DCNR Invasive Exotic Plant Tutorial for Natural Land Managers

Species Management and Control Information

Spotted knapweed
Centaurea maculosa Larmarck or *C. biebersteinii* DC.

Source: The following information is taken from a number of sources and those sources are identified at the beginning of the referenced information. The intent of this resource is to provide the user with as much of the information that exists for management and control of this species as is practical. It is important to note that new and improved methods are added regularly which will require you to visit the websites provided for updates on this information. Bibliographies and resources referenced by these sources are not included here, but are included at the websites from which this information was extracted.

READ THIS FIRST!

Before administering any of the following management and control options, it is imperative that you are familiar with the background information provided under the General Management and Control Section.

For additional, and potentially more current, information on management and control of this species, use the Mid-Atlantic Exotic Pest Plant Council (MA-EPPC) listserve or any of the other listserves identified in theResource - Listserve section of this tutorial. You will find directions for subscribing to the list serve there. The MA-EPPC listserve has an archives feature that saves past discussions (beginning in 1999) about specific species control. These messages are at: http://groups.yahoo.com/group/ma-eppc/messages.

GENERAL MANAGEMENT CONSIDERATIONS:

Plant Conservation Alliance, Alien Plant Working Group - Weeds Gone Wild - Fact sheet - Spotted knapweed- http://www.nps.gov/plants/alien/fact/cebi1.htm - Author(s): Michael Carpinelli - May 1, 2003.

The most cost effective management strategy for spotted knapweed is to prevent its spread to non-infested areas. Spread by seed can be minimized by avoiding travel through infested areas; by cleaning footwear, clothing, backpacks, and other items after hiking through infested areas; by not grazing livestock when ripe seeds are present in the flower heads; and by using weed free hay.

Delaware River Invasive Plant Partnership - Fact Sheets - Spotted knapweed - http://www.paflora.org/DRIPP.html - Authors: Ann F. Rhoads and Timothy A. Block, Morris Arboretum of the University of Pennsylvania - April 2002.

Outlying plants should be controlled before main populations. The most effective way to control spotted knapweed is to begin a program when small patches of the plant appear. When patches are small, herbicide use is cost effective. Costs of herbicides for controlling knapweed may be prohibitory on large areas.

The Nature Conservancy - Species Management Summary (ESA or Element Stewardship Abstract): Centaurea maculosa -http://tncweeds.ucdavis.edu/esadocs/centmacu.html - Author(s): Teresa Mauer, Mary J Russo (Revision), Margaret Evans (Revision) - January 1987.

Most literature on controlling knapweed has focused on reestablishing valuable range, pasture, or cropland. None has looked at the problem from the point of view of restoration ecology, with the intent of restoring the native community.

Spotted knapweed is increasing in its range and frequency in western North America. It is important to monitor whatever means of control are used in order to determine the efficacy of the efforts and the effects of control upon the larger community.

The extent of infestation can be monitored with either low altitude aerial photographs or permanent photo plots. A permanent line transect should be established so that plant and/or stem density can be measured. The transect should extend outside the colony in order to measure the direction and rate of change in the size of the colony. If biological control agents are used, sticky traps and capitula dissection should be used to monitor insect populations, attack rates, and seed losses.

There are several methods of control for this species. It is important to determine and document the methods most effective for different sized infestations, different communities, and the specific characteristics of the site, including soil type, exposure, drainage, and degree of disturbance, human or otherwise.

Control of this species is receiving considerable attention by state agencies as well as colleges and universities in Oregon, Washington, Idaho and Montana. This species is very aggressive. In addition to the effects it could have on elements, control of this species is mandated by county and state agencies. In most states and provinces it is under the "A" weed list for eradication.

