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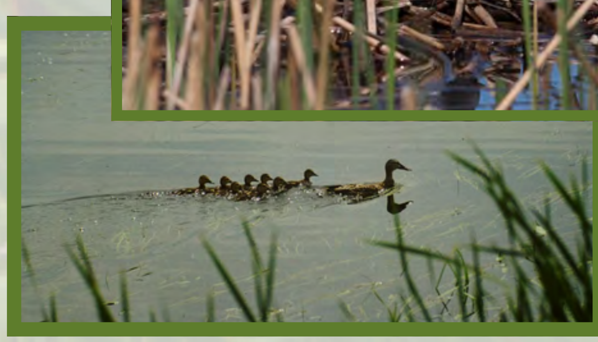
2016

# Cattail Management in the Northern Great Plains:

## Implications for Wetland Wildlife and Bioenergy Harvest



Environment and Natural Resources Trust Fund

# ABOUT THE Authors

Flower heads (female or pistillate) of the three types of cattails of the Northern Great Plains. Narrow leaf cattail (*Typha angustifolia*) is on the left and common or broadleaf cattail (*Typha latifolia*) is on the far right. At this stage, the male or pollen-bearing flowers at the tip of the spikes have fallen off. The most noticeable distinguishing feature between the plants is the wide (> 1.5 in.) spacing (see red brackets) between pistillate and the staminate flowers on narrow leaf while the flowers generally touch in broadleaf. Hybrid plants (*Typha x glauca*) in the center are typically intermediate in spacing. In late fall and winter, these spikes will break apart and thousands of fluffy seeds will be wind-dispersed. Photo courtesy of Rhett Johnson, MN DNR.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# Acknowlegements

**THIS BOOKLET IS ABOUT CATTAILS,** their natural history, invasive properties, and particularly how to manage them. In many settings of the Northern Great Plains, they have overtaken wetlands to the exclusion of other species. These monotypic stands of cattail have diminished the ecological integrity, wildlife habitat value, and, over time, even the hydrologic functions of wetlands.

Managing the invasive actions of cattail is most often about controlling the extent and density of cattail stands.  Control can take many forms, herbicides, cutting, disking, and water level manipulation. It is often difficult and expensive. Harvesting cattails for bioenergy, livestock bedding, nutrient recovery for agriculture, and soil supplements has the potential to offset some of these costs. While these uses are in their infancy in the U.S., our neighbors to the North have developed some proven market strategies.

The primary geographical area for this study has been the Northern Great Plains. Hopefully these discussions will have application in other regions as well. Earlier work to inventory cattails and assess their bioenergy potential in northwestern Minnesota was supported by the Northwest Minnesota Foundation and the University of Minnesota's Institute for Renewable Energy & the Environment.

Thanks to Ron Gagner of Northwest Manufacturing in Red Lake Falls for lending us pelletizing equipment and Mike Knudson of North Dakota Extension for GIS assistance in mapping cattails.  Editorial assistance was provided by; Liz Tollefson-U of MN Crookston, David Hansen-U of MN St. Paul, and Rhett Johnson of MN Department of Natural Resources. Cover photos of Mallard brood provided by Jay Huseby-Red Lake Indian Reservation, Black Tern from Bruce Flaig, and cattail baler from Richard Grosshans. Thanks to Shane Lishawa, Beth Lawrence, Nancy Tuchman, and Dennis Albert who hosted a most informative 2015 workshop at Loyola University to discuss invasive plant management in the Great Lakes area. Primary sponsorship and logistical support was provided by the Northwest Research and Outreach Center of the University of Minnesota with cooperation from the University of Minnesota Crookston, the Red Lake Watershed District, the U.S. Fish and Wildlife Service, Minnesota Department of Natural Resources, University of North Dakota, North Dakota State University, the Red River Basin Commission, and the International Institute for Sustainable Development (IISD) in Winnipeg, Manitoba. Principal financial support for the project was provided by a two-year grant from the Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizens Commission on Minnesota Resources (LCCMR).

The synergy that has occurred in the last five years has been stimulating and fulfilling. Farmers, inventors, entrepreneurs, agency biologists and managers, legislators, students, and university professors have all benefitted from the sharing of ideas and experiences; none more so than the principal investigators. We thank all participants in the learning journey.

In this booklet, we aim to help the reader better understand the nature of cattails, some dynamics of invasive species, wetland management options, and opportunities for environmental and possibly financial gain through their harvest for bioenergy. As with most publications, this is a progress report on how we understand things at this point in time. For a list of cattail-related resources, visit the web site of the U of MN - Northwest Research and Outreach Center, https://www.nwroc.umn.edu/research/wildlife-management-biofuels

And finally, a huge thanks to my fellow co-authors of this booklet and numerous others who have contributed suggestions on how to "connect the dots" in this effort to benefit both people and nature.

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# INTRODUCTION

Wetlands are essential features of the Northern Great Plains landscape. They capture excess nutrients and other pollutants from runoff before they reach rivers and lakes, stabilize water supplies during drought and floods, and enhance biodiversity. Wetlands are home to a wide range of specialized plants and animals and provide a unique setting for fish and wildlife recreation, especially wildlife watching and hunting (Mitsch and Gosselink 2015). Tragically, wetlands have been systematically destroyed to make room for cropland or other land use developments. However, awareness of the ecological goods and services that wetlands provide has grown, leading the U.S. and other nations to accelerate efforts to conserve and restore them. In addition to direct losses, the quality of remaining wetlands has suffered. For example, many wetlands are being dramatically altered by invasive plants "from the inside out." Purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), and yellow flag iris (*Iris pseudacorus*) are invasive non-natives from other continents. Others, like cattail (*Typha* spp.), may be more difficult to define because they may have both native and non-native origins. However, there is no doubt that cattail can and does increasingly exclude other species. Invasive wetland species, as a group, can aggressively crowd out other plants, limiting both plant and animal biodiversity, and altering wetland functions.

**FIGURE 1.** Aerial view of Burnham Creek Wildlife Management Area near Crookston, MN. 16 July 1990. Note dark area of restored marsh dominated by hardstem bulrush.

**FIGURE 2.** Aerial view of Burnham Creek Wildlife Management Area near Crookston, MN. 22 August 2003. Note green area of hybrid cattail, which has filled in former open sedge lowland and much of the former hardstem bulrush marsh.

Hybrid cattails (*Typha* x *glauca*) in particular, have become a serious problem in Northern Great Plains wetlands over the last 100 years. Svedarsky observed a dramatic example of this in the early 1990s while doing a biological inventory of the Burnham Creek Wildlife Management Area (BCWMA), a flood control impoundment project near Crookston, Minnesota (Svedarsky 1992). Part of the project involved diverting nutrient-rich runoff into a formerly drained hardstem bulrush (*Scripus acutus*) marsh that had been primarily fed by somewhat saline seepage water. The runoff water drowned out wet prairie and sedge lowlands, which were rapidly colonized by hybrid cattail. The bulrush marsh was more slowly invaded and eventually dominated by cattails (Figures 1 and 2). The area adjacent to the BCWMA would become the Glacial Ridge National Wildlife Refuge. Launched in 2001, the refuge was billed as the largest contiguous prairie and wetland restoration project in the U.S. Within this 23,000-acre landscape, about 3,000 acres of shallow wetlands were restored, most without water control structures. Predictably, most of these wetlands became dominated by cattails in wetter parts and reed canary grass and willows in fringe areas. This vast habitat complex became the impetus for a project to explore a multi-functional approach of reducing cattails for wetland wildlife management while looking for ways to use cattails as a resource. The research of Murkin et al. (1982) served as a guide to create a "hemi-marsh" setting and restore wetland functions.

**FIGURE 3.** Hemi-marsh located near Waconia, MN and open water accentuated by muskrat activity. 10 April 2016.

On many public lands (national wildlife refuges, wildlife management areas, waterfowl production areas, flood control impoundments) in northwestern Minnesota, cattail growth has far exceeded the 50:50 distribution recommended by Murkin and others for optimum wetland wildlife habitat (Weller and Spatcher 1965, Murkin et al. 1982). Figure 3 shows more of an optimum configuration of open water and emergent vegetation that has been further enhanced by muskrat activity.

During discussions of quantifying the extent of cattails in northwestern Minnesota and exploring options to harvest cattail biomass, David Ripplinger of North Dakota State University mentioned the cattail work underway by Richard Grosshans and the International Institute of Sustainable Development (IISD) in Manitoba. The Canadian work focused initially on using cattails in the Netley-Libeau Marsh at the south end of Lake Winnipeg for nutrient removal to reduce the eutrophication of the lake. Secondarily, Grosshans (2011) and his colleagues were evaluating cattail bioenergy. They demonstrated that pelletized cattails have energy comparable to wood pellets at 7,500 Btu per lb. Thus, cattail-dominated basins could be managed simultaneously for wetland wildlife and bioenergy.

Since the U.S. is heavily dependent on fossil fuel energy, using cattails as a partial substitute for fossil fuels could help mitigate climate change by reducing greenhouse gas emissions. Other forms of biomass as a renewable energy source are being evaluated and used nation-wide in efforts to transition from non-renewable fossil fuels to renewable resources. In Minnesota, this includes hybrid poplar, agricultural and forest residues, prairie vegetation, and switchgrass (*Panicum virgatum*).

The Canadian work has evolved into a multi-faceted project with numerous sponsors and benefits (Grosshans and Grieger 2013, Grosshans 2016). It also provided important guidance for the Minnesota work summarized here.

# HISTORY OF CATTAILS

Common or broadleaf cattail (*Typha latifolia*) is native to North America (Kantrud 1992). The status of the narrow leaf cattail (*T. angustifolia*) as a native or introduced species is unclear. In the 1830s, two species of narrow leaf *T. gracilis*, a native, and *T. angustifolia*, an introduced European species, were reported in eastern North America. By the 1850s, taxonomists had merged them into one species, *T. angustifolia* (Kantrud 1992).

Prior to the 1880s, *T. angustifolia* had only been collected in a few wetlands along the North Atlantic seaboard. It spread west to the Great Lakes during the late 1800s and continued westward during the early and mid-20th century. Disturbed wetlands along roads, ditches, and railroads provided the likely pathway. It was first recorded in Wisconsin in the 1920s, Iowa in the 1930s, and North Dakota in the 1940s. It spread rapidly across much of the remaining Great Plains in the last 50 years. According to Kantrud (1992:2), "even more noticeable in the prairie pothole region has been the great increase in wetlands dominated by the robust plant most botanists consider a hybrid between common cattail and narrow leaf cattail, named *T.* x *glauca*."

> *Hybrid and narrowleaf cattail have eliminated waterfowl and shorebird use of many of our remaining seasonal wetlands. These shallow wetlands are critically needed for spring migration and breeding habitat.*
>
> Ray Norrgard, MN DNR

Dabbling and diving ducks and their broods prefer wetlands with openings in the marsh canopy. Many pastured semi-permanent wetlands in western Minnesota and the eastern Dakotas were dominated by semi-open stands of hardstem bulrush a few decades ago. When they were idled they became dominated by dense stands of cattails (Kantrud 1992). Reductions in density and height of tall emergent plants generally increase use by breeding ducks whether caused by fire, flooding, grazing, mowing, or biomass harvest. The process makes little difference to the ducks.

Another problem with cattail-choked wetlands is that large numbers of migrant blackbirds (i.e., Red-winged Blackbirds [*Agelaius phoeniceus*], Common Grackles [*Quiscalus quiscula*], and Yellow-headed Blackbirds [*Xanthocephalus xanthocephalus*]) roost there and damage nearby crop fields (Linz and Homan 2011). These problems present the opportunity to develop an integrated management tool for wetlands. Harvesting cattails for bioenergy could help create desirable hemi-marsh conditions while reducing roosting habitat for blackbirds that damage crop fields.

# BIOLOGY OF CATTAILS

The best approach to managing a species is to look at its life cycle to find a vulnerable physical or physiological stage. With a holistic approach, coordinating control tactics with specific seasons of growth, dormancy, or reproduction, the manager can better accomplish restoration goals with reduced effort, less money spent, and less habitat disturbance.

