APPENDIX

5B Invasive Species Control Information

Species included in Appendix 5B:

Hybrid cattail (Typha glauca) and Narrow-leaf cattail (Typha angustifolia)
Purple loosestrife (Lythrum salicaria)
Reed canary grass (Phalaris arundinacea)
Common buckthorn (Rhamnus cathartica)
Glossy buckthorn (Rhamnus frangula)
Common reed grass (Phragmites australis, syn. P. communis)
Canada thistle (Cirsium arvense)
Crown vetch (Coronilla varia)
Bird's foot trefoil (Lotus corniculatus)
Sweet clover (Melilotus officinalis and M. alba)
Wild parsnip (Pastinaca sativa L.)
Spotted knapweed (Centaurea maculosa)

Invasive species can be plants, animals, or other organisms such as insects or microbes. They spread mostly as the result of human actions and are often one of the most important management considerations throughout all aspects of a restoration project.

Invasive species should be considered for all phases of a project from site preparation to long-term management. This appendix is intended as a reference for how to control the most common invasive plant species associated with wetland restoration projects in Minnesota and the Upper Midwest. The section begins with species that can be found in emergent and lowland regions, then moves to species found in upland areas. Each species listed begins with an overview of the target plant and then lists recommendations for control strategies.

Recommendations and strategies are given in alternative scenarios: **Mechanical Control, Chemical Control, Prescribed Fire, and Biological Control**. Timelines for optimum control are noted, but consideration should be given to unique regional or micro-climatic conditions of the site as sprouting/blooming/dormancy times may differ according to region of the state. Management recommendations are provided as a guide, but it should be noted that there are often many ways to conduct invasive species control depending on specific site conditions. There is also many ways that management strategies can be combined to accomplish effective control.

For many species recommendations are given for low, medium and high quality sites. These rankings refer to the quaility of reconstructed plant communities but may also apply to native (remnant) plant communities in many cases. Consultation with experienced professionals should be sought before initiating work in remnant plant communities.

Listed below are the four control categories and their respective definitions (Mechanical, Chemical, Prescribed Fire, and Biological Control).

Mechanical Control: This control method includes both manual and mechanical methods. This includes: cutting, pulling, trimming, mowing, trampling/crushing, and flooding. Pulling can be done by hand or with a weed wrench. Cutting and trimming can be accomplished with hand clippers, saws, weed whippers, etc. Mechanical methods such as pulling or cutting with hand clippers, and saws and brush saws is typically used for small stands of invasives or for

areas of high quality where other methods such as chemical control are not recommended. Mowing is effective when stands are large or when it will help native vegetation outcompete invasives. Mowing is also conducted to promote new growth of invasive speices to increase the effectiveness of herbicide treatment. Flooding is often recommended as a tool to drown out homogeneous stands of wetland invasive species such as hybrid cattail, narrow-leaf cattial and common reed grass. Flooding is often used in combination with cutting to limit oxygen transport of plants and aid removal.

Chemical Control: Herbicides can be used as a stand alone method or used in combination with mechanical methods or prescribed fire. Common strategies include applying herbicide to foliage or flower heads with backpack sprayers or wick applicators. Alternative methods include applying herbicide to cut stumps or injecting the herbicide into tree cambium with hydro-axes or other equipment.

There are many considerations with the use of herbicides including not overspraying, knowing the limits of the herbicide, and knowing what other species can potentially be harmed (including wildlife species). Some herbicides target only specific species such as broad-leaf plants, legumes, or composites. Others are less selective and can kill any plant it comes into contact with. This guide is intended only as a reference for timing and control strategies. Researching your product, reading its label, and knowing the site conditions are all critical in effective chemical treatments.

Some herbicides like Glyphosate are widely available, but most herbicides are sold through licensed dealers, are more expensive, and require a certified person to perform the applications. If using a herbicide by water or saturated soils, the product must also be aquatically certified and some states (including Minnesota) require signage near the area of application to warn passers-by of the risk. Always wear proper clothing and gloves when handling herbicides.

The chart below shows the most common herbicides, their applications, and other valuable information.

Herbicide	Brand Names	Chemical Name	Aquatic Certification	Target Weed Species	Mode of Action	Aver age Soil Half-life	Common Use in Wetland Restoration
2,4 D	Aquakleen® Navigate®, Class®, Weed-Pro®, Justice®	(2,4-dichlorophe-noxy) acetic acid	aquatic certification for Aquakleen®, Navigate®, and DMA*4IVM®	broadleaf weeds	Auxin mimic	10 days	Removal of broad-leaf weeds near water. Effective on sweet clover and tansy. Also: Purple Loosestrife, Canada Thistle, Wild Parsnip
Aminopyralid	Milestone®	triisopropanolamine salt)		Broadleaf weeds	Auxin mimic	30 days	Treatment of Canada thistle in grass dominated stands
Clopyralid	Reclaim®, Curtail®, Transline® Stinger®	3,6-dichloro-2-pyridinecarboxylic acid		annual and perennial broadleaf weeds	Auxin mimic	40 days	Treatment of Canada thistle in grass dominated stands. Stump treatment of black locust. Also: Birds foot trefoil, Crown vetch, Spotted knapweed. Does not kill tree seedlings.
Fluazifop-p-Butyl	Fusilade DX®, Fusion®, Tornado®	(R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoic acid		annual and perennial grasses	Inhibits acetyl-CoA carboxylase prohibitng fatty acid synthesis	15 days	Treatment of reed canary grass amonst sedges and forbs
Fosamine	Krenite®	Ethyl hydrogen (aminocarbonyl) phosphonate		trees and bushes	Bud inhibitor	8 days	Foliar treatment of buckthorn in fall
Glyphosate	RoundUp®, Rodeo®, Accord®, AquaMaster®, AquaPro®	N-(phosphonomethyl) glycine	aquatic certification for Rodeo®,	annual and perennial weeds	Inhibits the shikimac acid pathway depleting aromatic amino acids	47 days	Simulataneous removal of grasses and forbs. Used for Cattails, Purple loosestrife, Reed canary grass, Reed cane grass, Buckthorn, Canada thistle, Birds foot trefoil, Crown vetch, Wild parsnip

Imazapic	Plateau®, Plateau Eco-Pak®, Cadre®	(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-methyl-3-pyridine-carboxylic acid		annual and perennial weeds	Inhibits AHAS synthesis, blocking amino acid synthesis	120-140 days	Treatment of spotted knapweed
Imazapyr	Habitat®, Chopper®, Arsenal®, Assault®	**(RS)-2-(4-Methyl-5-oxo-4-propan-2-yl-1H-imidazol-2-yl) pyridine-3-carboxylic acid**	**EPA Aquatic registration for** Habitat®	annual and perennial weeds	**blocking amino acid synthesis**	**25-141 days**	**Treatment of reed canary grass, cattails and non-native phragmites**
Sethoxydim	Poast®	2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one		annual and perennial grasses	Lipid synthesis inhibitor	5 days	Treatment of reed canary grass amonst sedges and forbs
Triclopyr	Garlon®, Garlon 3A® Remedy® , Renovate3®	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid	Only triclopyr-TEA formulation is aquatically Certified (namely Renovate3® And Garlon 3A). Specific label recommendations apply.	woody and annual broadleaf weeds	Auxin mimic	30 days	Stump and basal treatment of woody vegetation as foliar application of herbaceous vegetation

(Adapted from TNC 2001)

Prescribed Fire: Prescribed burns can be used in the control of many species. It can be used as a stand alone method or in combination with other control methods. In areas where fire was a historic part of the natural system, burns help to stimulate native seed germination, release nutrients back into the soil, and suppress non-native species such as many cool-season grasses. Fire can be useful even in cases where fire was not part of the natural system to remove the previous season's duff layer, eradicating homogeneous stands of vegetation, or to stimulate germination of the invasive species seedbank. Managing with prescribed fire should not be taken lightly. In determining if it is appropriate, consider the condition of the seedbank and existing vegetation, availability of experienced crews, cost effectiveness, and probability of success in controlling the desired species. Burning can be effective at controlling woody establishment in wet meadows but can sometimes promote reed canary grass and Canada thistle due to the release of nutrients and increased sunlight. For more information about prescribed burning see Appendix 6A-2 of the Minnesota Wetland Restoration Guide.

Biological Control: Biological controls include the use of animals, insects, or microbes for the management of invasive species. This can be in the form of grazing, introducing an insect that feeds or reproduces in the plant and does harm in the process, or through the release of pathogens to infect a plant. Since the invasive species is usually not native to the site in question, these biological controls are taken from the invasive species home-range and reintroduced into the new area. This of course presents an issue with the control agent also becoming a nuisance species. Much research is done when a potential control agent is considered to make sure that it has the potential to not only control the invasive population but also so that it does not become a hazard to native populations or nearby crops.

It is recommended that biocontrol agents are obtained through state or federal agencies . There should also be long-term monitoring and management of the biocontrol to ensure its safety and effectiveness in the release environment.

Hybrid & Narrow Leaf Cattail Control Strategies

Narrow-leaf (Typha angustifolia) cattail is believed to be native to the eastern United States and to have migrated along waterways into the Midwest. Broad-leaf cattail (Typha latifolia) is considered native to Minnesota and is part of more intact plant communities. It is believed that as narrow-leaf cattail entered habitats with broad-leaf cattail a hybrid variety developed (Typha x glauca), that has higher salt tolerance (similar to narrow-leaf cattail) and is tolerant of fluctuationg water levels, making it well suited to disturbed wetlands, and resulting in large monoculture stands in many urban as well as rural/agricultural wetlands.