Several grasses and forbs, most of them non-native, have been used to explore the possibility of replacing Centaurea species by the seeding of a competitor. A. H. Bawtree, Provincial Range Specialist in British Columbia cited a group of studies from which he recommended the application of picloram at no more than 6 oz. per acre followed by fall seeding of crested wheatgrass (Bawtree 1988). An Oregon State University study found six species--Palestine orchardgrass, Berber orchardgrass, Nangeela subterranean clover, Mt. Baker subterranean clover, and Covar sheep fescue--that over the course of six years were able to establish themselves and outcompete yellow starthistle (Centaurea solstitialis) (Johnson 1988). A two-year study of four grasses--Paiute orchardgrass, Covar sheep fescue, Critana thickspike wheatgrass, and Ephriam crested wheatgrass--found that the greater the biomass produced by the grass, the more it reduced the number of diffuse knapweed (Centaurea diffusa) seedlings. The species are listed in the order of their effectiveness. The researcher also indicated that those species whose growth period overlap the growth period of diffuse knapweed would be more effective at competing for moisture and nutrients (Larson, 1988).

Mowing is a method of control that would be possible only in areas that are not too rocky or steep, or without shrubs. If mowed in the early flowering state, the plants will usually regrow and produce abundant late season seeds. Those mowed even the same day as florets appear out of the bud have enough energy to produce seed. Among those mowed within ten days after flowerheads opened, none produced more than four filled seeds per head, and the greatest viability of these filled seeds was 57%, reached nine days after the flowerhead opened. Although these results indicate that mowing greatly reduces the seed set, a well-established seed bank, such as would be present on a large or severe infestation, would most likely be able to compensate for this loss. Mowing would probably be a way to control populations, but not eradicate them.

No detailed research on vegetation response to knapweed control exists in the literature. The use of seeded or planted native bunchgrass species has not been explored. No studies have explored control by timed removal of flower capitula. Most studies have been designed to tackle infested areas on a large scale, and scale might prohibit removal of capitula by manual methods. However, relatively small areas that might be encountered on TNC preserves may be more amenable to this sort of management. Documented successful control in small areas by capitula removal would add valuable new information to the control literature.

Chemical and biological control have been proposed for spotted knapweed, and most of the control literature addresses these two categories:

Herbicides C. maculosa can be controlled with picloram (4 amino 3,5,6 trichloropicolinic acid) and 2,4 D but there are problems. Control by 2,4 D is temporary since it does not prevent germination from seeds in the soil. Picloram persists in soils but in 4 years, enough is lost from a .4 .6 kg/ha treatment to allow germination and reinfestation (Harris and Cranston 1979). The costs of applying picloram are estimated at $37/ha, and are prohibitive for very large infested areas (Maddox, 1979).

Other methods of control should be explored:

Mowing although this would not be feasible in rocky, or sagebrush areas, in some knapweed stands with little other vegetation it might be possible to mow the plants just after most flowering has ended but before seeds have matured. This would make regrowth unlikely since moisture levels late in the season are probably too low for continued growth, but would offer a possible advantage of reducing reserves for flowering the following year.

Hand Removal by August, in central and eastern Oregon, soils are often dry and dusty, and it may be possible to pull up a large number of seedlings, rosettes and reproducing plants in a small infested area. However, effects of soil disturbance on knapweed seed germination are not well documented. Even if seed germination of knapweed were not a problem, colonization by other weed species may be.

Hand Clipping: This method might alleviate the soil disturbance problem outlined above. Again, this would probably be feasible only in small infested areas. Timing would be the same as mowing and the stems and capitula would be removed from the area. Again, control might be slower, due to continued emergence from seedbank reserves.

Burning although no literature specifically mentioned this as a control method for knapweed, it might be considered in areas with enough surrounding vegetation or litter to carry a controlled burn. Often however, dense stands of knapweed have little surrounding vegetation, possibly due to allelopathy. Litter from the previous year's stems often decays or scatters during the current season, but it may accumulate in very dense stands and create more favorable burning conditions.

Wisconsin Department of Natural Resources - Non-native Plants Fact Sheets - Centaurea maculosa - http://www.dnr.state.wi.us/org/land/er/invasive/nonnative.htm

Prevention is extremely important--spotted knapweed spreads readily in hay and on vehicle undercarriages. Caution is also necessary when using hay from the road ditches of primary roadways, or hay purchased from known infested areas. Outlying plants should be controlled before main populations.

MANUAL AND MECHANICAL CONTROL:

Plant Conservation Alliance, Alien Plant Working Group - Weeds Gone Wild - Fact sheet - Spotted knapweed- http://www.nps.gov/plants/alien/fact/cebi1.htm - Author(s): Michael Carpinelli - May 1, 2003.

