Weeding Out a Solution: Best Management Practice for Canada Thistle

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Control methods mentioned in this paper are only examples. They have not been tested unless stated. It is advised that if you are to assimilate any of the control methods discussed in this thesis that you better know what you are doing or understand if the treatment is right for your infestation problem. Also, there are a plethora of other control methods for managing Canada thistle (*Cirsium arvense*). The methods in this thesis should not be regarded as implying that other methods as inferior.

Weeding Out a Solution: Best Management Practice for Canada Thistle

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A non-native invasive species, Canada thistle is mandated by state and federal laws in the U.S. to be managed and controlled in order to support human and environmental health. Using single management techniques do not prevent Canada thistle from reoccurring annually. An integrated multi-dimensional approach at managing Canada thistle can benefit a spectrum of variables and can control the re-growth and reoccurrence of Canada thistle. Interdisciplinary evaluation, and analyzing each management technique, can improve savings in time, money, and resources.

(From here on in, Canada thistle will be addressed in the paper as C. thistle.)

According to the United States Department of Agriculture, C. thistle is a noxious invasive species. The buds of a C. thistle plant bloom into a purple flower that becomes a seed head in late spring and early summer. The plant's perennial invasive characteristics stunt the effectiveness of single control methods. Minnesota private and public landowners are mandated by state and federal laws to control C. thistle and prevent it from spreading. Single management techniques, such as grazing pastures, mowing infestations, and applying chemical pesticide, have all prevented or eradicated some degree of infestations. However, the reoccurrence of the plant, even after being treated, becomes a problem that fuels more time, money, and resources into invasive species control.

Integrating multiple management techniques can solve the problem of single management practices, which are costly and inefficient. Creating an Integrated Pest Management (IPM) plan that includes a multi-dimensional management of C. thistle can ensure successful control of infestations. An IPM plan includes monitoring and surveying C. thistle in its early growth stages by using current technologies such as GPS (Global Positioning Satellite) and GIS (Geographical Information Systems). Next, an integrated schedule of chemical, physical, mechanical, or biological control methods is created and implemented.

An integrated multi-dimensional plan for C. thistle benefits the land and landowners economically, environmentally, and effectively. A well planned IPM plan can save time, money and resources by evaluating, analyzing, and creating an efficient management system.

Introduction

Southern Canadian providences and the northern half of the U.S. are carpeted with fragmented infestations of C. thistle. Infestations generally establish on agricultural lands, prairies, grassy outcrops on mountainsides, and roadsides. Since it negatively affects crop production and the health of the environment, landowners generally try to control infestations with single control methods. Some landowners might plant vegetation or native grasses to compete and fight against the establishment of the invasive. Other landowners might use chemical treatment, such as applying pesticides directly on the infestations. There are multiple ways of controlling C. thistle, however, some control methods are more expensive, less effective, and environmentally degrading. Using a control method that is low in cost, high in effectiveness, and environmentally friendly can be done by integrating multiple methods of control. Carefully inspecting the infestation, scheduling treatments when they are most effective, and evaluating the results of treatments; results in savings for landowners, less harm done to the environment, and increased effectiveness in controlling C. thistle infestations.

This plant was supposedly introduced to North America by a contaminated crop that was shipped from European countries to American colonies in the seventeenth century.[1] Infestation spread westward probably by contaminated crops and hay transported from the colonies by early pioneers making their way across the Great Plains. The earliest action taken to control C. thistle was legislation passed in Vermont in 1795 and New York in 1831[2]. State action has still continued by passing legislation against the establishment of infestations. On January 3, 1975, the federal government passed the Noxious Weed Act. It raised awareness and control efforts on invasive noxious weeds federally. The law

[1] Boersma, P.D., and S.H. Reichard, and A.N. Van Buren. *Invasive Species: In the Pacific Northwest.* Pg.91
[2] Ibid. Pg.91

calls for creating a branch or office that would, "cooperate with Federal, State and local agencies, farmers associations and private individuals in measures to control, eradicate, or prevent or retard the spread of such weeds.[3]" The mission of this branch or office also includes educating others about the threats that invasive species have on human health and the environment, economics, and crop yields.

The impacts that C. thistle has on crop yields and the environment can cause a loss in income and environmental degradation. C. thistle can take over crop fields and reduce the productivity of the land, adversely costing farmers losses in crops and expenses in control practices. In the state of Montana, depending on the density of the infestation, wheat yields can be reduced from 15% to 60%[4]. Other crops such as peas, corn, beans, and alfalfa are also seriously threatened by C. thistle. In Montana, 48%[5] of an alfalfa stand can be reduced by C. thistle infestations. In terms of money, C. thistle can cause annual economic losses of about $74 million[6]in North Dakota alone. Losses are generally due to reduced feed and pasture production, especially since the usual grazing livestock avoids the noxious invasive. The cost of environmental degradation can be significant. Lands set aside for wildlife habitat are impacted in forage production and wildlife abundance. Bird watchers, hunters, and plant enthusiasts lose a variety of habitat from C. thistle invasions. The Fish and Wildlife Service spent, in 2001, $150million[7] on invasive species control to, "manage migratory bird populations, restoring wildlife habitat," and, "conserve, protect, and enhance fish, wildlife, and plants.[8]"

[3] U.S. Fish and Wildlife Service, "Federal Noxious Weed Act," FWS CLA Resource Laws.
[4] Jacobs, Jim, and Joanna Scoegienka, and Fabian Menalled. *Ecology and Management of Canada thistle.* Pg.1
[5] Ibid. Pg.6
[6] Samuel, Walter Luke. *Aminopyralid effect on Canada thistle and Native Plants in Western North Dakota.* Pg.1
[7] U.S. Department of the Interior: U.S. Fish and Wildlife Service: National Invasive Species Management Strategy Team. *The National Strategy for Management of Invasive Species*., 2003. Pg.2
[8] U.S. Fish and Wildlife Service, "Comprehensive Conservation Plan," Minnesota Valley National Wildlife Refuge.

