# ELEMENT STEWARDSHIP ABSTRACT
for

# *Populus spp.*

## North American invasive poplars/aspens

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# The Nature Conservancy
# Element Stewardship Abstract
# For *Populus* spp
# (North American invasive poplars/aspens)

Common-Name: aspen

Description:
The following descriptions are taken from Barnes and Wagner 1981 and Rosendahl 1970. Further taxonomic description is available in these texts.

Populus balsamifera is a shade-intolerant tree 6-30 m high with gray or greenish bark that becomes darker and furrowed on older trunks. Resinous buds are large; twigs are stout and lustrous turning gray-green with age. Alternate simple leaves are ovate-lanceolate or cordate-ovate with acute or acuminate tips and finely crenate margins. The aromatic leaves are glabrous and dark green above, and pale silver or rusty brown beneath. Staminate catkins are 3-5 cm long; pistillate catkins 3-5 cm long. The fruit is an ovoid capsule 7-9 mm long. Balsam poplar has numerous shallow spreading roots and forms clones.

Populus grandidentata is a shade intolerant tree 10-20 m high with smooth gray tan or yellowish-green bark that becomes furrowed and darker with age. Stout twigs are white tomentose becoming reddish brown to greenish-gray with age. The alternate leaves are ovate and coarsely sinuate-toothed. Young leaves are densely white tomentose beneath; older leaves are glabrous, yellow green or dark green. Young suckers often have larger leaves than mature plants. Staminate catkins, 4-7 cm long, are silky pubescent; pistillate catkins are 3-5 cm elongating in fruit to 10-15 cm.

Bigtooth aspen has a wide spreading lateral root system with larger and fewer roots than P. tremuloides, and sinker roots (vertically penetrating roots) to 3 m. This species forms clones by root-suckering. Suckers are distinguishable from seedlings because they have a thickening that develops on the distal side of the parent root next to the sucker (Maini 1972).

P. tremuloides is a shade intolerant tree 6-20 m high with smooth greenish-white or gray bark, turning darker and slightly furrowed with age. Twigs are slender, glabrous and reddish-brown, turning gray with age. The thin, alternate leaves are ovate to orbicular, truncate or sub-cordate at the base and short acuminate at the tip. Leaves are glabrous when mature, have finely serrated margins, and range from bluish to dull green in color. Young suckers frequently have much larger leaves than older plants. Staminate catkins are 3-6 cm long with silky hairs. The fruit is a capsule about 5 mm long. This species is typically clonal, with suckers arising from extensive lateral roots. Quaking aspen has "sinker roots" like bigtooth aspen and distinction between seedlings and suckers is the same as with P. grandidentata.

Elements included in EMG:
Populus balsamifera
Populus tremuloides
Populus grandidentata

## II. STEWARDSHIP SUMMARY

The goal of aspen management on Midwest prairie preserves is the prevention of aspen invasion from forest borders and isolated clones, and may include complete elimination of large clones. Intense shading prevents the establishment of grasses and prairie forbs within an aspen clone. If left alone, the clones will continue to grow and spread into the prairie through vegetative reproduction. Although aspen can be top-killed by fire, the lack of fine fuels and the moist, shady microenvironment inside a clone create an extremely fire-resistant situation.

Standard control procedures include prescribed burning, brushcutting or mowing of small suckers, cutting or girdling larger trees and herbicide application. Repeated burning, apparently at any time of the year, effectively reduces aspen cover, and can reduce large clones to patches of small suckers if the canopy is opened by mechanical or chemical means and fine fuels allowed to grow inside the clones. Burning or cutting when carbohydrate reserves are lowest (June to early July) may be more effective than earlier or later when reserves are higher. Fall burns may be more effective than early spring burns because the soil and fuels are likely to be drier. Cutting suckers on the clone periphery allows more sunlight to enter the clones and enough fine fuels may grow to carry a fire at least part of the way inside. Repeating this procedure over a number of years should lead to eventual elimination of the clone. To speed up the process, large trees may be cut and stacked at the clone center or girdled and left standing. Cutting trees is labor-intensive and will cause substantial suckering. Summer cutting (June-early August) will stimulate fewer and less vigorous suckers than cutting at other times of the year. Girdling trees will cause eventual death, further opening the canopy, and will also prevent suckering if performed carefully. Herbicides, particularly cut stump and basal applications of 2,4-D or triclopyr, can be very effective at controlling aspen but may be considered unnecessary where cutting and/or girdling in conjunction with burning is adequate. Research is being conducted on the use of goats to remove suckers and to girdle trees in large clones, and on the injection of an aspen fungus that kills the trees by attacking the phloem.

## III. NATURAL HISTORY

Range:
Most of the following range description is taken from Fowells, H.A., compiler, 1965, Silvics of Forest Trees of the United States, USDA Agriculture Handbook No. 271.

P. balsamifera: Newfoundland, Labrador to northwest Alaska, northeastern British Columbia, east through Alberta, northern portions of the Great Lakes states, northern New England, and locally from Iowa to Connecticut and in the Rocky Mountains.

P. grandidentata: Nova Scotia to Manitoba, south to northeastern Missouri, east to Virginia, and locally in the eastern United States.

P. tremuloides: Newfoundland, Labrador to southern Alaska; British Columbia through Alberta to New Jersey. Locally in Virginia, Missouri and mountains of western United States and northern Mexico.