Small infestations of spotted knapweed can be controlled by persistent hand-pulling done prior to seed set. Gloves should be worn because of the possibility of skin irritation. Because spotted knapweed can regrow from the base, care must be taken to remove the entire crown and taproot.

Delaware River Invasive Plant Partnership - Fact Sheets - Spotted knapweed - http://www.paflora.org/DRIPP.html - Authors: Ann F. Rhoads and Timothy A. Block, Morris Arboretum of the University of Pennsylvania - April 2002.

Small populations can be removed by digging or pulling. This is best done where the soil is moist. The entire root should be removed. Mowing has not been successful; plants merely re-flower at a lower height. Established stands of knapweed may be controlled by hot prescribed burns followed by selective pulling and digging once the population has been reduced. Annual burns have reduced populations from 5-90 percent. Reductions seem to correlate to the intensity of the burn administered; burns that remove nearly all the duff are most effective. Following a burn, it is important to reseed quickly with native species. The potential effects of intense burning on native species must be taken into consideration when planning a burn. Tillage that results in burying the seeds can be effective in preventing germination.

Wisconsin Department of Natural Resources - Non-native Plants Fact Sheets - Centaurea maculosa - http://www.dnr.state.wi.us/org/land/er/invasive/nonnative.htm

The most effective control is early detection and removal of pioneering plants. Small populations can be removed by digging or pulling. This is best done where the soil is moist. The entire root should be removed. Mowing has not been successful--plants merely re-flower at a lower height.

PRESCRIBED FIRE:

The Nature Conservancy - Weed Notes: Spotted knapweed (Centaurea maculosa) - http://tncweeds.ucdavis.edu/esadocs/centmacu.html- TunyaLee Morisawa - June 1999.

Hot prescribed burns may reduce established stands of knapweed. A follow-up of selective pulling and digging will further reduce populations. Annual burns have reduced populations by 5-90% and may be correlated with burn intensity. Reseeding with a native species is recommended. However, single, low intensity burns may actually worsen the problem since it is not hot enough to prevent re-sprouting and seed germination. Also, fires may disturb the area promoting colonization.

Wisconsin Department of Natural Resources - Non-native Plants Fact Sheets - Centaurea maculosa - http://www.dnr.state.wi.us/org/land/er/invasive/nonnative.htm

Once established, knapweed may be reduced by hot prescribed burns. These can be followed by selective pulling and digging once the population has been decreased. Annual burns have reduced populations anywhere from five to ninety percent. Reductions seem to correlate to the intensity of the burn administered; burns that remove nearly all the duff are most effective. Following a burn, reseed with native species. The potential effects of intense burning on native species must be taken into consideration when planning a burn.

GRAZING:

Plant Conservation Alliance, Alien Plant Working Group - Weeds Gone Wild - Fact sheet - Spotted knapweed- http://www.nps.gov/plants/alien/fact/cebi1.htm - Author(s): Michael Carpinelli - May 1, 2003.

Long-term grazing by sheep and goats has been found to control spotted knapweed.

BIOCONTROL:

Van Driesche, R., et al., 2002, Biological Control of Invasive Plants in the Eastern United States, USDA Forest Service Publication FHTET-2002-04, 413 p. http://www.invasive.org/eastern/biocontrol/13Knapweed.html.

Establishment and Spread of Agents
: Of the natural enemy species released against spotted knapweed in the eastern United States and Canada, the following have been established: Urophora affinis (Virginia, New York, Pennsylvania, Minnesota, Wisconsin, Michigan, Quebec); Urophora quadrifasciata (Connecticut, Indiana, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, Wisconsin, and Quebec); Metzneria paucipunctella (Virginia); Agapeta zoegana (Minnesota); and Larinus minutus (Indiana, Minnesota) (Hoebeke, 1993; Wheeler, 1995; Wheeler and Stoops, 1996; Mays and Kok, 1996; Lang et al., 1997; Lang, pers. comm.) (Table 1). Except for the two Urophora species, particularly U. quadrifasciata, dispersal of the knapweed agents has been modest. An assessment of the Urophora spp. spread was conducted in Montana (Story et al., 1987).

