# ELEMENT STEWARDSHIP ABSTRACT
for

*Carduus nutans*

Musk Thistle

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The Nature Conservancy
Element Stewardship Abstract
For *Carduus nutans*

# I. IDENTIFIERS

Common Name: MUSK THISTLE Global Rank: G?

General Description:
"Musk thistle" in the United States and Canada includes a complex of closely-related species of the Carduus nutans group. Species in this group are tall (up to 1.5m) facultatively biennial or annual herbaceous thistles with deeply lobed, spiny, decurrent leaves.

Diagnostic Characteristics:
Size and shape of the imbricate, spine-tipped involucral bracts is used to distinguish members of the group from closely related species and from each other.

Members of the genus Carduus are distinguished by their simple pappus hairs from members of the genus Cirsium, which have feathery, plumose pappus hairs. Within the genus Carduus, members of the nutans group are distinguished by their large nodding heads from closely related, small- flowered plumeless and Italian thistles (C. acanthoides, C. crispus, C. pycnocephalus, and C. tenuiflorus) (McCarty 1984, Mulligan and Frankton 1954, Trumble and Kok 1982).

Carduus thoermeri is distinguished from other members of the nutans group by the broad (4-8 mm) fairly short blade of the involucral bract, which converges to a short awn tip. Carduus macrocephalus is distinguished from other North American members of the nutans group by the raised mid-vein of the long, broad, uniformly tapering involucral bract. Carduus nutans conforms to the illustration in the 3rd edition of Britton and Brown's illustrated flora (Gleason 1957). The involucral appendage is much narrower than in other members of the group. The involucral blade is narrow (1.5-3 mm), more or less hairy, and tapers gradually to an awn. Carduus sp. from British Columbia is characterized by a broad, fairly short involucral bract, converging slowly but not uniformly to the tip (McCarty 1985, Tutin et al. 1976).

In addition to these morphologically distinct species, hybrids of intermediate appearance have been reported between Carduus sp X C. thoermeri, C. thoermeri X C. macrocephalus and Carduus nutans (sensu latu) X C. acanthoides (McCarty 1985, Moore and Mulligan 1956, 1964, Mulligan and Moore 1961).

# II. STEWARDSHIP SUMMARY

Monitor natural areas for the presence of musk thistle. Control dense musk thistle populations along roadsides and in degraded areas by spot use of herbicides and in higher quality areas by a persistent program of hand chopping. Monitor indirect effects of fire on litter and light penetration as they affect musk thistle.

## III. NATURAL HISTORY

### Range:

Members of the genus Carduus are native to Europe and Asia. The first records of Carduus nutans (sensu latu) in North America are from Harrisburg, Pennsylvania, between 1853 and 1866 (Stuckey and Forsythe 1971), and from Chatham, New Brunswick in 1878 (Mulligan and Frankton 1954). The musk thistle complex has been found in at least 3068 counties in 40 of the mainland states, with 12% of those countries rating their infestation as "economic" (Dunn 1976). The present North American distribution extends from the east to west coast in the deciduous forest and prairie biomes, from Canada southward through the central states. In the east, in the Great Valley of the Appalachians, Ohio, Kentucky, and Tennessee, musk thistle is most commonly associated with soils derived from limestone (Stuckey and Forsythe 1971, Batra 1978). In the Great Plains and the West this relationship does not necessarily hold true (Batra 1978). The near-absence of members of the C. nutans group from the Great Basin and the Nebraska sandhills is probably attributable to its moisture requirements for germination. Within the Nebraska sandhills, musk thistle is found in pockets of finer-textured soil (Steuter pers. comm.).

Nursery studies of plants from throughout the United States suggest that Carduus thoermeri is the most widespread species of the group in both the United States and Canada. Carduus macrocephalus is the dominant species in Montana and the intermountain region and Carduus sp. (unnamed) is restricted to British Columbia (McCarty 1985).

