TYPHA REVIEW

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November 2007

EXECUTIVE SUMMARY

Typha spp., commonly referred to as "cattail," is considered to be an invasive native in aquatic communities worldwide. Cattails' tolerance to varying climatic conditions and environmental changes helps them achieve widespread dominance in a variety of habitats (Murkin and Ward 1980). Their tendency to spread rapidly and displace other species gives rise to several management concerns. Although Typha spp. is critical to maintaining habitat health, dense monospecific stands of Typha spp. reduce overall species diversity and richness. A 50:50 ratio of open water to emergent vegetation is a typical objective of wetland management. When cattail stands are equally interspersed with open water, they provide nest cover and building material for birds, food and shelter for muskrats and deer, and many other benefits (Beule 1979).

Resource managers worldwide are taking steps to control the spread of Typha spp.. Understanding the characteristics, distribution, and impacts of Typha leads to better decision making and management planning. This document discusses the life history and characteristics of Typha, the impacts it may have on the environment, and the different management strategies that have been used to control it.

Different species of Typha exist. *Typha latifolia* L. (broad-leaved cattail, common cattail) can be found in relatively undisturbed habitats, whereas *Typha angustifolia* L. (narrow-leaved cattail) and the hybrid, *Typha x glauca,* typically occur in more unstable and saline environments (Grace and Harrison 1986). Management strategies are relatively the same for the three different species.

Several methods have been developed to effectively manage Typha spp. These methods include spraying herbicides, cutting, crushing, disking, prescribed burning, grazing, shading, manipulating water levels, altering salinity levels, and implementing biological controls. Many researchers believe that an integration of different management techniques proves to be most effective in reducing cattail growth (Thayer and Ramey, 1986).

When considering implementing a particular management strategy, all aspects of the wetland and management goals must be taken into consideration. According to Ralston, Linz, and Bleier "there is a need to insure habitat manipulation is not significantly affecting non-target species" (2004). The consideration of physiological, ecological, and temporal factors will aid managers in determining a wetland's response to management (Sojda and Solberg 1993).

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DESCRIPTION

Scientific Name

The genus Typha spp. is commonly referred to as the "cattail genus." Three species of this genus, *Typha latifolia* L. (common cattail or broadleaved cattail), *Typha angustifolia* L. (narrow-leaved cattail), and their hybrid, *Typha x glauca* (hybrid cattail) are widespread throughout North America (Grace and Harrison 1986).

Structure

Typha spp. is an erect, rhizomatous, perennial aquatic herb which bears flowers on a slender stem 1 – 3 meters tall. The minute flowers, clustered together into spikes, form a cylindrical inflorescence with the staminate (male) flowers located above the pistillate (female) flowers (Stevens and Hoag 2000). The reddish to blackish-brown staminate flowers can be 7 to 13 cm long, whereas the dark brown pistillate flowers grow between 2.5 to 20 cm long (Mitich 2000). Creeping lateral rhizomes, or underground stems, extend from the base of the plant's leaves, reaching up to 70 cm in length and 0.5-3 cm in diameter. The plant's grayish, green leaves are flat, linear, and long, often overtopping flowering spikes (Mitich 2000; Grace and Harrison 1986; Motivans and Apfelbaum 1987).

HABITAT and DISTRIBUTION

Cattail populations can be found throughout the world, from tropical to temperate zones, and from humid to dry climates. Their tolerance to varying climatic conditions and environmental changes helps them achieve widespread dominance in a variety of aquatic plant communities (Mitich 2000; Murkin and Ward 1980). Cattails can occur in any place where the soil remains wet or saturated: roadside ditches, reservoirs, lakeshores, bogs, wet meadows, marshes, etc. (Grace and Harrison 1986). Although the cattail is a freshwater aquatic plant, it can tolerate some degree of salinity and acidity (Grace and Harrison 1986). It is also tolerant of perennial flooding, poor soil conditions (Stevens and Hoag 2000), and high concentrations of lead, zinc, copper, and nickel (Motivans and Apfelbaum 1987). *Typha latifolia* can be found in relatively undisturbed habitats, whereas *Typha angustifolia* typically occurs in more unstable and saline environments (Grace and Harrison 1986). According to Wilcox et al. (1984), *Typha angustifolia* is considered a pioneer in secondary succession of disturbed bogs. When the two species occur together, *Typha angustifolia* is generally restricted to deeper waters and more saline conditions. *Typha latifolia* thrives in shallow water. Their hybrid species, *Typha x glauca*, has similar habitat requirements to *T. angustifolia* (Motivans and Apfelbaum 1987). *Typha latifolia* can be found in aquatic communities at all stages, from early to late successional, whereas *T. angustifolia* and *T. x glauca* typically occur in early to mid-successional communities and are frequently found in disturbed wetland sites (Grace and Harrison 1986). According to Grace and Harrison, all species of Typha spp. can occur in dense, monospecific stands, or as scattered individuals, or clumps in stands of mixed vegetation (1986). Typha spp. is often surrounded by or intermixed with other plants such as *Phragmites australiis, Lythrum salicaria, Spartina sp., Acorus calamus, Scripus sp., and Sagittaria latifolia* (Motivans and Apfelbaum 1987).