Suppression of Target Weed:
Effects of imported natural enemies on spotted knapweed densities in the eastern United States have not been examined. However, impact information has been collected at sites in the western United States. Studies in Montana indicate that the two Urophora spp. are reducing spotted knapweed seed production by a minimum of 40% (Story et al., 1989), seed reduction by the Urophora spp. is further increased when M. paucipunctella is present (Story et al., 1991a), and A. zoegana is significantly reducing the biomass of spotted knapweed at some sites (Story et al., 2000). Spotted knapweed density is significantly reduced at two sites in western Montana where C. achates is well established (Story, unpub. data). Clark et al. (2001b) reported that spotted knapweed stem density, at 13 sites in Montana and adjacent states where U. affinis and one or both root feeding species of natural enemies (A. zoegana, C. achates) were established, declined from about 15 plants per m2 in 1991 to1993 to seven plants in 1997 to 1998. Effects on

Native Plants:
Neither the impact of these released agents on native, non-target plants, nor the recovery of native plant communities as weed densities, decline have been examined.

Plant Conservation Alliance, Alien Plant Working Group - Weeds Gone Wild - Fact sheet - Spotted knapweed- http://www.nps.gov/plants/alien/fact/cebi1.htm - Author(s): Michael Carpinelli - May 1, 2003.

A variety of natural enemies are used as biological control agents for large infestations of spotted knapweed. Most biocontrol techniques use insect larvae to damage the root, stem, leaf, or flower. Two species of seed head flies, Urophora affinis and U. quadrifasciata, are well-established on spotted knapweed. The larvae of these species reduce seed production by as much as 50% by feeding on spotted knapweed seed heads and causing the plant to form galls. Three moth species (Agapeta zoegana, Pelochrista medullana, and Pterolonche inspersa) and a weevil (Cyphocleonus achates) that feed on spotted knapweed roots have also been released. The collective stress on the plant caused by these insects reduces seed production and may lead to reduced competitiveness. Biological control agents may be more effective when combined with other control methods such as herbicides, grazing, and revegetation with desirable, competitive plants.

Delaware River Invasive Plant Partnership - Fact Sheets - Spotted knapweed - http://www.paflora.org/DRIPP.html - Authors: Ann F. Rhoads and Timothy A. Block, Morris Arboretum of the University of Pennsylvania - April 2002.

In total, 14 insect and fungal species are presently being introduced or considered for introduction in North America to control spotted knapweed. Biological control agents include 2 root-mining moths, a flower moth, and a root-mining beetle. These have met with varying degrees of success. Most promising are 2 flies that attack the seed heads; Urophora affinis and U. quadrifasciata, have reduced seed production 95 percent in experimental populations. Both flies are being released experimentally in Wisconsin.

The Nature Conservancy - Species Management Summary (ESA or Element Stewardship Abstract): Centaurea maculosa -http://tncweeds.ucdavis.edu/esadocs/centmacu.html - Author(s): Teresa Mauer, Mary J Russo (Revision), Margaret Evans (Revision) - January 1987.

Four insect species have been introduced into North America for biological control of knapweeds. Two gall flies, Urophora affinis and Urophora quadrifasciata (Diptera: Tephritidae) (Maddox 1982, Story and Anderson 1978, Harris 1980 a and b, Myers and Harris 1980, Berube 1980) and a moth, Metzneria paucipunctella (Lepidoptera: Gelechiidae) attack seed capitula (Englert 1971, Myers personal communication). A beetle which attacks the roots, Shenoptera jugoslavica (Coleoptera: Buprestidae) has also been introduced more recently (Zwolfer 1976).

U. affinis lays its eggs into young buds of C. maculosa. Egg hatch is synchronized with rapid growth of the receptacle in which each larva forms a gall. The seeds are not destroyed directly, but the diversion of nutrients to the gall reduces seed production by the plant as a whole (Harris 1980b). One generation of flies per season is usual, but a small proportion of the population completes a second one. Reported percentages of capitula attacked range from 10 50%, with up to 97% reduction in seed numbers per capitula.