Biology

Managing C. thistle infestations is important. The plant's advantageous biology and invasive nature decreases crop yields and restricts biodiversity. This explains why federal and state statutes order management of C. thistle infestations.

C. thistle's biological structure allows it to have a competitive advantage over other plants. The thick network of roots can choke up native plants and produce homogeneous infestations. The plants seed heads, able of producing numerous seeds, are easily dispersed; therefore, generating future infestation and spread of C. thistle. Adversely C. thistle noxiously inhibits crop yields, bio-diversity, and wildlife habitat. The plant's ability to crowd out native vegetation and crops is in-part due to its root system. C. thistle has been defined to a variety of habitats.[9] It has been known to root itself in a range of soils, from poor soils near roadsides to rich agricultural soils.[10] The roots of C. thistle are rhizomatous, meaning that once established in the soil, roots are capable of regenerating and producing new growth. Reserves of carbohydrates in the root system power roots regeneration and production. The reserves also allow C. thistle to be dormant in the winter and flower in the spring. The perennial characteristic of C. thistle makes control of infestations even more difficult. The roots are able to grow laterally up to 10-12 feet per year[11] and can have a taproot 6 feet[12] below the soils surface. In consequence of its perennial and regenerative root systems, C. thistle infestations not only have the ability to eliminate plant and wildlife diversity, they also invade crops and vegetation habitats.

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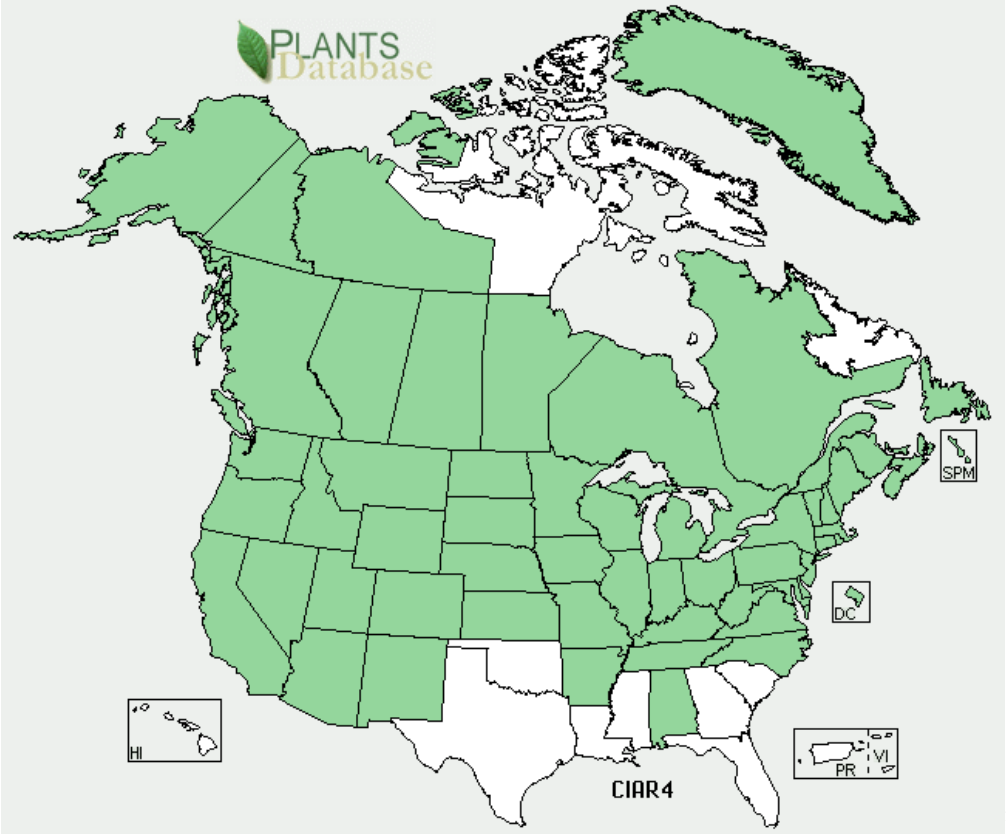
[9] Jacobs, Jim, and Joanna Scoegienka, and Fabian Menalled. *Ecology and Management of Canada thistle*. Pg.1
[10] Czarapata, Elizabeth J. *Invasive Plants of the Upper Midwest*. Pg.56
[11] Howe, Katherine, and Mark Renz, and Kelly Kearns, and Jennifer Hillmer, and Ellen Jacquart. *A Field Guide to Invasive Plants of the Midwest*. Pg.18
[12] Czarapata, Elizabeth J. *Invasive Plants of the Upper Midwest*. Pg.56



[13]

Fig.1 – Current range of presence in the United States and Canada.

By establishing a homogeneous colony C. thistle can, year after year, encroach other plants habitats and eliminate native flora. As a result of this behavior, C. thistle has been known to lower crop yields and alter environmental regimes. Harvests of wheat contaminated by C. thistle have been known to produce reduced yields anywhere from 15- 60%. Infestations also have altered environments and habitats by changing plant species abundance, changing fire regimes, altering water flow, and decreasing wildlife species abundance.[14]

[13] USDA."Plants profile for Canada thistle." Available at (http://plants.usda.gov/java/profile?symbol=CIAR4).
[14] Cronk, Quentin C.B., and Janice L. Fuller. *Plant Invaders*. Pg.4-7