The distribution of the three different species varies across North America. Up until the end of the 19^{th} century, *T. angustifolia* was limited to the eastern coast of northern N. America. Since then, *T. angustifolia* has spread inland and westward becoming widespread throughout

Canada and the northern United States, resulting in increased mixing with *T. latifolia,* and the subsequent production and spread of hybrids (Grace and Harrison 1986).

LIFE HISTORY

The cattail life cycle (phenology) includes spring leaf production, early to mid summer flowering (May and June and sometimes up to late July), and high clonal growth occurring in the fall (Motivans and Apfelbaum 1987). *T. angustifolia* has an earlier flowering period (Grace and Harrison 1986). Their inflorescences are wind pollinated, often bearing up to 420 million pollen grains per inflorescence (Mitich 2000). The pollen grains can remain viable for at least four weeks, if not severely affected by high humidity and temperature extremes (Grace and Harrison 1986). The pollen grains attach themselves to the stigmas on the female flowers, which also remain exposed and receptive for up to four weeks after the pollen is released (Grace and Harrison 1986).

More than fifty percent of the pollinated flowers produce seeds. A single inflorescence can produce 20,000 to 700,000 small single seeded fruits. The fruits remain inside the inflorescence in humid conditions, but as conditions dry, the inflorescence bursts, releasing the fruits into the air. When the fruits come in contact with water, they open, and the seed is released and sinks downward into the water (Grace and Harrison 1986). Conditions must be favorable for the seed to germinate: sufficient moisture, temperature, light intensity, and light quality. Such conditions are most present in the spring and fall. If conditions are not favorable at the onset of seed dispersal, the seed will remain viable for long periods of time (Mitich 2000). According to Beule, germination generally occurs on moist mud flats, where very little, if any, surface water remains (Beule 1979). Soils disturbed by crushing activities create excellent seed beds for cattail seedling germination. They can also germinate on floating "bog mats." In well established cattail colonies, the soil is replete with cattail seeds (Mitich 2000). It is important to note for management purposes, that such seeds are very sensitive to chemical conditions in the water and sediments. Also, water levels, wave action, and sedimentation can inhibit seed germination and growth. After a seed germinates and becomes a newly established plant, it quickly produces shoots and then rhizomes, rapidly spreading by clonal growth (Grace and Harrison 1986). According to Fiala (1978), "T. latifolia has a greater rate of clonal spread while T. angustifolia generates a greater density of shoots" (Grace and Harrison 1986).

Spring growth is usually sudden and dramatic, but varies according to water depth and the occurrence of late frosts (Grace and Harrison 1986). According to Grace and Harrison, deep-water shoots tend to sprout before those of shallow water (1986). The extensive amount of rhizomes and roots can become entwined with floating plant debris, forming what is known as the "bog mat," which can sometimes be 17 inches thick (Beule 1979). The dense and widespread cattail growth and litter often prevents other plants from establishing or surviving (Motivans and Apfelbaum 1987).

IMPACTS

Beneficial

Cattails play an important role in maintaining ecosystem health. They have been considered "scrubbers" in polluted aquatic systems (Motivans and Apfelbaum 1987; Grace and Harrison 1986). They protect shorelines from erosion and are of great value to wildlife and waterfowl (Mitich 2000). More specifically, cattail stands provide nesting sites for numerous bird species including; long-billed marsh wrens, redwing blackbirds, yellow-headed blackbirds, and least bitterns (Stevens and Hoag 2004; Sojda and Solberg 1993). They also provide excellent habitat for wintering white-tailed deer and ring-necked pheasants. Cattails create protective and spawning areas for fish. The cattail's starchy, underground stems are an important source of food for muskrats and geese (Mitich 2000). Moose and elk eat the fresh spring shoots (Stevens and Hoag 2004). The cattail has also been long regarded by the native peoples of North America as a valuable food source (Grace and Harrison 1986).