Habitat:
Climatic conditions vary throughout the ranges, but are often characterized by low seasonal temperature provided by high altitudes or northern latitudes, and short growing seasons.

Most of the following habitat description is taken from Fowells, H.A., compiler, 1965, Silvics of Forest Trees of the United States, USDA Agriculture Handbook No. 271.

P. balsamifera most frequently grows in moist soils of various textures including subirrigated sandy and gravelly soils, calcareous clay loams, or silt loams. It grows at elevations from sea level to about 5,500 feet (1,676 m). It is usually found in cool lowlands such as alluvial bottoms, sandbars, stream banks, lake shores and swamps. It grows in pure stands or in the following forest types: aspen, balsam fir-paper birch, white spruce-balsam fir-paper birch, black ash-American elm-red maple, aspen-birch, white spruce-aspen, and black cottonwood-willow (Fowells 1965).

P. grandidentata is usually found on drier sites than the other two species, at elevations from 500 to 2,000 feet (152 to 660 m). Soil textures include sand, loamy sand, light sandy loams, and, less frequently, heavier textured soils. High water tables closer than 18" (45.7 cm) to the surface reduce aeration, and increase chances of windfall (Fowells 1965). It is most commonly associated with quaking aspen, gray birch, paper birch and red maple.

P. tremuloides tolerates a wide range of soil conditions from rocky soils or loamy sands, to clay soils. The most favorable soils are porous, and loamy soils that have abundant lime and humus. Growth in clay soils is reduced because of poor aeration; growth in sand is poor because of low moisture and nutrient levels. Rocky soils can hinder the spread of lateral roots. Quaking aspen grows at elevations up to 5,800 feet (1768 m) in the north, and rarely below 8,000 feet (2438 m) in lower California. It grows at sea level only as far south as Maine and Washington. In the southwest United States, quaking aspen often grows in cool shaded mountain slopes, canyons, and on stream banks, at about 6,500 to 10,000 feet (1981 to 3048 m) in elevation. It grows with other aspens and often in the following forest types: Jack pine-aspen, white spruce, balsam fir-aspen, black spruce-aspen, aspen-paper birch (Fowells 1965).

## ECOLOGY:

### SEXUAL REPRODUCTION:

Flowers of all three species appear before leaf expansion, usually in April or May. Phenology varies between clones, with air temperature, and geographic locations (Maini 1972). Following wind pollination, fruits ripen in May or June and are dispersed by wind or water May through July. The light seeds have a silky hair aiding in dispersal. P. grandidentata flowers, fruits, and disperses fruit about ten days later than P. tremuloides in Ontario (Maini 1972).

Most aspens are capable of flowering at ten years (Maini 1972) and 20 year old trees of P. tremuloides and P. grandidentata produce good seed crops every four or five years (Fowells 1965). A 23 year old P. tremuloides tree 33 feet tall in Ontario produced 1.6 million seeds (Maini 1972). Under favorable natural conditions, seeds of P. grandidentata and P. tremuloides maintain viability up to two or three weeks. P. balsamifera seed is viable for a few days (Fowells 1965).

### ASEXUAL REPRODUCTION:

In established aspen clones, root suckering accounts for most reproduction of the three species. Stump sprouting is less frequent. Suckering sometimes occurs within undisturbed clones, but survival is low. Suckering is most profuse following top removal, and removal of other cover species by cutting, fire, windthrow, and disease. Tens of thousands of suckers per hectare follow clearcutting of P. tremuloides and P. grandidentata (Perala 1981). Plants as young as two years old, and both male and female plants are capable of suckering (Fowells 1965). In Michigan, P. grandidentata produces a maximum number of suckers at age 40; P. tremuloides at age 35 (Graham et al 1963). Number of suckers and length of time required for their initiation varies between clones in P. tremuloides (Barnes 1966) and P. grandidentata (Garrett and Zahner 1964).

Suckers arise from adventitious buds produced on an extensive lateral root system that rises and falls just below the soil surface. Some suckers arise from dormant buds; most suckers are from buds initiated the same season. These buds form where the parent root is closest to the soil surface; usually in the top 5.1 to 7.6 cm of soil, and often above mineral soil (Sandberg 1951). P. grandidentata suckers originate about 5 cm deeper than P. tremuloides suckers (Perala 1974a). Parent roots usually are .76 to 1.78 cm in diameter in P. tremuloides (Sandberg 1951), and range from .51 to 11.43 cm in P. grandidentata (Maini 1972). In P. tremuloides, suckers most often arise at intersections of lateral branch roots, in underdeveloped branch roots, in irregularities in roots, and as an injury response (Sandberg 1951).

Sucker initiation and growth is influenced by growth regulator levels, carbohydrate levels, light, and temperature. Root suckering of Populus species is inhibited by the auxin effect of apical dominance (Farmer 1962, Eliason 1971, Schier 1973). Auxin production is highest in apical buds during maximum spring shoot elongation, usually in June, and translocation of auxin to the roots inhibits suckering. Removal of the above-ground plant portion in June or July after maximum auxin production results in fewer suckers than top-removal during the dormant season. Suckers formed early in the season also exhibit apical dominance by reducing the number and success of suckers formed later in the same season (Schier 1972). Seasonal variation in suckering is probably also influenced by other growth regulators including cytokinins and gibberellins (Schier 1972). Cytokinins produced in the roots stimulate suckering (Schier 1981).