Control of narrow-leaf and hybrid cattail can be complicated due the density and hydrology of stands. They often appear as monocultures, but all three types of cattail may be present *(Typha latifolia, T. angustifolia, and Typha x glauca)*. Since these stands are mixed, it is sometimes advised to control the spread and thin where hybrid and narrow-leaf cattails are in the highest density rather than totally eradicating all cattails. Cattails can be controlled in most restored wetlands, though DNR permits are needed for control in any public waters. A variety of methods can be used to control cattails including mechanical methods such as cutting or scraping, prescribed burning, chemical control, and conservaton grazing. Muskrats can also aid cattail control, particularly for new stands in restored wetlands, or stands that are regenerating after control efforts.

Mechanical Control – Small colonies in high quality habitats can be managed by hand or mechanical cutting of stems in winter (over ice), or in early spring, and allowing natural spring flood levels to submerge and suffocate the cuts. It is recommended to cut stems as low as possible, and to ensure that even dead stems that could transport oxygen are cut. Prolonged inundation is needed for sufficient control. If shoots or cuttings penetrate the water surface, they can still supply air to the root system and the plant will continue to grow. Ideally, cut stems should be inundated by about 3-feet of water after snowmelt, but lesser amounts can still achieve control if the water level is maintained through much of the growing season.

An alternative method of control that has been used for small areas (such as intact plant communities) involves mechanically cutting cattail stems below the water during the growing season. Pulling can also be used to control cattails but this is most effective when cattail are very young and root systems are not well developed.

Narrow-leaf and hybrid cattail can form as dense thatch layer that promotes their dominance over other species in wetlands. Methods to remove the thatch, as well as rhizomes through scraping and raking of the wetland surface have been successful in achieving control. In some cases this material can be moved into the base of ditches in wetlands that are being restored. These mehtods are most effective when rhizmes are removed along with the thatch layer.

Prescribed Fire – Burns for cattail control are most often conducted in winter, early spring or late summer during drought years when the thatch layer can be burned and the plants are effectively stressed. Burning in winter or early spring is often done following a drawdown and prior to increasing water levels that may aid control efforts. An advantage of spring burning is that new leaves are pulling up starch from the roots and the low starch reserves makes the plant vulnerable' to burning and flooding. The risk of peat fires should be assessed before burning cattail stands.

Conservation Grazing - Grazing by cattle can help control cattails in some cases, though a combination of grazing and trampling. The amount of time that cattail will spend in a cattail stand will vary depending on available water sources and availability of more desirable food sources. A grazing plan should be developed to guide grazing efforts.

Chemical Control – Herbicides are typically used for cattails only when other options are not available. Use of an aquatically certified glyphosate or Imazapyr herbicide is most common, and permits may be required. Wick, boom, or spray application of glyphosate to the foliage during the late summer/early fall have been effective. Annual or biennially repeated applications will likely be necessary. As with any non-selective herbicide, care must be taken not to spray non-target species.

Hybrid & Narrow-leaf Cattail Control Strategies		
Site Conditions	Recommended Strategy	Herbicide/Rate
Small colonies of newly etablished cattails	Mechanical – Hand pull seedling cattail. Mechanical - Flood above height of cattail stems if newly establishing native vegetation will not be damaged. Chemical - Spot spray young cattail	2-4% qts of aquatically certified glyphosate with label recommended surfactant or Imazapyr at label rates.
Small colonies of established cattails, adjustable water levels	Mechanical – Cut stems in late winter or spring. Raise water levels above cut stems for as much of the growing season as possible.	
Small colonies of established cattails (no-method to control water levels)	Mechanical - Scrape (or mechanically rake) cattail stands and remove scraped material. Prescribed Fire – Winter, spring or late summer burns when fuel is dry enough. Follow burn with raised water levels for entire season if possible. Chemical - Use of wick type applicator to treat stems.	2-4% qts of aquatically certified glyphosate with label recommended surfactant or Imazapyr at label rates.
Large colonies, adjustable water levels	Mechanical – Cut stems or burn in late winter or spring. Raise water levels above cut stems for as much of the growing season as possible. Chemical - Use of wick type applicator to treat stems.	2-4% qts of aquatically certified glyphosate with label recommended surfactant or Imazapyr at label rates.
Large colonies (no method to control water level)	Mechanical - Scrape (or mechanically rake) cattail stands and remove scraped material. Prescribed Fire – Winter, spring or late summer burns when fuel is dry enough. Follow burn with raised water levels for entire season if possible. Conservation Grazing - Conduct conservation grazing following a grazing plan in spring and summer to suppress cattail growth. Chemical - Use of wick type applicator to treat stems.	2-4% qts of aquatically certified glyphosate with label recommended surfactant or Imazapyr at label rates.
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology and other environmental conditions		

Sources

** Czarapata, Elizabeth J. Invasive Plants of the Upper Midwest: an illustrated guide to their identification and control University of Wisconsin Press, 2005.

**Invasive Plant Species page: Narrow leaf cattail fact page. Wisconsin Department of Natural Resources website. Accessed 2/10/08 http://dnr.wi.gov/invasives/fact/narrow_cattail.htm (updated 10/03/04).

Purple Loosestrife Control Strategies

Purple loosestrife *(Lythrum salicaria)*, a native to temperate regions of Europe and Asia, was brought to America in the early 1800s. However, it did not spread vigorously into wetlands until the 1930s. At that time it most likely cross-pollinated with the native winged loosestrife, creating an aggressive hybrid (Anderson 1993). Purple loosestrife is found in deep and shallow marshes, inland fresh meadows and shorelines of lakes and streams. The establishment of purple loosestrife is often initiated by disturbance from agricultural use, drainage, pasturing, siltation, or water level fluctuations (Eggers and Reed, 1997). It is a prolific seed producer (100,000 – 300,000 seeds annually per stem) and is not killed easily by burning or cutting. European beetles have been released to control growth, and have resulted in successful control in many cases.

Mechanical Control - Purple loosestrife can be controlled by hand if the population is sparse or if the site is relatively small. Larger sites usually mean that an enormous seed bank is well established and chemical or biological control methods will be necessary to control the population. Herbicides can be used to spot-treat smaller stands, but hand pulling is more selective and has less impact on surrounding desirable species.
Early detection is necessary for hand pulling to be successful. The best time is mid-late June, right when the flowers are beginning to form. This makes identification easier and also leaves a window open for chemical treatment if necessary. Garden forks work well for pulling out entire root systems. When pulling make sure that any remaining root stock is taken up after pulling the plant, as it can easily resprout from these remaining roots. If the plant has already gone to seed, then the heads need to be carefully bent over and then cut off into a plastic bag before pulling the remainder of the plant. Removed material can be brought to an authorized landfill, burned or composted on-site.

Chemical Control - Chemical control of purple loosestrife can be used when infestations are large and dense. There are many different herbicides on the market, but the most frequently used are glyphosate based products (Rodeo® or equivalent), aquatically labeled 2,4-D products (Navigate® or equivalent). While 2,4-D both have been successful in selective applications, aquatically certified glyphosate is most commonly used.

When choosing the chemical control method, consider the surrounding vegetation. If there is a lack of other vegetation within the stand, glyphosate is an option. Since glyphosate is a non-selective herbicide, extreme care should be used with its application. The plants that will establish after romoval of the Purple loosestrife could accidentally be damaged if too much is applied. The best time to apply glyphosate is when plants begin to flower, usually late June. Cut flower heads into bags and apply glyphosate at a 30% by volume solution to the raw cut areas of the pants. If detected early enough in the season, a second and third treatment every three weeks is recommended to control remaining plants that may have been missed during the first treatment. If cutting is not feasible, reduce the solution to 3% by volume of glyphosate and apply to foliage. Sites should be revisited about every 3 weeks during the flowering stage (late June to Early August). Both treatment options require annual visits with repeated applications until the population is under control.

Chemical Application Tips: For smaller stands that can be treated entirely during a single visit, application of the herbicide should start in the middle of the stand and should work outward to prevent walking through sprayed vegetation and moving seed about the site. Also, using a combination of a dye with herbicide will limit overspraying and aid in tracking which plants have been treated. When chemically treating infestations near or in water, the herbicides must be formulated for aquatic use and label recommendations must be followed. In Minnesota, if near open water, a sign must be posted "Loosestrife Control Site" in order to warn boaters, swimmers, and fishers of the potential risks. See Minnesota DNR for permitting and signage requirements.

Biological Control - Biological control for purple loosestrife has been effective in Minnesota. There are currently four insects that have been introduced with success. There are two leaf eating beetles Galerucella pusilla and G. calmariensis, which defoliate plants and limit overall production. The root-boring weevil Hylobius transversovittatus, lays its eggs in the root system and the hatchlings feed on root tissue and limit overall nutrient uptake. The flower-feeding weevil Nanophyes marmoratus limits seed production by eating the flower heads.

The MNDNR originally offered starter kits to rear insects for release into an infestation. Now that populations of insects have been successfully established in over 90% of introduction sites the DNR has transitioned from rearing new insects into a 'collect and move' program. This program requires the collection of insects from an established site and moving them to new infestations that need control.

While biological controls have proven effective with purple loosestrife it should be noted that populations of the plant will not be eradicated. What occurs is that the plant populations are controlled and their numbers are more representative of a diverse wetland rather than an invasive-dominated wetland.

For more information on biological controls of purple loosestrife and the 'collect and move' process, contact the Purple Loosestrife Coordinator at the Minnesota Department of Natural Resources.