### Habitat:

Musk thistle is most prevalent in disturbed areas such as roadsides, grazed pastures and old fields, but can invade deferred pastures and native grasslands (Feldman et al. 1968, Nagel pers. comm., McCarty pers. comm.). At both Willa Cather Prairie and Pawnee Prairie, Nebraska, musk thistle infestations have been observed in areas with dense prairie sod and tallgrass cover (Nagel pers. comm., McCarty pers. comm.).

### Reproduction:

Musk thistle is a monocarpic species requiring a cool period of vernalization in order to bloom (Medd and Lovett 1978, Hadding and McCarty 1980). Under natural conditions, musk thistle most often functions as a spring biennial, fall biennial, or winter annual (Lee and Hamrick 1983, McCarty et al. 1969). The species is very plastic (McCarty pers. comm.). Ten percent of plants in a Kentucky nursery study functioned as true annuals (Lacefield and Gray 1970).

There appears to be a cline in flowering strategy from south to north. Although plants are reported to behave as biennials and winter annuals from Oklahoma (O'Bryan and Peeper 1986) as far north as Minnesota (Durgan pers. comm.), Canadian plants are treated as biennials (Mulligan and Frankton 1954).

Plants of all ages overwinter as rosettes. Both flowering and seed production are positively correlated with rosette size. In one Kansas study, plants greater than 14 cm in rosette size in late April flowered the following summer regardless of their age (Lee and Hamrick 1983).

Bolting begins as early as March in Kentucky (Lacefield and Gray 1970) until as late as May in Minnesota (Durgan pers. comm.). Flowering begins from early June in the south to as late as mid-July in the north and may continue for up to seven weeks (McCarty 1982). Within a single flowering head, florets develop centripetally over a period of 36 to 48 hours. Pollinators include bees (Apis mellifera), bumblebees (Bombus spp.), and sphinx moths (Hyles spp.). Florets on the same head are self-compatible (Lee and Hamrick 1983).

Seed maturity and dispersal occur within 7 to 10 days of flowering (McCarty and Scifres 1969) and begin as early as the first week in June in Kentucky (Lacefield and Gray 1970). Seed production can be as great as 11,000 seeds per plant (McCarty and Scifres 1969). Terminal heads average 1000 seeds per head, whereas the last blooming side branches average only 125 seeds. Early-maturing, terminal seeds are heavier and exhibit a higher rate of viability than later-maturing seeds from secondary branches (McCarty 1982). The bulk of the seeds fall near the parent plant with less than 1% being carried further. Experimental studies in Virginia suggest that seeds do not travel far from the parent plant, with over 80% of seeds deposited within 40 m of the parent plant (Smith and Kok 1984). However, McCarty (pers. comm.) reports that a pilot in Nebraska flew through a cloud of musk thistle seeds at an altitude of 500 feet.

Seeds have been reported to remain viable in the soil for periods as long as ten years (Burnside et. al. 1981).

In one Kansas study, less than 2% of the seeds falling within the boundaries of the population germinated the following year and about 30% of the new seedling cohort came from seed carried over from previous years (Lee and Hamrick 1983).

Studies of germination requirements in Nebraska indicate that a period of dormancy is not necessary before germination (McCarty et al. 1969). However, in Kentucky only 2% of fresh seed germinated, whereas 50% of seeds germinated after 8 weeks and 90% of year-old seeds germinated (Lacefield and Gray 1970). McCarty et al. found in laboratory studies that cold, moist treatment resulted in low rates of germination. Even when moisture is adequate, soil cover is required before a high percentage of seeds will germinate (McCarty et al. 1969).