Parental root carbohydrate reserves do not affect the number of suckers initiated, but do influence early sucker success. Following initiation, suckers are dependent on parental root reserves until they emerge above the soil and produce their own photosynthates (Schier and Johnston 1971). Root carbohydrates are lowest in aspen clones after leaf flush (Tew 1970) and remain low until late July (Schier and Johnston 1971). Both root carbohydrate reserves and early photosynthates are used during this time, primarily for shoot elongation and cambial activity. In Wisconsin, maximum cambial activity in P. tremuloides is in late May and early June. Rates decrease rapidly in July until, in late July and early August, no cambial cell division occurs (Davis and Evert 1968). In a study of P. tremuloides (cuttings) in Alaska and Utah, root carbohydrates were found to significantly increase in late July to a maximum level about September first, and then decreased slightly with leaf senescence (Schier and Zasada 1973). Because of this seasonal growth pattern, suckers that initiate growth before maximum shoot growth probably benefit most from carbohydrate reserves in parental roots. Amount of sucker initiation increases with abundant light (Zehngraff 1949) probably because of increases in soil temperature. In one study, root cuttings of P. tremuloides formed roots most readily at 74 degrees F (23 degrees C), and burning and clear-cutting resulted in increased soil temperature and sucker formation (Maini and Horton 1966b). The heat absorption by blackened soil following fire may increase the number and height of suckers (Shirley 1931,1932). In Alberta, drought and high soil temperature in one season increased sucker invasion by P. tremuloides the next season (Bailey and Wroe 1974). Diurnal temperature fluctuations possibly increase sucker initiation (Maini and Horton 1966b).

SEEDLING ESTABLISHMENT: Seeds of these species germinate readily within a day or two of dispersal if they reach an exposed moist site. Alluvium or the exposed mineral soils following fire are appropriate sites for establishment (Weigle and Frothingham 1911). P. tremuloides and P. grandidentata are capable of germinating while submerged in water, and at temperatures between 32 degrees F (0 degrees C) and 95 degrees F (35 degrees C) (Fowells 1965). Under controlled conditions, 80-95% germination is possible, but germination is less under natural conditions. Maini (1972) gives the following reasons for seedling failure of P. tremuloides and P. grandidentata:

1. Short seed viability
2. Presence of a water-soluble germination and growth inhibitor in the seed hair
3. Inadequate moisture conditions on upland sites
4. Susceptibility of seedlings to high temperatures possible on soil surfaces blackened by fire
5. Fungal pathogens
6. Diurnal temperature fluctuations hindering early seedling growth
7. Unfavorable chemical composition of substrate (e.g. high pH, high salt concentrations)

SUCKER ESTABLISHMENT:
Early sucker growth and survival depends primarily on time of sucker initiation, root connections to parent roots, and ample light. The most numerous, tallest and competitive suckers are produced when above-ground portions are removed during the dormant season. Summer top-removal results in short suckers that compete poorly with shrubs, herbaceous species (e.g. Pteridium aquilinum (L.) Kuhn.) and overstory species (Perala 1972). They are also susceptible to winter injury (Zehngraff 1949). However, top removal in the summer results in continued suckering the next season, so that by the end of the second season, the effects of top-removal are sometimes negligible (Graham et al 1963).

Suckers depend primarily on parent roots during the first season of growth (De Byle 1964) when adventitious root production by suckers is low. The number of root interconnections between suckers and parents decreases with age. After two to five years P. tremuloides has self-sustaining roots and root connections to parents either may be destroyed by rotting or remain indefinitely (Sandberg 1951). P. grandidentata depends partially on parent root functions for 25 years but relies more heavily on adventitiously produced roots after the first six years of sucker establishment (Barnes 1966, Zahner and De Byle 1965).

All three species require abundant light for early growth. In green-house tests of P. tremuloides cuttings, the maximum light level tested stimulated the most root development, secondary growth, and consistent height growth of suckers (Sandberg 1951). Under full sunlight, dominant suckers of P. tremuloides and P. grandidentata can grow 4 feet to 8 feet (1.22 m to 2.43 m) the first season. Growth rate of suckers is rapid for about five years after clearcutting. Then rates slow as suckers compete for light and moisture (Graham et al 1963). An aspen stand initially producing 40,000 suckers/A can be reduced to 1,000 to 1,500/A in 30 years (Maini 1972).

Growth of P. tremuloides is influenced by its capacity for bark photosynthesis. Schaedle and Foote (1971) found that 5 and 6 year old suckers in a clone provided 5 to 10% of total plant photosynthetic activity by bark photosynthesis.

P. tremuloides is less drought tolerant than P. grandidentata. The moisture stress response of stomatal closure occurs much slower in quaking aspen than in bigtooth aspen (Tobiessen and Kana 1974). This probably limits its habitat to areas of ample moisture or reduces growth during drought.

CLONES:
Asexual reproduction results in a group or clone of suckers that has its origin in a seedling established tree (the ortet). The clone is composed of genetically identical stems (ramets) that often remain interconnected by roots to form a single functional unit (Blake 1963).