Cattails are a common wetland plant. Easily recognizable by their tall leaves and signature brown pistillate spike, they grow along marsh edges in emergent wetlands throughout the world. Although they can cause problems when growing out of control, they are also a necessary keystone species. They provide shelter for birds and mammals, shade water to cool fish, and their energy-rich rhizomes and shoots are a nutritious food source enjoyed by many animals including humans (Linde et al. 1976, Sojda and Solberg 1993).

**FIGURE 4.** Hybrid cattail rhizome with roots.

Cattails are well suited to live in an environment of fluctuating water levels and high fertility. Their seeds germinate quickly in marshy mudflats, making them quick to recolonize after human or natural disturbances. They can grow in a wide range of shallow water depths depending on species, age, and condition of the stand. Maximum water depths are typically 2-3 feet, although greater depths can be tolerated for brief periods. Cattail can even grow as floating mats on the water's surface, helping it to colonize water deeper than it could grow in otherwise (Linde et al. 1976). Once a stand of cattails is established, it alters its habitat. New stems and root/rhizome masses grow and accumulate on dead stalks and other organic material. As sediments accumulate, they alter nutrient cycles and prevent light from reaching the substrate, thus excluding other plants (Gleason et al. 2012). The accumulation of sediments and root mass eliminates shallowly flooded marsh edges. Cattails are also excellent at filtering polluted runoff containing sediment, fertilizer, and heavy metals. By capturing these pollutants, they prevent, or at least delay, them from having larger negative effects in the environment.

Cattails are "rooted" from their rhizomes, which are actually underground stems (Figure 4). Rhizomes anchor the plant in the substrate and send out water and nutrient-absorbing roots. Clonal propagation occurs via rhizome growth. Cattails are perennial, meaning they grow back year after year, thanks to the stored energy in rhizomes. Cattail researchers have found that often a large dense stand only consists of a few genetically unique plants; each connected through a network of rhizomes and from which emerge dozens of stalks (Linde et al. 1976). These stalks, 3-10 feet high, have long, sheathing leaves emerging from the base of the plant. In cross section, the leaves contain loosely packed aerenchyma cells (Figure 5). This spongy tissue serves as a kind of straw and brings air to rhizomes even when the substrate is underwater and the leaves are dead; an important point to remember for cattail management (Linde et al. 1976).

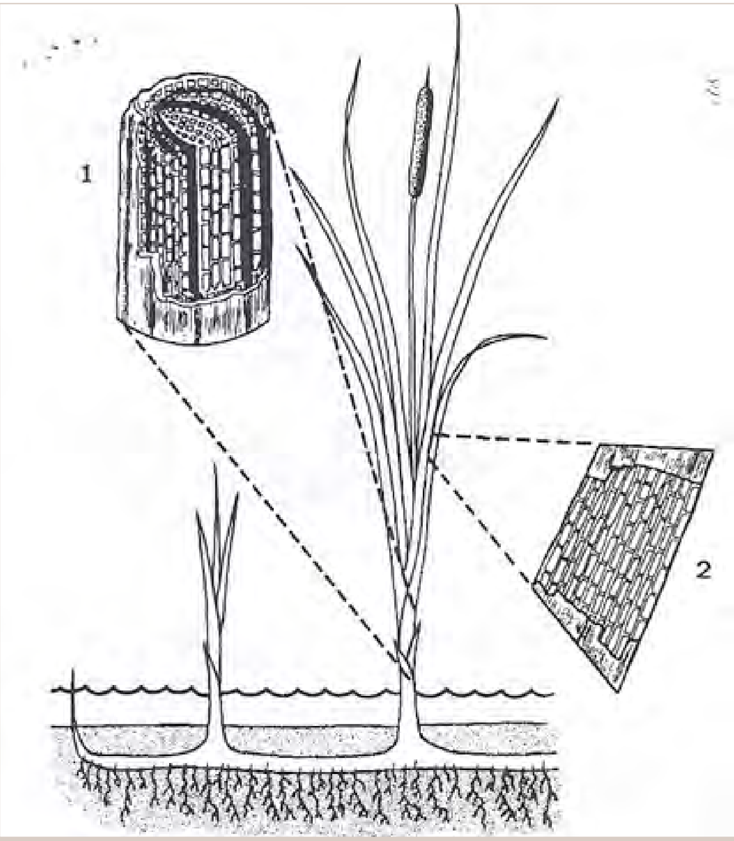



FIGURE 5. Cross-section of cattail stem (1) and longitudinal section of a leaf (2) showing aerenchyma tissue. From Sojda and Solberg (1993).

The cattail inflorescence (botanically known as a spike) is at the top of stems and begins developing within sheathing leaves in late May or early June. By late June, leaves open and show the two-tiered spike: the top containing tiny male flowers with pollen and the lower, pistillate spikes holding the females flowers, where seeds will develop. Both flower types are densely packed, making it hard to identify individual flowers. When spikes first emerge, they are green but turn brown as they mature then break down as pollen. Later fluffy seeds are shed (Linde et al. 1976).

The most noticeable distinguishing feature between the two species is the wide (> 1.5 in.) spacing between pistillate and the staminate flowers on narrow leaf while the flowers generally touch in broadleaf. Hybrid plants are typically intermediate in spacing. Broadleaf cattail prefers shallower water and is overall less robust than narrow leaf. As narrow leaf spread westward in the past 100 years, their ranges overlapped and they began to hybridize. The resulting hybrid is more resilient in a wider range of hydrologic conditions than either parent thus allowing it to be extremely invasive. Hybrid cattail generally produces sterile seeds, so it often occurs where its parent species overlap. Travis et al. (2010) attributed the increasing invasiveness of cattail throughout the past few decades to be caused in large part by the emergence of this new hardy hybrid.

Cattail dominance is largely due to its rapid growth. As the weather starts to warm in April and May, cattails become active. Fueled by the photosynthetic sugars produced the previous summer and stored over winter in rhizomes, stalks sprout from rhizome nodes and grow rapidly. Since energy use is dependent upon oxygen reaching the rhizomes and roots, if dead leaves have been cut and old stalks are submerged, flooding a stand inhibits energy metabolism and weakens the plant. The rapid growth that occurs from April to July represents a period of draining energy reserves from the rhizome.  The stores of energy are replenished once growing has slowed in midsummer and continues until the leaves die back in late fall. Late summer is also the time for clonal reproduction; rhizomes grow out from nodes, extending the spread of the plant, and new stalk buds develop, waiting to sprout in the spring.

# BIOLOGY OF CATTAILS

Cattail pollen is released and fertilization occurs in midsummer, seeds being released throughout the fall, winter, and into the following spring. Linde et al. (1976) determined that carbohydrate reserves are lowest just as the green spikes emerge, generally sometime in mid-June. From a control standpoint, this is the ideal time to cut stalks as this both limits the cattail's ability to produce viable seed and prevents the build-up of carbohydrate reserves in rhizomes. Combining midsummer mowing with spring flooding severely weakens plants and may allow other wetland plants a chance to get established. However, water levels and wildlife use in early to mid-summer often restricts accessibility during this time.

From late November to late April, cattail plants go dormant as they release fluffy, wind-dispersed seeds, as many as 20-700,000 per inflorescence (Baldwin and Cannon 2007). Over the years the stalks, which grow quickly but decompose slowly, build up in the stand and shade out other plants. As they decompose, often in methane-producing anaerobic conditions, captured nutrients are released back into the system.

> *According to the IBI (Indices of Biological Integrity) results, approximately 17% of depressional wetlands and ponds have plant communities that are in good condition while 56% are in poor condition…Mixed and monospecific stands of invasive Cattail (Typha x glauca Godr. and T. angustifolia) were the most widespread invasive plants inhabiting the emergent zone of depressional wetlands and ponds, accounting for greater than 50% cover of the sample plots in 37 out of 99 study sites.*
>
> Page 20. Status and Trends of Wetlands in Minnesota: DWQA (2007 – 2012). July 2015. Minnesota Pollution Control Agency

# REGIONAL HIGHLIGHTS

## 1. THE MANITOBA EXPERIENCE

For the past decade the International Institute for Sustainable Development (IISD) with their partners from industry, academia, NGOs, and government have pursued innovative strategies to better manage water, land, and energy resources in the Lake Winnipeg watershed in Manitoba, Canada. Their process: harvesting cattail and other emergent plants that naturally take up nutrients (i.e. phosphorus) and contaminants, from marginal agricultural land, water retention sites, and drainage ditches to capture and remove nutrients, and using their abundant plant biomass for sustainable bio-products and low carbon renewable energy to replace fossil fuels (Grosshans 2014, Grosshans et al. 2010, 2011, 2013, 2014, 2015).

Richard Grosshans, Henry David Venema (former Director of the Natural and Social Capital Program), and colleagues at IISD began their cattail research in 2005 in partnership with the University of Manitoba and Ducks Unlimited Canada. Their initial goals were to find innovative ways to reduce the phosphorus entering Lake Winnipeg and help reduce algae on the lake. Lake Winnipeg is the 10th largest freshwater lake in the world, and is considered one of the most eutrophic. It is the receiving water body for a 247,000,000 acres (1 million square km) watershed that drains an area primarily of agricultural land across the Canadian and U.S. prairies. Much of the phosphorus entering the lake is carried downstream during snowmelt and flooding in the spring, as well as large summer rain events.

In 2005, Lake Winnipeg's issues with phosphorus and algae had not been in the public spotlight for long. An initial focus of IISD's research program was to evaluate the cattail and other plant communities in the Netley-Libau Marsh, a 61,750-acre wetland at the south end of Lake Winnipeg, as a means of nutrient removal especially, eutrophication-causing phosphorus and nitrogen. Netley-Libau Marsh is located where the Red River flows into the lake, a river that is the source of about 30% of the nitrogen and over 60% of the phosphorus even though comprising only 11% of the inflow. They were also interested in whether plants such as cattail and other large aquatic plants could be harvested farther upstream in the watershed from water retention sites, marginal land areas, or highway ditches to capture phosphorus and the other contaminants these plants absorb. A number of questions arose from their initial investigations. Once harvested, could this biomass serve as sustainable low-carbon energy and other bio-products? What were the impacts of harvesting? How much phosphorus did cattail absorb? Could that phosphorus be removed by harvesting and could it be harvested successfully? Their work demonstrated that the answers were yes.

IISD's research through the award-winning Netley-Libau Nutrient-Bioenergy Project (Grosshans and Grieger 2013) from 2006-2010 demonstrated how nutrients and contaminants taken up by plants such as cattails could be removed through harvesting (i.e., phosphorus). They also demonstrated that this harvested material is valuable biomass for sustainable low carbon biomass energy to reduce global carbon emissions, as well as other higher-value biofuels, biochar, biogas, and fiber bio-products. They further proved that by displacing coal with cattail and other biomass, valuable carbon offset credits were generated that could be sold to fund watershed management efforts. This provides another incentive to use renewable biofuel in that Canada offers carbon credits. Once certified by the Carbon Commission of Canada, credits can be sold to companies to displace carbon emissions.

The project was only meant to last 3 or 4 years, but with financial support from agencies such as Manitoba Liquor and Lotteries, Manitoba Hydro, Royal Bank of Canada, both provincial and federal governments, the research has continued and has been expanded to the watershed scale. The success included a commercial scale bioenergy program, working closely with industry and government partners towards implementation and commercialization.

> *Wow, the wildlife habitat we have created there (Pelly's Lake) is unbelievable. The site is attracting all kinds of waterfowl and marsh birds. In the old days, Ducks Unlimited would have done this type of management for the wildlife habitat benefits alone.*
>
> Richard Grosshans, Senior scientist, International Institute for Sustainable Development. Winnipeg, MB

Using cattail for nutrient removal was a not a new idea, nor was the notion to burn them for energy. However, their approach was innovative for not looking at these problems in isolation or as a cost, but holistically considering the environmental, economic, and social benefits together. They moved beyond the pilot stage in 2010 to demonstrate these concepts at a large scale in a low-lying basin known as Pelly's Lake located some 60 miles southwest of Winnipeg, but still part of the Lake Winnipeg watershed. It was important to demonstrate the bioenergy use of cattail at the commercial scale to be seriously considered by local governments in Manitoba. There had to be a reason to harvest beyond just cleaning out the ditches and retention sites and capturing phosphorus.