In Kansas, both musk thistle rosette survival and earlier germination were enhanced in study plots dominated by Bromus japonicus, a winter annual that formed dense protective litter retaining moisture during the dry summer months. Summer mortality and later germination were observed in plots dominated by perennial weeds that lost their lower leaves but continued evapotranspiration during the summer months, decreasing protection of Carduus nutans and increasing competition (Lee and Hamrick 1983). In Kansas greenhouse experiments optimum levels of germination, survival and growth occurred in habitats with a light covering of litter that reduced evapotranspiration. Thick litter layers reduced germination and establishment by preventing seeds from reaching the soil surface (Hamrick and Lee 1987).

## IV. CONDITION

Threats:
The rate of expansion of musk thistle populations in North America has been very rapid since the mid-1950's, when it was first recognized as a weed (Dunn 1976).

In agricultural systems the contagious nature and large rosette size of musk thistle populations results in competition with crops for space, nutrients, and light and in large areas that are unpalatable to stock. A single musk thistle per 1.49 m2 has been reported to reduce pasture yields by 23% (Kates et al. 1972). The region of most serious infestation is in Kansas and Nebraska. Infested grazing lands in Nebraska have lost value because the per-acre cost of aerial spraying approximates annual income (Nagel pers. comm.).

Musk thistle is a major problem in natural areas only in the midwest, especially in Nebraska and Kansas where it can invade natural communities (Nagel pers. comm., McCarty pers. comm.). Elsewhere in the midwest, southeast, northeast and west it generally infests disturbed areas, edges of preserves and buffer zones (MacDonald 1987, Rose 1987, Evans 1987, Snyder 1987, Cooper 1987). In such areas its presence in natural areas is a public relations problem because of its listing as a noxious weed. Problem infestations of musk thistle occur on Willa Cather Prairie, Nebraska (Nagel pers. comm.). Infestations at Konza Prairie, Kansas have been brought under control (Gelroth pers. comm.) by repeated cutting and those at Hole-in-the-Mountain Prairie, Minnesota, by natural succession (Dana pers. comm.).

## V. MANAGEMENT/MONITORING

Management Requirements:
Musk thistle infestations are economically important in agricultural systems because they compete with crops for space, light, nutrients, and water and because their spiny habit renders them unusable for livestock. Although musk thistle seldom poses a threat to established natural communities or "element" species, infestations in natural areas require management because of noxious weed laws. Unless an effort is made to control listed noxious weeds, county weed inspectors may enforce the law by "managing" the infestation themselves (with herbicides) and billing the landowner (Winter 1987).

Retention of musk thistle on preserves for the purpose of overwintering weevil populations has been tried at Konza Prairie, Kansas since 1978 (Gelroth 1987), but was not considered feasible at Willa Cather Prairie, Nebraska because of public relations with the neighbors (Nagel 1987).

Cultural, mechanical, biological and chemical control methods have all been used on musk thistles with varying degrees of success in different parts of the country. The effectiveness of individual treatment methods and of integrated pest management varies with the target species, the time of treatment, and (in the case of biological control agents) the biotype of the control agent.

Cultural and Mechanical Methods: Except in rare instances, musk thistle species are pioneers, favored by abandoned fields and overgrazed pastures. The relationship of musk thistle infestations to litter build-up is complicated (McCarty pers. comm.). Although dense ground cover with a closed canopy can reduce infestation because of light reduction, a light litter cover favors germination because it helps retain moisture. In one study at Kansas State University, uninfested sites had an average litter depth of 1.27 cm, but infested sites a depth of .98 cm. In this study, musk thistle did not do well where there was no litter (Fick pers. comm.).

Heavily grazed pastures are more susceptible to musk thistle development than rotationally grazed or deferred pasture (Feldman et al. 1968).

It is unclear how long a process of natural succession would be required to eliminate musk thistle from natural areas. At Pawnee Prairie in Nebraska, musk thistle populations persisted over a 12-year period in an unmanaged area (McCarty pers. comm.). At Hole-in-the-Mountain Prairie, Minnesota, thistle populations decreased rapidly after grazing was removed and natural succession began to take place (Dana pers. comm.).