Clones of both P. grandidentata and P. tremuloides are usually small. In the Great Lakes states, clones of .04 to .08 ha are common (Perala 1981, Barnes 1966). Larger clones have been recorded in Utah (10.1 and 43.3 ha) and the southern Rocky Mountains (81 ha) (Perala 1981).

Intraclonal ramets are of the same sex, have similar bark color, leaf forms, branching habits, and disease and insect pest susceptibility (Barnes 1966). Phenological patterns including time of leaf flush and fall coloring are also similar, with slight variations from the center to the edge of a clone (Barnes 1969). This intraclonal similarity of ramets is useful in distinguishing one clone from another where clones intermix.

Interclonal differences include ramet density, ability to sucker, and growth rate (Barnes 1969). Clone profiles indicate ramet origin or topographical variations. Truncated clone profiles usually indicate simultaneous ramet origin (fire, windthrow, clearcutting). Dome-shaped clones result when suckering occurs at the periphery, especially into open sites such as grasslands. Wavy or notched clones usually indicate specific limits to expansion (severe slope, soil texture changes, fluctuating water levels, blowouts, etc.) (Maini 1960).

Expansion at the clone periphery is encouraged by favorable moisture, abundant light, and lack of competition by other ramets (Barnes 1966). Ramets on the periphery usually lack taproots or "sinker roots". In prairies the superficial aspen roots are mixed in the upper soil layers with grass and forb roots. Clones can function opportunistically by expanding under optimal growing conditions, and contracting under stress.

ALLELOPATHY: There is some evidence of aspen allelopathy. Freshly fallen leaves of P. tremuloides have been shown to decrease early growth of Festuca elatior, F. rubra and Poa pratensis (Younger et al 1980). Jobidon and Thibault (1981) showed that extracts of various parts of P. balsamifera (leaf litter, fresh leaves, buds) variously inhibited germination, radicle and hypocotyl growth of Alnus crispa.

Impacts:
Aspen invasion of grasslands especially at the prairie-forest border has increased primarily because of fire suppression (Buell and Buell 1959, Maini 1960, Blake 1963). In Saskatchewan, Maini (1960) found that the age of the oldest P. tremuloides corresponded to dates of post-settlement fire suppression. Aspen groves that were present in the prairie just prior to that time often were of small, brush-like trees instead of tall specimens. Increased wetland drainage probably also has encouraged aspen invasion (Buell and Facey 1960)

Undisturbed aspen clones expand into adjacent prairie when light, moisture and soil conditions are appropriate especially for vegetative growth (Maini and Horton 1966b). Vigorous root suckers emerge in the prairie at the periphery of a clone, where other woody plants also frequently invade the prairie. As these suckers grow, and crowns coalesce, aspen shades out desirable grassland species.

Rate of invasion is related to disturbance, clone phenotype, slope, wind, moisture, drainage, soil texture and climate. Some examples of invasion rates include:

1. 11 m in 15 years (P. tremuloides) upslope into a dry prairie from a ravine woods, parallel with wind direction (Wisconsin) (Chavannes 1940).

2. An average 1.5 m per year for 23 years (P. tremuloides) in a low rolling prairie near the prairie forest border in Minnesota (Buell and Buell 1959).

3. 10 m in 10 years (P. grandidentata) on a hillside (Indiana) (Duncan 1935). 4. 18 m in about 25 years (P. tremuloides) following a peat-burn in a southern Wisconsin marsh (Vogl 1969).

Aspen persists in prairie regions because of its preference for full sun and its vigorous vegetative reproduction and clonal growth that is well-adapted to top removal (fire, cutting, browsing) and drought.

## IV. CONDITION

Threats:

PESTS AND DISEASE: Populus spp. have many natural enemies. The forest tent caterpillar, Malacosoma disstria, is one of the most important insects to attack bigtooth and quaking aspen. It will feed on foliage of balsam poplar only when that of the other two species in the same area has been completely destroyed. The poplar and willow borer, Cryptorhynchus lapathi, is the most serious insect pest of balsam poplar and causes considerable mortality of saplings (Fowells 1965). The fungus Marssonia populi induces a leaf and twig blight of P. tremuloides that periodically becomes epidemic over extensive areas of the northwestern U.S. Clones vary in their susceptibility to the disease, and may become anywhere from only slightly damaged to entirely defoliated. The last reported epidemic occurred over large areas of northeastern Utah, southeastern Idaho, and western Wyoming (Harniss and Nelson 1984).

The most serious diseases of quaking and bigtooth aspen are the wood-rotting fungi and cankers. Fomes ignarius is a wood-rotting fungus that attacks these species throughout their range, causing decay of heartwood and sapwood (Fowells 1965). Hypoxylon canker is widely distributed in the Northeast and Lake States and causes heavy losses of aspen in these regions. French (pers. comm.) stated that perhaps 15-20% of all trees in the Lake States are infected with Hypoxylon. The Hypoxylon fungus attacks the phloem, and kills the tree within 2-4 years of initial infection (French pers. comm.). Bigtooth aspen is less frequently attacked than quaking aspen, and infection in the balsam poplar has so far been negligible (Fowells 1965). More information on the numerous pests and diseases of aspen is available in forestry literature (e.g. Graham et al. 1963, Fowells 1965, and USDA Forest Service Gen. Tech. Rep. HCl 1972). Moderate browsing by mammals such as deer causes little permanent damage to suckers. Mice, voles, and rabbits can girdle suckers, and beaver frequently cut larger trees.