U. quadrifasciata lays its eggs into florets inside more mature buds. Both species of Urophora can coexist in the same capitula. Some studies (Harris 1980) have found that U. quadrifasciata may attack capitula missed or more lightly attacked by the earlier attacking U. affinis, and result in a higher overall attack rate among capitula.

Metzneria paucipunctella lays eggs at the base of spotted knapweed buds and a young larva bores into the capitula after hatch. It feeds first on florets, then directly on seeds and does not form a gall. Establishment of this species has been somewhat difficult and increase has been slower than the fly species.

Female Sphenoptera beetles oviposit at the base of C. maculosa rosettes, and first instar larvae feed externally on plant tissues. After the first molt, the larva enters the plant tissue and mines into the root. A gall forms as the rosette terminates aestivation and resumes growth. The larva overwinters in the rosette root and pupates the next spring in a pupal chamber in the root crown. Adult beetles emerge and feed on knapweed leaves, adding to the root damage imposed by larvae.

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Insects are available from USDA sources and could be released in target areas as a first step for control with relative ease and at no or little cost. Seed capitula attack percentages seem to rise quickly within a few years, but noticeable decreases in reproductively mature plants will take longer because of seed bank reserves and dormancy. This method, though slower, may be desirable because of minimal disturbance to soil and surrounding vegetation.

In addition to the biocontrol agents listed in the ESA, a seedhead weevil, Bangasternus fausti (Reitter), that is native to Europe, was released in the US in 1991 for the control of spotted knapweed, diffuse knapweed (C. diffusa) and purple star-thistle (C. calcitrapa). The weevil has become established in several states: Montana, Nebraska and Oregon. It has not been shown to reduce populations or even significantly slow their spread. While the larvae can destroy 100 percent of the seeds in a seedhead, not all seedheads are affected and so seed production is still high. Many seeds that do develop may not germinate. TNC has not used this biocontrol and gaining approval would be a formidable task.

Wisconsin Department of Natural Resources - Non-native Plants Fact Sheets - Centaurea maculosa - http://www.dnr.state.wi.us/org/land/er/invasive/nonnative.htm

Several biological controls exist, including two root mining moths, a flower moth, and a root mining beetle. These have met with varying degrees of success. Most promising are the two seed-head attacking flies Urophora affinis and U. quadrifasciata. Congruently, these two flies have reduced seed production 95% in experimental populations. While both flies are being released experimentally in Wisconsin, their effectiveness here is still unknown. These insects were not available for general use at the time of printing. The USDA should be consulted to determine the current status of these controls.

CHEMICAL CONTROL:

Plant Conservation Alliance, Alien Plant Working Group - Weeds Gone Wild - Fact sheet - Spotted knapweed- http://www.nps.gov/plants/alien/fact/cebi1.htm - Author(s): Michael Carpinelli - May 1, 2003.

Control of spotted knapweed infestations using three chemical herbicides (2,4-D, clopyralid, and picloram) has been reported but is problematic. Existing plants can be killed with 2,4-D but it needs to be reapplied yearly to control new plants germinating from seed stored in the soil. Picloram is a more persistent herbicide and has controlled knapweed for three to five years when applied at 0.25 lb/acre at any stage of plant growth; or with clopyralid (0.24 lb/acre) or clopyralid (0.2 lb/acre) plus 2,4-D (1 lb./acre) applied during bolt or bud growth stage. In the absence of desirable native grasses, longevity of control may be increased by re-vegetating with competitive grasses and forbs. Picloram may pose a risk of groundwater contamination where soils are permeable, particularly where the water table is shallow.

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Chemical controls are an effective means of eliminating spotted knapweed. A 3% solution of triclopyr in the water-soluble formulation has been found to be effective. This application should be repeated 3-4 times per year for two years to control plants growing from the seed bank. Triclopyr will not affect grasses. Experimentation to test the effectiveness of glyphosate is needed.

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Clopyralid (Transline) applied at 0.13-0.19 L/ha (0.66-1.0 pt/acre) or clopyralid + 1.12 kg/ha 2,4-D (Curtail) provide control with little soil residual. Apply during the bolt or bud stage. Less control was achieved when applied to the rosette, flowering and after flowering stages.