Cattail blended fuel pellets have potential as a commercial source of clean energy just like any other fuel pellets on the market. During the past decade biomass energy has gained momentum in Manitoba because of policies and mandates aimed at addressing climate change and carbon reductions. The Government of Manitoba brought in a ban on the use of coal for space heating in Manitoba in 2014 creating an increased demand for quality processed biomass fuel. Manitoba's Hutterite communities are the biggest users of coal for space heating since many of them are not located near natural gas pipelines. Colonies have decided to either switch to natural gas if near a natural gas line, to electric heat, or to biomass. Lignite coal picked up from Estevan, SK is often used in Manitoba and has a total cost of about $100 (CAD) to $120/T including transportation, plus an added coal tax. Biomass currently has a similar cost of $100/T to $180/T for processed fuel pellets. Integrating unconventional biomass feedstocks, such as cattail, or "ecological biomass" that brings with it many added environmental benefits, increases the available biomass sources for processing, while helping reduce phosphorus loading to rivers and lakes.

The years 2014 to 2016 were a monumental success for IISD's Cattail Harvesting for Nutrient Capture and Sustainable Energy Project; having reached large-scale harvesting and commercial biomass fuel production simultaneously. With a growing need and demand for compressed or densified biomass fuel in Manitoba (i.e. fuel pellets), a primary focus for 2015/2016 was increasing the scale of harvesting for commercial scale production of blended cattail biomass fuel. In their fourth year of commercial scale harvesting at the Pelly's Lake site near Holland, Manitoba, IISD with their partners PAMI (Prairie Agricultural Machinery Institute) and Biovalco harvested about 800 tons of biomass, which removed over 2,200 lbs. of phosphorus and 22,000 lbs. of nitrogen from the Lake Winnipeg watershed. This is equivalent to the amount of phosphorus in 3,000 bags of lawn starter fertilizer. There are about 2-4 lbs. of phosphorus contained in one cattail bale or 12 or so lbs. per acre.

In 2015 and 2016, IISD with their industry partners Biovalco and BRG Manufacturing, produced over 1,500 tons of blended biomass fuel (primarily cattail:wood, cattail:grass:wood) and 1,500 tons of wood based fuel pellets. This generated 5,000 tons of $CO^2$ equivalents of offsets, equivalent to the average annual greenhouse gas emissions from 1,000 cars[1]. This provided over 50,000 GJ (gigajoules) of heat energy - enough to heat several Hutterite colonies or 500 Manitoba households for an entire winter. During the winter of 2015-2016, fuel pellets were used for space heating in larger-scale boiler facilities at Providence College and on several Manitoba Hutterite colonies, as well as in residential pellet stoves at the Living Prairie Museum and several farm buildings. Current analysis indicates these blended cattail:wood pellets are a premium fuel blend with excellent burn characteristics, low ash (3%), and high heat energy (19.8 GJ/T). Pure cattail fuel pellets contain about 6 % ash after burning, and this contains some 88% of the phosphorus. The rest of the phosphorus is bound in clinkers or slag in the boiler system. Fertilizer trials showed the phosphorus in the ash is not readily available in the short term but is a slow release like any other ash when land applied.

IISD has also been collaborating with the City of Winnipeg for the past several years in an urban example of processing the cattail and prairie grasses harvested as part of city maintenance into fuel pellets or compost. In 2015, 470 tons of cattail were harvested from Winnipeg drainage ditches within the city and diverted to the new Brady compost facility. Harvesting captured about 617 lbs. of phosphorus and 4.000 lbs. of nitrogen. Without diversion, in previous years this material was either left to decompose on the sides of ditches or sent to a general landfill.

In addition to the nutrient capture, biomass, and carbon offset benefits, harvesting combined with water level management in the Pelly's Lake water retention site has restored incredible wetland habitat. In 2014, the Pelly's Lake Watershed Management Project was initiated in the basin to

[1] *https://www.epa.gov/sites/production/files/2016-02/documents/420f14040a.pdf*

store some 1,200-acre feet of runoff water and includes a water control structure. The control structure was fully operational for the first time in the spring of 2015. The response of wetland wildlife has been remarkable with spring flooding after the fall harvest of cattails (Figure 6). Richard Grosshans (personal communication) reported, “Wow, the wildlife habitat we have created there is unbelievable. The site is attracting all kinds of waterfowl and marsh birds. In the old days, Ducks Unlimited would have done this type of management for the wildlife habitat benefits alone.” This demonstrates further environmental benefits of biomass harvest, as a component of sustainable watershed management.

Along the way, IISD and research colleagues have also explored other high-value products such as biochar, bioethanol, anaerobic digestion and biogas, and fiber. Nevertheless, the current demand and market in Manitoba is for compressed fuel products. They are also  expanding their research program to evaluate other bioremediation options, using floating bio-platforms of plants designed by Curry Industries in Winnipeg, Manitoba, to treat wastewater in lagoon systems, and potentially oil ponds or landfills. Significant too, is the multi-dimensional model, which the Manitoba project has demonstrated as a pattern for other areas such as, Minnesota, North Dakota, the Great Lakes

**FIGURE 6.** Residual cattail bales after 2014 fall harvest in Pelly’s Lake basin (upper left) and after 2015 spring runoff ( upper right). Lower left shows cattail/ open water interspersion on 2 June 2016 and lower right is an aerial view of the Pelly’s Lake Watershed Management Project on 21 July 2016.

region, Germany, and other areas in terms of bioenergy and nutrient recovery potentials at the watershed scale.

For more information on the IISD experience in Manitoba, see the following:

- http://www.iisd.org/blog/cattails-clean-energy-where-here
- http://www.iisd.org/pdf/2011/netleylibau_marsh.pdf
- http://www.iisd.org/sites/default/files/publications/cattail-biomass-to-energy-commercial-scale-harvesting-solid-fuel.pdf
- https://www.iisd.org/library/smart-sourced-fuel-products
- https://www.iisd.org/library/cattail-biomass-watershed-based-bioeconomy-commercial-scale-harvesting-and-processing
- https://www.iisd.org/library/cattails-harvesting-carbon-offsets-and-nutrient-capture-lake-friendly-greenhouse-gas-project
- https://www.iisd.org/library/our-lake-our-solutions-two-years-progress-and-partnerships
- https://www.iisd.org/library/cattail-typha-spp-harvesting-manitoba-legislative-and-market-analysis-operationalization-and
- https://www.iisd.org/library/netley-libau-nutrient-bioenergy-project

## 2. THE DAKOTAS EXPERIENCE

A rather comprehensive cattail management symposium occurred in Fargo, North Dakota in 1992. The primary focus was on using herbicides in the eastern Dakotas to break up cattail-choked marshes to reduce crop depredation by roosting flocks of blackbirds (Linz 1992). Sunflowers were the primary crop of interest since, at least in 1992, 69% of the sunflowers grown in the United States were grown in North Dakota. That work continued over a number of years under the sponsorship of USDA-Animal and Plant Health Inspection Service (APHIS), National Sunflower Growers Association, North Dakota State University, South Dakota State University, and the U. S. Fish and Wildlife Service. Linz et al. (1992) started evaluating Rodeo (glyphosate) herbicide in1989 to fragment cattails in marshes. They found July/August applications controlled cattails for two years and were effective in deterring blackbirds. In 1990, they treated 70-90% areal coverage of their study sites and reduced that in 1991 to 50-70%. Enhanced waterfowl use was noted; however, Linz suggested there was a probable decrease in rail and Marsh Wren *(Cistothorus palustris)* use; until cattails grew back. Reducing cattail coverage limited the number of Red-winged Blackbirds, Yellow-headed Blackbirds, and Marsh Wrens (Linz et al. 1996). A 70:30 open water to emergent vegetation ratio was recommended by Linz et al. (1992) to simultaneously deter roosting blackbirds and benefit wetland wildlife. Messersmith et al. (1992) found cattail control was good to excellent when glyphosate was applied at 2.3-3 lbs./acre and suggested the best application time was from late July to early September. Another species that may have benefitted from glyphosate treated wetlands was Black Terns *(Chilodonias niger)*; a species considered endangered in some states. Linz et al. (1994) found a positive relationship between Black Terns and dead cattail coverage.

Solberg and Higgins (1993) found waterfowl breeding pairs increased in glyphosate-treated wetlands in northeastern South Dakota in 1986 and 1987. Henry and Higgins (1992) found no detrimental effects on six species of invertebrates (a primary food source of waterfowl and shorebirds) due to glyphosate treatment. Linz et al. (1999) assessed the response of six invertebrate species one and two years post-treatment after reducing cattail coverage with glyphosate and observed similar numbers of invertebrates between treated and reference wetlands.

Herbicide control of cattails received "cautious support" (Stromstad 1992) by wildlife interests at the Fargo symposium. However, concern was raised that often cattail-dominated marshes provide the only winter cover for Ring-necked pheasants *(Phasianus colchicus)* and White-tailed deer *(Odocoileus virginianus)* in an intensely farmed landscape. Larger cattail-choked wetlands might be more desirable to open up than smaller ones. Creating spatially dispersed openings in these larger marshes could enhance their winter cover values while still discouraging blackbirds. A mosaic pattern would be better than strips or blocks. Ray Norrgard has suggested that treating smaller wetland basins (< 10 acres) could restore the seasonal wetland component to habitat complexes. Cattail choked, smaller wetlands could "trap" pheasants and deer during winter storms because they rapidly fill with drifting snow while larger expanses of cattail provide more secure cover.

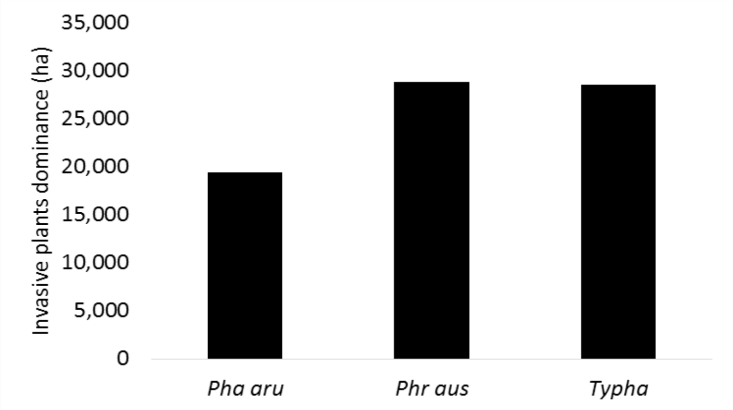



**FIGURE 7.** Area of Great Lakes coatal wetlands dominated by the three most dominant invasive emergent plants: *Phalaris arundinacea, Phragmites australis,* or invasive *Typha*.

## 3. THE GREAT LAKES EXPERIENCE

Great Lakes (GL) basin wetlands deliver an array of ecosystem services beyond what their size alone would indicate (Wetzel 1992, Wei et al. 2004). Their diverse plant assemblages (Albert and Simonson 2004) are recognized for providing critical fish and wildlife habitat. This includes; habitat for >90% of the fish occupying the Great Lakes (Jude et al. 2005, Uzarski et al. 2009), major stopover points along migratory corridors for waterfowl and shorebirds (Prince et al. 1992, Ewert and Hamas 1995), high invertebrate diversity (Burton et al. 2004, Uzarski et al. 2004), and habitat for rare fauna (Kost et al. 2007).

Biodiversity and ecological functions in species-rich GL coastal wetlands are threatened by aggressive invasive cattails. Great Lakes-wide, invasive cattails are among the most abundant macrophytes, dominating approximately 30,000 acres of GL coastal wetlands (Figures 7 and 8). In the St. Marys River, Les Cheneaux Islands, and Michigan's northern Lower Peninsula, an area harboring the highest quality remaining GL coastal wetlands, invasive cattails are the most common, and ecologically detrimental, aquatic invasive plant. Invasive cattails dominance reduces plant diversity (Frieswyk and Zedler 2007, Wilcox et al. 2008) and alters plant community structure (Lishawa et al. 2010) in these coastal wetlands. As stands of cattails age, plant diversity decreases and litter accumulates (Mitchell et al. 2011, Lishawa et al. 2013), resulting in reduced seed bank recruitment and seed germination (Frieswyk and Zedler 2006).