## V. MANAGEMENT/MONITORING

Management Requirements:
Goals of aspen management vary according to preserve or to specific rare species protection. This Element Stewardship Abstract pertains mostly to prairies where management most often has recovery and maintenance phases. Recovery involves intense initial aspen reduction followed by scheduled maintenance of desired stand density, structure, etc. In other cases, elimination, containment or rejuvenation of aspen are possible goals.

Aspen clones present a problem for management with fire because they shade out the understory creating a moist microclimate with little or no fine fuels to carry a fire. Even a fairly intense prairie fire can easily die out at the edge of an aspen clone (Johnson pers. comm.). In clones with large trees, the challenge for management is to remove the canopy and allow more light to penetrate the understory so that enough grasses and other fine fuels can grow, enabling a fire to spread into the clone. Two methods for tackling aspen clones on prairies managed with prescribed burning are presented below, followed by a more detailed discussion of burning, cutting, girdling, herbicide application, and biological control procedures.

1. A good way to eliminate aspen clones in theory is to mow or brushcut suckers at the clone periphery, use a chain saw to cut down larger trees, pile all the brush and trunks at the clone center and allow them to cure for a year, then run a fire through the following year. In practice this is possible, but it is extremely labor intensive, dangerous (even for those well-trained in the use of chain saws) and expensive (Cochran 1984, Johnson pers. comm.).

2. A more feasible, although slower, method than No. 1 above is to remove only the suckers on the clone periphery that can be mowed or brushcut. This will allow for some sunlight penetration and growth of fine fuels inside the clone, and a prescribed burn the following year should penetrate at least a short distance into the clone interior. Repeating this procedure over a number of years, depending on the initial size of the clone, will continually decrease clone size and may eventually eliminate all the larger trees. Modifications of this procedure include girdling large trees

(theoretically reducing canopy cover and preventing stimulation of suckering at the same time), the use of herbicides to kill larger trees or to kill trees and suckers alike, the use of goats (that's right, goats) to accomplish sucker removal and girdling of larger trees, and possibly the injection of an aspen fungus into larger trees to weaken and kill them.

## BURNING:

A single burning of established aspen in the dormant season most often increases the number of suckers, but sometimes reduces sucker vigor. Perala (1972) reported an increase in aspen suckers from 17,000/A to 24,000/A after a dormant season burn of a forest. Perala (1974b) found that fall dormant season burning increased the number of aspen suckers, but decreased vigor as measured by volume growth. Repeated burning, apparently whether conducted in a dormant season, late spring or summer, is effective at reducing aspen invasion into prairies and grasslands. Buckman and Blakenship (1965) found that repeated dormant spring burning can reduce both number and vigor of aspen suckers. In a Minnesota study, the number of suckers was reduced by 68% in plots burned in two successive years, 86% in plots burned three years, and 94% on those plots burned four years as compared to the number of suckers after one burn. They recommended leaving 2-3 year intervals between fires so that additional fine fuels can develop and dead aspen can break down and become available as fuel. Plots burned three times with 2 year intervals between the burns were nearly free of aspen suckers. They cautioned, however, that it is important that all of the standing aspen be killed by the first fire or by other means, otherwise these trees will sucker abundantly when killed by subsequent burns (Buckman and Blakenship 1965). Perala (1974a) suggested that spring dormant season burns are less successful than fall because high ground moisture, matted leaves and herbaceous matter result in poor burn coverage.

Svedarsky et al. (1986) reported a reduction in aspen suckering from both biennial and annual spring burns over a 13 year period, with suckers reaching their lowest densities 5-6 years after the onset of burning. From 1971 to 1983, suckers declined an average of 62.5% in annual burn plots, 57% in biennial burn plots and 41% in no burn controls. Sucker shoots in the no burn controls were larger than in the burn plots and decreased in density due to competitive shading, which also adversely affected the composition of the understory grasses and forbs. They suggested that more effective control could be achieved by severing the lateral roots from the parent trees at the edges of aspen stands in the prairie, since the fires did not carry into these stands and the parent trees were able to supply nutrients to sucker shoots (Svedarsky et al. 1986). Preliminary data on summer burning from Svedarsky et al. (1986) suggests that summer burns might be more effective at controlling aspen invasion than spring burns. A plot burned June 16, 1980 and again on June 6, 1983 showed a 76% decrease in sucker shoots whereas plots burned once (June 16, 1980) showed an average increase in suckers of about 70% (Svedarsky et al. 1986). Biennial burning was recommended over annual burning because it provides comparable aspen control and stimulation of native grasses, and the work is reduced by half. Burning in later spring (or summer if feasible) was recommended over earlier spring burns because both aspen and Kentucky bluegrass (Poa pratensis) have lower carbohydrate reserves later in the season making them more susceptible to injury from fire (Svedarsky et al. 1986). Clones in which the larger trees are killed by girdling and/or herbicide application and are left standing present a safety problem when burned in that they throw fire brands, especially if there is a good wind. Johnson (pers. comm.) considered this less of a safety hazard than using chain saws to cut the trees down, however.