Fire has not been effective as a method for directly controlling musk thistle. At Willa Cather Prairie, Nebraska, plants bolted and bloomed after the rosettes were scarred by a late spring fire (Nagel pers. comm.). In order for fire to provide effective direct control, the fire would need to be hot enough to destroy the root crown (McCarty pers. comm., Fick pers. comm., Dana pers. comm.). Long-term secondary effects of fire have not been documented. At Pawnee Prairie, Nebraska, where both 12 years' litter accumulation and a musk thistle seed source were present, the immediate effect of spring burning was a tremendous crop of musk thistle seedlings (McCarty pers. comm.). However, Fick (pers. comm.) notes that the likely long-range result is reduction of musk thistle populations by increased competition from warm-season grasses.

Because of the high temperatures required to injure the root crown, Heitlinger (pers. comm.) suggests an experimental treatment of individually burning rosettes with a hand torch until the crowns are injured. Although this methods is labor-intensive, it is perhaps no more labor intensive than hand chopping or glove herbicide application would be.

Hand-cutting or mowing can provide control if repeated over a period of years. The effective control is obtained when cutting is done with a sharpened shovel at the base of the bud and the top of the root crown. If only the terminal bud is destroyed, the side buds can develop into leaders and set seed (McCarty pers. comm.).

At Konza Prairie, Kansas, repeated hand-chopping at ground level just before anthesis over a four-year period eliminated musk thistle from a 350 acre pasture. The number of thistles cut declined as follows over a five- year period: 1977--9354 thistles, 1978--4448 thistles, 1979--66 thistles, 1980--16 thistles. In 1981, no thistles were observed. This method of eliminating thistle is labor-intensive. 1977 control required 10 person days but 1980 control still required 5-person days because of the time involved in searching for thistles (Gelroth 1987).

Research in Fillmore County, Minnesota, indicates that effective control requires cutting (or preferably chopping the root crown) at the onset of blooming. Treatment before plants are fully bolted results in regrowth (Durgan pers. comm.).

Repeated visits at weekly intervals over the 4 to 7 week blooming period provide most effective control because not all plants bloom simultaneously and it is important to cut them after first anthesis but before seed set (Durgan pers. comm.). In Nebraska, mowing of musk thistle within 2 days of first anthesis in the terminal heads eliminated production of germinable seed from all mowed stalks. Delay of treatment until 4 days after anthesis resulted in production of germinable seed (McCarty and Hadding 1975).

Biological Control: 93 European insects have been evaluated as potential control agents for Carduus species. Several promising species have been rejected either because of their impact on crops such as artichoke and lettuce or because of their impact on native species (Boldt 1978, Trumble and Kok 1982, MacDonald 1987). Successful control hinges on the identity and phenology of the target musk thistle species, the biotype and host- specificity of the control agent, and the timing of its life-history state (Trumble and Kok 1982). Synchrony between host and control is very important (McCarty pers. comm.).

The most widely introduced species is Rhinocyllus conicusus (Coleoptera: Cuculionidae). Larvae of this European weevil feed on the immature heads of Carduus and three other genera (Turner pers. comm.). Since 1969, R. conicus has been released in a large number of states including Maryland, Virginia, Pennsylvania, West Virginia, New Jersey, Missouri, Nebraska, Minnesota, North Dakota, Montana, and California (Trumble and Kok 1982, Boldt 1978). The greatest success in control has been achieved in Montana's Gallatin Valley, where the target thistle is Carduus macrocephala. Musk thistle populations that averaged 37.4/m2 at 5 release sites in 1974, were reduced by 1977 to 9.9/m2. A large decline of seedlings in 1976 was attributed to oviposition on 88% of the primary flowers with 17.8 larvae per seed head. The population is considered to be sufficiently established to assure that most of the seeds of C. macrocephalus will be destroyed each year by R. conicus with the possible sporadic assistance of a native Lepidopteran Homeosoma electellum. Enough seeds from late-blooming flowers will be missed to maintain the population of R. conicus from year to year (Rees 1978, 1980, Hodgson and Rees 1976).