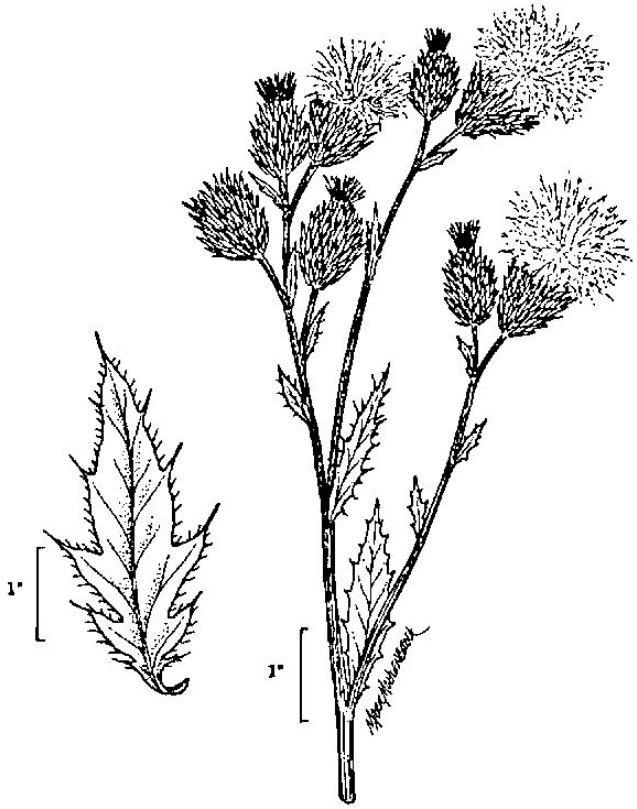


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Fig 2 – Line Drawing of *Cirsium arvense*, Canada thistle's leaf and flowers.

The seeds produced by C. thistle contribute to its invasiveness. Female plants can produce up to 5,000 seeds. Some of these seeds can lie dormant in seed banks for up to 20 years.[16] Seed banks are pockets of seeds in the soil that lie dormant until activated by proper growing conditions. The flower head, colored pink or lavender, is able to contain around 93 seeds.[17] Wind, animals, mowing, and generally any other way of disturbing a C. thistle seed head, disperses and transports the seeds.

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[15] USDA. "Plants Profile for Canada thistle." Available at (http://plants.usda.gov/java/largeImage?imageID=ciar4_009_avd.tif).

[16] Czarapata, Elizabeth J. *Invasive Plants of the Upper Midwest*. Pg.56 & Jacobs, Jim, and Joanna Scoegienka, and Fabian Menalled. *Ecology and Management of Canada thistle*. Pg.4-5 & Uva, Richard H, and Joseph C. Neal, and Joseph M. DiTomaso. *Weeds of the Northeast*. Pg.132 & Howe, Katherine, and Mark Renz, and Kelly Kearns, and Jennifer Hillmer, and Ellen Jacquart. *A Field Guide to Invasive Plants of the Midwest*. Pg.18 & Royer, France, and Richard Dickinson. *Weeds of the Northern U.S. and Canada*. Pg.33

[17] Jacobs, Jim, and Joanna Scoegienka, and Fabian Menalled. *Ecology and Management of Canada thistle*. Pg.4

However, in comparison to the success of rhizome reproduction, the establishment of infestations by seed is less of a threat.[18]

Laws and Regulation

The economic and environmental affects that C. thistle infestations cause has led to federal and state laws ordering control and elimination of C. thistle infestations. The National Invasive Species Council, established by executive order February 3, 1999, arranges control strategies that improve coordination, prevention, and control of invasive species[19]. Federal agencies are ordered by this council to actively minimize the impacts of invasive species when carrying out any federally related activities.

C. thistle is notorious for being identified as a noxious weed. It is labeled as noxious in 32 out of 51 state statutes[20]. In 2009, Minnesota called for the control and eradication of noxious weeds in its, "New Minnesota Noxious Weed Law." The law states that noxious weeds need to be prevented and controlled to protect the residents of the state from, "the injurious effects of noxious weeds on public health, the environment, public health, the environment, public roads, crops, livestock, and other property."[21]

Interview: County Agricultural Inspector- Greg Senst

Unique to Minnesota is the County Agricultural Inspector (CAI). Enacted by the Minnesota Noxious Weed Law, the CAI's responsibilities include inspecting the land with their municipalities, issuing property owners a notice to control noxious weeds, and inspecting seed, applicator licenses, animal feed, and fertilizer. A CAI also answers to reports given by citizens reporting cases of infestations on others properties. CAI duties are to inspect the eyewitness reports, check the suspected property, and if there is an infestation of noxious weeds, issuing a notice to the landowner. If, by chance, the land

[18] Czarapata, Elizabeth J. *Invasive Plants of the Upper Midwest*. Pg.56
[19] United States Department of Agriculture: Animal and Plant Health Inspection Service. Invasive Species and Forest Health.
[20] United States Department of Agriculture: Natural Resources Conservation Sciences.
[21] State of Minnesota. *New Minnesota Noxious Weed Law: 18.75.*

owner does not cooperate with the notice, then by law, he or she has committed a misdemeanor and may be penalized a fine no greater than $700 and 90 days in jail.[22]

In the past year a new Minnesota Noxious Weed Law has been authored by groups and organizations, and also by Hennepin County Agricultural Inspector, Greg Senst. Here is a list of some of its authors: Association of Minnesota Cities, Association of Minnesota counties, Minnesota Association of Minnesota Townships, DNR, Agricultural groups (such as Farm Bureau, Farmers Union, Minnesota Association of County Agricultural Inspectors), University of Minnesota, Board of Water and Soil Resources and Greg Senst. Greg Senst has been the CAI for Hennepin County for 21 years. Over the past 21 years, he has seen multiple control methods performed. The most unique method for controlling C. thistle was a spray boom converted to a "flame thrower type machine.[23]" In operation, the spray nozzles on the boom would spit flames out to burn the flowers off of the C. thistles.