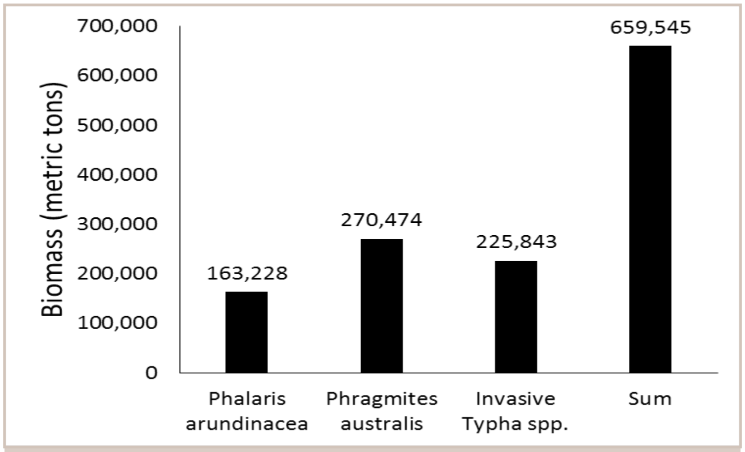



**FIGURE 8.** Estimated quantity late-summer standing biomass (dry weight) among the three most dominant species of invasive macrophytes in the Great Lakes Region.

Mechanical harvesting of invasive cattails resulted in increased plant species diversity in northern GL coastal wetlands (Lishawa et al. 2015). Furthermore, experimental work indicates that herbicide treatments are less effective than harvesting at maintaining native plants and also increased post-treatment nutrient concentrations in treated wetlands (Lawrence et al. 2015). Together, these results illustrate that in certain GL coastal wetlands, mechanical harvesting of invasive cattails is a more effective and less environmentally deleterious management technique than herbicide treatment.

Invasive cattails are highly productive and their biomass is a suitable feedstock for both bioenergy use and nutrient and carbon recycling via composting. Using invasive plant biomass has the potential to solve a suite of seemingly intractable environmental problems, while simultaneously providing a low-input sustainable biomass source for the production of renewable energy and agricultural fertilization.

**FIGURE 9.** Late fall baling of cattails in constructed wetland. American Crystal Sugar Company, Crookston, MN.

## 4. THE MINNESOTA EXPERIENCE

In the 1980s Wendell Johnson (U of MN, Crookston) and Doug Pratt (U of MN, Minneapolis) explored the values of cattails (planted *T. angustifolia*) as a bioremediation tool to remove nutrients (N, P, and K) from sugar beet processing effluent at Crookston (Johnson et al. 1987). They used a constructed wetland or lagoon that could be drained. While

# REGIONAL HIGHLIGHTS

FIGURE 10. Winter harvesting of cattails with forage chopper in constructed wetlands at American Crystal Sugar Company, Crookston, MN.

August harvest extracted the most nutrients, the material was too wet for practical use as an energy crop. They used late fall-winter harvested material for spreading on agricultural fields (Figures 9 and 10) and measured 6-8 tons of biomass per acre. (Dubbe et al. 1988). (More recent work using cattails for wastewater bioremediation in constructed wetlands has been conducted in Spain with subsequent use of harvested material for biofuel {Ciria, et al.2005}.)

In 2012, Svedarsky commenced a study sponsored by the Northwest Research and Outreach Center and the Northwest Minnesota Foundation (NWMF). The primary goals were to, 1) estimate the extent of cattails in expanses 20 acres or greater in the 10 counties of northwestern Minnesota and 2) preliminarily assess the logistics of harvesting cattails as a biofuel crop in the region. The study identified 95,498 acres of wetlands with cattails; most in excess of the 50:50 ratio of open water to emergent vegetation (Svedarsky

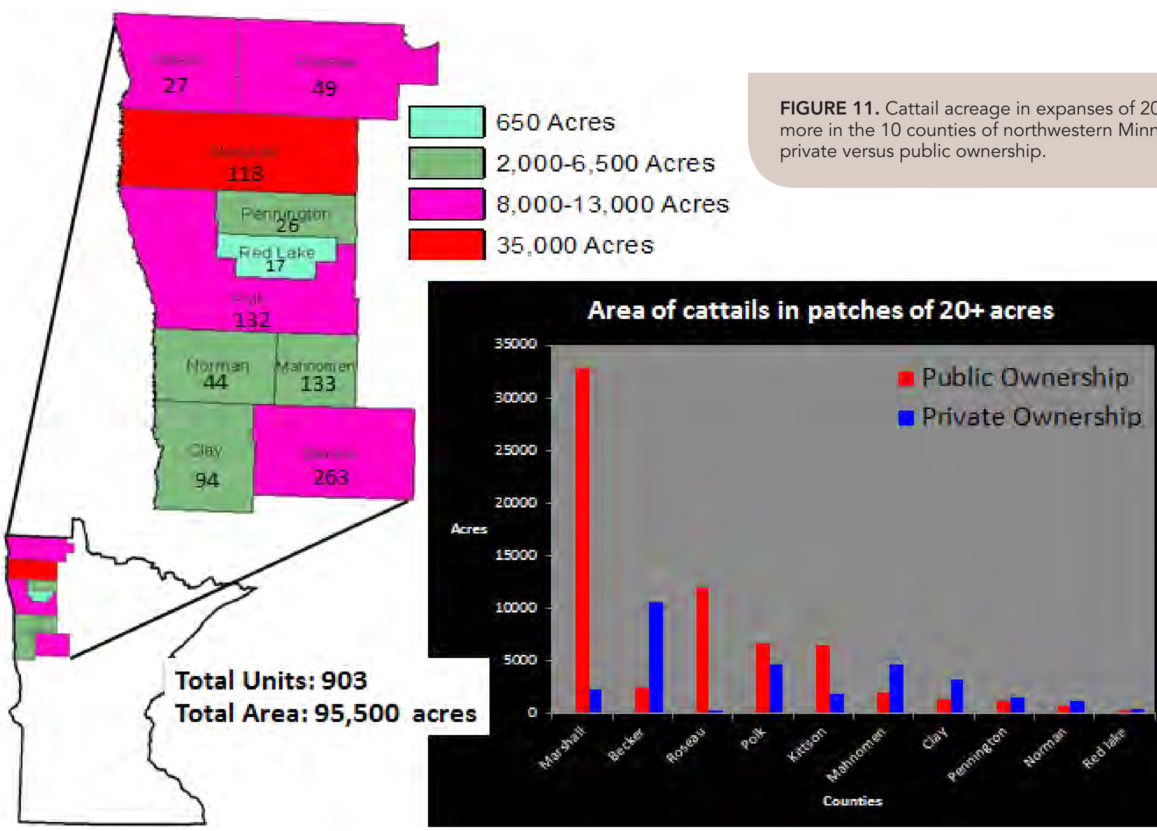



FIGURE 11. Cattail acreage in expanses of 20 acres or more in the 10 counties of northwestern Minnesota and private versus public ownership.

et al. 2013). Most were under public ownership. This suggested the potential to extract a bioenergy harvest while simultaneously enhancing wetland wildlife habitat. Figure 11 shows the total acreage delineated using the National Wetlands Inventory (NWI) and other digitizing methods.

Public land managers were interviewed on their attitudes towards cattail harvest, wildlife habitat effects, logistical considerations, and other opinions on cattail management. (Appendix A). A sample of round bales of cattails were harvested at the Glacial Ridge National Wildlife Refuge near Crookston in the dry fall of 2012 to preliminarily evaluate pelletizing characteristics, energy potential, and chemical properties.

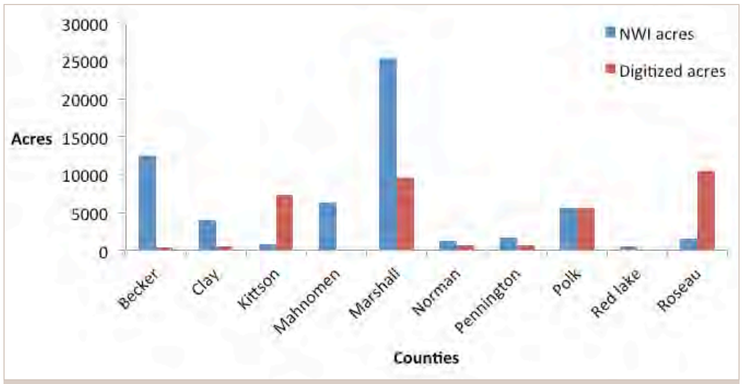



**FIGURE 11** (CONTINUED). Cattail acreage in expanses of 20 acres or more in the 10 counties of northwestern Minnesota and private versus public ownership.

In 2014, the Legislative Citizen's Commission on Minnesota's Resources (LCCMR) provided a two-year grant to further evaluate cattails as bioenergy in the region and explore various harvest and control options (Svedarsky 2014). Biological data were collected on the response of birds, amphibians, and vegetation to certain management applications in three different study sites. A number of logistical challenges were encountered in the LCCMR study that limited the extent of some of the harvest demonstrations that were envisioned to occur after pre-treatment biological data were collected.

The three study sites were as follows:

**Glacial Ridge National Wildlife Refuge** (GRNWR) is a 23,079-acre prairie and wetland restoration project located in northwestern Minnesota, 15 miles east of Crookston. The area was a patchwork of tallgrass prairie remnants and agriculture until the mid-1970s when large-scale agricultural intensification began. Some 17,000 acres were under cultivation in 2000 when the property was purchased by The Nature Conservancy. Prairie and wetland restoration were commenced in 2001, eventually resulting in 20,015 acres of prairie and 3,064 of shallow wetlands (Gerla et al. 2012). The area was designated a national wildlife refuge in 2004. A sample of these wetlands was selected for the biological evaluation. They were generally less than two feet deep with little capacity to lower water levels.

**Agassiz National Wildlife Refuge** (ANWR) is comprised of 61,500 acres located 23 miles northeast of Thief River Falls. The area had a history of unsuccessful attempts to convert poorly drained swampland, brushlands, and wetlands to farmland before it became a national wildlife refuge in 1937. A system of dikes and water control structures established 20 wetlands ranging in size from 100 to 10,000 acres and from 2-5 feet deep.

The **Parnell Flood Control Impoundment** (PFCI) is located 12 miles northeast of Crookston and is managed by the Red Lake Watershed District. The project is designed to reduce flooding on downstream agricultural lands and urban areas by retaining up to 4,000 acre-feet of runoff from

FIGURE 12. Demonstration of hemi-marsh creation by cattail mowing only (especially in lower right portion of photo) at the Parnell Flood Control Impoundment near Crookston, MN. 13 November 2014.

a drainage area of approximately 23 square miles. The impoundment incorporates a two-pool design (with no permanent pool), two separate outlets, and an inter-pool connecting channel. It was completed in 1999.

Treatments and Methods. Pre-treatment biological data were collected in 2014 with some management actions occurring that fall. Cattail dominated wetlands at Glacial Ridge NWR were treated by combinations of herbicide, mowing, disking, and fire; not always in a manner that provided a clear measurement of cause and effects. At Agassiz NWR, a combination of herbicide, fire, and water level manipulation was implemented as treatments. In the fall of 2014, the Parnell Impoundment was mowed in a checkerboard pattern to simulate a 50:50 distribution of open water to vegetation except no material was removed (Figure 12). Birds were sampled by point counts and transects, and vegetation by quadrats and line transects. General responses of bird and vegetation to treatments are summarized in Table 1. Responses were somewhat confounded by the 2014 field season being dry and the 2015 season being normal to slightly wetter.

Bryce Olson and Steve Windels (personal communication) are currently engaged in hybrid cattail control efforts at the edge of the Rainy Lake system at the Voyageurs National Park near International Falls, MN. They are evaluating mechanical harvesters to remove cattails and deposit onto nearby shores where it is composted and/or burned (Figure 13). They plan to restore wetlands using locally sourced native vegetation. Cattails are spreading significantly at the park. Muskrat populations have been quite low for decades so are not an effective natural control. They are also investigating these muskrat population declines and the potential for reintroduction.

