Canada Thistle: A Literature Review of Treatment Success Specific to Current Land Management on Waterfowl Production Areas in the Rainwater Basin

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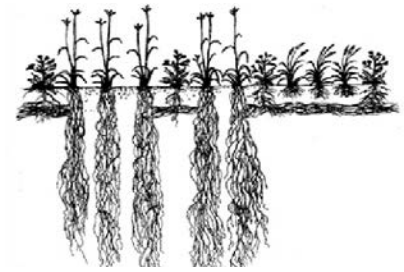
1 Background

1.1 History

Canada thistle is a native of southeast Europe, North Africa, and central Asia, that was introduced accidentally as seed contamination to North America in the late 1600s (Mitich 1988). Mitich (1988) found historical records indicating the rapid spread of Canada thistle prompting control legislation in Vermont (1795) and New York (1831). Since that time it has spread throughout most of Canada and the United States, north of the 35th parallel, where it is considered one of the most tenacious and economically damaging agricultural weeds (Reece and Wilson 1983, Haggar et al. 1986). Canada thistle in Nebraska causes $2.5 million in annual lost production (Wilson 2002). In fact, the Nebraska Department of Agriculture's Noxious Weed Program (Title 25, Chapter 10), regulating the Noxious Weed Control Act (Section 2-945.01-2.968) has identified Canada thistle as a noxious weed in Nebraska, requiring all landowners to control this species[1].

1.2 Biology

Canada thistle has the potential to rapidly form dense stands through vegetative reproduction, and the spread of these clones may continue indefinitely, crowding out and displacing native grasses and forbs through shading, competition, and possibly allelopathy (Hutchinson 1992). Dioecious (male and female) plants may exacerbate control efforts since this plant spreads primarily through vegetative rootstocks rather than seed dispersal, creating entire stands of male or female plants that still have the ability to regenerate from vegetative portions (Wilson 1979). Canada thistle invasion can change the structure and species composition in natural areas and reduce plant and animal diversity (Hutchinson 1992). Dewey (1991) cited research from the Northwestern U.S. indicated the acreage infested by Canada thistle increasing at an annual rate of 10%, causing an average 42% reduction in range carrying capacity on infested lands.



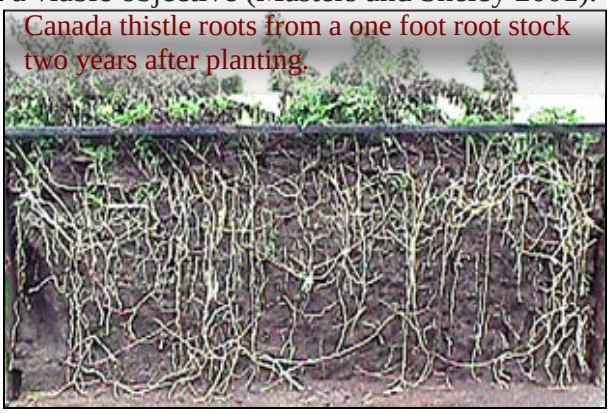
This image depicts the root zone battle and how deep rooted native species can block the spread of Canada thistle (and other perennial weeds) that have lateral root growth and are typically shallow rooted (Judie Shore)

Vigorous native plant communities are the best defense against Canada thistle invasion, and can help to shade and weaken Canada thistle plants on sites already infested (Hutchinson 1992). In fact, many researchers reflect on the fact that native species

[1] http://www.agr.state.ne.us/regulate/bpi/actbb.htm

diversity appears to be the main factor influencing exotic invasion (Masters and Sheley 2001, Houlahan and Findlay 2004, Samuel and Lym 2008, Middleton et al. 2010). For example, Middleton et al. (2010) and Pokorny et al. 2001 found that exotic species density decreases as native diversity increased. Samuel and Lym (2008) pointed out that Canada thistle invaded areas with more bare ground and that annual and biennial species tended to establish in and move out of these areas more readily. Therefore, Canada thistle distribution, density, and abundance are directly linked to the native stand conditions that occur on each Waterfowl Production Area (WPA).