As an experienced CAI, Greg Senst believes that the most common control method for controlling C. thistle is by mowing infestations. This method is preferred by, MNDOT, private and public landowners, and county, city townships. "I have seen mowing work as a long-term control method only when mowing is done several times per year, and when native or competitive plants are seeded into the area being mowed.[24]" Subsequent to mowing, chemical control methods, such as spraying herbicides and pesticides, are commonly practiced. Provided that the product is safe to the environment ("whatever that means, I believe that pesticides have a place and when used properly are very effective[25]") pesticides or herbicides can be very effective.

When asked what management technique do you think offers the most attention to the environment, economics, and effectiveness, Greg Senst answered.

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[22] Greg Senst. Interview. October 28, 2009.
[23] Ibid.
[24] Greg Senst. Interview. October 28, 2009.
[25] Ibid.

> " The way I recommend C. thistle control is to mow them during the flower stage (late June-July) than come back in the fall after the first frost or two (late September- mid October) and apply a herbicide. I like Milestone because it is not harmful to the environment, but there are also other mixtures that work really well at low rates this time of year. In the fall the plant is storing food for winter so the herbicide is trans-located through the plant better this time of year. The theory is that if the chemical does not kill the weed out right, the plant will be weakened so that winter will kill the plant. I would then seed or plant desirable vegetation into the site.[26]"

In Hennepin County the lands that are most commonly infested by C. thistle are housing developments. "The bigger the lots (2-10 acres) the bigger the problem.[27]" After sale, the lots are managed by owners who may mow up to one acre for lawn purposes. The rest of the lot is meant to become "natural." The belief that the remaining land is going natural is a common misunderstanding with lot owners. The land left un-mowed becomes an infestation zone for "C. thistle, sweet prairie clover, and daisy fleabane.[28]" If landowners want to let their land to go natural they need to sow native seed mixes and manage the land for a native habitat.

Mechanical Control Methods

One of the fastest and easier ways of controlling C. thistle is by using mechanical devices to mow infestations. Mechanical devices, such tractors and mowers or brush cutters, are known for their byproducts or emissions that release Green House Gases (GHG) into the atmosphere. Releasing GHG's into the atmosphere is known to encourage global warming. Machines can also transport C. thistle stalks or seed heads to other places.

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[26] Ibid.
[27] Ibid.
[28] Greg Senst. Interview. October 28, 2009.

Using machines allows land owners to control large infestations quickly and efficiently.[29] Tractors equipped with mowers have been known to reduce populations of C. thistle 86% to 100% after four years.[30] The U.S. Fish and Wildlife Service(USFWS) – Minnesota River Valley NWR(MRVNWR)[31] and the Arboretum at Saint John's University[32] use mowers and brush cutters in controlling C. thistle infestations. The frequency of mowing may be from 3-6 times a year, during the months of June-August.[33] The organizations use machines because machines are fit for controlling the number of acres that need to be managed. Personally, during my summer internship with the MRVNWR I had the experience of mowing C. thistle on multiple USFWS Waterfowl Protection Areas (WPA). It took me 8 hours to mow 8 acres of C. thistle infestation. Depending on the size and impact of the infestation, using mechanical control methods can be reasonable, if time efficiency is an important goal.

To prevent the spread of C. thistle infestations mechanical equipment, especially the blades of the mowers, need to be cleaned before leaving an infestation site. After mowing infestations, equipment may become a vessel for spread and growth of the plant. Tires on tractors, mowers, or brush cutters may carry mud or dirt with seed deposits embedded within it. Stalks and seed heads might also be hung up on equipment or even wrapped around the blades of the mowers. Before transporting or using a machine at a new site, operators should do a pre-check for any remnants of C. thistle. [34]

The costs associated with using tractors equipped with mowers include the retail and fuel costs for the machines. Chris Trosen, the Invasive Species Management Supervisor at the USFWS MRVNWR,

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[29] Trosen, Chris. *Invasive Species Management*. Interview. November 20, 2009. & Vogel, Daniel A. *Forest Technician at the Saint John's University Arboretum*. Interview. November 15, 2009. & U.S. Department of the Interior: U.S. Fish and Wildlife Service: National Invasive Species Management Strategy Team. *The National Strategy for Management of Invasive Species*., 2003. Pg.33

[30] Jacobs, Jim, and Joanna Scoegienka, and Fabian Menalled. *Ecology and Management of Canada thistle*. Pg.7

[31] Trosen, Chris. *Invasive Species Management*. Interview. November 20, 2009.

[32] Vogel, Daniel A. *Forest Technician at the Saint John's University Arboretum*. Interview. November 15, 2009.

[33] Vogel, Daniel A. *Forest Technician at the Saint John's University Arboretum*. Interview. November 15, 2009.

[34] U.S. Department of the Interior: U.S. Fish and Wildlife Service: National Invasive Species Management Strategy Team. *The National Strategy for Management of Invasive Species*., 2003. Pg.33

said that using a tractor with a triple flail mower costs $30/acre.[35] This figure represents the average cost of purchased fuel in the months of May and July, in relation to acres mowed. Most agricultural machines use diesel No. 2 for fuel. The average cost of fueling up an agricultural machine or mower in the months of May, June and July are around $1.936/Gallon of Diesel No. 2[36]. The cost for a John Deere 6430 ComfortGard Premium Cab Tractor, similar to the tractor used at the USFWS- MRVNWR in 2009, is around $72,759.[37] Investing in mechanical control can cost a lot of money, especially if the equipment is not dually used for agricultural practices. The first year cost of managing C. thistle with machines is around $72,789 for one acre, $75,000 for 100 acres, and $90,000 for 500 acres of infestation.