Purple Loosestrife Mechanical Control - Before flowers go to seed	
Removal Schedule	Removal Method
Yr 1: Late June – early August (before flowers go to seed)	Young plants can be pulled by hand. Older plants should be removed by the root with a garden fork.
Yr 2: Late June – early August (before flowers go to seed)	Pull newly sprouted Purple Loosestrife
Yr 3: Late June – early August (before flowers go to seed)	Pull newly sprouted Purple Loosestrife
Following Years: Late June – early August (before flowers go to seed)	Pull newly sprouted Purple Loosestrife until no evidence of new infestations
**Note: Timing and recommendations will vary depending on site conditions.*	

Purple Loosestrife Mechanical Control - After flowers go to seed	
Removal Schedule	Removal Method
Yr 1: Early August and later (After petals begin to drop and seeds begin formation)	Remove flowers and seeds by cutting flower spike over a plastic bag. After removing heads, young plants can be pulled by hand and older plants can be removed by the root with a garden fork.
Yr 2: Late June – early August (before flowers go to seed)	Pull newly sprouted Purple Loosestrife
Yr 3: Late June – early August (before flowers go to seed)	Pull newly sprouted Purple Loosestrife
Following Years: Late June – early August (before flowers go to seed)	Removal of newly sprouted Purple Loosestrife until no evidence of new infestations
**Note: Timing and recommendations will vary depending on site conditions.*	

Purple Loosestrife Chemical Control - Large Stands		
Removal Schedule	Removal Method	Herbicide application
Yr 1: Late June – early August (before flowers go to seed)	Apply glyphosate judiciously to flower heads and foliage, glyphosate is most effective when flowers are present. Repeated visits every three weeks from late June to August and follow-up annually for repeated treatments until controlled.	Apply 1%-3% by volume solution of glyphosate
Yr 2: Late June – early August (before flowers go to seed)	Spot spray or pull newly sprouted Purple Loosestrife	Apply 1%-3% by volume solution of glyphosate
Yr 3: Late June – early August (before flowers go to seed)	Spot spray or pull newly sprouted Purple Loosestrife	Apply 1%-3% by volume solution of glyphosate
Following Years: Late June – early August (before flowers go to seed)	Spot spray or pull of newly sprouted Purple Loosestrife until no evidence of new infestations	Apply 1%-3% by volume solution of glyphosate
**Note: Timing and recommendations will vary depending on site conditions.*		

Purple Loosestrife Chemical Control - Small Stands, Selective Cut and Spray		
Removal Schedule	Removal Method	Herbicide application
Yr 1: Late June – early August (before flowers go to seed)	Cut flower heads into bags and remove from site. After cutting treat cut area with glyphosate. Visit monthly during flowering season.	Apply 30% by volume solution of glyphosate
Yr 2: Late June – early August (before flowers go to seed)	Spot spray foliage or pull newly sprouted Purple Loosestrife	Apply 30% by volume solution of glyphosate
Yr 3: Late June – early August (before flowers go to seed)	Spot spray or pull of newly sprouted Purple Loosestrife	Apply 30% by volume solution of glyphosate
Following Years: Late June – early August(before flowers go to seed)	Spot spray or pull of newly sprouted Purple Loosestrife until no evidence of new infestations	Apply 30% by volume solution of glyphosate
**Note: Timing and recommendations will vary depending on site conditions.* ***Note: Always follow instructions on herbicide labels.*		

Sources

**(MNDNR site is source for biocontrol)
**Stefeler, M., et al. 1996 Isosyme characterization of genetic diversity in Minnesota populations of purple loosestrife. American Journal of Botany 83:265-273
** Czarapata, Elizabeth J. 2005. Invasive Plants of the Upper Midwest: an illustrated guide to their identification and control. University of Wisconsin Press
**Eggers, S.D., 1992. Compensatory Wetland Mitigation: Some Problems and Suggestions for Corrective Measures. U.S. Army Corps of Engineers, St. Paul.
**Eggers, S.D., and Reed, D.M., 1997. "Wetland Plants and Plant Communities of Minnesota and Wisconsin. U.S. Army Corps of Engineers, St. Paul District, pp. 263.
**Anderson, N.O., and P.D. Ascher, 1993. "Male and Female Fertility of Loosestrife (Lythrum) Cultivars". J. Amer. Soc. Hort. Sci. 118, 6.

Reed Canary Grass Control Strategies

Reed canary grass *(Phalaris arundinacea)* is a species native to Minnesota, but it was crossed with non-native varieties and selectively bred for use as a forage and silage crop. Now the native and un-selected form of the species may not exist in Minnesota. Reed canary grass has been planted for many years in grass waterways, pastures and roadsides due to its ability to establish quickly and produce dense stands of vegetation. These traits cause the species to crowd out native vegetation, often forming monotypes. It also limits nesting and foraging opportunities for wildlife and its dense stands impede the movement of some species. It s stems are easily matted down in the winter, providing little wildlife cover (Henderson et al. 1999).

Dense stand of reed canary grass

Due to extensive root systems and prolific seed production, control of reed canary grass can be difficult. It is important that there will be a long-term committment to control for restoration sites with a dominance of reed canary grass. The weed seedbed must be controlled to the extent possible before seeding(Rhinehardt Adams, Galatowitsch 2008). A variety of techniques such as **digging, prescribed grazing, flooding, prescribed fire, haying, scraping, scarifying, herbicide application and tilling** are used for removing and managing reed canary grass. Please also see the managment recommendations from Wisconsin Department of Natural Resources at: http://dnr.wi.gov/topic/ForestManagement/documents/pub/FR-428.pdf

Cattle grazing reed canary grass in a restored wetland

Digging - Hand digging can be conducted can be conducted for small clumps but it is important to remove all of the rhizomes. This technique often requires reseeding afterward to compete with reed canary grass seedlings.

Prescribed Grazing - Cattle typically prefer reed canary grass to sedges and forbs in wet meadows, as a result, carefully timed grazing can set back the species, prevent seed production and in some cases decrease species abundance. Horses have also been effective at grazing reed canary grass and favoring sedges growth. Grazing plans are needed with grazing efforts to ensure that the activity will not harm desirable native vegetation or other natural resources.

Flooding - Reed canary grass can also be drowned out by raising water levels to 12-18 inches (above all grass leaves) for a growing season after mowing or grazing. However, the fringe zone must still be treated with herbicide or it will spread back into the basin once water levels are lowered. Plants can also be cut a few inches below the water surface to drown plants but this can be difficult with hand held equipment.

Prescribed Fire - Burning around the time that reed canary grass is flowering (with sufficient fueld) has been effective in setting back reed canary grass but not in achieving removal. Burning can be useful to remove the thatch layers and possibly reed canary grass seed prior to herbicide treatment. Reed canary grass seedlings and resprouts often grow quickly after burning, providing good conditions for additional herbicide application.

Haying - Haying can aid the control of reed canary grass by removing nitrogen from wetlands and decreasing the competative advantage of reed canary grass. It can also be a good method of removing above ground growth and the thatch layer to allow for regrowth before herbicide application and to promote the growth of other species.

Scraping - Scraping the top six to twelve inches of vegetation and soil from a site has also been successful for some projects. Scraping can get expensive on large sites unless there is a convenient place to place scraped soil (such as

private ditches). An analysis should be undertaken to ensure that there is six to twelve inches of expendable soil; this method works best in areas where sediment has accumulated. It is important to ensure that as many rhizomes as possible are removed and that rhizomes are not mixed with the remaining soil, allowing them to later germinate.

Scarification - Scarification of upper soil layers with power brushes and rakes to remove the thatch layer and stress reed canary grass plants has become more common. This technique is beneficial in intact communities (such as fens and bogs) where herbicide treatment may damage native vegetation establishing from seedbank or dormant vegetative parts. The removed thatch must be transported away from the site or piled in an area where it can decompose.

Herbicide Application - Aquatically certified glyphosate herbicides are commonly used as part of reed canary grass control efforts. When using these herbicides it is important to ensure thorough application to leaf surfaces (making sure that application equipment is traveling at an appropriate speed), Dyes are sometimes used when treating reed canary grass clumps to track where treatment has occured.

Grass specific herbicides are also used for removal of reed canary grass, particularly around native forbs and sedges that are not killed by these herbicides. Grass specific herbicides in common use include Quixolofop P-Ethyl (Assure II), Sethoxydim (Poast/Vantage) and Clethodim (Select). Grass specific herbicides are most effective when used in late spring or early summer. These chemicals work best on young plants but can also set-back or kill mature reed canary grass. They are not 100% effective in controlling grasses that have underground buds on their rhizomes. Research has shown that disking (with a disk that will not flip the soil) prior to herbicide application may be beneficial to control of mature reed canary grass (Annen, C. 2008). Repeated applications of grass specific herbicide (following mowing or grazing) over more than one season may be needed to eliminate mature stands. These herbicides take 4-6 weeks for symptoms to be visible. The advantage of using grass specific herbicide is that native sedges will survive. A limitation is that native grasses such as manna grasses and Canada blue-joint grass are susceptible along with the reed canary grass. It is important to note that grass specific herbicides are not aquatically certified so they cannot be used near open water or areas that may wash into open water. It is important to follow label recommendations when using grass specific herbicides.

The following information summarizes key considerations for their use (Annen, C. 2007):

- Check herbicide label for proper mixing order of adjuvants and herbicide.
- Agitation may be required to mix the herbicide thoroughly with its additives.
- Apply grass-specific herbicides when UV light levels are low (avoid spraying mid-day and on bright sunny days).
- Apply grass-specific herbicides when air temperatures are greater than 70 degrees.
- Apply grass-specific herbicides only to actively growing reed canary grass that is not under drought stress.
- When applying herbicides in hard water, add an acidifier or conditioning agent, (before herbicides are added).
- Add crop oil or surfactant-oil blend according to label recommendations.