**North Ottawa Impoundment**

The Bois de Sioux Watershed District owns and operates the North Ottawa Impoundment (NOI) located in Grant County, Minnesota, designed primarily for downstream flood control and reduction of crop damage. The impoundment is part of the Rabbit River sub-watershed, which drains a 75-square mile agriculture dominated region of the Red River basin. The Red River Basin Commission has partnered with the Bois de Sioux Watershed District and the Minnesota Department of Natural Resources in an integrated, multi-benefit effort to provide a model for future flood damage reduction projects by linking flood control with water quality improvements and wildlife enhancement benefits. Overall goals of the management plan

**TABLE 1.** Effects of cattail management at three study sites in northwest Minnesota, general changes from 2014 to 2015.

| Treatment | Glacial Ridge NWR | Agassiz NWR | Parnell Flood Control Impoundment |
|---|---|---|---|
| **Control** | Cattail increased from 16 to 22% coverage while other vegetation increased from 8 to 14% *<br>Bird species richness increased from 7.00 to 8.75 **<br>Sedge Wren max. counts down, Red-winged Blackbirds up ** | Cattail increased from 16 to 17% coverage while other vegetation decreased from 54 to 39%<br>Open water increased from 12 to 13%<br>Bird species richness increased from 6.22 to 7.22<br>Both Marsh Wren and Sedge Wren max. counts up | Cattail increased from 13 to 22% coverage<br>Open water decreased from 30 to 14%<br>Bird species richness increased from 7.00 to 7.50 |
| **Chemical** | Cattail decreased from 10 to 4% coverage while other vegetation decreased from 9 to 7%<br>Open water increased from 33 to 48%<br>Bird species richness increased from 6.75 to 7.75<br>Marsh Wren and Red-winged Blackbird max counts up and Sedge Wren down | Cattail decreased from 20 to 1% coverage while other species of vegetation increased from 10 to 27%<br>Open water decreased from 43 to 16%<br>Bird species richness decreased from 6.58 to 6.25<br>Marsh Wren max counts down and Sedge Wrens up | N/A |
| **Fire** | Cattail increased from 15 to 25% coverage<br>Bird species richness increased from 5.75 to 7.25<br>Sedge Wren and Red-winged Blackbird max. counts up | N/A | N/A |
| **Chemical x Fire** | Cattail decreased from 10 to 7% coverage while other vegetation decreased from 31 to 14%<br>Open water increased from 39 to 45%<br>Marsh Wren and Red-winged Blackbird max. counts up, Sedge Wren down | N/A | N/A |
| **Mow** | Cattail increased from 10 to 22% coverage while other vegetation increased from 22 to 31%<br>Marsh Wren max counts down, Red-winged Blackbirds up | | Cattail decreased from 7 to 3% in coverage<br>Open water decreased from 42 to 36% in 2015.<br>Bird species richness increased from 5.50 to 6.50<br>Species richness increased from 7.00 in 2014 to 8.50 in 2015 from transects. |
| **Mow x Chemical** | Cattail decreased from 21 to 4% coverage while other vegetation decreased from 15 to 5%<br>Open water increased from 29 to 41%<br>Red-winged Blackbird max. counts down | N/A | N/A |
| **Mow x Disk** | Cattail increased from 27 to 35% coverage while other vegetation increased from 17 to 18%<br>Marsh Wren, Sedge Wren, and Red-winged Blackbird max. counts down | N/A | N/A |

** Based on quadrat sampling*
***Based on point counts*

include; reduce downstream flood damage, improve water quality by removing nutrients from surface runoff through biomass harvesting, wildlife habitat enhancement through a moist soils management rotation, crop production, and downstream flow augmentation.

The 1,920-acre impoundment has a storage capacity exceeding 16,000-acre feet during flood events. The impoundment has a unique design of a flood storage reservoir that allows for individual water level manipulation in eight, 160-acre cells and two, 320-acre cells (Figure 14). The

**FIGURE 13.** Floating cutter operating along Rainy Lake, Minnesota.

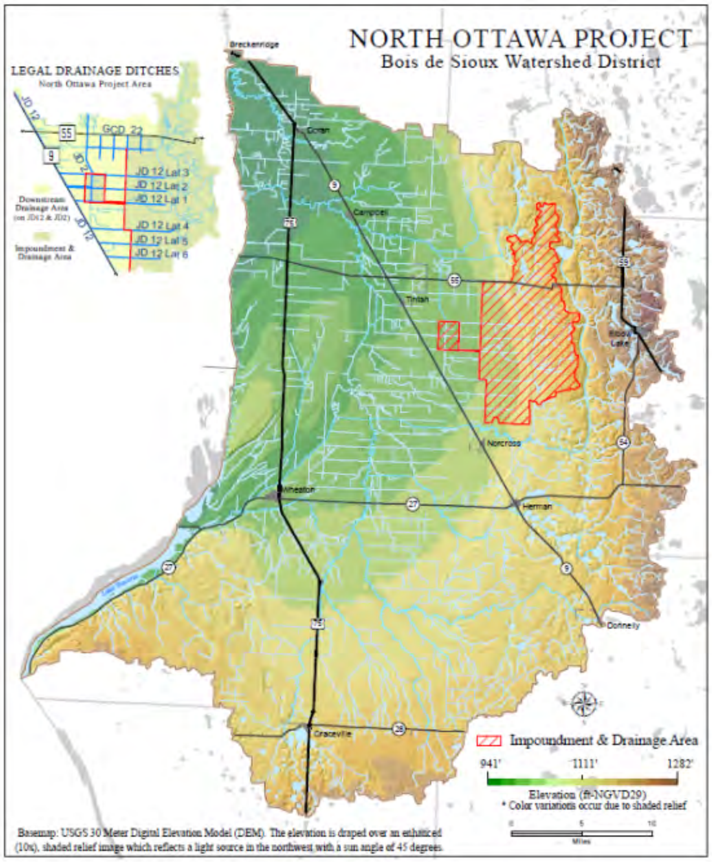
water quality project objectives are to manage water levels in treatment cells to maximize nutrient settling and vegetative growth, harvest vegetation during optimal times of the growing season to maximize nutrient removal, and identify biomass utilization opportunities including agricultural soil amendments, fiber, and bioenergy. Significant reductions in sediments and nutrients have already been documented during water quality monitoring. A moist soils and shallow wetland rotation has resulted in improved habitat conditions for migratory waterfowl and shorebirds. Two cells are used for traditional crop production when flood damage reduction management is not required. Spring runoff is captured and slowly released downstream which augments fisheries habitat.

Harvesting aquatic biomass for nutrient recovery is a somewhat unique practice in the Northern Great Plains to reduce nutrient loads coming from agriculture-dominated watersheds. Biomass harvest activities within the impoundment will be facilitated by dropping water levels and using conventional harvesting equipment. Harvesting activities will target two times; the first harvest (growing season) will be used as green manure on agricultural land within the upstream drainage area to potentially reduce fertilizer needs. The second round will be to collect biomass at a lower moisture content (fall) to use as fiber (board, insulation, bio-composites) and to densify (into pellets, cubes, briquettes) for bioenergy use. These additional opportunities offer added value and increased economic returns, which are necessary to sustain the development and adoption of this methodology.

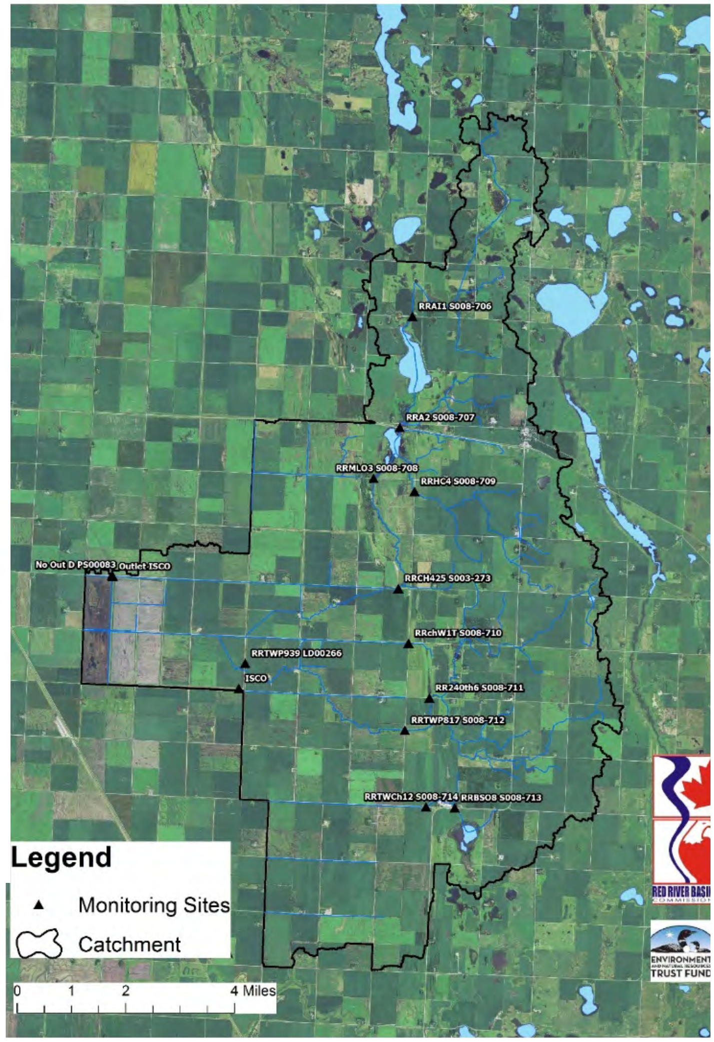
Requests for additional information can be directed to: Aaron Ostlund, Project Coordinator at the Red River Basin Commission office in Fargo, ND. aaron@redriverbasincommission.org

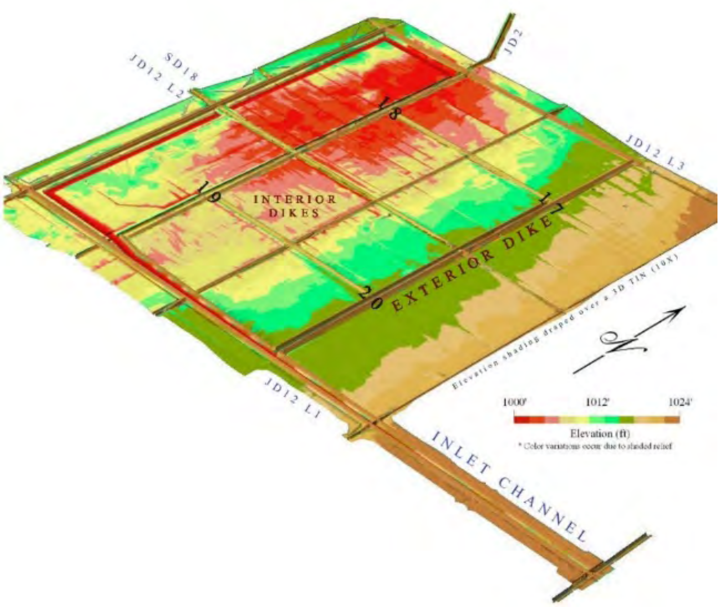
> *The North Ottawa project will evaluate the potential for capturing nutrient runoff from mostly nonpoint sources by using cattails or other vegetation within existing shallow flood storage reservoirs. Over 80% of the phosphorus and nitrogen loads that are being discharged downstream are coming from nonpoint runoff mostly from agricultural fields*
>
> Jeff Lewis, Executive Director,
> Red River Basin Commission

FIGURE 14. North Ottawa Impoundment project near Breckenridge, MN. Cross-hatched area in upper left shows the drainage area and the receiving impoundment.




North Ottawa Catchment




# MANAGEMENT TECHNIQUES

Cattail, particularly hybrid cattail, management has been the topic of much research, observations, and action, over the last 50 years. Potential management is challenged by a number of variables including wetland depth, nutrient status, salinity, source of inflow water, natural sanctuary versus former cropland, type of cattail (we can practically assume that hybrid cattail is or will be present), water level control options, and desired outcomes for that particular basin. Drought occurrence is another important variable in the mix as is the availability of livestock if grazing is to be considered part of a control option. Muskrats can also be a significant and dynamic variable since their population levels are affected by drought, over-winter water levels, and disease. Clearly, "one size does not fit all," when one is devising a management plan. Often, more than one practice is applied.