In respect to the environment, mechanical control methods emit global warming green house gas emissions and destroy habitats of non-targeted wildlife. Most large agricultural machinery used are fueled by diesel No. 2, a fossil fuel. The combustion of diesel yields energy for the machine and emits carbon dioxide, methane, and nitrous oxide as a byproduct. Recognized by the Energy Information Administration and the Department of Energy, emissions from diesel fuel are contributors to global warming. These emissions are carbon dioxide, methane, and nitrous oxide. One gallon of diesel fuel emits 22.37 pounds of carbon dioxide[38], .26 grams of nitrous oxide[39], and 1.44 grams of methane[40]. Emitting large amounts of these green house gases in theory will increase the amount of time infrared heat is contained within the atmosphere. One main hypothesis is that an increase in green house gas emissions will lead to catastrophic global warming.[41]

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[35] Trosen, Chris. *Invasive Species Management*. Interview. November 20, 2009.
[36] Department of Energy: Energy Information Administration.
[37] John Deere, "John Deere 6430 ComfortGard Premium Cab Tractor,"
[38] Energy Information Administartion. *Documentation for Emissions of Greenhouse Gases in the U.S. 2005*
[39] United States Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emission Sinks: 1990-2005.*
[40] Ibid.
[41] McKinney, Michael L., and Robert M. Schoch, and Logan Yonavjak. Environmental Science:Systems and Solutions. Fourth Edition. Pg. 474.

Physical Control Methods

Mechanical control methods are dependant of machines doing all the labor. Physical control methods are more concentrated on utilizing non-mechanized practices, such as fire, grazing, and hand pulling. The time of year, the size, and the location of the infestation are factors that dictate which physical control method should be used.

Manually pulling C. thistle is generally a technique used in gardens and other small tracts of land because of its time consuming and laborious procedure. Pulling an entire plant up, root and all, is almost impossible. The root system of C. thistle can extend laterally 10 to12 feet[42] and 6 feet deep.[43] After pulling out a plant, the root remnants left in the soil that are greater than or equal to a quarter of an inch long by one eighth of an inch in diameter,[44] can generate new growth from carbohydrates stored in its reserves. Continuous pulling of weeds over an extended period of time, however, may control small infestations. Repetitive pulling starves the roots and stems of energy and can control re-growth and reproduction. It is advised that pulling be done only in small infestations for maximum efficiency. Larger infestations are to be left to other methods such as grazing.

Breeding or cultivating donkeys, sheep, or goats allows landowners to control C. thistle infestations by grazing. In the country of Australia sheep are used to feed on shoots of C. thistle.[45] The sheep in Australia are also cultivated to support its wool industry. Using livestock like sheep to control C. thistle provides landowners an opportunity to profit from controlling C. thistle infestations; and also profiting from the sale of the sheep's wool. Economically this is a win-win situation for landowners controlling C. thistle.

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[42] Howe, Katherine, and Mark Renz, and Kelly Kearns, and Jennifer Hillmer, and Ellen Jacquart. *A Field Guide to Invasive Plants of the Midwest*. Pg.18
[43] Czarapata, Elizabeth J. *Invasive Plants of the Upper Midwest*. Pg.56
[44] Beck, K.G. *Canada thistle*.
[45] Jacobs, Jim, and Joanna Scoegienka, and Fabian Menalled. *Ecology and Management of Canada thistle*. Pg.7.

Grazing does, however, limit biodiversity in pastures. Animals that graze remove their food plants and indirectly change ecosystems and plant communities. Grazing animals can also alter ecosystems and plant communities by trampling on and fertilizing the landscape. When grazing animals reduce native plant cover and alter the landscape. The susceptibility of invasion by exotic species increases. New invasive species taking over these altered landscapes can be avoided by selective grazing animals, resulting in another infestation problem.

To avoid introducing new invasive species to pasturelands, intense grazing on one part of the land should be avoided. Rotating grazing animals to new pastures every now and then, helps keep plant communities and ecosystems resilient to invasive species infestations. By using "ocular estimation," cultivators monitor the site conditions an make an executive decision when to move the herd.

Using goats to control C. thistle is an economically and environmentally wise method. Goats grazing habits, compared to sheep, are unselective. Goats have been known as an effective control agent for C. thistle, oxeye daisies, hawkeyes, and horsetails.[46] Goats tend to generally graze openly on weeds and tree saplings. However, the thorns that develop on the C. thistle plant don't seem to bother goats. The U.S. Fish and Wildlife Service, Minnesota River Valley NWR, used goats in 2008 to control a patch of buckthorn located near the main office in Bloomington, Minnesota.[47] The major investment with grazing is purchasing and setting up a fence line. The total cost for controlling one acre in one year is $17,253.78. Renting a herd from a nearby farmer will reduce the total cost. Compared to the cost of using pesticides, $7,803.04, it seems that chemical control is cheaper. However, after five years of grazing with goats, the annual cost is comparable, and even less than, $7,803.04.[48]

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[46] Booth, L. Annie, and Norman W. Skelton. *The Use of Domestic Goats and Vinegar as Municipal Weed Control Alternatives*. Pg.14.
[47] Trosen, Chris. *Invasive Species Management*. Interview. November 20, 2009.
[48] Booth, L. Annie, and Norman W. Skelton. *The Use of Domestic Goats and Vinegar as Municipal Weed Control Alternatives*. Pg.14.

The last physical method of controlling C. thistle is by using prescribed burns. If done properly and in the right season, prescribed burns can be an effective way of controlling C. thistle infestations. Burning infestations at the wrong time of the year risk post-infestations of C. thistle. The plant's deep network of roots intensifies infestation after early spring burns. In the early spring, C. thistle roots, which anchor down 6 feet[49] in the soil, bud new growth and promote sprouting and reproduction. Burning in the fall similarly enhances post fire re-occurrence of C. thistle infestations. The best time to burn is in late spring Burning infestations at this time of the year "effectively discourages[50]," C. thistle.

Burning, in general, risks the possibility of magnifying invasive infestations by setting fire to shading canopies, burning away competitive native flora, and exposing soils rich in inorganic nitrogen. Burn sites absent of native flora, and with exposed soils, are vulnerable to wind deposited C. thistle seeds from adjacent infestations. Seeds that are blown onto post fire sites have little competition with other plants for nutrients in the soil. After a burn, soils have high levels of inorganic nitrogen making post fire sites hot spots for C. thistle infestations.