## CUTTING:

Cutting in summer after leaf expansion will stimulate fewer and less vigorous suckers than cutting at other times of the year. Four and a half years after a June clearcutting of aspen in Wisconsin, 30% to 70% fewer suckers were initiated as compared to the original number of stems (Stoeckler 1947). Plants cut in early August showed slightly greater reduction in sucker size and weight over those cut in June, both of which showed substantial reductions in sucker size and weight over December and April cuttings. Cutting for sucker reduction is probably effective until active cambial growth ceases in late July or early August. Stoeckler (1947) attributed the success of summer cutting (June through August) to low root carbohydrate reserves and adverse weather conditions for sucker survival in late summer and over winter. Numerous forestry recommendations advising dormant season cutting, girdling and shearing to maximize suckering and coppicing also indicate that summer cutting can reduce sucker growth (Perala 1981, Perala 1983, Zehngraf 1949, Ek et al. 1983, Strong and Zavitkovski 1983, Graham et al. 1963).

Cutting methods may influence sucker survival. Stoeckler (1947) experimented with cutting at different heights and observed no appreciable difference in the amount of sprouting from stumps cut to 36 or to 12 inch heights in June, whereas cutting in a dormant season (December or April) presented a marked advantage for reduction in suckering by cutting 36 inch stumps. Stoeckler (1947) also found that a double cutting of stems in June, first at 36 inches then at 12 inches after two to 24 hours, resulted in fewer suckers than a single cutting when measured 5.5 years after cutting. However, Kline (1983) cut 22 P. grandidentata stems 1.5 to 3.5 cm in diameter on August 13 at 11 a.m. and again at 3 p.m. and found 26 resprouted suckers the following August. Similar cuttings of P. tremuloides also resulted in more numerous shoots than found originally (Kline 1983).

Haglund (pers. comm.) recommended cutting suckers twice in one season, once in June and again in August for maximum reduction in sucker survival over winter. The August cutting is critical because suckers that sprout at the end of the season will be particularly susceptible to frost and many may not survive the winter. Haglund (pers. comm.) also found hand pulling of aspen suckers to be very successful on sandy soils. He reported being able to pull up the entire main root mass, perhaps 25 feet long, of young suckers by simply squatting down and pulling them up from the base of the shoot.

GIRDLING:

Girdling trunks is another method of controlling resprouting while eliminating larger trees. Girdling removes the phloem, which is part of the bark, but does not affect the xylem. The roots will continue to move water and minerals up to the tops through the xylem, but the leaves will be unable to translocate photosynthate back down to the roots. The leaves will stay green and look healthy, but there will gradually be fewer of them as the root reserves are used up. Since suckering is controlled largely by physiological processes occurring in the tree tops (shoot apical meristems), as long as the tops are still there and apparently healthy the roots are "fooled" and do not sprout suckers. By the time the leaves and tops die back (the normal signal for suckering to occur), the root reserves are depleted and unable to support suckers.

Girdling can be accomplished using an ax or saw and surrounding the trunk with two parallel cuts about three inches apart, cutting in through the bark slightly deeper than the cambium (where the xylem, or wood inside the bark, begins). The bark is then knocked out between the cuts with a blunt object, such as the back of an ax (Packard 1985). Bob Djupstrom (pers. comm.) recommends using a leaf spring sharpened on one side, called a "spud", which is jammed through the bark and used as a pry bar to easily twist off large sheets of bark. Girdling with a spud or any other method is most easily accomplished when the sap is readily flowing, usually just as the leaves are emerging.

Girdling has been used with somewhat mixed results. Packard (pers. comm.1987) reported that it was by far the most effective method for preventing resprouting; if performed correctly there will be zero resprouting. All of the trees larger than about two inches dbh should be girdled and then checked several weeks later to ensure that the girdles are complete. The smaller suckers should be cut at about the same time (within a month or so of the girdling) to prevent them from replacing the parent trees in later years. Girdling, in conjunction with cutting small suckers, has been so effective in Illinois that herbicides are no longer used to control aspen, and Packard (pers. comm. 1987) even recommended eliminating a clone of small stems (less than 1.5 inches dbh) by cutting half of them and allowing the other half to grow until they are large enough to girdle.

In Minnesota, Winter (pers. comm.) compared suckering response in two clones that were clear cut with another clone in which all suckers less than three inches dbh were cut and all larger trees were girdled (a three to four inch wide strip of bark cut out of the trunks with a hatchet). The first year the girdled clone suckered less than the clearcut clones, but the following year there were many suckers in both clearcut and girdled clones. One reason for the limited success in suppressing suckering in this experiment could be that some small trees capable of suckering were cut along with the rest of the suckers in the small dbh class, instead of being girdled with the larger trees. It must be remembered that plants as young as two years are capable of suckering, and that dominant suckers can grow 4-8 feet tall in one season. Packard's success (see above) could be due to the fact that he girdled all trees larger than about 2 inches dbh, whereas Winter was apparently cutting this size tree and girdling only those larger than 3 inches dbh.

In Wisconsin, Haglund (pers. comm.) reported excellent control of suckers five years after girdling at one experimental site, but suckering occurred at some sites where dying tops broke off of girdled trees apparently before root reserves were well-depleted. In sandy Ohio soil, Huffman (pers. comm.) reported moderate control of suckering after girdling all trees larger than about 3 inches dhb in several clones of P. tremuloides and P. grandidentata. The clone with the greatest reduction in suckering was a P. gradidentata clone, which was girdled in 1986 and burned in May of 1987.