Management programs for controlling Canada thistle can range from prevention, to reduction and containment, to eradication. It is important to point out that reducing infestations to manageable levels is often a viable objective (Masters and Sheley 2001). Effective long-term control of Canada thistle includes killing the roots and root buds, and preventing seed production and re-infestation by seedlings (Haderlie et al. 1991). Because Canada thistle has extensive root systems, it can store mass amounts of reserves protecting it from most environmental stressors and making it very difficult to control with single treatments (Haderlie et al. 1991). Anderson (2001) found that a 0.25” by 0.125” root has enough stored energy to develop a new plant. Also, these small roots can survive at least 100 days without nutrient replenishment from photosynthesis. Anon (1996) found further evidence that control should focus on roots after planting a 6 inch root piece that developed into 644 feet of roots and 336 feet of above-ground shoots in 15 months. Therefore, control efforts should focus on depleting carbohydrate stores in root reserves before terminal treatments are utilized (Haderlie et al. 1991).

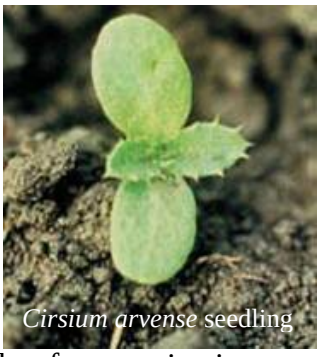

Canada thistle roots from a one foot root stock two years after planting.

Adult or perennial plants will require at least 2 years of treatments before a determination on treatment success can be made, although integrated weed management may require 5-10 years of effort (Donald 1990). Successful treatments are directly influenced by clonal structure, growth stage, season of treatment, weather conditions, ecotype, soil type and available nutrients, and control methods used (Donald 1994, Tworkoski 1992). Donald (1994) also identified that treatment combinations effective on one site may be ineffective at other sites.

Cirsium arvense seeds, Julia Scher

Canada thistle develops fewer seeds than Musk thistle, with a range of 1,000 to 1,500 seeds per flowing shoot (Beck 2008). Seed viability develops within 8 to 10 days (Wilson 2002). Seed dispersal may appear to be a primary concern but wind driven Canada thistle seeds typically (80%) fall within 130 ft from parent plants with a maximum average range <322 ft (Smith and

Kok 1984). Beck (2008) explained this phenomenon by indicating that the feather pappus breaks off easily during wind dispersal. Invasions near water, such as Funk WPA, seed dispersal can increase when flooding occurs during flowing periods. Additionally, flooding may limit native hydrophyte growth, creating additional bar ground areas that Canada thistle and other invasives can occupy.


Cirsium arvense seedling

Canada thistle seeds have no seed dormancy requirements (McCarty et al. 1969). Seeds will germinate readily within the top 1.0 cm of moist soil when temperatures are $68-86^{\circ}F$ (Wilson 1979, Hutchinson 1992). Hutchinson (1992) also found that ~90% of the seeds germinate within year one and seeds can last 20 years in the soil. Wilson (1979) found that Canada thistle in the two leaf stage (19days old) were able to resprout after defoliation. Seedlings will develop perennial growth characteristics (lateral root development) within 3 weeks of germination creating a control window roughly 2.5 weeks after germination (Haderlie et al. 1991). Fourteen to 16 hour photo periods promote bolting and flowing, but growth ceases when temperatures exceed $85^{\circ}F$ for extended periods (Iowa State Extension Service 2010).

After seed set, Canada thistle produces a second flush of growth. Some of it comes from buds on the spring stems, and a lot of it comes as new shoots from the root system. Instead of growing tall and flowering, the second flush of growth produces just enough foliage to 'recharge' the root system. This second flush should be the target of fall herbicide application. Treatments at this time will reduce the plants ability to store carbohydrates, weakening the overall vigor of the stand.