Detrimental

Although Typha is part of the natural habitat, it can become an invasive monoculture in disturbed aquatic communities (Motivans and Apfelbaum 1987). Cattails often respond to disturbances by forming dense monocultures, ultimately closing open water, eliminating vital wildlife cover and food, and reducing the opportunity for other plants to grow and survive (Motivans and Apfelbaum 1987). Unbroken stands of cattail provide for little or no wildlife use or production (Murkin and Ward, 1980). According to Motivans and Apfelbaum in their element stewardship abstract for the Nature Conservancy, "three basic events precede the growth of cattail monocultures: 1. modified surface hydrology, 2. wildfire suppression, and 3. wetland enrichment (1987). The NRCS states that "ecologically, cattails tend to invade native plant communities when hydrology, salinity, or fertility change" (Stevens and Hoag 2004). Typha can also cause a significant amount of water loss through evapo-transpiration (Grace and Harrison 1986). Dense monocultures can reduce oxygenation and microbial activity in lakes and wetlands (Messersmith, Christianson, and Thorsness 1992). Most waterfowl prefer open water interspersed with vegetation (Ralston, Linz, and Bleier 2004).

Many detrimental effects are caused by the cattail litter. The litter buries nutrients and mineralized substrates necessary for other plants to germinate. Beneath the litter, substrates are cool and moist, optimal conditions for a seed bank, but not for seed germination. Dense cattail growth and litter inhibits the growth and survival of other plants (Apfelbaum 1985).

MANAGEMENT

When cattail stands are equally interspersed with open water, they provide nest cover and building material for birds, food and shelter for muskrats and deer, and countless other benefits (Beule 1979). A 50:50 cover:water ratio for optimum wildlife use and overall production is recommended (Beule 1979). Cattail management is vital to maintaining this ratio.

"Cattail control is difficult due to the large rhizome system that enables the plant to reestablish rapidly after top-growth is killed" (Messersmith, Christianson, and Thorsness 1992). The emergence and dominance of cattail in open water communities can eventually lead to sedge meadow, followed by shrub-carr or wet prairie, eliminating vital wildlife food and cover plants (Beule 1979). Beule, in his report of cattails in southeastern Wisconsin states that, "Areas with good histories of waterfowl production and good plant and water interspersion are now often covered by solid masses of cattail" (Beule, 1979). Wetland management is essential for maintaining healthy and diverse plant and wildlife communities. Apfelbaum gave three reasons why cattail management would be desirable in some situations: "1. Control the spread and domination of potential habitat by cattail in and perhaps adjacent to natural areas. 2. Circumvent declines in other plant species with cattail proliferation. 3. Prevent development of monotypic cattail growth and loss of habitat heterogeneity" (Apfelbaum 1985).

Several methods have been developed to effectively manage cattails. These methods include chemical control, physical control, prescribed burning, grazing, shading, manipulating water levels, and others. Some of the methods discussed in this paper would not be recommended for use in designated nature preserves or natural areas (Apfelbaum 1985). Many researchers believe that an integration of different management techniques proves to be most effective in reducing cattail growth (Thayer and Ramey, 1986).

The first step towards implementing an effective management plan is identifying the existing stage in the cycle of a wetland or semi-permanent marsh: dry, regenerating, degenerating, or lake marsh. In certain conditions and areas, no cycle is apparent (Sojda and Solberg 1993). Also, determining the extent of cattail monocultures in the area is important. Aerial surveys and sampling transects can help determine and monitor cattail spread. According to Ralston, Linz, and Bleier (2004), "there is a need to insure habitat manipulation is not significantly affecting non-target species, hence knowing what portion of the total cattail habitat is being manipulated is critical."

Management strategies are relatively the same for the three different Typha species discussed in this paper.

Chemical Control

Chemical applications may not be appropriate for designated preserves or natural areas (Apfelbaum 1985). In a study conducted by Nelson and Dietz (1966), Dalpan was sprayed at 8.8-35.3 kg/acre (4-16 lb/acre), reducing cattails in a mowed area by 74 to 97 percent after ten months (Apfelbaum 1985). Control was most effective when treated areas were flooded up to 4-5 in. or deeper and cattails were cut below water depths. Such success could strictly be attributed to cutting and flooding, rather than chemical spraying. Weller (1975) tested the effects of Amitrol, Rodopan, and Doupon herbicides. The results were similar; the herbicides effectively created and maintained water openings for at least three years after spraying, but surrounding cattail quickly encroached upon the treated areas. The application of high doses of MCPA or 2,4D in diesel oil (2.2-4.5 kg per acre) during flowering also proved to be effective. According to Apfelbaum, herbicide applications were found necessary for up to three years in some areas (Apfelbaum 1985).

Beule reported that herbicides were most effective when applied after pollination and staminate tops were lost (Beule 1979). Aerial application of herbicides is an efficient means of controlling cattails over a large area or several smaller, inaccessible locations (Sojda and Solberg 1993).

