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Typha angustifolia Management: Implications for Glacial Marsh Restoration

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Typha spp. (cattails) are aquatic macrophytes often regarded as weeds in North America due to their ability to form dense monospecific stands which reduce the biodiversity of wetland systems and clog drainageways (Sale and Wetzel 1983, Bell 1990). *Typha angustifolia* (narrow-leaf cattail) is an exotic, invasive species in North America that has developed characteristics which allow it to thrive in disturbed and early successional marsh systems. This paper will identify the characteristics which allow *T. angustifolia* to dominate in systems such as glacial marshes, discuss management techniques for its control, and present considerations for the use of such techniques in restorations.

Life History

T. angustifolia was first recorded in North America in 1820 floras written for Boston, New York, Philadelphia, and other east coast localities. Its absence from North American floras prior to this date suggests that it was introduced with European settlement (Stuckey and Salamon 1987). Later floras reveal that the species was restricted to the north Atlantic seaboard of the U.S. for most of the 19th century, but then began to migrate westward along canals, railroad swales, and roadside ditches, following the development of transportation networks (Stuckey and Salamon 1987). Its current range extends west to the Pacific coast, north to Saskatchewan, and south to Arkansas (Flora of North America Association 1999).

Within this geographical range, *T. angustifolia* exists largely in early successional habitats with basic, calcareous, or somewhat salty soils (Fassett and Calhoun 1952). The glaciated prairie region of North America, which covers areas of Iowa, Minnesota, the Dakotas, and southern Canada, overlaps part of *T. angustifolia's* range (van der Valk 1989). This region contains numerous marshes well-suited for *T. angustifolia* establishment. Glacial marshes in this region formed from iceblock depressions in drift left behind by the Wisconsin glaciation, which ended approximately 10,000-12,000 years ago (Eldrige 1990, Wright et al. 1973). They generally have poorly drained, calcareous soils resulting from limestone and dolomite fragments as well as fine-textured clayey till found within the glacial drift (Wright et al. 1973). Salinity in glacial marshes varies widely from fresh to very saline due to variations in climate and position of the water table (Eldridge 1990). When disturbed, these marshes provide ideal habitat for *T. angustifolia* establishment.

T. angustifolia can be distinguished from native *T. latifolia* (common cattail) by a 2-12 cm gap that is present between pistillate and staminate portions of the spike and by its long, narrower, planoconvex leaves generally 5-11 cm wide (Gleason and Cronquist 1991). *T. latifolia* is commonly found in most marshes throughout temperate North America, and is the only *Typha* spp. found in relatively undisturbed habitats with peaty soils (Smith 1967). Both species are wind-pollinated, and when their ranges overlap, can hybridize to form *T.* x *glauca*. Smith (1967) studied experimental and natural *T.* x *glauca* and reported that hybrids have morphological characteristics intermediate of the two parents, produce functional pollen grains (though the quantity is varied and less than that of the parents), and perform successful backcrosses to *T. angustifolia*, thereby allowing trihybrid and F_1 X F_1 crosses. The high level of variation that is created by introgressive hybridization, as well as by significant amounts of variation that can occur within a species in response to latitude, altitude, and physical conditions, can cause difficulties in taxonomic identification, primarily concerning the distinction between *T. angustifolia* and *T.* x. *glauca* (McNaughton 1966, Smith 1967).

Competitive strategies

T. angustifolia's invasiveness in restored or disturbed systems stems from the development of several strategies for outcompeting other emergent species. One strategy encompasses the ability to quickly colonize and establish open sites. A *T. angustifolia* plant allocates 20% of its biomass to sexual structures, which produce approximately 1.7 x 10^7 pollen grains and 20,000-700,000 seeds (Grace and Wetzel 1982b, Grace and Harrison 1986). Wind is the primary method for dispersal, allowing pollen and seed to be dispersed over large distances (Grace and Harrison 1986). High seed production and wind dispersal increase the chance for seeds to reach newly disturbed sites or areas of disturbance within a colonized site. Unlike other emergent species such as *Sparganium eurycarpum* (common burreed), *T. angustifolia* seeds do not require a dormancy period before germination (Baskin and Baskin 1998), allowing germination to occur at any time during the growing season when favorable light and temperature conditions exist (Grace and Harrison 1986). When germination conditions are not favorable, *T. angustifolia* seeds are capable of surviving for long periods of time. Wienhold and van der Valk (1989) showed that some *T. angustifolia* seeds were able to survive up to 70 years in seedbanks of drained glacial marshes. Germination of *T. angustifolia* in general is high, and can occur over a wide range of moisture and salinity conditions (Bedish 1967, McMillan 1959).

