this work, we have made an assumption that future surveys would be done by scouts working singly, and that they would organize chosen segments into runs of *n* segments, then total time for a run (C_r, in minutes) would be:

$$C_r = 2L + n(S) + (n-1)(T)$$

Based on the data recorded in the 2008 surveys, and assuming scouting 6 segments per person per day:

Cr = person-hrs/segment

Variance = 0.544 acres-per-mile (Table 2.23)

RNP = length/cost x length/variance
= (0.0426136miles / 1.06 hrs x (0.0426136miles /0.544 acres/mile)

= 0.003082652 miles^2/acre-hr

3.2.2. Calculating RNP - 14-ft sampling plan

Length = 14-ft = 0.00265 miles

Assuming future surveys would be done by scouts working singly, and that they would organize chosen segments into runs of *n* segments, then total time for a run (C_r, in minutes) would be:

$$C_r = 2L + n(S) + (n-1)(T)$$

Based on the data recorded in the 2008 surveys, and assuming scouting 6 segments per person per day:
Cost is evaluated as = 0.5 person-hrs/segment

Because the results obtained in the fitting of recorded data to the Kono and Sugino model yielded weak fit (Section 2.8), further attempts to apply the presence-absence sampling plan in estimating infested density would be unnecessary. It was therefore, not necessary to pursue efforts of comparing the two sampling plans, especially in respect to their survey and mapping (density) applications.

Variance = NOT DETERMINED

RNP = length/cost x length/variance
= (0.00265miles / 0.5hrs x (0.00265 miles /UNKNOWN acres/mile)
= ?? miles^2/acre-hr

Table 3.5: Summary on time spent inspecting the 150, 14-ft sampling sites surveyed in Management Sub-districts of Mn/DOT_D4 (2008).

Subdistrict	Median	# Sampling Units	Transit Time (mins.)	Scouting Time (mins.)
Alex	0	18	200.0	56.3
	1	6	52.2	17.5
Fergus	0	22	332.5	65.2
	1	15	212.00	73.6
Moorhead	0	17	280.72	25.2
	1	8	173.00	63.6
Morris	0	40	485.80	78.6
	1	0	0.00	0.0
Total D4		**97**	1299.02	225.18
		29	437.17	154.75
Average D4	**0**		**10.39**	**1.80**
	1		**3.50**	**1.24**

Based on calculations in the analyses, the average time spent surveying a 14-ft segment in a divided highway was 6.0 (±2.4) minutes, while it took 3.0 (±1.3) minutes surveying an undivided highway. These results are as expected, where the usually larger rights-of-way area in the divided highways would require much more time to inspect.

Table 3.6:.Summary of time spent travelling *(transit) surveying the 225-ft sampling units (outliers deleted).

Subdistrict	Median	# Sampling Units	Transit Time (mins.)	Scouting Time (mins.)
Alex	0	9	418.0	342.0
	1	9	51.0	88.0
Fergus	0	17	432.0	322.0
	1	12	306.0	451.0
Moorhead	0	13	461.0	543.0
	1	5	52.0	194.0
Morris	0	22	374.0	388.0
	1	0	0.0	0.0
Total D4	0	61	1685.0	1595.0
	1	26	409.0	733.0
Average D4	**0**		**13.5**	**18.3**
	1		**3.3**	**8.4**

Table 3.7: Summary of time spent surveying (scouting and transit) the 225-ft sampling units.

Subdistrict	Median	# Sampling Units	Transit Time (mins.)	Scouting Time (mins.)
Alex	0	9	418.0	557.0
	1	9	51.0	344.0
Fergus	0	17	432.0	350.0
	1	12	52.00	246.0
Moorhead	0	13	461.00	628.0
	1	5	52.00	246.0
Morris	0	22	374.0	505.0
	1	0	0.0	0.0
Total D4	0	61	1685.0	2040.0
	1	26	155.0	836.0
Average D4	**0**		**13.48**	**16.32**
	1		**1.24**	**6.69**

Table 3.8: Summary of time spent surveying (scouting and transit) the 14-ft sampling units.