Physical Control

Control can also be achieved by hand or mechanical cutting, followed by submergence of all cattail stems (Apfelbaum 1985). The Nature Conservancy's management plan for cattails suggests, "control techniques of fire and physical removal (cutting) in conjunction with flooding are most appropriate" (Motivans and Apfelbaum 1987). According to the Nelson and Deitz study (1966), control is best if cattails are cut in late summer or early fall and if the two clippings are followed by stem submergence to at least 3 in. Cutting cattails too early in the season stimulates growth. Conducting two to three clippings in one growing season before flower production has also proven to be 95-99 percent effective (Apfelbaum 1985).

The effectiveness of cutting mature cattails at least three inches below the water surface depends on the cutting of old residual stems as well as new green stems. Continual submergence of cut stems is necessary for maximum control (Beule 1979). The disadvantages of cutting include the difficulty of moving equipment in marshy areas. Cutting in early spring before the ground thaws can eliminate this problem (Murkin and Ward 1980). The high expense of manpower and time should also be considered (Murkin and Ward 1980).

Crushing, another form of physical control, injures developing rhizomes and shoots (Apfelbaum 1985). This method is most effective when conducted multiple times, after June, and when standing water remains after treatment. Crushing was most effective in deeper water areas (Apfelbaum 1985). Crushing was also tested as an effective management technique by Beule (1979). Different factors affected the success or failure of crushing. The presence of surface water after crushing contributed to the eventual control of cattail. Beule found that "openings were preserved for 4 years after a single crush when adequate surface water (15 cm; 6 inches or more) was maintained over the plot." However, where soils are exposed in summer, crushing must be repeated annually to maintain water openings. "The timing of crushing to coincide with the low point of carbohydrate storage should maximize and hasten control" (Beule 1979).

Disking, although not appropriate for natural areas (Motivans and Apfelbaum 1987), is also one way to achieve cattail control. This technique can retard shoot formation and damage rhizomes (Sojda and Solberg 1993). Yet, disking alone will not control cattail growth and spread. Manipulation of the water level is necessary. Also, disking must be conducted in the fall and again the following spring and summer.

Such treatments of cutting, crushing and disking, are most effective when conducted during a three week window from one week before to one week after the pistillate spike is lime green and the staminate spike is dark green (Sojda and Solberg 1993).

The most expensive form of physical control is using a bulldozer or cookie cutter. Floating cattail mats can only be removed with such equipment (Sojda and Solberg 1993). Not only is the effect of a bulldozer or cookie cutter short-lived, it may also alter wetland basin morphology (Sojda and Solberg 1993).

Although cattails are well adapted to growing in anaerobic soil conditions (Sojda and Solberg 1993), cattail control is most effective when all dead or living leaf material on the water is removed, eliminating all aerial connections to the roots and rhizomes (Grace and Harrison 1986). According to Sojda and Solberg (1993), it is thought that "a single leaf can provide oxygen to underground rhizomes for a radius of a few feet from that leaf." Many studies have shown that three below-water cuttings during the growing season, along with the removal of above-water connections, is enough to effectively manage cattail (Grace and Harrison 1986).

When deciding on a management strategy, costs must be considered. Thayer and Ramey (1986) state that, "cost calculations for mechanically harvesting an acre of vegetation depend on the length of the growing season and how often the same area will need harvesting, the size of the area to be harvested, harvester capabilities in terms of acres per day and/or tons per day, of fuel cost, maintenance and repair cost, "down-time" for repairs, insurance and administrative costs, cost incurred in the conveying, transporting and disposal of harvested materials, and other miscellaneous expenses" (Thayer and Ramey 1986). Thayer and Ramey also give a list of questions managers should ask before implementing such a strategy: Can this management strategy outstrip the growth of the weed? Will the harvest have retardant effects on the reestablishment and growth of the target plant? Will harvesting reduce the nutrient load of the water column? Does the problem justify the financial and environmental costs of mechanical control? (Thayer and Ramey 1986). For a list of advantages and disadvantages of using mechanical harvesting/physical control systems, see Thayer and Ramey's article, "Mechanical Harvesting of Aquatic Weeds" (1986).

Prescribed Fire

To achieve cattail control by fire, the underground roots must be destroyed. Because most fires only burn above ground biomass, prescribed fire rarely provides cattail control (Apfelbaum 1985). Although, one study conducted in Utah found that drying the land for two years in preparation for burning was effective in controlling cattails. Fire can also be used along with other control methods, such as providing better access for mowing and clipping, or for cattail litter cleanup. Implementation of a regular burning program would gradually reduce typha vigor, enhancing the natural quality of a site (Apfelbaum 1985). According to Sojda and Solberg (1993), "planned fires must be combined with water management that ultimately controls the cattails."