Introduction of R. conicus in other areas has met with varying degrees of success. Nebraska populations in their second year reached densities of 20 larvae per head, sufficient to eliminate seed production in infested heads. This weevil population was subsequently lost (McCarty et al. 1979). Although ability of R. conicus to overwinter was originally considered as an important measure of success (Puttler et al. 1978, Strand 1976) weevil populations may actually be more limited by summer temperatures. The most successful introductions have occurred on mountainous areas where night temperatures remain cool longer into the season. Weevils produce a finite number of eggs that are laid rapidly and depleted in warmer areas but laid over a longer period of time where night temperatures are cooler (McCarty pers. comm.). McCarty believes that in warmer areas, the musk thistle bloom period outlasts the weevil's egg- laying capacity so that late blooming heads go uninfested. If this hypothesis is true, biological control by weevils should be most effective in areas with cool summer temperatures. The hypothesis is supported by the fact that effectiveness of weevil establishment in Virginia and Canada was enhanced by spring weevil releases (Kok 1975, Trumble and Kok 1982, Zwolfer and Harris 1984, Boldt 1978).

Weevil populations have been established at two sites on Konza Prairie, Kansas. In both instances, the sites are well within the Preserve, out of sight of neighbors. Standing musk thistles are kept to harbor overwintering weevils. At one site the musk thistle population appears to be contained; at the second the weevil population is not large enough and hand-cutting is required to keep the thistle population from expanding (Gelroth 1987).

A second European weevil, Trichosirocalus horridus (also known as Ceuthorhynchidus horridus) weakens Carduus plants by infesting the crown tissues of the rosettes. Tests in Virginia indicate that although infested spring rosettes exhibit a higher initial rate of necrosis, infested overwintering rosettes have a lower recovery rate (Sieburth et al. 1983). The species has been released in Virginia and Canada but is not suitable for release in California because it damages lettuce and artichokes (Trumble and Kok 1982, Boldt 1978).

One practical limitation of the use of biological control agents in natural areas is the requirement that low numbers of host thistles must be kept to support populations of the control agent from year to year. In states where musk thistle is considered a noxious weed and biological control agents are not widely accepted, this requirement can present a public relations problem. An offer of weevils for control of musk thistle at Willa Cather Prairie had to be rejected because the neighbors objected to standing thistles (Nagel 1987).

None of the beetles presently in use in the United States are sufficiently host specific to meet present-day standards for introduction as control agents (Turner pers. comm.).

Chemical Control: The effectiveness of chemical control is influenced both by weather and by growth stage. Choice of chemicals will depend on cost, effectiveness of initial treatment, effect on production of germinable seed, side effects on non-target species, and residual effects. Residual effects can result in lower post-treatment seed production, pre-emergence control of new seedlings, or control of the first-year rosettes and new seedlings at the time of treatment. Chemical control of all types is most effective in the rosette stage and least effective after plants are fully bolted and have begun to flower (Roeth 1980, Durgan 1987, Feldman et al. 1968).

2,4-D ester at 2-4 lb/a (4.48 kg/ha) is the most commonly used herbicide because of its low cost (McCarty 1979, Durgan 1987). Application can be made aerially, with a tractor-mounted sprayer, with a backpack sprayer, or in granular form. Effectiveness of 2,4-D is dependent on application during favorable growing periods when temperatures are not too cool nor the weather too dry. For this reason, its effectiveness is often limited for early spring applications or for fall applications in Nebraska, where fall weather is often dry (Feldman et al. 1968). 2,4-D is most effective when applied 10-14 days before bolting in the spring (Nilson and Fick 1982). 2,4-D at low rates is less effective than picloram or dicamba after plants have bolted. However, seeds from plants treated at flower height during early or late bloom with 2,4-D ester at 2 to 4 lb/a (2.24 kg/ha to 4.48 kg/ha) produce seedlings with abnormal root development (McCarty and Hadding 1975).