Cirsium canescens

Many native species of thistle occur in Nebraska are not considered noxious weeds, and some species may be declining (i.e. *Cirsium canescens* or Platte thistle, *Cirsium pulcherrimum* or Wyoming thistle). Because of the possibility of confusion with native species, Canada thistle should be accurately identified before any control efforts are attempted. Large infestations (> 0.5 acres) of dense stands should be mapped and recorded into RLGIS. These mapped stands should be monitored annually to characterize the overall success of previous year treatments. Furthermore, land managers should establish goals and objectives for each WPA where Canada thistle occurs. Well written goals and objectives will help determine the actual monitoring effort needed for each site.

2 Treatments

2.1 Cultivation

Prior to the development of herbicides, a recommendation for controlling Canada thistle was repeated tillage every 4 to 6 weeks for 2-3 years. Tillage segments roots and stimulates new plant development. Repeated tillage gives long-term Canada thistle control by depleting root carbohydrate reserves. A typical seedling, 14 days after emergence, does not yet have a perennial root, so it can be killed by cultivation. However, a 3-week-old seedling can regenerate after the top-growth is clipped. Tillage exposes roots to drying and freezing at the soil surface, and can be an effective method of control (Haderlie et al. 1991). Haderlie et al. (1991) also suggested late summer tillage increases the number of foliar shoots and leaf area creating more exposed surface area during subsequent herbicide application.

The Rainwater Basin (RWB) WMD has utilized cultivation as a means to eradicate Canada thistle from areas with dense infestations. It appears (casual observation) that multiple years of tillage and planting round-up ready crops has reduced the frequency and density of Canada thistle occurrence although no data has been collected to verity this method of control on RWB WPAs. However, without any monitoring, it is difficult to say that these visual inspections are accurate assessments of the areas condition.

2.2 Mowing

Mowing or cutting Canada thistle temporarily reduces aboveground biomass and can prevent flowering and seed production, but does not kill plants unless repeated at 7- to 28-day intervals for up to 4 years (Gover et al. 2007). Stems with flowers that have been open for 8-10 days can develop viable seeds and must be removed from the site in order to prevent seed distribution. Mowing short and below the terminal bud before stems elongate accelerates regrowth (Gover et al. 2007). Furthermore, when the primary stem of Canada thistle is removed, rootbuds are stimulated to produce new shoots that might otherwise be suppressed. Therefore, plants must be cut high enough to leave more than 9 leaves/stem or more than 8 inches (20 cm) of bare stem tissue. However, Gover et al. (2007) suggested that in situations where root growth would be restricted, such as habitats with high water tables, begin mowing when it is 12 to 15 inches tall.

Successful mowing/haying treatments have been documented in the literature. Ross and Vanderpoel (1991) for example, found that repeated hay meadow mowing in Illinois provided native prairie species the competitive edge to reestablish as the dominant plant community. Keep in mind that mowing or haying Canada thistle will stimulate new growth and increase stem density in most cases (Beck et al. 2000). However, it is important to reiterate the need for integrated control efforts annually (Masters and Sheley

2001). Mowing or haying combined with chemical control programs will have the most success (Beck et al. 2000, Gover et al. 2007).