Once germinated, *T. angustifolia* seedlings can achieve high growth rates in full sunlight conditions (Wesson and Waring 1969). Newly established plants rapidly produce large rhizomes from which ramets (rhizome with emerged leaves and flowering structures) can grow (Grace and Wetzel 1981a). This allows for quick formation and maintenance of extensive dense stands, which prevent competitor establishment by occupying available space and by reducing light penetration (Wesson and Waring 1969). *T. angustifolia* is a poor competitor for light due to its small leaf area, so establishing before other species permits its survival (Grace and Wetzel 1982c).

Another strategy that allows for *T. angustifolia's* survival and proliference is its ability to withstand conditions unfavorable to its competitors. *T. latifolia* outcompetes *T. angustifolia* by cloning more rapidly and colonizing available space, and by producing broad leaves which fan out and shade *T. angustifolia* (Grace and Wetzel 1982b). Grace and Wetzel (1982b) explored this competition and found that *T. angustifolia* persists by retreating into deeper waters where *T. latifolia* cannot survive. Both *T. latifolia* and *T. angustifolia* are dormant during the winter months and store carbohydrate reserves in their rhizomes which permit the initial growth of spring shoots. *T. angustifolia* produces a few, large parent rhizomes that are capable of storing enough carbohydrates to permit initial spring growth of shoots to heights great enough to exceed the surface of the water where photosynthesis can begin. *T. latifolia* produces many, small, lateral rhizomes which are unable to produce spring shoots tall enough to exceed 50 cm of water. *T. angustifolia* therefore co-exists with *T. latifolia* by adapting to water conditions outside of *T. latifolia's* tolerance range.

T. angustifolia exhibits another competitive strategy in its tolerance of highly saline waters. This tolerance can give *T. angustifolia* a competitive advantage in wetlands stressed by salt conditions. Wilcox (1986) documented *T. angustifolia*'s invasion into a bog contaminated by road salt runoff. Panno et al. (1999) reported *T. angustifolia*'s invasion into a fen-wetland complex receiving groundwater-borne anthropogenic contaminants from private septic systems and from deicing salts. Both studies showed that *T. angustifolia*'s distribution within the wetlands followed the plume of contaminants, and thus the areas where native species were less competitive.

Management

Typha management typically targets all *Typha* spp. within a site, rather than targeting individual species. This management strategy is forced upon managers because of the difficulty in identifying individual *Typha* species as well as the ability of all *Typha* species to co-exist within a site, forming one dense stand. Eradication is rarely the goal of management, as *Typha* spp. provide food and habitat for wildlife when limited in distribution. Weller (1975) reported that maximum avian use and production in a marsh occurs when a 50:50 cover-open water ratio exists with interconnected and well-interspersed pools larger than 9.14 m in diameter. Apfelbaum (1985) summarized *Typha* management goals as 1) controlling the spread and domination of potential habitat by *Typha* spp in and perhaps adjacent to natural areas, 2) circumventing declines in other plant species with *Typha* proliferation, and 3) preventing development of monotypic *Typha* growth and loss of habitat heterogeneity.

Linde et al. (1976) reported that an effective management program is one that considers the plant's biology and takes advantage of times when the plant is the weakest. An understanding of germination and growth requirements, as well as timing and conditions for allocation of carbohydrate reserves can be used to determine when the plant is most vulnerable and why, indicating the treatment and time of application that would produce effective results. Techniques most commonly used to control *Typha* stands include water level modifications, cutting and fire treatments, herbicide applications, and biological control. Other, less used treatments include crushing, explosives, and shading.