Chemical Control Methods

A controversial method of control that receives a lot of negative appreciation is chemical management. Chemical management is commonly defined as a treatment using synthetic herbicides and pesticides. However, chemical management is not limited to this method. Chemical management also includes applying vinegar as a chemical solution. An 8% solution of vinegar has tested and proved to successfully control C. thistle infestations. Researchers applied the solution by backpack sprayers in three-week intervals. They found that vinegar controls C. thistle, but "cannot eradicate thistle." In conjunction with controlling C. thistle the vinegar solution controlled other invasive species such as the ordinary dandelion. Using vinegar, however, negatively affected native forbs too, especially brome and

[49] Czarapata, Elizabeth J. *Invasive Plants of the Upper Midwest*. Pg.56
[50] Zouhar, Kristin, and Jane Kapler Smith, and Steve Sutherland, and Matthew L. Brooks. *Wildland Fire in Ecosystems: Fire and Nonnative Invasive Plants.* Pg.122.

timothy grass. The researchers found that red clover re-colonized some plots effectively, because it is an acid tolerant species.[51]

In comparison, the use of vinegar was half the cost of using pesticides. Managing C. thistle with vinegar costs annually $4,864.96 for control on one acre while managing with pesticides would cost an annual $7,803.26 for on acre.[52]

Applying vinegar doesn't require a special chemical applicators license or any special safety concerns. If animals ingest vinegar-treated vegetation or soil it just gets digested because there are no toxics.[53] Compared to pesticides and herbicides, vinegar is innocuous to the environment and plays no role in pollution.

On the other hand, pesticide and herbicide application can be detrimental to the health of the environment and of human beings. Environmental damage can be in the form of direct "point source" pollution, or indirect "non-point source" pollution. Applying pesticides near or in water wells, sinkholes, and storm sewers defines point source pollution. This type of pollution contributes to contamination of groundwater. Ground water pollution is nearly impossible to remediate making it an important source to protect from pollution. Found at the water table in what is known as the aquifer, the water very slowly renews itself every 1,600 – 9,700 years[54]. Ground water provides 70%[55] of human, industrial, and agricultural water consumption. Pollution of ground water is detrimental to human health and the dynamism of aquatic systems. Areas in southwest Minnesota have groundwater wells that children cannot drink from because of the amount of nitrogen present in the groundwater. Lakes and streams

[51] Booth, L. Annie, and Norman W. Skelton. "The Use of Domestic Goats and Vinegar as Municipal Weed Control Alternatives." *Environmental Practice* 11, no. 1(March 2009)Pg. 12
[52] Ibid. Pg. 12
[53] Booth, L. Annie, and Norman W. Skelton. "The Use of Domestic Goats and Vinegar as Municipal Weed Control Alternatives." *Environmental Practice* 11, no. 1(March 2009)Pg. 12
[54] Kalff, Jacob. *Limnology*. Pg.42, Table 4-1
[55] National Pesticide Applicator Certification CORE Manual. Pg.113

fed by polluted groundwater will have water saturated with amounts of a pesticide chemicals and nutrients resulting in changes throughout aquatic system's morphology, biology, and nutrient cycles[56].

After application, heavy rains may transport pesticides from application sites into water systems, plant communities, and animal's habitat or nests down slope. This type of situation is commonly labeled as run-off.[57] Increased vegetation cover, permeable soils, and a slow rate of water washing down-slope are factors that can reduce the impact of run-off on the water systems. Vegetation reduces the impact of run-off by sorbing chemicals and nutrients before it reaches a water system. Permeable soils allow increased uptake of precipitation in the soil, slowly releasing run-off chemicals. Low, flat slopes give run-off a slower rate of movement to the water systems.

Most mistakes in applying chemicals can be easily prevented if applicators follow the general guidelines offered in the National Pesticide Application CORE manual. Applicators should always be safe when mixing and applying chemical pesticides and herbicides. Mixing should be done in a well ventilated facility or outdoors, away from people, animals, open wells and other objects that can be contaminated.[58] Before applying pesticides, applicators should calibrate their equipment, make sure the correct amount of pesticide is being dispersed, and adjust equipment and nozzles to reduce drift. Pesticides should only be applied in conditions with low temperature inversions, no wind, mild relative humidity, and warm comfortable temperatures.[59] When applying pesticides to C. thistle, application should be in the months of May, June, and October.[60]