Shading

At the Eldorado Marsh Wildlife Area, where water level control was not possible, Beule attempted to prevent light from reaching the cattails by covering different stands with black polyethylene tarps. Heat from the sun, upward pressure from cattail growth, wind, and other forms of movement above the tarps, caused the tarps to deteriorate within a month. After the holes and tears were repaired, tree branches and cattail tops were placed on top of the tarps to hold them firmly in place. Beule reported that cattail control was proportional to the amount of time the stand remained covered. The longest period of covering (106 days) resulted in a 38% decrease in stem densities the following year. Although relative success was achieved, further testing was discontinued due to difficulties with repairing and weighing down the tarp, along with the improbability of using such a method on large areas. This management technique is restricted to only small areas (Beule 1979).

Water Level Modification

The ability to manipulate water levels is one of the single most important factors in managing cattails (Beule 1979). The ability to do this depends on several factors: availability of water, size and location of marsh basin, and the outlet structure. Beule states that "these abilities can be further modified by constructing sub-impoundments, pumping facilities and other features within the marsh itself" (Beule 1979). According to Beule, "a highly manageable marsh would have a dependable, all-season water supply, such as a flowing river of adequate volume, and is situated so that drainage is easily and quickly accomplished through an outlet structure. A marsh with little management potential is, for example, the depression that depends primarily upon field runoff for its surface water supply and whose only water release mechanism is percolation, evaporation and transpiration. Between these two extremes lie many possible gradations of flooding and drainage that ultimately determine the manageability of individual marshes" (Beule 1979). Water manipulation is conducted with greater efficiency on marshes of 405 ha (1,000 acres) or less. Such a process becomes slow and uncertain when conducted on larger marshes (Beule 1979).

Apfelbaum, in his article presenting various methods of cattail management, concluded that the most reliable control involves any technique that "reduces and maintains the stature of live and dead cattail stems below water levels for a period of one to three years" (Apfelbaum 1985).

In his study to assess the response of marsh plants to water level fluctuations and carp removal, Beule summarized that "After reflooding, cattail soon dominated all other emergent plants on the study areas. Once established, cattails at Horicon and Sinissippi dams withstood deep flooding (56 to 123 cm; 22 to 48 inches) for a two year period without apparent loss or thinning of plants. After 2 years of deep flooding, about half of the cattails did not produce living sprouts and stem densities were 50% lower than the previous year" (Beule 1979).

Differences between *T. latifolia* and *T. angustifolia* must also be considered when manipulating water levels. Mature *T. latifolia* and seedlings are killed by water depths of 63.5 cm (25 in.) and 45 cm (18 in) or more, respectively, whereas *T. angustifolia* requires 1.2 m (47 in.) or deeper. (Apfelbaum 1985). When manipulating water levels, managers must account for evapotranspirational losses to maintain a level effective in cattail control (Apfelbaum 1985).

Keeping areas flooded with at least 1 in. of water prevents germination. Such minor flooding is quick and inexpensive. Yet, shallow flooding often leaves surrounding areas unflooded and saturated; ideal conditions for cattail germination to flourish (Sojda and Solberg 1993).To kill existing plants and prevent new ones from growing, deep flooding is required. According to Sojda and Solberg (1993), "no minimum water depth can be prescribed, but a rule of thumb would be to maintain 3-4 feet of water over the tops of existing shoots in the spring."

When manipulating water levels, the effects on wildlife habitat must be considered. For example, changing the water level during waterfowl nesting season may cause hens to abandon their nests or implementing a drawdown during the brooding period would hinder the rearing of young ducks (Bedish 1967). All aspects of the wetland should be taken into consideration.

Grazing

Grazing by cattle, muskrats, and other herbivores affects the vigor of cattail growth. Direct mortality of mature cattails is unlikely. Grazing can however damage the plant's survival and reproductive capabilities, preventing it from contributing to the seed bank.
Also, grazing by Canada geese and greater snow geese, can directly kill seedlings (Sojda and Solberg 1993).

Muskrat grazing can greatly affect cattail communities. In some cases, they can totally set back a cattail stand for a season. These "eat outs" help maintain open water (Motivans and Apfelbaum 1987). Sojda and Solberg (1993) state that "population levels of 10 muskrat/acre can nearly eliminate cattails in 2 years if combined with high water levels in spring."

Heavy grazing should be implemented during the 3 week period when the pistillate is lime green and the staminate is dark green (Sojda and Solberg 1993).

Salinity Alteration

Increased water or soil salinities can prevent cattail seedling germination, retard their growth, and even kill mature plants. This increase in salinity can be accomplished through drought or purposeful drawdowns (Sojda and Solberg 1993).