Tilling - Plowing followed by tilling or repeated disking has been successful for removal of reed canary grass though disking may be needed through a full growing season or longer to achieve sufficient control. Growing Roundup Ready Corn in effectively drained areas has also been effective, though additional herbicide treatment may be needed before seeding to to fully remove weed seeds.

NOTE: Due to the difficulty in eradicating reed canary grass and the need to use a combination of control measures, the following sections are organized according to 'stand type' instead of 'control method'. Specific *schedules are included for some of the more complex removal scenarios. These schedules are included as guidelines to practitioners but should be adapted based on practitioner experience and site conditions.*

Control of monoculture stands with no seedbank

Monoculture without native seedbank: A variety of methods can be used for the managmeent of solid stands of reed canary grass. **Haying** can be used to prevent seeding if done in the spring and can be used to remove excess nitrogen and decrease the vigor of reed canary grass stands prior to further managment actions. **Scraping** to remove the zhizome mat can be effective if the right equipment is available, there is sufficient soil to remove from the site and a location for soil and rhizmome removal. If done well, scraping can leave a relatively clean seedbed for planting.

Reed Canary Grass Removal Schedule – For Monoculture Stands (No Native Seedbank) Scraping		
Treatment Timing	Treatment Approach	Other Considerations
Mid October - December	Remove surface material to the depth of reed canary grass rhizomes, ensuring that all rzhimes are removed.	Scraping can sometimes be conducted efficiently when the frost is approximately the same depth as the reed canary grass rhizomes, removing the soil in one layer.
Apring - June	Conduct herbicide application or other control of any reed canary grass that germinates the following spring.	
**Note: Timing and recommendations will vary depending on site conditions. It is essential that all reed canary grass seed be depleted to the extent possible before planting.*		

When **herbicide application** will be conducted it is common to crop areas with corn or soybeans if this treatment is appropriate for the site and the area is not too wet to allow the combination of tilling, and herbiciide application to aid control of reed canary grass..

If cropping cannot be conducted due to hydrology conditions or othe factors a common sequence invovles mowing in late summer followed by herbicide application with glyphosate or Imazypyr in the fall (between mid–September and October when herbicide most effectively removes rhizomes, followed by a prescribed fire in the fall or early spring to remove the thatch layer and weed seeds. The fall spraying and fall or early spring burning should be followed by spring herbicide treatment. Additional herbicide treatments or tilling may be used to remove seedlings. In some cases only additional herbicide treatment is conducted into the following year but the combination of tilling and herbicide application has been shown to increase effectiveness of removing rhizomes. It is important that the reed canary grass seedbank is depleted to the extent possible, so treatment may be needed through the entire season followed by late fall seeding or seeding the following spring. The following is a herbicide application scenario for reed canary grass removal in monoculture stands with no or very little native seedbank.

Reed Canary Grass Removal Schedule – For Monoculture Stands (No Native Seedbank) Combined Management Method		
Treatment Timing	Treatment Approach	Herbicide Application Rate
May 15-August 15	Mowing or haying of reed canary grass	
September 15-October 15	Conduct herbicide application (only aquatically certified herbicides if open water present)	Apply 3% concentration by volume of glyphosate or Imazypyr following label instructions
30 days after fall herbicide Treatment to March 15	Conduct a prescribed burn to remove thatch layer (two treatments if possible)	
April15 – May 15	Apply herbicide to seedlings	Apply 3% concentration by volume of glyphosate or Imazypyr following label instructions
May 15-May 30	Till or double disk to break up rhizomes	
May 30 - Until planting	Continue herbicide treatments or repeated tilling as needed	Apply 3% concentration by volume of glyphosate or Imazypyr following label instructions
Late fall or following spring	Broadcast seed and pack with a roller or cultipacker	
**Note: Timing and recommendations will vary depending on site conditions. It is essential that all reed canary grass seed be depleted to the extent possible before planting.*		

Monoculture with native seedbank

If there is a good chance that a native seebank is present at a site, scraping, scarification, or selective herbicide application are common strategies. Carefully managed prescribed grazing is also conducted in some caes. When **scraping** is conducted it is important that it is done at a depth that will remove rhizomes but not so deep that it removes additional soil containing native seedbank.

Reed Canary Grass Removal Schedule – For Monoculture Stands (No Native Seedbank) Scraping		
Treatment Timing	Treatment Approach	Other Considerations
Mid October - December	Remove surface material to the depth of reed canary grass rhizomes, ensuring that all rzhimes are removed.	Scraping can sometimes be conducted efficiently when the frost is approximately the same depth as the reed canary grass rhizomes, removing the soil in one layer.
Apring - June	Conduct herbicide application or other control of any reed canary grass that germinates the following spring.	
**Note: Timing and recommendations will vary depending on site conditions. It is essential that all reed canary grass seed be depleted to the extent possible before planting.*		

If the native seedbank is likely near the surface (not buried by sediment) then scarification, prescribed grazing or carefully planned herbicide application may be beneficial. With **scarification**, power brushes and rakes are used to remove the thatch layer and stress reed canary grass. Other control methods such as digging, spot herbicide application and grazing may be used in combination with scarification. **Prescribed grazing** may help increase native species dominance in sites dominated with reed canary grass by stressing plants, preventing the seeding of reed canary grass and removing excess nitrogen from the wetland. Grazing can also be used in combination with other techniques such as prescribed burning and spot herbicide application (timed when cattle will not be grazing).

If **herbicide application** will be used it is common to start treatment with glyphosate in the fall if only weeds are present, as glyphosate is a broad spectrum herbicide this treatment is commonly followed by prescribed burning and possibly tilling in the spring. Then grass specific herbicides can be used as native sedges and forbs establish (if the site is not domianted by cool-season native grasses) . The grass specific herbicide will not affect sedges, rushes or forbs, however, it will kill native wet meadow grasses. These herbicides do not have aquatic certification, so it cannot be used by open water. The best time to spray is early summer prior to flowering. It takes 4-6 weeks for control symptoms to become evident. Care should be taken to avoid contact with spraying of cool-season native grasses that are trying to establish. The following schedule summarizes the use of herbicides for monoculture stands with native seedbank present and no open water (allowing the use of grass specific herbicides).

Reed Canary Grass Removal Schedule – For Monoculture Stands (Native Seedbank present, no open water) Grass Specific Herbicide Method		
Treatment Timing	Treatment Approach	Herbicide Application Rate
Mid-September - MId-October	Conduct application of glyphosate herbicide if desirable native species are not present	Apply 3% concentration by volume of glyphosate
30 days after fall herbicide Treatment to Mid-March	Conduct a prescribed burn to remove thatch layer	
April - Mid-May	Tilling or double disking of soil	
Mid-May - Mid-July	Apply grass specific herbicide to reed canary grass seedlings if there is not too much risk to native grasses	Sethoxydim (VantageTM or PostTM)), Quizolofop P-Ethyl (Assure II) or Clethodim (Select). Apply per label instructions with surfactant
Mid-July - November	Monitor wetland for establishment of native vegetation and re-establishment of reed canary grass. If reed canary grass continues establishing amongst native sedges and forbs spray with grass specific herbicide as necessary to remove reed canary grass seedlings. Wetland grasses can be added after reed canary grass is fully controlled.	Sethoxydim (VantageTM or PostTM)), Quizolofop P-Ethyl (Assure II) or Clethodim (Select). Apply per label instructions with surfactant
Timing and recommendations will vary depending on site conditions. Native wetland grasses will be removed by grass specific herbicides so their presence should be assessed before application.		

Reed canary grass intermixed with native sedges and forbs, no open water

Where reed canary grass is growing amongst dicots (forbs) or other graminoids (sedges, bulrushes, and rushes) different options such as digging, scraping, scarification of the soil surface, prescribed grazing, and herbicide application are different options. **Digging** can be effective when reed canary grass clumps are small and all rhizomes can be removed. **Scraping** can be used for larger patches of reed canary grass if minimal disturbance will occur in other more intact parts of the wetland. Scraping can sometimes be effectively conducted in early winter when the upper layer of soil is frozen. **Scarification** and removal of thatch layers can be conducted as an alternative to scraping in larger reed canary grass patches. **Prescribed grazing** can be used if it is determined that the activity will not damage existing native vegetation (such as damaging hummocks/microtopography) and water resources, and a grazing plan is followed. Grazing may help increase native species dominance by stressing plants, preventing the seeding of reed canary grass and removing excess nitrogen from the wetland. Grazing should be carefully managed so that animals are removed after the reed canary grass is thoroughly grazed.

Reed Canary Grass Removal Schedule – For Reed Canary Grass Amongst Native Sedges and Forbs, No Open Water Prescribed Grazing		
Treatment Timing	Treatment Approach	Other Considerations
May-Early June	Allow intense grazing of reed canary grass when it is putting resources into flower development to stress plants.	Cattle should be removed when reed canary grass is grazed and cattle start to feed on native sedges and forbs.
April - September	Allow intense grazing of reed canary grass before it starts pulling resources into its rhizomes in fall to stress plants.	Cattle should be removed when reed canary grass is grazed and cattle start to feed on native sedges and forbs.
**Note: Timing and recommendations will vary depending on site conditions.*		

When **herbicide application** will be used for removal, clumps of reed canary grass can be sprayed with aquatic certified glyphosate. When no water is present and reed canary grass is intermixed, grass-specific herbicides can be used. There has been success with fall or spring burning, spring application of grass specific herbicide, mowing in later August or ealry September, and spraying grass specific herbicide in Mid-September to Late-October. This should be repeated for three years (see sequence below).