Care must be taken when girdling to avoid cutting too deep, which causes damage to the xylem sapwood and premature toppling of the trees, and to avoid incomplete girdling, which leaves some of the phloem intact. Johnson (pers. comm.) cautioned against using a chain saw for girdling as the cuts tend to be made too deep. Care must also be exercised with an ax or hatchet: cuts should completely remove the bark in a 3-4 inches wide strip around the trunk but, again, should not be made deep enough to damage the sapwood. A spud may be the easiest method for removing large strips of bark without damage to the sapwood, although it has not been tested. The Minnesota TNC Field Office will be experimenting with this method in 1988.

HERBICIDE USE:
Some examples of herbicides used for aspen control are summarized below:
1) 2,4,D
2) picloram and 2,4-D
3) glyphosate
4) hexazinone
5) triclopyr
6) AMS. Basal injections or basal bark applications are particularly good means of controlling aspen with herbicides because application is relatively easy and avoids injury to other species.
1.Foliar spray: Friesen et al. (1965) recommended applying sprays at full leaf expansion, and increasing concentrations or repeating spraying of 2,4-D to control the more resistant P. balsamifera. For foliar sprays , 3 lbs of 2,4-D ester in 20 gallons of water is recommended. In Manitoba, a water solution of 2,4-D applied as an aerial spray in August showed 75% topkill of both P. balsamifera and P. tremuloides (Pratt 1966). There was no suckering in P. tremuloides; 8% suckering in P. balsamifera. In the aspen parklands of Alberta, aerial spraying of 2,4-D effected an increase in herbaceous species along woodland edges, but did not effectively control P. tremuloides growing in woods (Hilton and Bailey 1974). Bailey and Anderson (1979) found a combination of burning and foliar application of 2,4-D more successful than either burning or spraying alone for control of balsam poplar and quaking aspen. P. balsamifera and P. tremuloides burned in May, then sprayed six weeks later with 2,4-D ester in diesel oil resulted in 96% topkill of balsam poplar and 88% topkill of quaking aspen. After five years the burning followed by spraying treatment was most effective in causing a downward shift in distribution of tree size classes. Burning stimulated suckering, but the follow-up herbicide application reduced suckers and small stems (Bailey and Anderson 1979).

Basal application: Friesen et al. (1965) recommended year-round application of 1.5 lbs of 2,4-D ester in 10 gallons fuel oil as a basal spray applied on stems from ground level up to two feet. Arend (1953) found that growing season applications were more effective than dormant applications. Dormant season applications did not control suckering. In New York, herbicides defoliated P. grandidentata and P. tremuloides trees 4 to 8 inches dbh but had less effect on larger trees (8-12 inches dbh) perhaps because chemical amounts were too low to penetrate the thicker bark of older trees (Morrow 1953).

Tree injection: 10% solutions of 2,4-D in diesel oil applied in June to complete girdles of aspen Populus cf. tremula L. completely topkilled trees a year later and killed newly formed suckers (Il'in 1964).

2. A mixture of picloram + 2,4-D provides excellent aspen control as a foliar or stump spray when applied during the growing season.

Foliar sprays: In studies of P. tremuloides and P. balsamifera, Sharma and Vandenborn (1970) found greatest foliar penetration in June and July, and at higher relative humidity and higher temperatures (greater penetration at 40.5 degrees than 10 degrees or 25 degrees C). Removal of cuticular waxes and addition of a surfactant increased penetration. Bowes (1981) found in Saskatchewan that a combination of 2,4-D (2.2 kg) + K salt of picloram (0.5 kg) in a water solution sprayed at full leaf stage of P. tremuloides controlled aspen regrowth one or two years after application. In Minnesota, a water mixture of 0.5 lbs picloram + 2 lbs 2,4-D at 2 lbs a.i./A (active ingredient per acre), was sprayed on foliage on the first or the 20th of August. A year later, both treatments showed little resprouting, but the earlier treatment showed greater topkill (97%) than the later treatment (77%) (Perala 1971). Aerial spraying in

July with picloram (0.5 lbs) + 2,4-D (2 lbs) per gallon (2.5 lbs a.i./A) in Minnesota resulted in 47% resprouting of P. tremuloides (Perala 1980). Another Minnesota aerial spraying of P. tremuloides with an aqueous mixture (10 gal total volume/A) of 1 lb picloram + 4 lbs 2,4-D in mid-July, followed by a May burn resulted in 100% topkill with little resprouting 15 months after the burn (Perala and Williams 1970).

Stump sprays: Stump sprays of picloram + 2,4-D at 2.5 or 5.0 lbs ahg (total acid equivalent per 100 gallons) between July 25 and August 17 in Minnesota provided more control than the same treatment in the dormant season (March). Summer treatments resulted in 512 suckers/A; dormant season treatment resulted in 3,980 suckers/A (Perala and Sorenson 1979).