**FIGURE 15.** Growing season burn. From Gleason (2012).

A number of review papers have addressed the biology and control options for cattails (Linde et al. 1976, Sojda and Solberg 1993, Baldwin and Cannon 2007) with Baldwin and Cannon providing a convenient summary of best management practices in Table 2. However, little work was being done at that time to harvest cattails (2005-2006) so it was not included in their management strategies summary. It will be discussed here along with some comments on updating other control methods.

**FIGURE 16.** Dormant season cattail burn. Photo by Jason Ekstein, MN DNR.

## 1. PRESCRIBED FIRE

The landscape of the Northern Great Plains is adapted to fire. Burning can, at least temporarily, suppress dominant plants such as cattails and give other, less aggressive plants a better chance of recovering. Burning breaks down dead leaves and organic matter that builds up in dense stands, severs air-conducting leaf aerenchyma tissue, and mineralizes nutrients. Burning is limited by water levels. Soft conditions for travel and volatile fuels, including the fluffy cattail seeds, can be dangerous. Gleason et al. (2012) conducted a study on six wildlife areas ranging from Agassiz NWR in northwest Minnesota to the Iroquis NWR in western New York to evaluate the comparative effects of growing season versus dormant season burns (Figures 15 and 16). The study concluded: 1) water level control is key during either season but the necessary infrastructure is often lacking, 2) growing season burns are generally preferred to damage cattails due to low carbohydrate reserves present in the rhizomes at that time, and 3) a combination of methods is commonly applied for success.

**TABLE 2.** Comparative table of best management practices (Baldwin and Cannon 2007).

| | 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). |

> *Probably the biggest question I'm still wondering about as a manager is if, in the future, we can combine a spray, then harvest approach and still have a viable biofuel product. In my opinion this gives wetland managers the biggest bang for their buck because the open water areas will persist for several years, rather than cattails likely growing back "happier" than ever after being hayed only.*
>
> Gregg Knutsen, Manager. Glacial Ridge and Rydell NWR

**TABLE 2.** Comparative table of best management practices (Baldwin and Cannon 2007).

| | Application timing/season | Benefits | Costs | Application procedures |
|---|---|---|---|---|
| **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). |

**TABLE 2.** Comparative table of best management practices (Baldwin and Cannon 2007).

| | Application timing/season | Benefits | Costs | Application procedures |
|---|---|---|---|---|
| **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 kills 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 noctuid moth larvae, Bellura oblique. The result was that total plant production was reduced by 55% (Grace and Harrison 1986). | | |

A systems approach is useful in order to take advantage of changing weather and climate conditions (e.g. drought) in order to maximize plant injury while not adversely affecting wildlife populations at vulnerable periods of their life cycle. In short, "It's complicated!"

## 2. CHEMICAL

There are benefits to using chemical control. It is relatively quick, requires minimal labor if the spraying is contracted, and can be done regardless of water levels. The herbicide glyphosate, sold under a variety of names such as Round-Up and Rodeo, is a systemic chemical that is most effective when applied to the leaf surface in late summer. This is the period of maximum carbohydrate movement to rhizomes and the chemical moves from the leaf surface throughout the plant. Glyphosate blocks a unique metabolic pathway that produces key amino acids in plants. This pathway does not occur in animals or invertebrates so the chemical is labeled safe for aquatic use; at least at this time. Glyphosate is water-soluble and binds strongly to soil, where it could potentially harm beneficial soil microorganisms and mycorrhizal fungi. There is some evidence suggesting that glyphosate can damage DNA, and in March 2015, the International Agency for Research on Cancer determined that the chemical was "probably carcinogenic to humans" (Cressey 2015).

Other herbicides that have been effective for cattail control include Habitat@ (Imazapyr) and Clearcast@ (Imazamox). Both chemicals have been reported as having greater selectivity and longevity than glyphosate. Like glyphosate, they are systemic herbicides that are applied to foliage and translocated by plant functions to the root systems. The timing of applications is very similar to glyphosate. Rogers and Black (2012) reported greater selectivity with Clearcast.

Lawrence et al. (2015) evaluated Roundup effects on hybrid cattail in Michigan along with mowing and removal (harvest). They found that while chemical treatment was an effective control, it caused a release of nutrients (N and P) which could accelerate growth of other invasive plant species and the eutrophication of receiving waters. It also reduced the diversity of other plant species in trial plots presumably because of the chemical effects and shading by the canopy of dead cattail material. They recommended that cattail harvest would be better than herbicides at removing nutrients from the system and would not reduce the biodiversity of other wetland plants.

## 3. MOWING

The effectiveness of mowing for cattail control depends primarily on season and other factors such as water levels. If stems can be cut at, or below, water or ice level, the rhizomes and roots could be deprived of oxygen if water levels can be raised enough. However, hybrid cattail is much more resistant to this treatment than common cattail. Mowing is most effective for cattail control in mid- summer, just as the flowering spikes appear. This is when rhizome carbohydrate reserves are lowest and they have the most difficulty recovering.  Repeated annual mowing for several years may be necessary with maintenance mowing at longer intervals after that. Two mowings the first year in mid-summer would be good. There may be constraints as far as access, often requiring a track-mounted vehicle.

Mowing in frozen conditions is often more convenient but will have little effect on the rhizomes without substantial increases in water levels. In fact, winter mowing of wetland margins without increases in water levels in spring may increase cattail seed germination by removing the overstory. The informal historical guide was to cover the cattail stubs with at least 6 inches of water. While that was somewhat effective for common cattail it falls far short for hybrid cattail, particularly mature stands with well-developed rhizomes. Although it requires additional research, some field practitioners recommend 2-3 feet of inundation to have much of an impact.

Mowing has relevance to nutrient management in runoff water.  Road ditches that are cattail filled are often fall mowed to provide better drainage and for snow management. This has the effect however, of releasing a flush of nutrients when the material decomposes in part because of the increased surface area (Richard Grosshans, personal communication). Harvesting and removing this biomass would reduce this effect. The application and effectiveness of mowing and other physical alteration techniques are discussed more thoroughly in Baldwin and Cannon (2007) and Sojda and Solberg (1993).

## 4. GRAZING

Grazing by native herbivores (bison, elk) is a natural disturbance of wetlands that can be simulated by cattle if they are available. Increasingly, grazing is used in conjunction with prescribed fire as a management tool in areas that have uplands for grazing. The practice is known as "Patch-Burn-Grazing" (Fuhlendorf and Engle 2004) and "flash grazing" is being applied on many public wildlife areas.  Cattle, as well as bison, are attracted to the new growth following a burn as well as to the mud, which they coat their lower legs with to deter insects. This technique is being applied at the Glacial Ridge National Wildlife Refuge and is adding a significant element of heterogeneity to the landscape. Such "stomped-down" perimeters of cattail marshes are attractive feeding areas (due to the openness and manure deposits) for shorebirds and can provide a level of cattail control if applied periodically (Figure 17). Like mowing, grazing effects are short-lived unless incorporated into planned maintenance of the site.

**FIGURE 17.** Stomped down cattails in a patch/burn/graze unit at Glacial Ridge NWR. Photo by Sean Lofgren, USFWS, 15 July 2014.

Mero et al. (2014) used prescribed burning and grazing, alone and in combination, to manage common reed

(*Phragmites australis*) in a large marsh system in Hungary. All three treatments were effective in adding the heterogeneity of open areas to the wetland and improving marshland bird habitat. They recommended late summer burning followed by grazing as essential to maintaining a high diversity of marshland habitat. This management period is timed to avoid the breeding season and precede migration and wintering.

Muskrat are an effective aquatic grazer and can be a significant control factor for cattail as illustrated in Figure 3. Their population dynamics can be rather complex and there is little that humans can do except regulate fur harvest and control water levels in situations where such is possible. Higher over-winter water levels are generally beneficial to muskrat and Sojda and Solberg (1993) recommended 4-5 foot depths are needed in most areas. Some practitioners believe the robust rhizomes, heavy root mass, and high stem density of mature hybrid cattail stands are unattractive to muskrats. This is particularly true of floating root masses. It may be that muskrat effects are most pronounced in newly established cattail stands.

## 5. WATER LEVEL MANIPULATION

Well-timed flooding or draining of wetlands can limit cattail growth and is commonly used in concert with defoliation techniques, such as mowing or harvesting. Flooding can prevent seedlings from germinating and cut off oxygen to rhizomes if stalks are cut far enough below the water level. As previously mentioned, it can be an indirect factor by affecting the over-winter survival of muskrats.

## 6. HARVESTING FOR BIOENERGY AND NUTRIENT RECOVERY

Some current methods of cattail management involve an integrated, holistic approach of harvesting and removing material from a wetland basin. This considers the bioenergy content, the nutrient dynamics of cattails as it affects water quality leaving the wetland, and the possibility of nutrient recovery. The work in Manitoba, the Great Lakes, and the North Ottawa Impoundment project was presented earlier but bears further elaboration here. Douglas Pratt, Wendell Johnson, and others at the University of Minnesota pioneered work in the late 1970s to evaluate the properties of cattails for nutrient bioremediation and bioenergy (Brody 1979, Dubbe et al. 1988, Johnson, et al. 1987). Cattails are proficient at trapping sediment and absorbing nutrients, especially nitrogen and phosphorus, primary contributors to the eutrophication of lakes and rivers.

Grosshans and colleagues at the IISD have been applying the integrated concept at the landscape scale within the watershed of Lake Winnipeg in Manitoba since 2005 (Grosshans and Greiger 2013, Grosshans et al. 2014 ). More recently, Jeff Lewis and Aaron Ostlund have applied the concept in a 1,920- acre impoundment (NOI) complex at the headwaters of the Red River Basin (which also drains into Lake Winnipeg). NOI lies within in a 48,000-acre watershed near Breckenridge, Minnesota (Lewis 2014)

Why cattails for bioenergy? Cattails provide advantages over some other biomass sources. Some biomass sources compete for land that is suitable for agriculture or forestry. Cattails occur in wet areas unsuitable for agriculture unless drained. They are a renewable resource if only the above-water leaves and stalks are harvested. Tillage and replanting are not necessary. Furthermore, if cattails are only partially harvested in strips or a mosaic, that action can restore a desirable wetland wildlife habitat (Brody 1979, Murkin et al. 1982). Unlike burning fossil fuels, cattails are carbon neutral since they require $CO^2$ to grow thereby re-using the $CO^2$ released by burning.

Harvesting a wetland basin with cattails depends on adequate access for equipment. When and how to extract a harvest can be problematic without specialized equipment. The material must be removed and stored unless it can be used immediately. If a basin has water level control structures, that can both facilitate access for harvesting and be used to control cattails by flooding. The installation and maintenance of these structures involves yet another set of costs.

### a. Seasonality:

Harvest timing depends on the goal of harvest. For example, if managing primarily for nutrient removal, summer or early fall would be optimum. This timing could also reduce stand density if harvest occurs before the plant has stored sufficient energy to prepare for the next growing season. On the other hand, if the goal of the harvest is sustainable bioenergy, dormant season harvest (late fall, winter, spring) would be best. During this period cattails have stored energy for the next growing season, they are drier, and there is no significant decline in energy content.