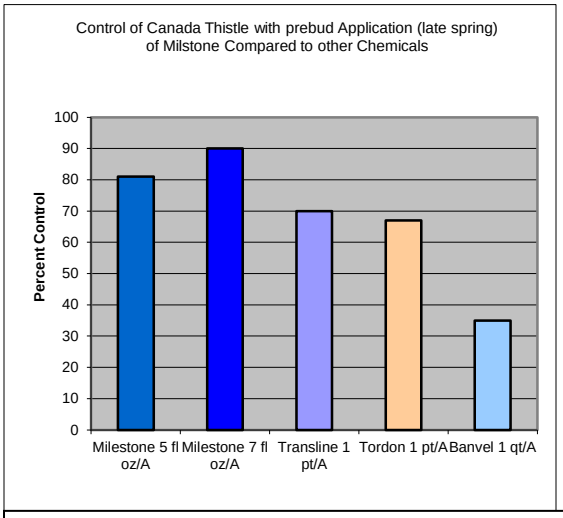
2.3 Fire

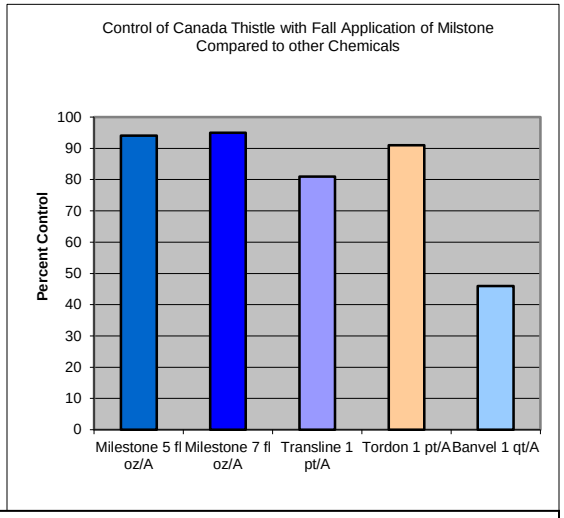
There is evidence in the literature to suggest that fire will reduce the relative abundance and reduce the potential spread of Canada thistle seeds, therefore it can be expected to help reduce the rate of spread. In fact, empirical literature supports the argument that correctly functioning ecosystems (e.g., fire, herbivory, disturbance) support species richness commonly associated with fewer invasive species (Schwartz et al. 2000, Middleton et al. 2010). However, few studies have incorporated aggressive fire regimes to reduce canopy cover and stem densities. Some research indicates late spring burns effectively discourage this species, whereas early spring burns can increase sprouting and reproduction. Spring burns in Illinois for example increased infestation (Hutchinson 1992, Morghan et al. 2000), but this response could have been due to previous management treatments or lack thereof. Rosburg (2001) found late spring burns (10 May) had no impact on native forb survivorship and Morghan et al. (2000) found frequently burned native stands were more resistant to reinvasions by invasive plants.

Fire severity also influences native stand vigor and the potential for invasion of undesirable species. Cooper and Jean (2001) found low severity fires had negligible increases in invasive species; however, high-severity fires increased invasive species density. Canada thistle increased to 15% of the canopy cover after very hot fires.

2.4 Herbicide

Canada thistle shoots are relatively easy to kill with herbicides; it's the extensive root system that makes the weed so difficult to bring under control. However, research indicates herbicide use for controlling and eradicating Canada thistle has not been consistent. Apparently, numerous genetic strains exist that vary in susceptibility to





These tables published by Dow AgroSciences (2008) represent chemical treatment evaluations 1 year after treatment. Study sites (22) were located in VA, ND, SD, NE, WY, CO, and WA.

various chemicals. For example, Stinger was found to be more effective than Tordon when each herbicide was only allowed to contact foliage (Hartzler 2002). Yet herbicide programs containing either picloram (Tordon) or clopyralid (Stinger) have proven to be most effective when controlling Canada thistle (see Appendix A for more information). Prior to the development of Milestone, chemical application results showed 52% control in June and 81% control in September, 1 year post treatment (Wilson 2002). Although Federal regulations prevent the use of some of the most effective chemicals on WPAs, an acceptable range of results can be achieved with aminopyralid (Green et al. 2006, Enloe et al. 2007, Bukun et al. 2009), clopyralid (Wilson et al. 2006, Bukun et al. 2009), dicamba (Wilson et al. 2006), glyphosate (Wilson et al. 2006), and triclopyr (Green et al. 2006).