Reed Canary Grass Removal Schedule – For Reed Canary Grass Amongst Native Sedges and Forbs, No Open Water Grass Specific Herbicide Method		
Treatment Timing	Treatment Approach	Herbicide Application Rate
October - Mid-March	Conduct a prescribed burn to remove thatch layer	
Mid-May - Mid-June	Apply grass specific herbicide (Note in a relatively low quality wetland disking with a straight disk to cut up rhizomes prior to treatment may be beneficial but regulatory approval may be needed).	Sethoxydim (VantageTM or PostTM)), Quizolofop P-Ethyl (Assure II) or Clethodim (Select). Apply per label instructions with surfactant
Late-August - Mid-September	Flail mowing or haying	
Mid-September - Late October	If reed canary grass continues establishing amongst native sedges and forbs, spray with grass-specific herbicide as necessary to remove reed canary grass seedlings	Sethoxydim (VantageTM or PostTM)), Quizolofop P-Ethyl (Assure II) or Clethodim (Select). Apply per label instructions with surfactant
Mid-May - Mid-June **Year 2 and 3 as necessary**	Continue application of grass-specific herbicide if reed canary grass is present.	Sethoxydim (VantageTM or PostTM)), Quizolofop P-Ethyl (Assure II) or Clethodim (Select). Apply per label instructions with surfactant
Late-August - Mid-September **Year 2 and 3 as necessary**	Flail mowing or haying	
Mid-September - Late October **Year 2 and 3 as necessary**	If reed canary grass continues establishing amongst native sedges and forbs, spray with grass-specific herbicide as necessary to remove reed canary grass seedlings	Sethoxydim (VantageTM or PostTM)), Quizolofop P-Ethyl (Assure II) or Clethodim (Select). Apply per label instructions with surfactant
Note: Timing and recommendations will vary depending on site conditions. Follow label recommendations for herbicide additives and timing.		

Reed canary grass amongst native sedges and forbs, open water present

Where reed canary grass is growing amongst native sedges and open water is present cutting below the water level, or herbicide application can be used. **Cutting below the water level** will likely drown reed canary grass plants with prolonged inundation. This technique is difficult with hand held equpment so it is not commonly done.

If **herbicide application** will be used and water levels cannot be drawn down wicks with aquatically certified glyphosate, or backpack sprayer with aquatically certified glyphosate may be used. Grass-specific herbicides cannot be used in open water as they are not aquatically certified and can harm aquatic organisms. In some cases wicks are attached to the front of specially designed amphibius equipment with tracks that can used in open water. Late season applications of Rodeo herbicide after some native species have gone dormant can be effective, however some native species may also be eliminated. The reed canary grass should be treated while the majority of stems and leaves are still green. The following schedule summarizes the use of herbicides for patches of reed canary grass amonst native vegetation with open water present (requiring aquatically certified herbicide).

Reed Canary Grass Removal Schedule – For Patches Amongst Native Vegetation, With Open Water Glyphosate Herbicide Spot Treatment Option		
Treatment Timing	Treatment Approach	Herbicide Application Rate
Mid-October - Late October	Conduct spot treatment application after other vegetation is dormant (possible use of herbicide wands)	Apply 3% concentration by volume of aquatically certified glyphosate or Imazapyr following label instructions.
Year 2 Mid-June - Mid-July 15	Conduct spot treatment application after other vegetation is dormant (possible use of herbicide wands)	Apply 3% concentration by volume of aquatically certified glyphosate or Imazapyr following label instructions.
Year 2 Mid-October - Late October	Conduct spot treatment application after other vegetation is dormant (possible use of herbicide wands)	Apply 3% concentration by volume of aquatically certified glyphosate or Imazapyr following label instructions.
Year 3 Mid-June - Mid-July	Conduct spot treatment application after other vegetation is dormant (possible use of herbicide wands)	Apply 3% concentration by volume of aquatically certified glyphosate or Imazapyr following label instructions.
Year 3 Mid-October - Late October	Conduct spot treatment application after other vegetation is dormant (possible use of herbicide wands)	Apply 3% concentration by volume of aquatically certified glyphosate or Imazapyr following label instructions.
**Note: Timing and recommendations will vary depending on site conditions.*		

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Common and Glossy Buckthorn Control Strategies

Both common (Rhamnus cathartica) and glossy buckthorn *(Rhamnus frangula)* were brought to the United States from Eurasia for use as ornamental shrubs. Both species can form dense stands that create significant shade, subsequently inhibiting the growth of ground layer plants. Buckthorn species can handle a variety of moisture conditions and as a result are found in a variety of wetland as well as upland communities. Like purple loosestrife and reed canary grass, buckthorn species can be difficult to control. Management for buckthorn should be approached with the understanding that only in rare instances will a one-time treatment of the invasive produce the desired long-term result. Developing (and sticking with) an integrated and adaptive approach using multiple tools (cut/treat, fire, grazing/browsing, supplemental seeding, herbicide application, biocontrol-if available, etc.) is critical for success. . I generally discourage soil disturbance. Removing thick stands of buckthorn creates a vacuum that can be readily recolonized by buckthorn or other weeds. Soil disturbance (i.e. by using a weed wrench or similar) also has the potential to also damage desirable native plants (further increasing the likelihood that undesirable plants will recolonize). Unless the site is exceptionally native species-poor AND supplemental native seeding will be conducted, soil disturbance should be avoided.(Paul Bockenstedt, Stantec)

Mechanical Control – Controlling buckthorn mechanically (pulling, girdling, and mowing) is good for small populations, smaller trees, or in conjunction with chemical methods. The best time for mechanical control is either before trees show fruit or late fall after most fruit has fallen. In late fall, buckthorn is easy to identify as it is often the last green tree in the forest late fall. Also, most other plants are dormant by late fall, which makes chemical control methods a bit safer for surrounding vegetation.

For small shrubs, pull by hand or with a weed wrench, making sure all roots are taken up. Be sure that fruits are not tracked around the site when hauling out debris. Pulling usually requires spot checks annually, since new sprouts from the existing seed bank will shoot up the following years. After pulling, tamp the ground down by foot. Disturbed soil can also be covered with leaves to prevent light penetration for remaining seeds.

With girdling, make 2 horizontal, parallel cuts lower on the stem, 4-5 inches apart, cutting through bark slightly deeper than the cambium. Then strip away bark and remove the phloem but not xylem. This is effective but slower since the tree essentially is being starved. Follow up visits will be necessary to ensure bark has not grown back over the cut or that new suckers have not sprouted from the roots.

Repeated mowing with bursh hogs, lawn mowers, or brush saws have been effective for control, particularly for seedling buckthron. Repeated mowing every few weeks in the growing season will provide the most effective treatment.

Chemical Control – Used in conjunction with cutting, chemical control is currently the most common method of controlling buckthorn. The standard stump-and-treat method involves cutting the stem low to the ground and treating with herbicide. After stumps are cut, they can immediately be treated with Garlon. Other products can be used; these include Trimec (a formulation of 2,4-D, MCCP and Dicamba) or Glyphosate herbicide to prevent resprouting. Glyphosate is a non-specific herbicide and kills all photosynthetically active vegetation. On the Glyphosate label it recommends a rate of 50-100% for cut-stump treatment, but a 50% solution has proven effective. In wetland regions, Rodeo (a glyphosate formulation approved for wetland use) can be used for cut-stump treatment. Rodeo is a non-specific herbicide and is effective when diluted to 50%. Like pulling and cutting buckthorn, autumn is the best time to cut and stump-treat buckthorn since other plants are dormant at this time and harm to non-target species can be minimized. Cutting can be accomplished with chainsaws, brush saws, and in some cases brush-hogs if conducted in the winter. The use of brush-hogs will increase the amount of herbicide needed to treat stumps.

An additional method to control seedlings is to use Krenite. Krenite is a bud inhibitor which keeps foliage from ap-

pearing and essentially starves the plant of its lifeline, photosynthesis. Keep in mind that this is an application for even-aged seedlings, about knee-high. Timing is critical not only in the site preparation, but also in the application of Krenite to the foliage. Cut back all buckthorn on the site in early summer to allow time for about two feet of regrowth to occur over the growing season. Wait until between September 15th and October 15th (when all other plants begin to go dormant) before applying Krenite to foliage. During this time, apply to all leaves on each plant and try to spot treat in order to minimize overspray unless there is a carpet of seedlings. The key is getting all of the foliage so buds in the following season don't develop fully. Foliage will appear where there are remaining untreated buds and the plant will likely survive the next season. Aside from precision of application, the mixture and other external factors need to be controlled carefully as well. Mix 3-4% Krenite with water. Mixes can go as high as 7% in the absence of sedges. Make sure that the water for mixing is 'soft' water (WaterSoft can be added per manufacturer instructions). It is also advised to use a surfactant to keep the agent on the foliage as long as possible, and a colored dye for keeping track of which leaves have been sprayed already. Finally, temperatures should be below 55° F and above 32° F for at least three days following the application. Always avoid spraying if rain is in the forecast.

Seedlings can be treated by foliar sprays with Glyphosate during the growing season. Because non-target species will also be sprayed, foliar application is restricted to solid stands of seedlings.

Another alternative to increase efficiency in the removal of medium sized buckthorn is to apply Garlon 4 directly to the lower 10-inches of bark during the dormant season. This eliminates the need for cutting, increasing efficiency, but it also has shown to kill other non-target species. Further testing needs to be done to determine whether it is the Garlon 4 or the Diluent Blue carrier that kills the other species. Either way, 10-20% mixes can be used for trees smaller than 3" and a 40% mix can be used for larger trees. A roller or paintbrush can also be used to apply the herbicide. The lower 10-inches of the stem is sprayed or painted around the stem. This technique is effective on stems up to 6-inches in diameter. This technique is also effective on Tartarian honeysuckle.