Picloram (Tordon) (0.28 kg/ha), as listed in the ESA for C. maculosa, can control plants and seedling for 2-3 years. However, as mentioned in the ESA, there is a long residual and it is costly (as is dicamba - listed below). The residual may be shorter on gravel soils, wet areas and areas with high soil organic matter. The optimum time for the application of picloram is during the rosette growth stage in the fall or in the bud to bloom stage in the spring. Picloram can not be used near water or in porous substrata overlying ground water. Picloram does not affect grasses, but long term affects have been observed from it on shrubs and trees, possibly due to it leaching in ground water.

Dicamba (Banvel) will also provide control of plants and shorter residual control of seedlings at a rate of 0.18-0.37 kg/ha (1-2 lbs/acre). A follow-up treatment of 2,4-D at 0.18 kg/ha (1 lb/acre) annually may be needed to prevent reinfestation.

2,4-D is listed in the ESA for control, however, after stem elongation it should not be applied since control is not very effective. There is no residual control and so annual applications are necessary.

Triclopyr (water-soluble formulation) applied at the rate of 3% a.i. can be sprayed on the plant (except the flower) 3-4 times a year for control. Triclopyr does not affect grasses.

For all chemical applications treat the area around C. maculosa patches (3-4.5 m). Follow-up treatments are extremely important for the continual control of spotted knapweed.

Wisconsin Department of Natural Resources - Non-native Plants Fact Sheets - Centaurea maculosa - http://www.dnr.state.wi.us/org/land/er/invasive/nonnative.htm

Chemical controls are an effective means of eliminating spotted knapweed, but they may also have the most adverse consequences. The recommendations from western rangelands involve the use of some very potent chemicals. These restricted chemicals are not recommended for use on quality natural areas, but may be appropriate on roadsides and other highly disturbed areas. Experimentation testing the effectiveness of less toxic broad-leaf herbicides such as triclopyr or glyphosate is encouraged.

A 3% active ingredient (a.i.) solution of triclopyr in the water-soluble formulation with dye can be sprayed on the entire plant except the flower, which should be spared for native fauna. This application should be repeated 3-4 times per year for two years. Triclopyr will not affect grasses. Picloram at 0.25 to 0.5 pounds per acre will control spotted knapweed plants and seedlings for 2-3 years, although the residual control period may be shorter on gravel soil, where soil organic matter is high, or in wet areas. Picloram should be applied either in fall when the plant is in the rosette growth stage, or in spring during the bud to bloom stage. Picloram should not be used near water or on sandy soils with ground water ten feet or less below the surface. Dicamba at 1-2 pounds (acid equivalent--see label) per acre also controls spotted knapweed, but may require annual follow-up treatment for a minimum of two years.

Clopyralid is more selective, affecting only legumes and composites. It can be applied at 0.25 pound acid equivalent per acre. A mixture of 0.19 pounds of clopyralid per acre plus 2,4-D at 1 pound acid equivalent per acre is also an option; both herbicides provide good control of spotted knapweed with less soil residual than picloram or dicamba. Spotted knapweed that is still in the rosette stage can be controlled by applying a 2,4-D low volatile ester, oil soluble amine, or water soluble amine formulations at 2 pounds per acre. Annual spraying for several years may be required to deplete the seed bank.

Picloram and clopyralid are the most commonly used and effective herbicides for spotted knapweed. Picloram causes the largest initial decrease in native forb cover, but the experiment that produced this data also concluded that most non-target forb populations were tolerant of herbicidal treatments and benefited from being released from knapweed competition after three years of selective herbicidal application. Application of these herbicides has not been found to decrease the frequency of occurrence of grasses, sedges, shrubs, or trees in the treated site. Herbicides were applied manually using a carbon dioxide pressure-regulated backpack sprayer at the concentrations listed in previous paragraphs.

OTHER CONSIDERATIONS:

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Burning, cultivation, and fertilization typically are not effective on spotted knapweed unless combined with other methods of control.

Source: http://www.dcnr.state.pa.us/forestry/invasivetutorial/Spotted_knapweed_M_C.htm