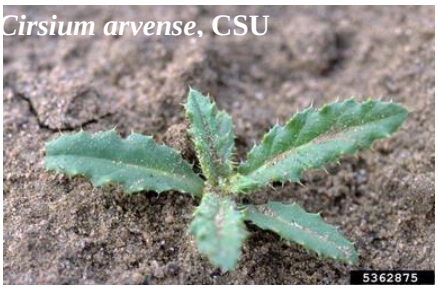
Aminopyralid is a relatively new auxinic (pyridine carboxylic acid) herbicide developed for use in range and pastureland and controls several invasive weeds such as Canada thistle at much lower rates than traditional herbicides (Carrithers et al. 2005, Hare et al. 2005). Fall Milestone treatment success found by Sleugh et al. (2008) indicated regrowth control was 87%, 90%, and 93% on Canada thistle two years after treatment at 5-7 fluid ounces per acre (90, 105, and 120 g aminopyralid ha-1), respectively. Additionally, nonionic surfactants (NIS) such as Cornbelt (Premier 90) will maximize the amount of chemical each plant will absorb (Bukun et al. 2009). Adding 1.2% (w/v) ammonium sulfate (AMS, Cornbelt Gardian Plus has 34%) to this mix (aminopyralid + NIS + AMS) can reduce the pH of the cell walls increasing the absorption of weak acid herbicides enabling acid trapping (Gronwald et al. 1993, Kirkwood 1993). This breaks down cell walls and increasing plasma membrane penetration, providing access to the phloem and increases the chemical absorption by an additional 12% (Bukun et al. 2009). It is not clear if this additional absorption is needed or cost effective at this time; however, the use of LI-700 (a penetrant, acidifier and a drift control agent) would potentially provide these benefits but no research has been conducted on its use in controlling Canada thistle. Currently, we use aminopyralid (Milestone) at a 1-4 oz/A rate with an NIS surfactant (Premier 90).

Successful Canada thistle control techniques typically incorporate some type of root-reserve reduction with fall systemic chemical application. Research has shown that at any given time of the growing season a significant percentage of the vegetative rootstocks are not directly connected to actively growing shoots (Gover et al. 2007, Wilson et al. 2006, Lym and Travnicek 2010). These disconnected rootstocks are unaffected by foliar applied herbicides. In addition, translocated herbicides may not be distributed evenly throughout the root system of actively growing plants (Bukun et al. 2009, Lym and Travnicek 2010). This may also reduce the effectiveness of early summer treatments (Wilson and Michiels 2003). Because of these two factors, it is believed that herbicides that are active both through the foliage and the soil have a greater likelihood of providing long-term Canada thistle control. Under field conditions the soil activity of aminopyralid and picloram probably contributes more to Canada thistle control than that of clopyralid. This suggests an extended benefit in chemical distribution to remaining plants after the initial treatment has been applied.

Products that contain metsulfuron (Escort, Cimarron Max, others) will "control" biennial thistles in the spring and will eliminate seed production when applied in the bolting to bud growth stages. However, the definition of control seems to be very disparate to terms like eradication or suppression (Beck and Sebastian 2000). Some authors make statements that cause more confusion than resolve such as "Canada thistle was reduced in treated sites but species richness was similar to the untreated control and species evenness was similar" (Samuel and Lym 2008). Most authors boast about decreases in stem frequency or canopy cover 1 year post treatment or; some even suggest control can occur by using within-year data collected after treatments. The fact remains that chemical applications at bloom stage (spring or early summer) effectively accomplishes chemical mowing or burn down (Wilson and Michiels 2003, Gover et al. 2007). Research at NDSU has found herbicide absorption and translocation to the roots of Canada thistle is greater when applied to the rosette growth stage than when applied to bolted plants, making fall treatment of rosettes the most cost-effective method for long-term Canada thistle control.