Biological Controls

Cattails respond to different insects in a variety of ways. For example, noctuid larvae initially feed on leaves, but after some time, bore on the stems. Calendra larvae are initially stem borers and after become rhizome borers (Grace and Harrison 1986). The presence of these larvae leads to death in the cattail's youngest leaves and abortion of the inflorescence. Some research has been conducted with experimental infestations of the noctuid moth larvae, *Bellura oblique,* on stands of *Typha latifolia* The result was that total plant production was reduced by 55% (Grace and Harrison 1986).

ADDITIONAL STUDIES

Smith and Kadlec studied the effects of fire in a Great Salt Lake marsh (1985). Prescribed burning followed by muskrat and waterfowl grazing significantly reduced *Typha latifolia* stands. The reduction of *T. latifolia* in burned sites revealed preferential grazing in these areas (Smith and Kadlec 1985).

Kostecke, Smith, and Hands (2004) monitored vegetation responses to cattail management at Cheyenne Bottoms, Kansas. They tested the effectiveness of prescribed burning, discing following prescribed burning, and cattle grazing (low and high intensity) following prescribed burning. They found that the disced and high intensity grazing treatments significantly lowered cattail densities, yet reduced overall species richness and diversity of the non-cattail community. They recommend discing and high intensity grazing following prescribed burning in areas where cattail suppression is the goal. Burning alone was not effective in preventing cattail growth. On the contrary, higher shoot densities were observed after burning. Discing following burning may have to be conducted every few years to maintain low cattail density. Burning is encouraged to prepare a site for additional management (Kostecke, Smith, and Hands 2004).

Linz et al. (2004) assessed the effects of a cattail management program created by the USDA that aerially sprays dense cattail stands with the herbicide glyphosate in order to disperse blackbirds. Approved by the EPA, glyphosate is considered non toxic to fish and other aquatic invertebrates. Cattail stands and floating mats may be present for two to three years after treatment, but eventually decompose, creating open water areas. Increased open water causes aquatic invertebrates to flourish, subsequently attracting a greater number of waterfowl to the area. Negative effects of spraying glyphosate include reduction in breeding populations of marsh wrens, which depend on dense stands of cattails. Mallards, muskrats, ring-necked pheasants, and white-tailed deer, which use the dense stands of vegetation for food and cover, are also affected. To lessen the negative effect, treatments can be staggered. It is difficult to maintain the 50:50 ratio of vegetation and open water, which would enhance numbers of all species (Linz et al. 2004).

Messersmith, Christianson, and Thorsness (1992) studied the influence of glyphosate rate, application date, and spray volume on cattail control. According to the researchers, herbicides provide the most effective control method. 1.5 and 3 pounds per acre of herbicide applied at the early flowering stage, resulted in 93 and 98 percent cattail control at 10 months. Control declined to 63 and 93 percent after 14 months. The herbicide should be applied in late July to early September.

Solberg and Higgins (1993) also tested the effects of glyphosate (Rodeo) on cattails, invertebrates, and waterfowl in South Dakota wetlands. They found that the herbicide effectively suppressed cattail for two years. Breeding waterfowl responded positively to the increase in open water. An increase in duck nesting sites was also observed. They also found that the herbicide should be applied in mid to late summer at a time when water depths are at 30 to 45 cm. Excessive application rates of glyphosate may negatively affect algae and aquatic invertebrates.

Aber et al. (2006) discussed small-format aerial photography for assessing change in wetland vegetation. The study took place at Cheyenne Bottoms, Kansas, a Nature Conservancy wetland site. The NC adopted a strategy to control cattails by taking advantage of drought episodes. When one such drought occurred, dead cattail thickets were removed by mowing and burning, and the area was restored into open marsh with emergent wetland vegetation. The drought conditions ended in 2004. Formerly dry mudflats revegetated rapidly with blunt spike and bulrush in the summer of 2004, but cattail did not recover. In 2005, small stands of cattail began to emerge. According to Aber et al. "it appears the strategy of the NC was partly successful for restoring open-water and mudflat marsh habitat attractive for migrating shorebirds and waterfowl." The removal of dead cattail thatch during a drought episode is essential to achieving such success.