Subdistrict	Median	# Sampling Units	Transit Time (mins.)	Scouting Time (mins.)
Alex	0	18	200.0	56.3
	1	6	52.2	17.5
Fergus	0	22	332.5	65.2
	1	15	212.00	73.6
Moorhead	0	17	280.72	25.2
	1	8	173.00	63.6
Morris	0	40	485.80	78.6
	1	0	0.00	0.0
Total D4	0	97	1299.02	225.18
	1	29	437.17	154.75
Average D4	**0**		**10.39**	**1.80**
	1		**3.50**	**1.24**

In the analysis of data from surveys with 225-ft sampling plan, it required approximately 42.7 (±2.5) minutes to survey a segment in a divided highway, and 24.6 (±1.4) minutes in n undivided highway. This is presented in Figures 3.2 and 3.3. This was evaluated to a weighted average time of 28 (±1.6) minutes required to complete survey of a segment in either a divided or undivided highway.

The analysis of time data recorded in surveys with the 14-ft segments yielded a weighted mean of 3.7 (±1.6) minutes; which translates to 6.0 (±2.4) minutes to survey a divided highway and 3.0 (±1.3) minutes to survey an undivided highway. These are as shown in figures 3.4 and 3.5.

3.3 DISCUSSION

To be able to effectively compare achievable precisions with the 14-ft sampling plan and 225-ft sampling plan, data on infested density (acres-per-mile) as recorded in surveys using both plans is necessary. Density values were obtained for the 14-ft plan through calculations in which evaluated proportion infested from data recorded with 14-ft sampling plan were applied to the Kono and Sugino (1958). Results obtained in these calculations would only be accurate and useful if application of the model on the previous years' (2007 and 2008) data to the Kono and Sugino model yielded good/significant fit. The 2007 data yielded a good fit to the model (R^2 = 0.8403) as seen in Figure 2.18; however, fitting model with data from the 2008 surveys yielded weak, statistically non-significant fit (R^2 = 0.083 – Figure 2.15).

With the data recorded in the 2007 surveys with the 14-ft plan (presence-absence data) provided nine (9) data points corresponding to weed absence/presence at the 9 categories (highway type - ecological zones classifications) within the survey area. With surveys conducted in 2008, a total of 18 data points were available for application in the Kono and Sugino (1958) empirical model on the 14-ft sampling plan data for more accurate evaluation of acres-per-mile infested. When these were in the Kono and Sugino equation to test potential application of the model in estimations of species density, a weak fit was recorded. These results argue against application of the Kono and Sugino model for evaluation of density infested based on the proportion infested data acquired under similar surveys using the 14-ft sampling plan.

The costs 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, further of data analysis was effected with aims of assessing costs associated with the application of the sampling plans adopted in surveys conducted in 2008. 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 showed surveys with the 14-ft segments requiring significantly less effort, hence costs. Larger differences in time were observed among scouting and traveling between sampling sites. Obviously, less time was required to inspect (scout) the much shorter 14-ft compared to the 225-ft segment. Because of the larger number (150) of the 14-ft segments, less time was required to travel between the more closely spaced sampling sites compared to the fewer and further spaced 225-ft ones. Traveling time from office to and from first and last segments, respectively, was the same for both the 14-ft and 225-ft segments.

Although the 14-ft sampling plan would not provide reliable data on density infested, it can be effectively applied to detection of new or early invaders in highway rights-of-way. The lower surveying costs make it an attractive choice of survey tools in early detection of new invaders, or migration of existing species.

3.4 CONCLUSIONS

The results of the analysis of data recorded in surveys with the 14-ft and 225-ft sampling plans conducted in the current implementation study, lead to the following deductions:

- Adoption of presence-absence plan in surveys to map infestation in highways-rights-of ways is not supported by findings of the study.
- Use of presence-absence sampling will be less expensive, but achievable sampling precision will not be satisfactory.
- If the purpose of surveying is to measure area infested by given species, then 225-ft plan is recommended.

If survey cost is important (which is normally the case), and the purpose of surveying is detection of rare species or new invasions, use of the 14-ft presence-absence plan is recommended.

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