Flooding

Sale and Wetzel (1983) investigated the growth and metabolism of *Typha* and discovered that internal aerenchyma cells in the stems of the plants form an oxygen-diffusion pathway that allows rhizomes to receive oxygen from the atmosphere and thus survive anaerobic conditions in the sediment. When aerial shoots die in the fall, they remain standing, allowing the pathway to remain functional. Oxygen diffuses through dead leaf tissue to rhizomes until the dead tissue decays in late winter or spring, or until young shoots emerge above the water in the spring to provide a new pathway. If the pathway is disrupted, anaerobic respiration begins, producing ethanol. *Typha* plants have not developed defenses against ethanol, so extended anaerobic periods can lead to extensive tissue breakdown or death. Flooding techniques are therefore aimed at blocking the diffusion pathway which leads to the death of the entire plant.

Several studies have used this strategy to determine flooding depths that would create openings in dense *Typha* stands. Flooding in these studies occurred as a result of using water control structures to manipulate water levels. Steenis et al. (1959) found that flooding to a depth of 45 cm killed *Typha* less than one year old, and that flooding at 45-50 cm did not kill second year growth but prevented vegetative spreading. Depths of 64 cm were sufficient to kill *T. latifolia*, but did not harm *T. angustifolia*. Other studies (Martin 1957, Grace and Wetzel 1982b) reported that *T. angustifolia* could be controlled when flooded to depths greater than 100 cm for at least one year. These studies show that flooding can be effective when sufficient depths are reached. In some instances, however, mature *Typha* stands which have formed dense-rooted mats may float to the surface and continue growing (Motivans and Apfelbaum 1995).

Mowing

Mowing simulates the cutting of *Typha* spp. by a large population of *Ondatra zibethicus* (common muskrat) (Bell 1990). When followed by flooding, it deprives *Typha* of oxygen, thereby driving tissue breakdown through anaerobic respiration. Nelson and Dietz (1966) reported that mowing during the growing season was inefficient and slow due to limitations associated with using heavy machinery on soft substrates. Bell (1990) found that mowing in the winter over ice followed by flooding for the duration of the growing season reduced a *Typha* stand by 89%. Other studies (Nelson and Dietz 1966, Apfelbaum 1985, Weller 1975, Sale and Wetzel 1983) showed that two or three mowing treatments made during the growing season followed by submergence could result in up to 100% control, depending on whether or not all cut stems were submerged after flooding.

Prescribed burning

Bell (1990) found that burning *Typha* stands over ice followed by flooding produced results equivalent to mowing when flooding was deep (60-80 cm), and slightly reduced when flooding was shallow (20-40 cm). Like mowing and flooding, this technique aims at disrupting the oxygen-diffusion pathway in *Typha* tissues. Burning, unlike mowing, does not require heavy equipment and is therefore cheaper and easier (Bell 1990). Mowing and burning treatments reduce the depth needed to submerge *Typha* shoots. As a result, flooding may be achieved naturally by spring snowmelt, making these techniques possible in sites lacking water control structures.

Drainage

Nelson and Dietz (1966) found that a 100% kill of *T. latifolia* could be obtained by draining a site for two years. Mallik and Wein (1986) and Steenis et al. (1959), however, reported significant increases in *Typha* cover after draining a site for three years and one year, respectively, possibly due to the stimulation of tillering. Several studies showed that draining in conjunction with another treatment could produce effective control. Mallik and Wein (1986) reported that draining followed by multiple summer burnings was effective in decreasing *Typha* dominance and increasing species diversity, achieving a state which remained for three years after the treatment. Nelson and Dietz (1966) showed that cultivation after drainage could produce complete kills, though cultivation was slow and required the marsh to be out of production for one year to sufficiently dry the soil prior to treatment.

Chemical control

Several herbicides and application techniques have been tested for their effectiveness in thinning dense *Typha* stands. Steenis et al. (1959) applied several herbicides with power-spray equipment to stands composed of *T. angustifolia* and *T.* x. *glauca*. Dalapon (a selective, general- use herbicide containing the sodium salt of 2,2-dichloropropionic acid), 2,4-D (a nonselective systemic herbicide containing 2,4-dichlorophenoxyacetic acid), and ATA (a nonselective systemic triazole herbicide containing 3-amino-1,2,4-triazole) all produced satisfactory results (greater than 70% kill), though some chemicals such as 2,4-D required mixing with other chemicals to achieve a high percentage kill. Thorsness et al. (1992) reported that applications of Rodeo (a post-emergent, nonselective herbicide containing the active ingredient isopropylamine salt of glyphosate (N-(physphonomethyl) glycine)) applied at 3.5 L/ha or greater with a backpack sprayer can achieve control greater than 80%. Other application techniques such as wicking followed by a manual clipping treatment, and aerial spraying from an airplane have also shown to be effective (Nelson and Dietz 1966, Applied Ecological Services and All Services Company in Motivans and Apfelbaum 1995).