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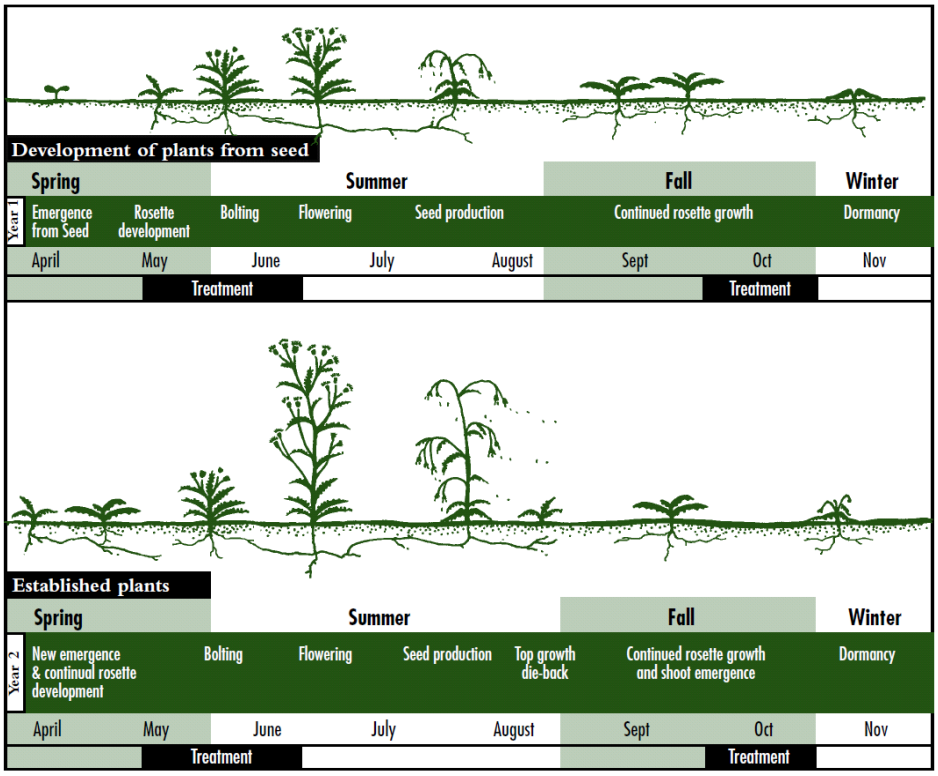
[56] Kalff, Jacob. *Limnology*. Pg.42
[57] National Pesticide Applicator Certification CORE Manual. Pg.114
[58] National Pesticide Applicator Certification CORE Manual pg 151
[59] CORE Manual pg 110
[60] Wilson, Robert. Noxious Weeds of Nebraska: Canada Thistle, May 2009. Pg.6

Figure 13. Life cycle of Canada thistle



[61]

Fig. 3 –Illustration of the life cycle and the best times to treat it with pesticides or herbicides.

Biological Control Methods

Another method for controlling C. thistle is by using either biological control organisms or vegetation that can compete with and overtake C. thistle invasions. Using bio-control organisms is an inadequate practice of controlling C. thistle. The unpredictable nature of bio-control organisms puts non-targeted species at risk of being affected. An example of a bio-control organism that eats non-targeted vegetation and its host plant is the organism meant for controlling musk or nodding thistle. The bio-control organism for the exotic musk or nodding thistle has shown to attack the native wavy leaf thistle only when the wavy leaf thistle is included in or closely surrounding an infestation of musk

[61] Wilson, Robert. Noxious Weeds of Nebraska: Canada Thistle, May 2009. Pg.6

thistle.[62] To avoid non-targeted species from being attacked by bio-control organisms, applicators should monitor and survey infestations. Surveying and monitoring can be done by taking photographs, recording the number of species affected by the bio-control organism, or by using a GPS to map out areas. Doing surveys and maps on the success or failure of bio-control organisms helps in future decision making for effective treatments.

Considering the failure rate of bio-control organisms, biological control can be expensive. The cost of bio-control depends upon a couple of conditions. The survival rate and "length of time taken for the bio-control agent to build up its numbers,"[63] governs the amount of money spent on bio-control organisms. "Programs for a single plant may take 5-10 years from conception to release and the cost can be in excess of $815,000."[64]

Bio-control organisms used for C. thistle include the Hadroplontus litura (stem boring weevil), Urophora cardui (stem gall fly), Larinus planus (bud weevil), Puccinia punctiformis (fungi pathogen), and Suerotinia sclerotiorum (fungi pathogen). Most effective bio-control organisms are the H. litura, U. cardui, and S. sclerotiorum. The H. litura stem weevil causes damage to the root crown making C. thistle susceptible to pathogens and diseases. The stem gall fly, U. cardui, forms a gall in the stem of the plant interrupting nutrient flow and making the plant susceptible to diseases. The U.cardui and H. litura are commonly used as treatment for C. thistle in Colorado. The Colorado Department of Agriculture allows land managers to purchase these two organisms from their office in Lakewood, Colorado. S. sclerotiorum, the fungi pathogen, attacks the plant from the roots. It has had success in eliminating 20-80%[65] of C. thistle shoots. It may attack, however, desirable broadleaf crops.

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[62] Leland, Russell F., and Svata M. Louda, and Tatyana A. Rand, and Stephen D. Kachman. *Variation in herbivore mediated indirect effects of an invasive plant on a native plant*. Pg. 419, 421.

[63] Cronk, Quentin C. B. *Plant Invaders*. Pg.56

[64] Ibid. Pg.56

[65] University of Nevada-Reno. *Managing Canada thistle*. Pg.3.

Instead of using bio-control organisms to manage C. thistle infestations, one can plant native vegetation or winter cereals. Native plant communities have been proven to control C. thistle by the many processes that go on under and above the soil amongst neighboring plant species. Native plant species have the advantage of controlling the soil composition, dominating the soil mass with deep root systems, and re-sprouting yearly. Communities of native species, however, are "often readily invaded by exotic species."[66] Therefore coordinating another practice of control would aid in avoiding any occurrence of C. thistle.

The perennial alfalfa and winter cereals have been known to compete and prevent the emergence of C. thistle. Growing and harvesting these two crops also offers profit gained by selling hay bales of alfalfa and harvests of winter cereals.

Integrated Pest Management

Landowners can save money by integrating multiple control methods for C. thistle. A highly effective treatment plan includes surveying infestations, and monitoring growth and reductions in infestations annually. Federal agencies such as the U.S. Fish and Wildlife Service and USDA (United States Department of Agriculture) advocate and implement integrated multiple control methods for controlling pests. The two agencies have labeled this practice as IPM (Integrated Pest Management). The agencies have adopted a four steps plant to follow when using multiple control methods to improve effectiveness and efficiency.