Similar to basal treatment, another treatment methods involves the use of hatchets or machetes that are designed to inject herbicide into cuts in the trunk of buckthorn. These types of equipment can increase efficiency in treating large buckthorn and may decrease the amount of herbicide used.

Prescribed Fire – Burning is very effective but only advised for areas that already exist with a regular fire regime or where otherwise feasible. Hot burns are most effective; burns need to be regular (every 1-2 years) to achieve elimination of buckthorn in 5-7 years. Fire should not be used if other vegetation will be adversely affected by a hot burn. Native seed banks could be damaged severely with intense burns, so take into account which species are targeted for succession, post-burn. Dry oak forests are an example where fire was a historic component, however, maple-basswood forest was not a fire-dependent community. Fire tends to be most effective on seedling buckthorn. If fuel load is insufficient, or if the community is not fire adapted, seedlings can be spot burned with a portable propane torch.

In areas where fire is to be used as part of an integrated management approach on buckthorn, fine fuels (i.e. grasses, and to some degree sedges) are key. If the pre-existing ground layer lacks fine fuels, supplemental seeding with native grasses such as bottlebrush grass, silky wildrye, Virginia wildrye and others is important. Along with oak leaf litter, fine fuels are critical to enable burning with appropriate frequency and intensity to keep ahead of buckthorn (Paul Bockenstedt 2012).

In high level infestations, prescribed burning, as frequent as leaf litter accumulation will allow has been an effective method as long as the buckthorn regeneration is smaller than ¼". To keep it small critical period cuts can be done in July when the plant has spent all the energy for the year. Brush saws can be used to cut the buckthorn, forcing it to re-sprout and expend more energy on growth (instead of sending energy to root stores. In the spring all of the new shoots are vulnerable to fire. With this method woodland herbs to bounce back dramatically and the native shrub diversity and abundance gains strength as well (Gina Hugo 2012).

Biological control – No effective biocontrol exists at the moment, but many options are in the research and development phases (Bockenstedt 2012).

Common and Glossy Buckthorn Control Strategies		
Site Conditions	Recommended Strategy	Herbicide/Rate
High quality site, scattered mature	Mechanical – before trees show fruit or late fall after most fruit has fallen - pull smaller trees with a weed wrench, making sure roots are taken up as well. Larger trees can be girdled, 2 parallel cuts, 5 inches apart, stripping away bark and phloem but not xylem. Prescribed fire can be used to control seedlings.	
High quality site, seedling dominant	Prescribed fire – late fall or early spring burn in fire adapted community can control seedlings. If prescribed burn is not an option (insufficient fuel load or non-fire adapted) then use a portable propane torch, hand pull, or repeated mowing to kill seedlings.	
Medium quality site, dense mature	Mechanical - Use a thrasher/chipper in winter or brush saws in July followed by prescribed burning in spring if sufficient fuel and fire dependent community. Chemical – Cut and treat stumps	-Glyphosate at 50%-100% concentration, 50% has proven effective Garlon 3A-diluted equal parts with water.
Medium to low quality site, seedling dominant	Prescribed fire – late fall or early spring burn in fire adapted community can control seedlings. If prescribed burn is not an option (insufficient fuel load or non-fire adapted) then use a portable propane torch, hand pull, or repeated mowing to kill seedlings. Chemical – Application of Krenite. Early season cut back all buckthorn near ground level. When regrowth is knee-high in mid-Sept to mid-Oct, spot-spray Krenite on ALL foliage with surfactant and colored dye.	- Krenite at 3-7% solution in soft water. Apply with surfactant and colored dye
Low quality site, dense mature stands or scattered mature stands	Mechanical - Use a thrasher/chipper in winter or brush saws in July followed by prescribed burning in spring if sufficient fuel and fire dependent community. Chemical – Application of Garlon 3A to basal area of cut stumps (within a few hours of the cut). Can be applied anytime, but in dormant season injury to other plants can be minimized.	Garlon 3A – diluted equal parts with water.
Low to very low quality site, dense to scattered mature stands	Mechanical - Use a thrasher/chipper in winter or brush saws in July followed by prescribed burning in spring if sufficient fuel and fire dependent community. Chemical – Application of Garlon 4 with Diluent Blue carrier. Apply during dormant season through winter to lower 10" of bark at 20-40% dilution depending on size of trees. Use only in Low quality habitats; or use of hatchets designed to inject herbicide.	Garlon 4 at 20-40% concentration with Diluent Blue carrier.
Low quality site, seedling dominant	Mechanical or Prescribed Fire – Late fall or early spring burn in fire adapted community can control seedlings. If prescribed burn is not an option (insufficient fuel load or non-fire adapted) then use a portable propane torch to kill seedlings or hand pull seedlings when soil is moist	
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology and other environmental conditions		

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Common Reed Grass Control Strategies

Common reed grass *(Pragmites australis, syn. P. communis)* is a tall perennial grass that inhabits wetlands around much of the world. There are native and non-native varieties, the non-native varieties are invasive and displace native plant species. These strains require close field inspection to identify before considering methods of eradication. Control of the invasive reed grass is difficult due to deep rhizomes and the large size of the plant (anywhere from 3-20 feet high). A helpful website for identification is **www.invasiveplants.net**.

Mechanical Control – Cutting and mowing alone are ineffective. These methods are best used in combination with flooding or herbicide treatments. Digging of the roots and rhizome is difficult since the rhizomes can fragment easily and resprout. Disposal of rhizomatic soil is also difficult. In areas where water levels can be sustained at a high level for the entire growing season an effective method is to cut the grass below the waterline (all standing and dead stems to prevent oxygen transport), and then increase water levels for a full growing season if possible. It may be ncessary to cut any resprouts that reach above the water level. Cutting is sometimes done once in the witner if water levles will rise above the cut stems in the spring. As root systems are interconnected, any plants growing out of the water will need to be treated with herbicide. Damage to native species should be considered before using flooding as a control method.

Chemical Control – When present in standing water, permits for chemical control will be required from the Department of Natural Resources. Use of aquatically-approved herbicides will be necessary.

For dense monocultures, an application of aquatically certified glyphosate or Imazapyr is applied to the upper foliage during flowering to early fall. Imazapyr tends to be effective in the summer and fall while glyphosate is most effecive in the fall. A backpack sprayer, appropriate dye and surfactant, and a 5-foot wand extension should be used. Mowing or a spring burn of the treated area will remove the dead plants and a follow up treatment in early June to the resprouts should result in a very high percentage of success. Visits in the following years may be necessary to ensure long-term control of stands. If the stand has intermixed native species cut stems and apply concentrated herbicide on the cut stems. Wick applicators can also be used to selectively treat the phragmites. Some efforts have bundled phragmites stems together to aid herbicide treatment while minimizing contact with non-target species.

Reed Grass Control Strategies		
Site Conditions	Recommended Strategy	Herbicide/Rate
Dense stands, monoculture (no flooding possible)	Conduct herbicide application via sprayer, dye, and 5' wand in early fall to upper plant. Mow in fall, winter or early spring or conduct a spring burn, repeat application of herbicide to resprouts in early June. Repeat following years as necessary.	Apply 1.5% solution by volume of glyphosate or Imazapyr at label rates
Dense stands, monoculture (flooding possible)	Conduct mowing late fall when water levels are drawn down making sure to cut all stems to prevent oxygen transport after flooding. Use water control structures to inundate cut stems for an entire growing seaosn is possible.	
Dense stands, intermixed natives	Wick application of glyphosate in early fall. Mow or conduct spring burn, repeat application of glyphosate to resprouts in early June. Repeat following years as necessary.	Apply 1.5% solution by volume of glyphosate or Imazapyr at label rates
Small stands	Hand cut stems near ground in July or August and drip glyphosate directly into cut stem. Drip treatment best if immediately following cutting.	Apply 25% - 50% solution by volume of glyphosate or Imazapyr at label rates.
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology and other environmental conditions		

Sources:

**Czarapata, Elizabeth J., 2005. "Invasive Plants of the Upper Midwest: an Illustrated Guide to their Identification and Control" University of Wisconsin Press

Canada Thistle Control Strategies

Canada thistle *(Cirsium arvense)* thrives in sunny, disturbed areas where it can invade upland habitats such as prairies and savannas and wetland habitats including sedge meadows and wet prairies. Seeds are dispersed by wind and can remain viable in the soil up to 20 years. Once established, the plants spread rapidly by rhizomes or root segments. Mechanical and chemical control strategies are often used in combination for Canada thistle. Conducting late spring burns is beneficial during the first three years of the control effort. Canada thistle can be treated with Clopyralid and Aminopyralid herbicide in mid-June prior to flowering.

Canada thistle is a perennial, while plumeless and bull thistles are biennials. The biennial thistles can also be treated with Transline, Stinger or Milestone or they can be cut or clipped. These biennials normally produce only rosettes (no flowering) the first year and then flower the second year. Clipping buds just as flowers begin to open the second year should prevent them from going to seed. Over time biennials will be out-competed by upland grassland species. Unless patches are very large, it is recommended that herbicide be applied selectively with back-pack sprayers, because broad leaf herbicides affect composites and legumes, both of which are components of upland prairie and woodland edge plantings.