Following a collaborative study, the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, North Dakota Animal Damage Control and U.S. Department of Interior, Fish and Wildlife Service developed recommendations for maximum cost-effective control in thinning *Typha* stands in large marshes for waterfowl habitat management and *Euphagus* spp. (blackbird) control (a species that nests in *Typha* stands and presents problems for sunflower farms adjacent to marshes) (Linz 1992). They suggested that aerial applications of Rodeo at 5.8 L/ha should be made to *Typha* marshes between August and first frost. They observed that treatments made between mid-July and early September are effective in killing *Typha* spp., but later applications will avoid most young waterfowl broods and decrease the possibility of spray drift damaging small grain crops adjacent to marsh sites.

Biological control

Typha control through indirect manipulation of *O. zibethicus* (muskrat) populations is a natural, efficient and inexpensive tool for creating dispersions of openings suitable to waterfowl use (Weller 1975). *O. zibethicus* populations can be encouraged by restricting commercial harvest by trappers or by regulating water levels between 1 and 2 m of depth over large areas (Aleksiuk 1974). Manipulation of wildlife numbers does not produce immediate results, however, and the lack of precise control may lead to exponential population growth of *O. zibethicus* and serious vegetation “eat-outs” (Ball 1990).

Several native insects such as *Arzama* spp. (boring-moth larva) have been reported to cause serious damage or to entirely eliminate dense *Typha* stands. Their use as a biological control method has not been investigated.

Other techniques

Nelson and Dietz (1966) tested mechanical crushing, explosive control, and shading as possible management techniques for opening *Typha* stands. Crushing stands using a tractor pulling a 55-gallon drum with angle-iron cleats was found to be a rapid and economical method for restricting *Typha* growth, though multiple treatments may be needed. They also found that explosives such as nitro-glycerine dynamite, war surplus tetrytol, and ammonium nitrate could cause excavations that would remain open for five years or longer, depending on the depth of the hole created. Shading using black polyethylene tarps to cover *T. latifolia* was found to be effective when active shoots were covered for at least 60 days. Problems with holding tarps down and their degradation reduce the efficiency and practicality of this technique.

Considerations for Restoration

The techniques described above have been developed largely for the purpose of restoring degraded marshes to increase waterfowl production. Most techniques resulted in control greater than 70%. Some key issues concerning their effectiveness and practicality must be addressed when considering their use in restorations.

Long-term effects

The longest duration of the studies reviewed, Mallik and Wein (1986), assessed the effects of draining and burning treatments three years after the treatments were made. The rest of the studies reviewed in this paper lasted only one to two years. Most techniques described above were found to achieve greater than 70% control of *Typha* stands. Whether the results of these techniques can be maintained over a long period of time has not been studied. Thorsness (1992) cautioned that chemical treatments may only kill *Typha* topgrowth and not affect large rhizome systems, leading to cattail reestablishment 1-4 years after treatment. Managers interested in these techniques must therefore consider them with the knowledge that many treatments will most likely need to be repeated in the future.

Effect on non-target species

Few studies reported how treatments affected non-target species. Nelson and Dietz (1966) reported that native plants such as *Potamogeton pectinatus* (sago pondweed) and *Scirpus americanus* (alkali bulrush) were able to establish in openings created by various techniques. Mallik and Wein (1986) reported that flooding, following a draining and burning treatment to reduce *Typha* spp., increases biodiversity by stimulating seeds in the seedbank to germinate. They also noted that draining, burning, and flooding treatments can lead to entirely different plant communities.

Studies reviewed in this paper did not assess the impact of chemical treatments on non-target species, though some information has been documented by other sources. Glyphosate, dalapon, 2,4-D, and ATA have been registered for use in aquatic systems because they present low toxicity to birds, fish, and aquatic invertebrates, and are relatively short-lived in aquatic systems (U.S. Environmental Protection Agency 1993, Pesticide Management Education Program 2000a,b,c,). Glyphosate, 2,4-D, and ATA are non-selective herbicides, so it is likely that there use for *Typha* management will adversely affect non-target emergent plants. Dalapon is selective, but can impact reed and sedge species as well as *Typha*, and thus may have similar impacts to marshes as non-selective herbicides.