The first important step is to identify the invasive plant and understand its biology. C. thistle is fairly similar to all other thistle species, especially bull or musk thistle. The thistle species all have cuspate leaves, but there are general characteristics that separate C. thistle from the others. After

[66] J.D.Fridley, J.J. Stachowicz, S. Naeem, D.F. Sax, E.W. Seabloom, M.D. Smith, T.J. Stohlgren, D. Tilman, and B. Von Holle. *The Invasion Paradox: Reconciling Pattern and Process In Species Invasions*. Pg.14.

identifying the species, information about the plants "life cycle, behavior and factors for its development," can be distinguished.[67]

The second step to follow is to monitor the growth or magnitude of the infestation.[68] Surveying and monitoring infestations can be done two ways. One is by physically observing the site. By visiting the infestation site, eyeballing a hypothetical boundary of the infestation, and tracing it on an aerial map, land managers can get an idea for the size of the infestation they have to control. The other way to survey an infestation is to use handheld GPS technology. Depending on the size of the infestation, monitoring can be done by setting a point or by plotting a shape for the infestation with a GPS. Large infestations are efficiently monitored by setting a point at the center of the infestation. "Drawing or plotting a boundary can become a waste of time when walking around larger infestations."[69] Recording a large infestation's GPS point coordinates in a spreadsheet or logbook, allows for extra details and information to be recorded on the conditions of the infestation. Smaller infestations can be surveyed by plotting GPS points around an infestation, in essence creating a shape boxing in the infestation.

The third step is to develop a schedule of control methods.[70] Different methods of control are effective in controlling C. thistle at different times of the seasons. Using the information gathered in the first and second step, proper methods can be developed and implemented to determine the size and location of a C. thistle infestation.

The final step to be taken when integrating multiple control methods is to evaluate the effectiveness of the management techniques.[71] This step helps in understanding what goes right or wrong. Evaluations can be recorded and archived for future reference. Logging information of who, what, where, when, how, and how much, can help determining future techniques to be used.

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[67] National Pesticide Applicator Certification CORE Manual. Pg 11
[68] Ibid. Pg 11
[69] Schmidt, Tom. Interview. December 1, 2009.
[70] National Pesticide Applicator Certification CORE Manual. Pg 13
[71] National Pesticide Applicator Certification CORE Manual. Pg 14

Preliminary monitoring and evaluations of infestation sites can protect wildlife hot spots or nesting habitats by raising awareness of their existence. Being able to archive the successes and failures of past control methods allow landowners and managers to review and effectively make right decisions in creating an IPM in the future.

Conclusion

In comparison, single management techniques may get rid of the problem for one season, but risks re-establishment in the future. Even after infestations are treated by singular management techniques, the plants reoccurrence will fuel more time, money, and resources in order to control it year after year. Using the four step IPM provided by the National CORE Pesticide Manuel will effectively reduce infestations year after year and produce environmentally aware management techniques. Unlike single management techniques, IPM plays as a double edge sword. Multiple treatments can be safely applied to manage infestations. By implementing a well thought out and evidence supported control method schedule, the magnification and density of current infestations can be effectively reduced. Over the long haul, the costs for control, resources, and environmental damage will decrease because of the degree of focus and the science that the IPM offers.

Case Study- US Fish and Wildlife Service

The U.S. Fish and Wildlife Service mission is, "Through partnerships, prevent, eliminate, or significantly reduce populations of aquatic and terrestrial invasive species throughout the Refuge System in order to protect, restore, and enhance native fish and wildlife species and associated healthy ecosystems," as stated in the National strategy for Management of Invasive Species, 2003. Responsibilities that the USFWS hold are "manage migratory bird populations, restoring wildlife habitat," and, "conserve, protect, and enhance fish, wildlife, and plants.[72]"

[72] U.S. Fish and Wildlife Service. "Comprehensive Conservation Plan." Minnesota Valley NWR.

The Invasive Species Specialist at the Minnesota River Valley NWR, Chris Trosen, works to control invasive species listed in the state and federal invasive species list. The lands that he manages are Waterfowl Production Areas (WPAs). These lands are managed to provide, "high quality nesting, brood rearing habitat for migratory waterfowl." The WPA's are purchased parcels of land that, "include native and diverse prairie that is free from trees and having many seasonal temporary and permanent wetlands." Controlling invasive species, such as C. thistle, provides a healthy habitat for migratory waterfowl and an environment that benefits wildlife and native vegetation.

Managing over 600 acres of land, Chris Trosen receives help in the summer months from volunteer groups, interns, and seasonal employees. The first step in managing the several hundred acres of land is to send out survey crews to trace the infestations location on a GIS generated map of the WPA. Depending on the size and magnitude of the infestations, either a chemical pesticide will be applied to the infestation or a tractor equipped with triple flails will mow the infestation. "No single technique works alone." Using multiple management techniques must be done, "to achieve desirable management." After infestations on WPAs are treated, areas that were mowed, or treated by chemical pesticide, are plotted as data points in a program, Arcpad, to produce a visual map of infestations increase, decrease in magnitude, and success with management techniques. The maps created are then archived to, "determine if actions are working."

Endnote

Using integrated techniques is not a simple control method. The process of creating a IPM demands and involves systematically thinking, problem solving, and excellent recording skills. Results of using an IPM plan are very rewarding. For Chris Trosen of the U.S. Fish and Wildlife Service at the Minnesota River Valley NWR, reason for controlling with an IPM is the ability to make visitors of the refuge satisfied. Chris is able to keep the wild lands healthy by keeping them free of pollution and using innocuous management methods, such as IPM. Using an IPM is rewarding to the farmer not only

because of the bountiful yields that are produced out of his ranch, pastures, and agricultural fields; but, also because of his ability to pass on a healthy land ethic to generations ensuing him. Private landowners reward their offspring or later generations by passing on healthy native habitat without undermining the health and vitality of the environment and its inhabitants.

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+responsibilities+Minnesota+River+Valley&hl=en&gl=us&pid=bl&srcid=ADGEESgYJCj1nye349qmixQTlzVtMVACmIclSJ0HlS9y8czeS-1TpUN4 (accessed November 14, 2009).

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