Mechanical Control – Hand pulling or cutting only work well if done frequently during the summer months . It is best if cutting/pulling occurs at least three times in the summer; once in June, once in August, and again in September. Due to persistence of seed bank in heavily populated areas, pulling or cutting alone may not be entirely effective. Chemical measures or burning may be required during subsequent springs, depending on quality of habitat and site conditions. Another alternative, in sites that are larger and fairly disturbed, is to mow as close to the ground as possible while the plant is in full bloom (June through late August). Mowing should be done at least once a year and will have to be repeated for several years thereafter. Some evidence has shown that mowing alone may be effective for setting back plants depending on soils, nutrients, moisture levels, and climate conditions.
Chemical Control – Chemical controls are not recommended in high quality habitats as the herbicide causes damage to native plants. Aminopyralid herbicides are often used in reconstructed prairies as they cause less damage to native forbs. In high quality reconstructed sites that have a substantial infestation, careful wick or spot spray application of Aminopyralid may be conducted. Chemical control is often conducted in restored sites in combination with mowing. See the discussion of "Combination Methods" below for specific recommendations.

Prescribed Burns – Fire is best when used in late spring (early May to early June). If the burn is done too early it may actually promote growth of Canada thistle. Burns should be once a year for at least three years to see significant reductions in dense populations. The impact on other species should be assessed for spring burns that will be conducted during subsequent years.

Combination of Methods – Whenever possible, spot treatment of thistle is recommended to minimize impact on native forbs. In situations where thistle covers large areas or where thistle is amongst solid grass stands, a combination of mowing and herbicide application can be used. Mowing is conducted in early June when thistle is in the bud stage. Mowing at this time of year will reduce the plants energy reserves. Herbicide treatment is conducted in the fall after the first or second hard frost, commonly with Aminopyralid (Milestone) herbicide at a rate of 5-7 oz. per acre. Waiting until after the fist or second hard frost (preferrable the second frost if it leaves time for treatment) allows some native species to go dormant minimizing impact to native forbs to some extent and ensuring that the herbicide is effectively taken into the root. This technique should not be conducted until after the second year of establishment. It can be helpful to conduct a fall burn a couple of weeks after the herbicide application followed by inter-seeding with native forbs. Having native grasses and fast growing forbs in the mix will help to out-compete any returning thistle the following spring. Additional treatments may be needed in subsequent years.

Canada Thistle Control Strategies		
Site Conditions	Recommended Strategy	Herbicide/Rate
Low Diversity	Mechanical - Hand pulling or cutting frequently during summer months to weaken/starve roots. Once in June, August, and September.	
Moderate to High	Mechanical - Mow patches each year in early June. Prescribed Fire - Late-spring prescribed burns during first three years of control – Do not conduct early spring burns as it will promote sprouting and reproduction. Combination of Methods - Combination of mowing and herbicide. Mowing in mid-late June. Apply Clopyralid or Aminopyralid (Milestone) mide to late fall.	Aminopyralid @ 5-7 oz/acre diluted with 20 gallons of water or Clopyralid per label instructions
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology, and other environmental conditions		

Sources:

**Czarapata, Elizabeth J. "Invasive Plants of the Upper Midwest: an illustrated guide to their identification and control" University of Wisconsin Press, 2005

**Invasive Plant Species page: Canada Thistle. Wisconsin Department of Natural Resources website. Accessed 2/10/08 http://dnr.wi.gov/invasives/fact/canada_thistle.htm updated 10/3/04

**Minnesota invasive non-native terrestrial plants: an identification guide for resource managers. Published by MNDNR 2002, Trails and Waterways Division

*** Habitat Forever, LLC (2008) "Canada Thistle Control" Internal document outlining approach to thistle control.

*** Natural Resources Conservation Service (NRCS) (2007). "Pest Management – Invasive Plant Control: Canada Thistle (Cirsium arvense)" Conservation practice job sheet MN-797

Crown Vetch and Bird's-Foot Trefoil Control Strategies

Crown vetch *(Coronilla varia)* was initially introduced as an erosion control plant for road sides and waterways. It is still being sold as a green fertilizer crop and easily moves into adjacent areas that have been disturbed. Crown vetch can be found in disturbed prairie remnants, woodland edges, and other disturbed edges of roads and waterways. Plant spreads vigorously by rhizome and seed.

Bird's-foot trefoil *(Lotus corniculatus)* is very similar to Crown vetch in that it was used for erosion control. It, too, invades disturbed sites and edges through seed and root systems, but can also spread by above-ground runners. Bird's-foot trefoil is also tolerant of a wider range of soils and precipitation conditions.

The below control methods apply to both Crown vetch and bird's-foot trefoil.

Mechanical Control – Smaller populations can be controlled by repeated hand pulling in sandy or moist soils. Larger patches can be controlled by mowing. Mowing can be done in late spring for several successive years. Alternatively, mowing can be done once in June and once again in late August. This schedule is timed with leafing periods and helps to deplete energy stores. This technique should also be done for several years until population is controlled.

Prescribed Fire – Prescribed fire can be used as a stand alone control measure in communities where fire is regularly tolerated. Spring burns for successive years have proven effective. Also, fire used in conjunction with chemical treatments can be used. See 'Chemical Control' portion of the 'Crown Vetch Control Strategies' section for details.

Chemical Control – Can be used as a stand-alone method or more effectively in conjunction with prescribed fire or spring mows. Spring burns or mowing can be helpful in clearing previous year's foliage to aid in identification and ease of chemical applications. In dense, heavily degraded stands, an application of clopyralid can be used and is more selective than the alternative, triclopyr. In higher quality habitats or less heavily invaded stands, spot treat with Amino pyralid (per label instructions). Triclopyr or glyphosate can both be used at 2% by volume concentration and applied to foliage in early spring.

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Crown Vetch Control Strategies		
Site Conditions	Recommended Strategy	Herbicide/Rate
Sparse population – High and medium quality reconstructed prairies	Mechanical – Pulling by hand, repeated visits over successive years.	
Sparse population – Medium to low quality reconstructed prairies	Mechanical – Pulling by hand, repeated visits over successive years. Mechanical – Mowing late spring - OR – Mowing once June and again late August (corresponding with leafing out periods). Both methods done for successive years until population under control. Chemical – Spot treat with glyphosate, or Aminopyralid, early spring for successive years. Glyphosate and triclopyr are non-selective, so limit use to homogeneous groupings and watch for non-target species. Clopyralid affects only sunflower and pea family members.	 Glyphosate or triclopyr, both apply at 2% by volume dilutions. Aminopyralid @ 7 oz/acre diluted with 20 gallons of water or Clopyralid per label instructions
Dense population – Low quality reconstructed prairies	Mechanical – Mowing late spring - OR – Mowing once June and again late August (corresponding with leafing out periods). Both methods done for successive years until population under control. Mechanical + Chemical – Mowing late spring. Spot treat when new growth appears with Aminopyralid, or glyphosate. Done for successive years until population under control.	 Glyphosate or Aminopyralid according to label rates.
Dense population – High quality reconstructed prairiesprairies	Mechanical – Mowing late spring - OR – Mowing once June and again late August (corresponding with leafing out periods). Both methods done for successive years until population under control. Mechanical + Chemical – Mow late spring if feasible, then spot treat with Aminopyralid when new growth appears. If mowing not feasible, spot treat only using clopyralid with wick or spray applicator in late spring. Done for successive years until population under control. Prescribed Fire + Chemical – Late spring burn in fire tolerant habitat, followed by spot application of clopyralid when new growth appears. Done for successive years until population under control.	 Aminopyralid @ 7 oz/acre diluted with 20 gallons of water or Clopyralid per label instructions Aminopyralid @ 7 oz/acre diluted with 20 gallons of water or Clopyralid per label instructions
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology and other environmental conditions		

Sources:

Minnesota Department of Natural Resources. 2002. Minnesota invasive non-native terrestrial plants: an identification guide for resource managers. MDNR Trails and Waterways Division.

**Czarapata, Elizabeth J. 2005. Invasive Plants of the Upper Midwest: an illustrated guide to their identification and control University of Wisconsin Press.

http://www.inhs.uiuc.edu/chf/outreach/VMG/wysclover.html has detailed info on sweet clover and trailing crown vetch (Coronilla varia L.).

Sweet Clover Control Strategies

Sweet clover *(Yellow: Melilotus officinalis and White: Melilonus alba*) is a biennial legume. It was introduced in the 1600's as a forage plant and for honey production. It has many commercial uses in medicine, rodenticides, bioremediation, and wildlife cover. Since it is widely sold on the commercial market, the best approach for control is prevention. Sweet clover invades open sites that are moderately disturbed. It can inhabit prairies, savannas, and dunes. It is a biennial producing seed during its second year of growth.

Mechanical Control – For small infestations, pull first year plants by hand in late fall after root crown buds have developed. Second year plants can be pulled in May and June, before flowering. Remove pulled plants from area after cutting to reduce spread of viable seed. In heavier stands with little native vegetation, a power brush cutter with a heavy duty saw blade can be used. Revisit site in the following weeks to check for missed plants.

Chemical Control – Use of herbicides is typically not necessary for control of Sweet clover. The best control methods are prescribed fire or mechanical methods.

Prescribed Fire – For larger infestations, fire is effective if done for successive years. The First year burn should be before green-up of plants, to stimulate seed germination. In late summer, check for new plants that have germinated. If new plants are present, return for a low intensity burn in the following spring, when the plants are 6-10 inches high. If flower buds have not developed some resprouting may occur. To eliminate resprouts after this burn, and also for eliminating small patches in general, use a propane torch after a rain event. The plant doesn't need to be totally burned, as moderately damaged plants will wither quickly. Spot burns after a rain are recommended so that other species do not catch fire during treatment. This treatment will have to be repeated as necessary to maintain control of the population.