The following are proposed advantages and disadvantages of various harvest times

- **Summer harvest** (July to September)
  - Advantages:
    - Cattails contain the greatest amount of nutrients in tissue
    - Greatest damage to the overall health of the plant or stand since they have the least amount of nutrients in their root reserves
  - Disadvantages:
    - Cattails have a high moisture content at this time
    - Most difficult time to harvest due to higher water and wildlife nesting
    - May reduce the sustainability of the plants since they have the least amount of nutrients in their rhizome and root reserves
    - May damage the wetland substrate since the soil is soft and compaction or rutting could result
    - Peak workload for likely participants
    - Unable to use conventional harvest equipment

- **Late fall**: (September to November)
    - ❍ Advantages:
        - Least damage to the plant as the plant has sent most nutrients to root reserves
        - Less moisture in biomass than  summer
        - Less wildlife impact since nesting is completed but some migratory species are moving through
        - Possible use of conventional harvest equipment if water levels are low
    - ❍ Disadvantages:
        - May be too much water, early snow could inhibit ice formation and impede harvest
        - Possibly impact late migrating wetland birds
        - Reduced winter wildlife cover for some species (deer, prairie grouse, pheasants)

**Winter** (December to March)

- ❍ Advantages:
    - Likely frozen conditions
    - Easier for equipment access
    - Least damage to soil and plant health
    - Moisture content of biomass low
    - Freeze/thaw breaks cells down to reduce slagging in boilers
    - Out of peak workload period for the field season
    - Avoid wildlife impacts for most species, especially waterfowl
    - Could use conventional farm equipment in some settings
    - Energy value is high
    - Nutrients have translocated to roots and rhizomes
- ❍ Disadvantages:
    - Low nutrients and limited cattail control
    - Snow may cause problems such as thin ice, reduced frost depth, and hard for equipment to operate depending on depth
    - Baling could be difficult in cold conditions due to belt slippage, brittle twine, and accumulated snow

- **Early spring** (March to mid-April)
    - ❍ Advantages:
        - Ground may still be frozen but some standing water may be present on surface
        - Depending on the frost conditions, could use conventional farm equipment
        - Lowest moisture content
        - Minimal effect on migrating birds
        - Least effect on plants since only last year's growth is being harvested
    - ❍ Disadvantages:
        - Minimal effect on cattail control
        - Nutrients have leached out of cattail plant tissue from freeze-thaw

- Lowest nutrient removal potential
- Possible high water levels from flooding depending on when spring thaw occurs
- Short time frame for harvest to occur due to presence of snow

Late fall/winter harvest generally provides the greatest number of advantages and would be best for most current equipment capabilities while having the least impact on substrate. However, it also has the least impact on improving habitat for wetland wildlife. In addition, a heavy snow early in the year could affect harvesting by limiting swathing, causing baling twine to slip, and slowing ice development.

**FIGURE 18.** Square baler operating at Pelly's Lake, Manitoba


**FIGURE 19.** Swather operating at Pelly's Lake, Manitoba.

### b. Equipment.

There are 3 general approaches to removing harvested cattails from a wetland; cut and bale into large (800-1,000 lbs.) square or round bales (Figure 8,18, and 19), cut and blow chopped material into a hopper of some sort (Figures 10, 29 and 30), and cut with an amphibious machine that operates in the water to cut and gather biomass (Fig 13).

***Baling.*** If conditions are dry enough or if the equipment has some sort of tracks or floatation tires, this is probably the most efficient way to collect cattail biomass since harvest sites are generally at some distance from processing sites. This necessities temporary outdoor storage. Stacking and transporting square bales is safer and more convenient than round bales. This is the method used by Grosshans at the Pelly's Lake site where they annually harvest over 1,000 high density bales (Figure 18). A MacDon rotary disc mower with conditioning rollers was used, similar to that used for cutting forage crops. It was determined in 2013 to be the preferred cutting method for harvesting cattails where conditions permit (Figure 19). Tire pressures were lowered to reduce the impact on the wetland. The MacDon mower cut heavy stands of cattail effectively, regardless of vegetation height or density. Cattails dried down significantly faster because the conditioning rollers crimp the cattail and produced a superior windrow compared to straight cutting. This method involves two passes; one to swath and another to bale.

Figure 20 shows a modified Pistol Bully trail groomer from Germany that can operate in soft conditions because of the track-equipped power unit and baler.

The challenge when using equipment pairing like this is that trail groomers typically have hydraulic systems to power implements on the front and rear whereas balers are driven by power-take-off (PTO). Furthermore, most trail groomers have 12 inches or less of ground clearance, hardly enough to pass over a cattail swath when production levels approach 8-10 tons per acre. Figure 21 shows a traditional Bombardier trail groomer with hydraulic power, front and rear.

It would seem to be most efficient to have a swather and baler combination to allow harvesting with a single pass like the Sumo Quaxi machine made in Austria (Figure 22). It is unknown if a machine such as this is operating in North America. Figure 23 shows a computer-generated model of the concept but a working system of this sort that has been adapted to operate in wet conditions has not been located in the Northern Great Plains.

Bi-directional tractors are available which have PTOs front and back that could be fitted with tracks to operate in wet areas (Figure 24). Figure 25 shows a conventional tractor fitted with tracks for trail grooming that probably has hydraulics on the front and assuredly PTO at the back that could power a baler. In northwestern Minnesota, there are tractors of this sort equipped to groom snowmobile trails. These could conceivably be available for rent during the fall cattail-harvesting window after fall frost and before the snow season. This scenario has not been confirmed at this time.

There are front-mounted mowers that run by hydraulics on tracked skid-steers (Figure 26). While they are fine for mowing cattails, they have low clearance and would probably chop the material up too much to bale. A rear-mounted mower is shown in Figure 27 on a "Marshmaster." This machine could operate in wet conditions but it is doubtful if it could be adapted to bale cattails due to limited power. It does have somewhat greater ground clearance than Bombardier trail groomers.

If a one-pass operation is desired, what is needed is a front-mounted swather on a track vehicle, similar to Figure 23. Another consideration might be to reduce the size of a baler if the horsepower of the power unit is a limitation. Also

**FIGURE 20.** Modified Piston Bully harvesting reed (*Phragmites sp.*) in Germany. Apparently, the unit converts hydraulics to run the PTO driven baler. Note the track-equipped baler and the supplemental radiator for additional cooling capacity of the hydraulic system.

**FIGURE 21.** Bombardier trail groomer with front and rear hydraulics for powering implements.

**FIGURE 22.** A single pass, swather/baler combination from Austria for harvesting reed. Made by Sumo Quaxi. http://duene-greifswald.de/doc/rrr2013/talks/Harvesting%20Techniques%202_Beckmann%202013%20-%20Harvesting%20Technologies%20 for%20reeds%20in%20Austria.pdf. Accessed 20 July 2016.

**FIGURE 23.** A computer generated model of bi-directional tractor with a front mower and rear baler.


**FIGURE 24.** A bi-directional tractor that has a hydraulic lift and PTO on front and back. These can be fitted with tracks.

**FIGURE 25.** Conventional tractor adapted for trail grooming from New York.

needed in any cattail harvesting operation is a second power unit to gather bales and move to higher ground as well as assist the retrieval of the baling unit should it get stuck; and they always do!

At this writing, it appears that the most practical means to bale cattail would be conventional farm machinery, but that is contingent on a dry fall or situations where the wetland can be de-watered. It can be difficult however to find a local farmer willing to take their equipment into wetlands due to unknown water conditions and the presence of rocks and other "unexpecteds." Using equipment modified with tracks or floatation tires would increase the utility of this approach. The sort of specialized equipment array to harvest cattails for bioenergy bales is quiet expensive and also requires experienced personnel to keep it working on a consistent basis during the late fall/ winter harvest window. In Minnesota, agency burn crews might undertake this sort of operation after the fall burning season is concluded. They already have some equipment that is capable of operating in wet conditions (Figure 28).

Alternatively, there may be private land management contractors willing to respond to this niche market. In Manitoba, there is considerable support by the Province and private industry with a high priority placed on renewable energy. Through an extensive process of trial and error, Grosshans and his many cooperators in Manitoba found that blending cattail and wood makes a superior fuel pellet and one can assume that a similar scenario would work best south of the border as well.

***Chopping.*** There are a variety of biomass choppers operating in Europe that are typically track-mounted and blow the material into a bin on the machine itself or into a towed wagon (Figure 29). A conventional forage harvester was used in this way in the early Minnesota work where cattails were used in bioremediation (Figure 10).Variations on this theme involve a hopper mounted on the collector/power unit such as the LogLogic machine manufactured in the U.K. (Figure 30). Shane Lishawa and his colleagues recently purchased one of these models and are using it to harvest cattails and *Phragmites* (reed) in the Great Lakes area. An additional consideration of harvesting chopped material is one of material handling; if it is dry, it could blow around and if it were wet, it would ferment if stock-piled. The latter would not be a problem if it were to be used for biogas production and a processing plant was nearby. At any rate, storage and transport would generally be a larger problem with chopped material than if it were baled.

***Water harvest*** Due to the unique logistics of harvesting very wet material such as cattails in deeper water, it will not be discussed here but the method is being used at International Falls, MN, as mentioned earlier. However, their end goal is not bioenergy production at this time.

### c. Transportation

As with the utilization of any place-bound resource (timber, sand and gravel, cattails from a wetland), transportation is a significant cost determinate. Currently, oil prices are relatively low, $ 45.95 per barrel as of 15 July 2016, compared to $ 151.72 in September of 2008. Although oil prices may decrease the market for biomass (used primarily for heat and electricity production) it lowers transportation costs. Fuel oil and natural gas prices are especially important in affecting the demand for biomass used for heating. Distances from a harvest site to a processing site and from processing to consumption sites are also key cost determinates. Obviously, locating processing facilities close to biomass supply sites is beneficial along with identifying large wetlands that could generate significant quantities of biomass. As previously mentioned, large square bales are easier to transport than round bales; however, a square baler require more horsepower to operate than round balers.


**FIGURE 26.** Front-mounted, hydraulically driven mower attached to skid-steer. Used to mow checker - board pattern at Parnell Flood Control Impoundment (Figure 12).


**FIGURE 27.** Marshmaster with rear mounted, hydraulically powered mower.

**FIGURE 28.** An example of a track-equipped tractor used by the Minnesota Department of Natural Resources for grassland and wetland prescribed burning. Such a unit could have a role in cattail harvesting.

**FIGURE 29.** Modified "Ratrak" snow machine from Poland.

**FIGURE 30.** A LogLogic harvester made in the U.K. harvesting reed.

**FIGURE 31.** Industrial tub grinder processing cattails in Manitoba.

### d. Processing

In this discussion, we assume that we start with cattail biomass in the form of large bales; round or square. It might be feasible in some settings to feed large bales directly into an industrial boiler like at an institution or power plant but here we assume that pellets, cubes, or briquettes will be the end product. Such products would be more flexible as far as uses in a range of residential and commercial stoves. Bales are typically broken apart with a "tub-grinder" such as livestock operators use to process hay bales. An industrial version is shown in Figure 31 where it is being used to process cattails in Manitoba. After the tub grinder step, the material may be run through a hammer mill to further reduce particle size and may be mixed with another material such as sawdust for better binding. This material then goes to a "densifier" which forms the material into pellets or cubes (Figure 32), usually with the aid of steam and heat, to make a product that is ready for storage or combustion (Figure 33).

<u>Torrefaction</u> After densifying, torrefaction is an optional step that can be added, depending on the end goal. According to Morey et al. (2013) torrefaction is a thermo-chemical treatment (roasting) of biomass at 390 to 600 °F (200 to 320 °C) in the absence of oxygen at atmospheric conditions. Torrefaction produces a solid, dry, brittle, blackened material (i.e., biocoal) and substantial amounts of volatile gasses that can be combusted in the process (Figure 34). The many advantages of torrefaction include higher energy density, more homogeneous composition, hydrophobic (repels water), elimination of biological activity, and improved grindability. The resulting biocoal typically has 130% of the energy per unit of mass compared to un-torrified biomass, so the energy content is similar to traditional coal and has improved grinding characteristics compared to unprocessed biomass. Like coal, it can be stored outside since it is hydrophobic in contrast to most biomass pellets (Morey et al. 2013).

Manitoba has demonstrated the commercialization of cattails as a viable bioenergy source, in loose or densified forms. Such can be used in larger bulk fuel stoker boiler systems, such as the Blue Flame Stoker boiler[1], as well as in smaller residential sized pellet stoves. A primary focus of IISD's research program in 2014/2015 was on the commercial scale processing of cattail as a feedstock for

[1]*https://www.biovalco.com/energy/technology/*

energy production. An important next step is to expand the biomass industry in Manitoba, and in turn expand the opportunity for ecological biomass harvesting as a watershed management practice. There is an increasing demand for processed biomass fuel in Manitoba because of the new ban on the use of coal for space heating, but there is currently a significant lack of companies making fuel products. IISD and its industry partners Biovalco, PAMI, and BRG Mfg have successfully produced commercial volumes of fuel products. This partnership will continue in 2016 to reach commercial production and conduct combustion burn trials in multiple biomass heating systems (Zubrycki and Grosshans 2016, Grosshans et al. 2015).