Burn down treatments will eliminate top-growth but root system damage is limited (Wilson et al. 2006, Gover et al. 2007). This fact supports the notion that the herbicide chosen for bloom stage applications are far less important than the herbicide chosen for fall applications. Furthermore, any treatment that reduces stand height, prevents the plants from flowering, and reduces nutrient reserves would have similar control on Canada thistle. Therefore, mowing, tilling, haying, grazing, or chemical applications during early bloom would all have similar success (Beck and Sebastian 2000). Recent research from U.S.D.A found that vinegar could be used as a substitute for "chemical burn off" and can be effective in controlling many types of weeds. Daniels (2003) found that either a 5% or 10% solution of vinegar burned off the top growth of Canada thistle. The plants grew back, but regrew from the roots. Acetic acid in vinegar kills plant tissue by dissolving the cell membrane, which causes the plant to dry out. Vinegar works best when used during sunny weather. BurnOut is a commercially sold product that contains 6.25% acetic and ethanoic acid (table vinegar is about 5% acetic acid) for $0.27/oz. sold at farming supply stores. At this time, vinegar is not registered with EPA for use as herbicide (Byczynski 2003).

Rosette technique: Many Canada thistle control methods already mentioned factor in the growth stage of the plant, many of these treatments attempt to prevent the plants from bolting. If for example mowing was used, this treatment would continue every 10-30 days until the photoperiod is less than 15 hours. After this period, remaining plants tend to regrow as rosettes only. In row crop situations, the rosette technique can control Canada thistle during the season and maximizes the number of rosettes present for better herbicide contact, absorption, and translocation in the fall.



Glyphosate fall-applied to Canada thistle in the rosette stage provides greater control than when applied to bolting or flowering plants (Wilson and Michiels 2003). Additionally, Stinger or Curtail fall-applied to Canada thistle in the rosette stage provides greater control than when applied to bolting or flowering stems (Lym and Travnicek 2010).

The following conditions are needed for maximum performance of foliar-applied downwardly-mobile herbicides on Canada thistle:

1. Adequate soil moisture from the soil surface well into the subsoil.
2. Green leaves, not wilted and generally free from extensive damage caused by insects, disease, drought, hard freeze, dormancy etc.
3. Shoot height is at least 10 inches tall in the early June and 8 inches or more in the fall.
4. Flowers not fully opened.
5. The thistle has not been disturbed recently (within 2 months) by tillage.
6. No mowing or cultivation should be done for 10 days after application.

Rainfall shortly after post-emergent herbicide application reduces weed control because herbicide is washed off the leaves before absorption is complete (see Table 1). Dew at application may reduce weed control effectiveness if spray, in combination with dew, creates leaf surface conditions that promote run-off. If no spray run-off occurs after application, weed control may be equal or greater than if no dew was present at application.

TABLE 1. Effect of rainfall on herbicide efficacy[2] (required Interval)	**Product**
1 hour	Plateau. Roundup UltraMax/ Roundup WeatherMax
2 hours	Milestone
4 hours	Accent, Ally + 2,4-D Amine, 2,4-D Amine, Cimmarron, Clarity4, Escort
6 hours	Curtail M, Tordon 22K, Rodeo, Redeem, Roundup/glyphosate

[2] NDSU 1999.

3 RWB Canada Thistle Monitoring

Invasive plant distribution monitoring and plant community assessment in conjunction with management treatments provides necessary feedback for integrated weed control programs (Cooksey and Sheley 1997, Johnson 1999). Time-repeated surveys are necessary to interpret results and determine needed modifications that will optimize management success (Masters and Sheley 2001). Future invasive species risk assessment models will utilize data collected from these monitoring efforts and current science to determine the course of action needed under an adaptive management strategy for dealing with Canada thistle invasion.

Management objectives play a critical role in determining monitoring needs. The predictable nature of many invasive species follows the same patterns on temporal and spatial scales when natural processes are eliminated or native communities are jeopardized by anthropogenic actions. In order to decrease the risk of invasion or the impacts of currently invaded stands by undesirable or invasive species, land managers should focus on increasing native plant diversity and stand vigor (Masters and Sheley 2001, Pokorny et al. 2004). These actions increase community stability and productivity over the long-term (Pokorny et al. 2004, Middleton et al. 2010). Monitoring protocols should focus on stand diversity and species density in order to track overall vegetative community health (Pokorny et al. 2004).