COMPARATIVE TABLE OF BEST MANAGEMENT PRACTICES

	Application timing/season	**Benefits**	**Costs**	**Application procedures**
Chemical Control	During flowering (Weller 1975); after pollination and staminate tops are lost (Beule 1979); glyphosate should be applied in late July to early September (Messersmith et al. 1992); should be applied in mid to late summer at a time when water depths are at 30 to 45 cm. (Solberg and Higgins 1993).	Can create and maintain water openings for three years after spraying (Weller 1975); aerial application can control cattails over a large area or several smaller, inaccessible locations (Sojda and Solberg 1993).	Inappropriate for designated preserves or natural areas; surrounding cattail quickly encroaches upon treated areas (Weller 1975); excessive application rates of glyphosate may negatively affect algae and aquatic invertebrates (Solberg and Higgins 1993).	Should be accompanied by cutting and flooding (Nelson and Dietz 1966); to reduce negative effects, treatments should be staggered (Linz et al. 2004).
Physical Control (cutting, disking, crushing)	Late summer or early fall (Nelson and Dietz 1966); conduct 2-3 clippings in one growing season, before flowering (Apfelbaum 1985); most effective when conducted during a three week window from 1 week before to 1 week after the pistillate spike is lime green and the staminate spike is dark green; *disking* should be conducted in the fall and again the following spring and summer; (Sojda and Solberg 1993).	*Crushing* and *disking* injures developing rhizomes and shoots (Apfelbaum 1985); openings preserved for four years after a single *crush* when adequate surface water is maintained over plot (Beule 1979);	High expense of manpower and time (Murkin and Ward 1980); fuel, maintenance and repair costs; transporting and disposal costs (Thayer and Ramey 1986); difficulty in moving equipment in marshy areas (Murkin and Ward 1980); where soils are exposed in summer, *crushing* must be repeated annually (Beule 1979); *disking* is not appropriate for natural areas (Motivans and Apfelbaum 1987); using a bulldozer or cookie cutter is expensive and alters basin morphology (Sojda and Solberg 1993).	*Crushing* is most effective in deeper water areas (Apfelbaum 1985); physical control is effective when all dead or living leaf material is removed from surface of water (Grace and Harrison 1986); continual submergence of *cut* stems is necessary for maximum control (Beule 1979); control techniques of fire and physical removal (*cutting*) in conjunction with flooding are most appropriate (Motivans and Apfelbaum 1987); *cut* old residual stems as well as new green stems (Beule 1979).

Water Level Modification	Water levels should mimic long-term (10-20 year) drought cycles of the local area; drawdowns in early spring stimulate germination of aquatic annuals such as smartweed and millet and then shallow flooding during summer stimulates the growth of annuals while eliminating germination of cattails; extremely high water levels in late spring and summer sufficiently stress the plants by reducing the quantities of the stored carbohydrates for subsequent spring growth (Sojda and Solberg 1993).	After 2 years of deep flooding, about half of the cattails did not produce living sprouts and stem densities were 50% lower than the previous year (Beule 1979); the most reliable control involves any technique that "reduces and maintains the stature of live and dead cattail stems below water levels for a period of one to three years" (Apfelbaum 1985); shallow flooding prevents germination and is quick and inexpensive (Sojda and Solberg 1993).	Slow and uncertain on marshes greater than 1,000 acres; dependent on water availability, marsh size, location, and outlet structure; shallow flooding often leaves surrounding areas unflooded and saturated which are ideal conditions for cattail germination to flourish (Sojda and Solberg 1993); changing the water level during waterfowl nesting season may cause hens to abandon their nests or implementing a drawdown during the brooding period would hinder the rearing of young ducks (Bedish 1967).	To kill existing plants and prevent new ones from growing, deep flooding is required (Sojda and Solberg 1993); Mature *T. latifolia* and seedlings are killed by water depths of 63.5 cm (25 in.) and 45 cm (18 in) or more, respectively, whereas *T. angustifolia* requires 1.2 m (47 in.) or deeper. (Apfelbaum 1985);
Shading		The longest period of covering (106 days) resulted in a 38% decrease in stem densities the following year (Beule 1979).	Heat from the sun, upward pressure from cattail growth, and wind caused the tarps to deteriorate within a month; difficulties with repairing and weighing down the tarp; restricted to small areas (Beule 1979).	
Prescribed Fire	Burning cattails is difficult during growing season, except during extreme low-water conditions; marshes can be burned when water levels are naturally low in fall and winter (Sojda and Solberg 1993).	Provides better access for mowing, cutting, or for cattail litter cleanup; prepares a site for the effective implementation of other control methods (Apfelbaum 1985).	Prescribed fire alone rarely controls cattails (Apfelbaum 1985).	Drying the land for two years before burning is effective in controlling cattails; implementation of a regular burning program would reduce typha vigor (Apfelbaum 1985); must be combined with water management (Sojda and Solberg 1993).