3. Glyphosate sprayed on P. tremuloides on August 22 in Ontario at rates of 2.24 kg a.i./ha, 4.48 kg a.i./ha and 13.42 kg a.i./ha resulted in complete control when plots were evaluated the following two years (Sutton 1978). Grossbard and Atkinson (1986) state that glyphosate is generally less effective for control of root sprouters like Populus spp. than for stump sprouters like Fraxinus and Betula spp. Chappell et al. (1979) reported more effective control of several woody species, including Populus, with glypohsate compared to picloram plus 2,4-D. Herbicides were applied as foliar sprays in Sept. 1977 and results evaluated in Oct. 1978 (Chappell et al. 1979).

4. June applications of hexazinone as 10% active pellets handspread at 2 lbs/A on P. tremuloides, P. grandidentata and P. balsamifera resulted in about 70% defoliation three months later on fine textured soils, and about 80% to 90% defoliation on coarse textured soils (Harris 1980).

5. Triclopyr as a 1% diesel oil basal spray (18-24 inches of stem above soil) applied to Populus spp. April through June in California provided 100% control (Warren 1980). Weidenfeller (1987) reported that triclopyr as a basal application (20% herbicide in fuel oil or other bark penetrating agent) provided excellent control of most woody weeds, including Populus spp. In Minnesota, triclopyr applied as an aerial spray at 1.5, 3.0, and 4.5 lbs a.i./A resulted in limited topkill and 100% resprouting one year later (Perala 1983).

6. AMS applied in the summer to cut stumps in a P. tremuloides clone in Illinois reduced suckering and even killed some nearby stems, but control was satisfactory after several years only when the entire clone was treated (Packard 1983).

BIOLOGICAL CONTROL: Goats eat almost anything, but they especially love brush (small trees, woody shrubs, bushes, etc.). If enclosed in a brushy area, such as an aspen clone, they will clip all of the suckers off close to the ground and completely strip the bark off the larger tree trunks. An electric fence can be constructed around an aspen clone fairly quickly and easily, and the goats allowed to do their job. Alternatively, goats can be trained to stay within an area enclosed by a simple electrical wire on or just below the ground that will impart an electrical shock to an animal collared with a receiver (Fay 1987). The Minnesota Field Office is proposing to experiment with goats to reduce large aspen clones to patches of small suckers beginning in the fall of 1987 on Bluestem Prairie. Theoretically, the goats will perform the job of mowing the clone periphery and girdling the large trunks of the interior, and then the area will be burned in the spring or fall of the following season. This method could substantially reduce the cost and labor input necessary for aspen control on the prairie.

Another area of biological control currently under investigation at the University of Minnesota is the use of a natural fungus, Hypoxylon mammatum, that affects aspen. This fungus kills the trees it infects by destroying the phloem tissue. Researchers began experiments in which the fungus was cultured in the laboratory then inoculated into aspen trees through holes drilled into the trunks. The first inoculations occurred in the fall of 1986 and results will be evaluated over the next few years (Svedarsky pers. comm.).

Management Programs:
Active management by cutting and/or burning continues in the following Nature Conservancy Field Offices:

Illinois - 8 S. Michigan Ave., Suite 900. Chicago, IL 60603

(312)346-8166.

Minnesota - 1313 5th Street SE, Minneapolis, MN 55414 (612)379-2134.

Ohio - 1504 West 1st Avenue, Columbus, OH 43212 (614)486-4194.

Wisconsin -333 W. Mifflin, Suite 107. Madison, WI 53703 (608)251-8140.

As of 1987, herbicides were no longer being used to control aspen on TNC preserves in these states.

Monitoring Requirements:
Monitoring should be conducted to check effectiveness of control procedures.

Monitoring is easily accomplished as the aspen clones and suckers are highly visible on the prairie. Qualitative observations are usually sufficient for monitoring the success of control procedures. However, when conducting experiments to compare suckering response to different treatments, it is advisable to collect quantitative data, such as number and height of suckers produced per unit area, preferably for several years following treatment.

Monitoring Programs:
See Management Programs

## VI. RESEARCH

Management Research Programs:
The Wisconsin Field Office of The Nature Conservancy (TNC) is continuing experiments with girdling and cutting. Contact: Brent Haglund, Director. 1045 E. Dayton St. Room 209, Madison, WI. 53703 (608)251-8140.

TNC's Minnesota Field Office has conducted girdling experiments and is planning to experiment with the use of goats to eliminate large clones. Contact: Brian Winter, Western Preserves Manager. 1313 5th Street SE, Minneapolis, MN 55414 (612)379-2134.

The University of Minnesota is investigating the use of the fungus Hypoxylon mammatum as a biocontrol agent for aspen. Contact: Dan Svedarsky, Natural Resources Dept., N.W. Ag. Expt. Sta., Univ. of MN-Crookston 56716. (218)281-6510.

Dave French, Dept. of Forestry, Univ. of MN, 306 Stakeman Hall, St. Paul, MN 55108. (612)625-8194.

Management Research Needs:
Research should continue to investigate cost and labor effective methods for eliminating aspen clones from natural prairies. Important research topics include suckering response to cutting and girdling, and biological control.

## VII. INFORMATION SOURCES

Acknowledgements:
We are indebted to all the botanists and ecologists who took the time to provide the information necessary for the preparation of this Element Stewardship Abstract.

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## VIII. DOCUMENT PREPARATION & MAINTENANCE

Edition Date: 87-09-02

Edition Author: Carmen K. Converse, Update By Nancy Eckardt
Herbicide information partly updated: TunyaLee Martin, 8/2001