Other treatments such as deep flooding, and crushing, have not been extensively examined for their impact on non-target species within the marsh. These techniques have the potential to inadvertently hinder the growth or expansion of native floral species by harming refugial plants or creating unfavorable conditions (such as high water or soil compaction) for growth or germination. They also may negatively affect animal populations by disturbing habitat or injuring individuals.

Recolonization after treatment

Success of natural recolonization by native species, which may be reduced by the rapid reestablishment of *Typha* spp. seedlings, was generally not addressed in the reviewed studies. Reestablishment of *Typha* seedlings can pose a problem to restorations of both degraded sites and historical marsh sites, which may have been drained for agricultural use. Martin (1957) reported that invading seedlings can be effectively eliminated by hand pulling, though this is time and labor consuming and not feasible for large sites. Steenis et al. (1959), found that *Typha* seedlings where suppressed by heavy growths of seeded *Echinocloa crusgalli var. frumentacea* (Japanese millet) and volunteer *Polygonum lapathifolium* (nodding smartweed) which established after the site had been drained. Competition in this case was not enough to produce satisfactory declines in *Typha* spp. abundance throughout the site, but this result suggests a potential for seeded cover crops with more contiguous cover to be effective in preventing *Typha* reestablishment.

Reinartz and Warne (1993) reported that artificially created wetlands seeded with a diversity of native wetland plants resulted in much higher species diversity and richness than sites left to natural recolonization. Naturally recolonized sites showed 55% *Typha* cover after two years, leading the researchers to conclude that natural recolonization, which depended on seed establishment from the seedbank as well as from seed dispersal, would develop into a near monoculture of *Typha*. This result emphasizes the speed at which *Typha* seedlings can establish a site, and therefore the need for further techniques such as seeding after initial management treatments to encourage native community establishment and discourage *Typha* monodominance.

Practicality of techniques

The practicality of each technique for use in a restoration will ultimately depend on site-specific factors such as goals for restoration, physical factors of the site, resources available, and public perception and approval of techniques. For example, if a restoration goal for a degraded glacial marsh is to create openings to increase migratory waterfowl use, then techniques that create interspersed and interconnected pools, such as management of muskrat populations or selective mowing, would be an ideal choice. If the site is in close proximity to public areas, natural options such as flooding and management of muskrat populations may be more preferable than treatments using chemicals or explosives. If money, labor, and equipment are limiting, then winter burning or flooding may be more feasible and cost-effective.

Conclusion

The literature reviewed in this paper revealed that *T. angustifolia* is an invasive species that can negatively affect the integrity of natural systems such as glacial marshes. Control techniques target all *Typha* spp. due to difficulty in identifying individual *Typha* spp. as well as the ability of all *Typha* spp. to co-exist and form one dense stand within a site. Several techniques have been considered successful in controlling established *Typha* stands for the purpose of improving waterfowl habitat. Further study is required, however, to improve current *Typha* management and to extend its application to projects focused on achieving goals such as increasing species diversity in a system or restoring native community structure.

The next step in improving *Typha* management is to focus research on long-term effectiveness of current techniques, and how these techniques can be adapted for use in projects concerned with goals other than improving waterfowl habitat. How non-target species and ecosystem functions are affected by current management techniques also needs to be explored, as well as development of new techniques (such as seeding and cover crops) to ensure that native species establish a site, and an assessment of whether established native communities can prevent further *Typha* invasions.

Ultimately, an understanding of the mechanisms that allow *Typha* to establish and maintain a monoculture is critical to effective management of *Typha* in the future, whether the goal is to increase waterfowl habitat or species diversity. If these mechanisms, which may be environmental (such as water chemistry disturbances from road salt) or evolutionary (such as the development of better competitive traits through introgressive hybridization), are understood, then control techniques which target the source of the problem (the mechanisms) can be developed. Such mechanisms and the extent of their influence are difficult to identify because they can work simultaneously, at different spatial and temporal scales and can vary between sites. However, this information is important to obtain because it would allow managers to determine what control measures will be most effective in different situations, to fully understand what resources and effort are necessary to achieve a successful restoration, and most importantly, whether or not a restored marsh system will ever become self-sustaining.

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