Grazing	Heavy grazing should be implemented during the 3 week period when the pistillate is lime green and the staminate is dark green (Sojda and Solbert 1993).	Damages plant's survival and reproductive capabilities; grazing by geese can directly kill seedlings; population levels of 10 muskrat/acre can nearly eliminate cattails in 2 years if combined with high water levels in spring (Sojda and Solberg 1993).	Direct mortality of cattail is unlikely (Sojda and Solberg, 1993);	
Salinity Alteration	Flooding a marsh during most of the growing season with water of 10 ppt salinity kills cattails (Sojda and Solberg 1993).	Prevent cattail seedling germination, retard their growth, and even kill mature plants (Sojda and Solberg 1993).		This increase in salinity can be accomplished through drought or purposeful drawdowns (Sojda and Solberg 1993).
Biological Controls		Some research has been conducted with experimental infestations of the nocutid moth larvae, Bellura oblique. The result was that total plant production was reduced by 55% (Grace and Harrison 1986).		

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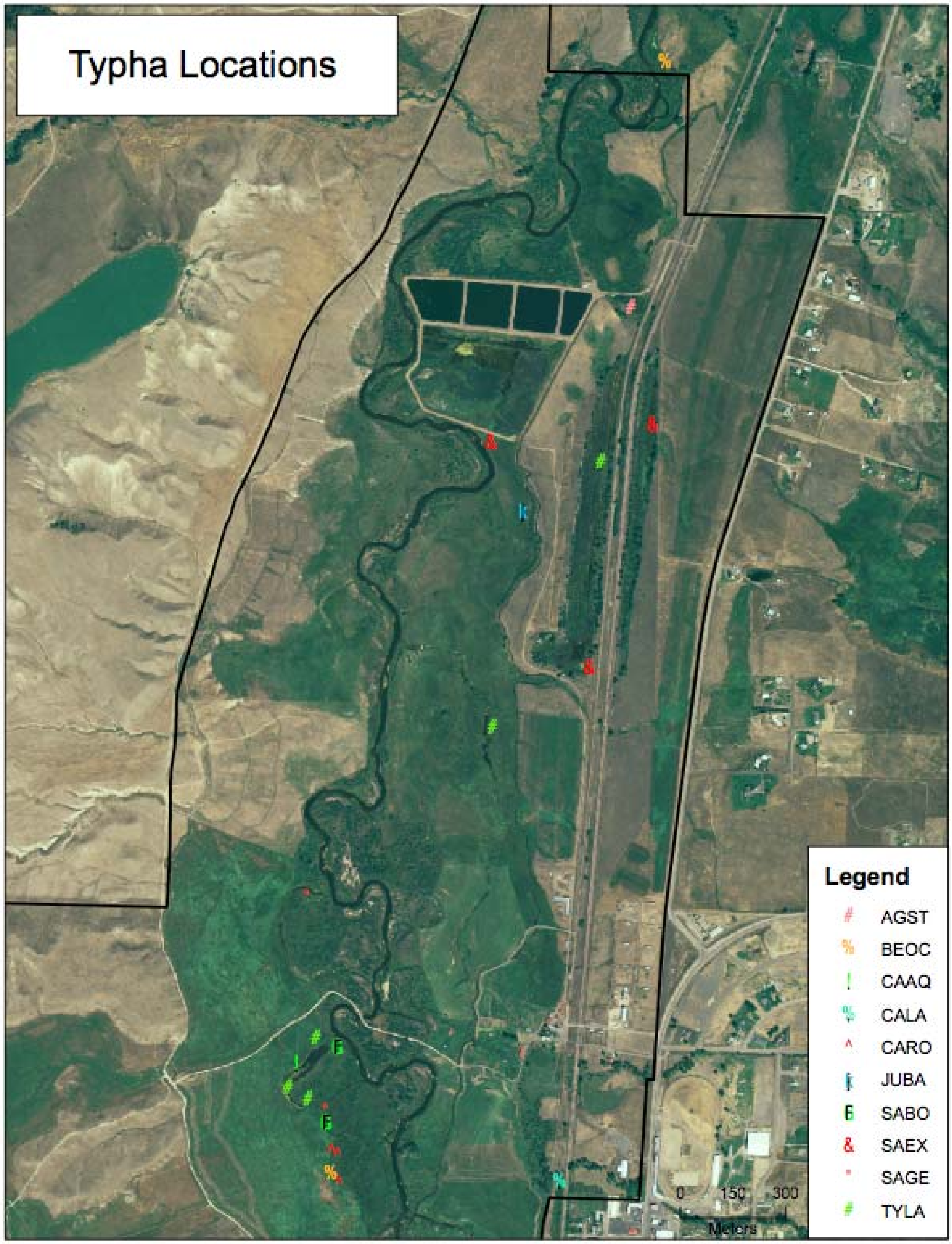
APPENDIX A: Locations of Grant-Kohrs Ranch NHS Typha Spp.



Field data collected by Peter Rice, University of Montana
GIS map produced by Brent Frakes, National Park Service Rocky Mountain Network Data Manager