Sweet Clover Control Strategies	
Site Conditions	Recommended Strategy
Small Infestations	Mechanical - Pull in late fall after root crown buds have developed.
Large to medium Infestations	Mechanical - Mow second year plants in May or June before flowering, mowing may be needed during successive years. Prescribed Fire - Conduct prescribed burns successive years with first burn before green-up to stimilate germination and second burn in spring when plants are 6-10 inches tall.
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology and other environmental conditions	

Sources:

Czarapata, Elizabeth J. 2005. Invasive Plants of the Upper Midwest: an illustrated guide to their identification and control, University of Wisconsin Press.

Wild Parsnip Control Strategies

Wild Parsnip *(Pastinaca sativa L.)* is a plant that is poisonous to humans and other plants (Photo-phyto toxic). When oils or sap from the plant come into contact with skin and exposed to ultraviolet light, boils and blisters will result which then form into a painful rash. Always wear protective clothing and make sure to change closth indoors to limit UV exposure and reaction times. Control efforts such as hand pulling should occur during evening hours when the sun is low.

Mechanical Control – Invasions need to be controlled early, right as blooms become evident to prevent plants from going to seed. Since wild parsnip does not bloom all at the same time, periodic visits to the site during the bloom stage are necessary. If the population is sparse, plants can be removed by cutting or pulling. To remove by cutting use a spade and cut the root 1-2 inches below soil and remove the plant. Cutting at the ground surface can also be done but resprouting may occur. Pulling after a spring burn can be effective as wild parsnip is one of the first plants to green up after a burn and is easy to identify. If invasions are dense mow when flowering begins and repeat mowing as needed.

Chemical Control - Both spot and broadcast herbicide treatments are used for wild parsnip depending on the site conditions. Timing is an important consideraton for control. In high quality reconstructed sites late season control minimizes damage to other plants that are going dormant by this time. Treatment is effective on basal rosettes March-May or August-October using a solution of 2,4-D (mix per label instructions), glyphosate (2% by volume) or Metsulfuron methyl (according to lable rates). Annual follow up visits will be necessary until the seedbank is depleted.

Wild Parsnip Control Strategies		
Site Conditions	Recommended Strategy	Herbicide/Rate
Sparse Population	Mechanical - Cut at root or hand pull before flowers go to seed (late June to early August).	
Medium to Dense Population	Mechanical - Mow mid summer when flowers are starting to form. Mow again every few weeks. Native vegetation will likely outcompete.	
	Chemical - If burning is part of the habitat regime, spot treat after a burn with glyphosate (Usually first plants to green after a burn).	Glyphosate 2% solution by volume
	Metsulfuron methyl, 2,4-D, or glyphosate application to basal rosettes in late spring, before flower stalk elongates or in fall after other plants are dormant. May need to repeat each spring for several years until seed bank is diminished.	Glyphosate 2% solution by volume 2,4-D or Metsulfuron methyl according to label rates
Note: Effectiveness of strategies may vary depending on season, weather, soils, hydrology and other environmental conditions		

Sources:

Eagan, David J., 2000. "Wild Parsnip II" Wisconsin natural resources magazine online, http://www.wnrmag.com/stories/2000/jun00/parsnip.htm#control
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Minnesota Department of Natural Resoruces. Minnesota invasive non-native terrestrial plants: an identification guide for resource managers. Published by MNDNR 2002, Trails and Waterways Division.
Minnesota Department of Transportation. 2009. Partial list of Pest Situations and Pesticide and Other Control Methods for Mn/DOT Roadside Vegetation Management on Rights of Way

Spotted knapweed Control Strategies

Spotted knapweed is a member of the Asteraceae family. It is named Centaurea stoebe L. subsp. micranthos (Gugler) Hayek with the synonyms C. biebersteinii and C. micranthos and was formerly called Centaurea maculosa Lamarck. Spotted knapweed is native to Europe and Asia. It is a perennial plant with an average lifespan of 3-5 years, but can live up to 9 years (Boggs and Story, 1987) with the potential for seed production each year, although flowering in the first year is uncommon. Propagation is primarily by seed. The seed can be moved by wind, water, wildlife, equipment, and vehicles. The movement of hay and gravel infested with knapweed seed allows knapweed to proliferate in new areas. Spotted knapweed reproduces quickly and is allelopathic (Fletcher and Renney 1963; Kelsey and Locken, 1987, Bais et al. 2003, and Weir et al. 2003, Perry et al. 2005) which means that it chemically inhibits the growth of other plants, allowing it to spread quickly forming monocultures that can span vast acreages. This can result in loss of species diversity (Tyser 1992, Tyser and Key 1988), degraded wildlife habitat (Watson and Renney 1974, Rice et al. 1997), and increased erosion (Tyser 1992).

Identification - Spotted knapweed has attractive pinkish-purple flowers and wooly, grey-green stems and foliage. The small florets are clustered to appear as solitary flowers at the tips of branched stems (Wilson and Randall 2003). The bracts have a black tip that gives a "spotted" appearance to the bract. Spotted knapweed grows to a maximum height of about 4 feet. From a seedling, knapweed forms a rosette with a strong taproot. The rosette can overwinter then bolt (send up flowering stalks) the following summer. In Minnesota, spotted knapweed generally blooms in July and August, although bloom time can vary depending on the situation. Individual flowers on a stalk bloom at different times to extend the overall bloom time.

Habitat - Knapweed prefers open, sunny areas with dry, sandy soils, but it can tolerate a wide range of soils. Disturbance can provide an opportunity for knapweed to proliferate by reducing or removing other plant competition. While disturbance aids the spread of knapweed, it is not necessary. Knapweed is perfectly capable of invading well-managed grasslands and natural areas (Lacey et al. 1990, Tyser and Key 1988).

Mechanical Control - Small infestations can be hand-pulled and dug (wear gloves). Make sure to remove the taproot. Since seed is produced from June through September, care must be taken when pulling not to broadcast seed. Flowering plants should be bagged and removed from the site. Cutting and mowing are ineffective at controlling knapweed and are a frequent means of spreading seed. Similar to a dandelion, knapweed will flower on very short, mowed stems. Follow up for at least three years because seedlings will continue to emerge from the seedbank.

Chemical Control - Herbicides can be a valuable tool for knapweed management. Spraying large infestations may not be cost effective, but using herbicides to contain large infestations and prevent them from spreading could be very effective. Some general information on herbicide use for knapweed control is listed below. Contact your University of Minnesota Regional Extension Educator www.extension.umn.edu/offices/ or County Agricultural Inspector www.mda.state.mn.us/plants/weedcontrol/cailist.htm for specific recommendations.

Timing the herbicide application is very important. Often knapweed plants are recognized and treated after flowering which is too late in the season. The plants may produce seed after herbicide application. Sheley et al. (2000) determined that spraying knapweed in the bolt (rosette sends up stalk) and bud (flower buds formed, but not opened) stage was the most effective. The general time period for these target growth stages is June in Minnesota. Hahn and Stachowski (2006) found that at 140 days after treatment with aminopyralid applied at a rate of 4 fl oz/acre, spotted knapweed was 50% controlled in a grass pasture. In contrast, Holden et al. (2007) demonstrated greater than 97% control with 2,4-D ester at 4 pt/acre, clopyralid plus 2,4-D at 2 pt/acre, aminopyralid at 5 oz/acre, and aminopyralid plus 2,4-D at 2 pt/acre. Concern for non-target broadleaf plants and environmental sensitivity (such as proximity to water) of the site may influence herbicide choice.

Herbicide treatments will require years of follow up. Knapweed seeds germinate throughout the growing season so seedlings may emerge after herbicides dissipate or leach into the soil (Jacobs and Sheley 1998). MacDonald et al. (2007) found no long-term decrease in knapweed density, biomass, or dominance with a single herbicide application.

Prescribed Fire - In the northern Midwest, annual prescribed burning can reduce knapweed infestations. Burn timing and frequency are important considerations. Abella and MacDonald (2000) suggest that fire can reduce seed germination and MacDonald et al. (2001) that spring burns could decrease seedling recruitment. At a site in Michigan, Emery and Gross (2005) found that annual summer burns for 3 years were consistently effective at reducing the spotted knapweed growth rate. In this study, spring burns were effective one year at reducing the percentage of flowering knapweed plants, but were not consistently effective. Fall burns were not effective at reducing knapweed (Emery and Gross 2005). In contrast, MacDonald et al. (2007) found annual spring burns for 3 years reduced knapweed populations and increased the growth of native warm-season grasses at a site in Michigan.

The advantages of integrating burning with other control methods depend upon the specific integrated practices. Biological control can be integrated with spring burning. Integrating summer burning with biocontrol has not been evaluated, but would be expected to negatively impact biological control populations.

Biological Control - Biological control is a cost-effective, long-term, sustainable choice for medium to large infestations, although it takes many years before an acceptable level of control is achieved. The prime time to implement biological control in Minnesota is from early July through mid-August. Seedhead weevils and root boring weevils are used in conjunction to control spotted knapweed. They are collected from established sites then released at new sites.

- Seedhead weevils, Larinus minutus and L. obtusus

Adult female seedhead weevils lay their eggs on knapweed flowers - then the larvae eat developing seeds. Since knapweed reproduces exclusively by seed and is a short-lived plant, these weevils thin out dense stands of knapweed over time by reducing seed production.

- Root boring weevils, Cyphocleonus achates

The larvae of the root weevil feed and develop in knapweed roots consuming plant resources and physically damaging the roots resulting in stunted or dead plants.
For more information about spotted knapweed biological control, contact your County Agricultural Inspector www.mda.state.mn.us/plants/weedcontrol/cailist.htm or Monika Chandler with the Minnesota Department of Agriculture 651-201-6537, Monika.Chandler@state.mn.us.

Resources
Spotted knapweed management www.mda.state.mn.us/plants/badplants/skw-control.htm
Biology and biological control of knapweeds www.invasive.org/weeds/knapweed/

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