Any management action is an experiment and we often neglect to monitor these actions. Monitoring efforts for Canada thistle control should focus on specific and quantifiable measures that relate to management objectives. Canada thistle control efforts will be monitored at Funk in 2010 and 2011. This monitoring will determine the success of integrated control efforts on Canada thistle and the replacement stands vigor. The objectives of our control efforts should be to: 1) reduce the canopy cover of Canada thistle to <1%; 2) reduce the stem density within established Canada thistle stands to <1%; and 3) improve native plant diversity and vigor to prevent further spread into areas currently not infested. Monitoring efforts will focus on objectives 1 and 2, determining treatment success by collecting canopy cover and stem density data.

3.1 Methods

Qualitative monitoring will include on-site mapping of Canada thistle patches >0.5 acres in size and photomonitoring. Mapping will be done in June or July when Canada thistle is blooming and easily seen. Photomonitoring points will be established at 10 locations.

Quantitative monitoring will address abundance parameters such as stem density and canopy cover. Frequency of occurrence could also be measured but this measure is not as useful for invasive species monitoring when species are prolific spreaders through rhizomatous growth. .

According to a recent GIS layer generated by Mark Pfost, patches of Canada thistle at Funk WPA average 39 A. However, it is believed that Canada thistle was not mapped in the field using hand-held GPS devises so the accuracy of these maps is questionable. Future Canada thistle mapping should, at minimum, map each Canada thistle patch that is greater than 0.5 A in size using a Trimble mounted on a 4-wheeler. Although this level of effort may seem excessive, it is virtually impossible to monitor Canada thistle management actions without some level of knowledge about its distribution and density.

On Funk WPA, I will randomly pick 3 different management units to monitor. Within these units I will randomly select 30 transect locations (n=90) that currently contain Canada thistle and place a $1m^2$ frame on the end point, situated such that the NW corner of the frame is covers the end point of the transect. Monitoring will occur in June and in October. I will estimate the percent cover of each species within each frame and count the number of thistle stems.

3.2 Statistical Design

All data will be tested for normality and measures of central tendency will be reported. Estimates of precision will include a 90% confidence interval and measures of variability. This monitoring design will be able to detect a 20% decline in the density of Canada thistle between 2010 and 2012, with 90% certainty that the change will be detected (power) and a 10% chance of concluding a change took place when it did not (Type 1 error rate).

Stem count data will be analyzed using a paired-samples *t* test to compare before and after data within year and across years. Two categories will be used, $\leq$ stems prior to treatment (SPT), and > stems prior to treatment. A one-way ANOVA will be used to analyze data collected from each management unit. .

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4 APPENDIX A

Chemicals and common herbicide names with suggested treatments and surfactants:

- 2,4-D (Low Volatile Ester or Amine). Apply in the spring at early bud stage and in the fall when plants are actively growing. Follow label directions and precautions.
- Picloram (Tordon). Restricted use pesticide. Do not apply to cropland. Follow label directions and precautions.
- Dicamba (Banvel, Clarity, Vanquish). Apply at early bud stage in the spring and at the rosette stage in the fall. Follow label directions & precautions.
- Glyphosate (Roundup). Apply at the pre-bud stage in the spring and when plants are actively growing in the fall. Follow label directions and precautions.
- Chlorsulfuron (Telar). Follow label directions and precautions.
- Clopyralid (Stinger, Transline). Apply from rosette to pre-bud. For most effective control of Canada thistle, apply as a broadcast treatment to the entire infested area. Follow label directions and precautions.
- Triclopyr (Garlon) + Clopyralid (Confront). For control of Canada thistle in turf. Follow label directions and precautions.
- Clopyralid + 2,4-D (Curtail). Follow label directions and precautions.
- Aminopyralid (Milestone, Milestone VM and VM Plus[3]). Apply in either spring to plants in prebud growth stage or in the fall to rosettes or regrowth. Follow label directions and precautions.
- Glyphosate + Diquat (QuikPro). Apply in prebud growth stage. Follow label directions and precautions.
- Diflufenzopyr + Dicamba + Picloram (Overdrive + Tordon 22k). Restricted use pesticide. Do not apply to cropland. Follow label directions and precautions.
- Nonionic surfactants (NIS) approved for over water use[4] include: Activate Plus, Agridex, Class Act NG, Induce, Liberate, LI-700, Preference, R-11, Widespread, and X-77.
- Ammonium sulfate (AMS) that lower pH: Deliver, Cornbelt Gardian Plus, and LI-700 that is not AMS but is a pH reducing adjuvant and drift control agent.