Dicamba can be used to extend the control season into the spring earlier than 2,4-D. Feldman et al. (1968) found that 1 lb/a (1.1 kg/ha) of dicamba applied during favorable growing conditions provided the same control as 2 lb/a (2.2 kg/ha) 2,4-D. In another Nebraska study (Roeth 1979), .5 lb/a (.6 kg/ha) of dicamba provided between 90 and 100 percent control in the year of treatment for three successive years, but residual control in the second and third years fell to 36% or less. Granular applications of dicamba at 1 lb/a (1.1 kg/ha) in Carver County, Minnesota were ineffective in controlling first-year seedlings, although over 80% of second year plants were controlled (Strand et al. 1981). In another Minnesota study, spring application of .25 lb/a (.28 kg/ha) dicamba in combination with 2,4-D ester at .5 lb/a (.56 kg/ha) gave 97% control by the fall of the same year (Durgan and Breitenbach 1986).

Picloram alone or in combination with either 2,4-D or dicamba gives the best late-season control (Feldman et al. 1968, Roeth 1979) but is more expensive (Durgan 1987) and carries more restrictions. These include restrictions on use near groundwater and restrictions on the season of use (McCarty 1979). Feldman et al. (1968) found that .27 lb/a (.3 kg/ha) picloram under favorable spring growing conditions gave control comparable to 2 lb/a (2.2 kg/ha) 2,4-D. Higher rates were required in Minnesota, where Strand (et al. 1978) found control with picloram was ineffective at rates below .56 kg/ha. The greatest attraction of picloram is that it provides excellent control during the cool dry autumn season when neither 2,4-D nor dicamba is as effective (Feldman et al. 1968, Roeth 1979), and when non-targeted vegetation is less susceptible. Autumn applications of .14 kg/ha provide excellent control in Nebraska (Feldman et al. 1968). Although picloram overcomes the effects of weather, it does not fully overcome the effect of growth stage

(Roeth 1979, 1980). Recent studies indicate that picloram can provide effective control in uniform height, dense stands of musk thistle when applied with a ropewick applicator after bolting. However, control of bolted plants by this method was poor where plant growth was uneven (Jentes 1985). Picloram is highly persistent and provides the best residual control. Roeth (1979) found that rates of .06- 12 lb/a (.07 and .14 kg/ha) provided 90% control two years after application. Concomitant with its greater effectiveness, picloram presents a greater risk of damaging non-target species. Applications of 1 lb/a (1.1 kg/ha) resulted in injury to cool-season grasses (Reece and Wilson 1983), but it should be noted that this is a much higher concentration of picloram than was used in other studies.

Other herbicides that have been used for musk thistle control include hexazinone in Nebraska and New Zealand and DPX-L5300+ X77, Clopyralid, and Tryclopyr with 2,4-D in Minnesota. Hexazinone with 2,4-D amine provides effective control but caused considerable grass burn (Roeth 1981). Control by DPX-L5300+ X77 is poor at all concentrations but clopyralid gives good control at both .25 and .5 lb/a (.28 and .56 kg/ha). Control with Tryclopyr and 2,4-D ester is less effective (Durgan and Breilenbach 1986).

Musk thistles are prime candidates for integrated pest management in which cultural, mechanical, biological and chemical controls complement each other. Two studies have addressed the effect of herbicides on biological control agents. Rees (1977) found that the effect of 2,4-D on Rhinocyllus conicus varied with weevil density in Montana. As larval populations increase, survival decreased. Studies in Virginia found that treatment with 2,4-D did not adversely affect either Rhinocyllus conicus or Trichosirocalus horridus (Trumble and Kok 1982).