[3] http://www.dowagro.com/ivm/invasive/product.htm
[4] http://www.fs.fed.us/r1/custer/projects/planning/weed_eis/appendix_j_efficacy_surfactants_rainfastness.pdf

5 APPENDIX B

Control methods commonly used for Canada thistle control (modified from Gover et al. 2007).

Timing	Treatment	Product Rate (oz/acre)	Comments
late spring	Roundup Pro	64	Roundup Pro is just one of many *glyphosate* products. A spot treatment with *glyphosate* is the recommended herbicide alternative in tree plantings because there is no soil activity that could lead to herbicide injury through root absorption.
late spring	broadleaf herbicide	See below	In grassland plantings, there are many relatively inexpensive products that will provide burn-down of Canada thistle. Examples include 'Weedmaster' and 'KambaMaster' (*dicamba + 2,4-D*),
late spring	mowing		If mowing once, mow at bud to early bloom stage to maximize root system depletion. Spot mowing may be necessary in grassland plantings. Mowing 3-5 times during the growing season will deplete the root reserves and can be particularly successful with chemical follow-up.
Spring	Curtail	64-96	*Clopyralid* - Spring application effective with the use of *2,4-D*. Apply 2-3 qts/A when the oldest plants enter the bud stage and the youngest plants are in the rosette to bolting stage.
fall	Forefront R&P	32	Forefront is a mixture of *aminopyralid* plus *2,4-D*, and provides a broader spectrum of control if other broadleaf weeds are present. This treatment will not injure established grasses, but should not be used in close proximity to desirable trees.
fall	Milestone	5-7	Milestone (*aminopyralid*) is very active against thistles and legumes. This treatment will not injure established grasses, but should not be used in close proximity to desirable trees (may affect locust, spruce, pine and cedar trees). Maximum application rates for broadcasting is 7 fl oz/A, 14 fl oz/A when spot spraying; however no more than 50% of the area may recieve 14 fl oz/A. Fall treatments are particularly effective because chemical activity carries over to the spring.
fall	Roundup Pro	128	Roundup Pro (*glyphosate*) is non-selective, and this rate will severely injure all contacted vegetation. This is the best option - as a spot treatment - for use in hardwood plantings and riparian forest buffers because *glyphosate* has no soil activity.
fall	Telar	2	At lower rates, Telar XP (*chlorsulfuron*) is safe to grasses, but this rate will cause significant injury to most grasses. Recommended at 1 fl oz/A for treating regrowth, especially in the fall. Use 25-50% v/v surfactant for adequate control.
Spring or Fall	Transline	18.9	Effective after plants have emerged, rosette or bud growth stages. Apply 1pt/A (18.9 oz/A) in the fall for best results.
fall	Vanquish (Banvel, Clarity)	48	Vanquish is a less-volatile formulation of *dicamba*, the active ingredient in the 'Banvel' products. This treatment will not injure established grasses, but should not be used in close proximity to desirable trees. These products do need *2,4-D* to increase effectiveness.