Management Programs:
The following persons are familiar with Carduus nutans (sensu latu) and can suggest control strategies:

Joe Gelroth, Site Superintendent, Konza Prairie Preserve, Kansas. (913) 539-1961.

Dr. Melvin McCarty, USDA-ARS, 62 Plant Sciences Hall, University of Nebraska, Lincoln, NE 68503.

Dr. Beverly Durgan, Extension Weed Specialist, Department of Agronomy, 1991 Buford Circle, University of Minnesota, St. Paul, MN 55108. (612) 625-8700.

Monitoring Requirements:
Management objectives may include eradicating populations, containing populations, or preventing establishment. Monitoring should be used to track the accomplishment of these objectives.

The best time to locate musk thistle populations is in early to mid-June when members of the Carduus nutans group can be easily identified by their large, nodding flowers (Gelroth 1987). Rosettes can be distinguished from April onwards.

Monitoring Programs:
Musk thistle has been monitored at Willa Cather Prairie, Nebraska (Nagel 1987) and at Konza Prairie, Kansas (Gelroth 1987). At Willa Cather Prairie, musk thistle populations have been mapped and tracked as part of a control program for several years. Monitoring at Konza Prairie has taken the form of records of numbers of plants cut down each year from 1978 to the present. The pasture with a history of most serious infestation is searched annually to see if the problem has redeveloped (Gelroth 1987).

Outside of natural areas, monitoring programs have been established to track the effectiveness of a variety of control measures. The following persons or facilities are involved in monitoring programs associated with control measures:

Dr. Beverly Durgan, Weed Control Specialist, Department of Agronomy, 1991 Buford Circle, University of Minnesota, St. Paul, MN 55108. (612) 625- 8700. Annual monitoring of herbicide test plots.

Dharma Sreenivasam, Minnesota Department of Agriculture. (612) 296-1350. Annual monitoring of weevil release plots.

VI. RESEARCH

Management Research Programs:
The major research project concerning the life history of musk thistle has been conducted by Dr. Melvin McCarty at the University of Nebraska. Although Dr. McCarty is retired, information regarding life history research can still be obtained from him. Contact: Dr. Melvin McCarty, 362 Plant Sciences Hall, University of Nebraska, Lincoln, NE 68583-0910.

The following contact is involved with investigation of biological control agents: Charles Turner, Biological Control of Weeds Laboratory, USDA, Albany, CA (415) 486-3408.

Persons listed in the Monitoring Section of this ESA are also involved in research programs.

Management Research Needs:
Almost all the research on musk thistle has concentrated either on the species autecology or on direct methods of control. Secondary effects of fire such as reduced litter or increased competition from warm-season grasses are a matter of speculation with no documentation (McCarty pers. comm., Fick pers. comm.). The most important research need in natural areas is probably the documentation of indirect effects of management practices on musk thistle populations.

The following contact people are involved in various types of research to control musk thistle:

Dr. Beverly Durgan, Extension Weed Control Specialist, Department of Agronomy, University of Minnesota, St. Paul, MN. (612) 625-7262. Dr. Durgan is investigating effects of season of treatment for various cutting regimes, labelled and unlabelled herbicides in southeastern Minnesota.

Dr. Ernst Horber, Department of Entomology, Kansas State University, Manhattan, Kansas. Dr. Horber has an active weevil release research project for biological control of musk thistle.

Dr. Walt Fick, Department of Range Management, Kansas State University, Manhattan, Kansas. (913) 532-7223. Dr. Fick's research is mainly on the effects of herbicides, but he has been interested in fire research as a method of facilitating herbicide application. His desire to pursue research on fire and musk thistle was limited by difficulties in locating a thistle-infested research site where fuel was sufficient to support a fire (Fick pers. comm.).

## VII. ADDITIONAL TOPICS

## VIII. INFORMATION SOURCES

Bibliography:

## IX. DOCUMENT PREPARATION & MAINTENANCE

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