**FIGURE 32.** A mobile pelletizer made by Buskirk engineering. Note the self-contained tub-grinder.

What about cattail biomass co-firing? The University of Minnesota Crookston (UMC) and others are considering biomass as a supplemental fuel source since the cost of energy derived from fossil fuels is increasingly volatile. The cost of conventional energy is just one driver that favors the expansion and utilization of bioenergy; others include energy security, environmental quality, and mitigation of greenhouse gas emissions. The primary heat source at UMC is coal. Co-firing cattail pellets with coal at UMC's heating plant could help the campus meet its goal of becoming carbon neutral by 2030. A feasibility study was conducted by Leroux (2012) of the UMC heating plant to determine the potential role of biomass as a renewable fuel. Up to 15% biomass could be co-fired with no modifications to the boiler. UMC has already modified the heating plant to receive truck-delivered coal instead of rail, which provides an opportunity to integrate biomass without further modification to the delivery system. Although the heating plant can take up to 15% biomass and could have biomass delivered, implementing a biomass feedstock at UMC would require addressing some challenges. Leroux (2012:6) stated, "these challenges include but are not limited to suitable storage, an additional feed system, pre-processing of biomass for optimal operations, and permitting regulations for air emissions". There could be other possible commercial uses of cattail biomass in the region due to the large quantity available; at least 95,500 acres of cattail biomass in the 10 northwestern Minnesota counties.

**FIGURE 33.** Cattail pellets made by Tim Hagen, Natural Resources Research Institute, U of MN, Duluth

**FIGURE 34.** Torrefied cattail briquette ("hockey puck") made by Tim Hagen, Natural Resources Research Institute, U of MN, Duluth.

# DISCUSSION AND NEXT STEPS

In 1979, the cattail work of Doug Pratt was cited in the New York Times with reference to the Agassiz NWR (Brody 1979), "At Agassiz, where perpetuation of wildlife is the primary goal, huge stands of cattails are periodically mowed down to maintain the ratio of half open water and half reedy areas that ducks and other waterfowl prefer." Pratt was quoted to say, "The gleanings from this periodic cleanup could warm the homes or fuel the vehicles of the very people who fight the cattails." The article noted the following advantages of cattails:

- Cattails are an annually renewable resource, whereas coal, oil, and peat take thousands or millions of years to form,
- Unlike nuclear power and fossil fuels, cattails do not add heat and carbon dioxide to the earth but recycle them,
- Since they grow in wetlands, cattails do not compete for land that could be used for crops and forests,
- Cattails use some pollutants as nutrients. Cattail farms near sewage treatment plant could clean troublesome nitrogen and phosphorus from effluent, and
- Harvesting cattails in strips is compatible with preservation of wildlife and makes replanting unnecessary.

This was prophetic at a time when there was heightened awareness of renewable energy spurred by the Arab Oil Embargo causing lines at the gas pumps. When the embargo was lifted, the U.S energy consciousness would "relax." It took only a couple of years before it was back to business as usual; leaving many biomass heating systems to be decommissioned along with smaller wind turbines. This was not the case in parts of Europe that heeded the wake-up call and continued the journey of developing renewable energy. There are significant exports of U.S. biomass to Europe. There is a recent resurgence of interest in renewable energy in the U.S., although dampened somewhat by current lower oil prices.

At the time of Pratt's work, there were logistical challenges of harvesting cattails for biofuel. While there still are challenges, projects like the IISD work in Manitoba have demonstrated not only the commercial feasibility of using cattails for fuel but also the associated co-benefits of water quality remediation, nutrient recovery for fertilizer, enhanced wildlife habitat, and possible stimulation of rural economies. What is needed now is *systems thinking* in order to simultaneously consider the aforementioned benefits along with biofuel demand by the commercial and residential sectors. The approach must include the complete energy and economic analysis of harvesting, transport, and processing (life cycle analysis); and the possible delineation of "fuelsheds." Fuelshed is a concept developed by Meschke and co-workers (2012). They scribed a 25-mile radius around Madelia, MN and analyzed the renewable energy sources and uses within.

**It is useful to ask, "What are the criteria for a successful bio-based industry in a state like Minnesota and what can be learned from Manitoba?**

Local rural economies could be boosted by harvesting an in-state, renewable resource since Minnesota has no fossil fuels. In the dry fall of 2012, it was determined that cattails can be effectively managed/harvested with conventional equipment, but methods must be developed that can be employed in average to wet years to assure a more dependable bioenergy harvest and fuel source.

The first step in creating a successful cattail bio-based industry is to have a steady supply of cattails. Our research identified 95,498 acres of potential cattail biomass in northwestern Minnesota. Cattail biomass from whatever source must be available throughout the year and year-to-year. The bio-based industry hinges on having a constant supply of biomass, which may fluctuate from year-to -year and season-to-season. Since the cattail harvest will be done only once per site annually, it is important to have other biomass sources to augment the supply to users as needed. For example, a dry year would make access to cattail biomass much easier; a wet year would likely decrease the availability. To overcome the seasonal availability of cattails, a supply of biofuels from agricultural lands, prairie (native and restored), brushlands, and woodlands would assist in fueling the bio-based industry.  There could be both, storage and supply issues.

> *At Agassiz (NWR), where perpetuation of wildlife is the primary goal, huge stands of cattails are periodically mowed down to maintain the ratio of half open water and half reedy areas that ducks and other waterfowl prefer. The gleanings from this periodic cleanup could warm the homes or fuel the vehicles of the very people who fight the cattails.*
>
> Jane Brody quoting U of MN researcher, Doug Pratt in New York Times. 4 September 1979

The second step is to determine when and how to harvest. Once cattails are harvested, they must be collected and transported to a processing site. Harvested cattails probably should not be transported more than 50 miles to reduce costs. Once at a processing complex, cattails would be densified and (and perhaps torrefied) stored at or near the processing complex in a dry area, since they will absorb moisture.

The third necessity for a successful bio-based industry is to create an economically competitive product. Not only must a reliable quantity and quality of product be assured but the total cost of delivering the end product to the end user must be less than or equal to other available fuels. At this time in the Northern Great Plains, the delivered cost of cattail pellets in terms of Btu/lb. has not been competitive compared to the relatively cheap coal, petroleum, and natural gas. Part of the reason for this is the well-developed existing infrastructure to efficiently deliver those products. This will change eventually. In addition, the efficiency of harvesting equipment, transportation, and processing, in the U.S. at least, is lacking. Manitoba, on the other hand, has some harvest sites that can be harvested by conventional machinery. In addition, Manitoba's current economy of scale is favorable, they offer carbon credits for renewable energy, and they have a ban on coal use.

This leads to the fourth and final ingredient of identifying end users. The end user should be close to a supply of cattail and have a desire for alternative energy. As mentioned, the University of Minnesota Crookston campus could be a potential end user by co-firing with coal.

**Further questions to be addressed include:**

1. Can the biofuel industry use cattail biomass (chopped or baled) that has been previously chemically treated; the "multi-tool approach?" Some wetland managers would favor the harvest approach more if the standing dead cattail could be immediately removed to create the desired open structure, otherwise a number of years may be required for the dead cattail to decompose.

2. There is a need to consider diversification of the biofuel feedstock supply by including lowland brush and agricultural residue. This ensures the sustainability of feedstocks and increases the availability of biomass end products. This is essential if a pelletizing plant is constructed.

3. Manitoba has determined that the best fuel pellet is a blend of cattails and wood. Minnesota could learn from these findings if the state wishes to advance the development of cattails as biofuel. There is an abundant supply of wood biomass in the forested and brushland areas of the state; often within 50 miles of significant supplies of cattails. Additional supply and transportation cost analysis is needed to refine this feasibility.

4. There is a need to put a value on the range of externalities of the biofuel production process including wildlife habitat, reduced crop predation by blackbirds, reduced flooding, reduced nutrient contributions to receiving waters, augmenting coal with biocoal, carbon emission offset credits, and others can be added to the list.

5. What is value of end products such as soil amendments, fertilizers in any form, raw material for construction panels, livestock bedding, biocoal?

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> Cattails are likely at a point where we can do no wrong and we need to be able to jump on opportunities like a dry year.
>
> Ross Hier, wildlife manager, MN DNR


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> *If you want to control cattail, you must control water.*
>
> Larry Hanson, wetland manager, U.S. Fish and Wildlife Service


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# APPENDIX A

## ATTITUDES OF LAND AND WATER MANAGERS TOWARDS CATTAIL CONTROL IN NORTHWEST MINNESOTA.

As part of the preliminary cattail study in 2012, interviews were conducted with land and water managers in northwest Minnesota representing the Minnesota Department of Natural Resources, the U.S. Fish and Wildlife Service, and watershed district personnel who manage flood control impoundments. The goal was to document concerns regarding cattail control and the possible application of bioenergy harvest.

Many land managers were somewhat overwhelmed with the amounts of cattail coverage and were currently planning to manage "cattail choke" in their areas; whether a watershed impoundment, ditches, or wetland habitats. Almost every interviewee stated they would allow a partial removal of cattails and believed it would be beneficial. Current management tools cost money to implement and require staff to conduct them. New harvesting methods could provide a new time and cost-effective tool. Interviewees agreed that the 50:50 interspersion of open water and emergent vegetation would be ideal.

One of the main concerns was about harvest. Some believed that a harvest wouldn't open up more water, and depending on harvest time it would not affect cattail stands at all. Some were concerned with an over-ice harvest and that it would have little effect on cattail health. They understood that a summer harvest would likely have the greatest effect on reducing cattails, but also acknowledged the difficulty involved. In addition, how much of the stand would have to be harvested to achieve the 50:50 interspersion goal? Maybe 100% would have to be harvested to achieve the 50 % open area. For some managers the 50:50 ratio was not appealing since they wanted the cattails eradicated from some areas, such as flood control impoundments. They agreed that any management would be beneficial.

Some areas that are choked off are also nearly impossible to harvest for a few reasons; obviously depth is an important factor when it comes to equipment use. The cattail substrate is important because it will affect equipment use and plant re-growth. An example of a complicated substrate is a floating mat; usually formed by cattail rhizomes and roots. To harvest on a floating mat, the easiest and safest method would be to sink the mat by draining the water if possible. Even after sinking and harvesting the cattails from this mat would resurface once water is returned. This will have little long-term effect on stand openness because cattails will be able to germinate and regrow. Another area where harvest would be nearly impossible is sensitive habitat types such as fens. Fens are very sensitive to any sort of disturbance, so moving equipment into such areas would be problematic because of physical damage and introduction of invasive species.

Managers expressed moderate concern with a partial harvest because of the seasonality of harvest. Common concerns dealt directly with wildlife effects, especially nesting and migrating water birds. The majority of managers believed a winter harvest would be ideal for wildlife since it would have the least impact on the nesting season and migratory wildlife use. Also, many managers realized that most wetlands would be frozen during this period, which should allow conventional harvesting equipment to be used. In contrast, managers also believed that a summer harvest would yield the best results as far as damage to cattail plants since they have not yet sent food reserves down to the rhizomes. The concern with summer is the high use by wildlife during this period; but some managers felt a short-term negative effect on wildlife is far outweighed by the long-term positive aspect of a summer harvest. Drought cycles could provide opportunities for summer harvesting.

Some managers also cautioned that some wildlife species rely on cattail patches to survive the winter using wetlands for cover, roost, and in some cases, to hunt for food. In northwest Minnesota however, it appears there is an abundance of cattail and reducing cattail coverage would have a minor effect overall on those wildlife species that rely on cattails for winter cover.

An additional concern was toward regulating a created biomass market. A few thought that harvesting of cattails could evolve into a business such as custom harvesting. If businesses started up based on cattail harvest they wondered how they would regulate it to keep it fair. People might have to submit applications to harvest, make sure they understand wetland regulations, and only harvest a certain tonnage. How would managers monitor harvest sites?

Harvesting would need to be conducted in an environmentally sustainable manner to ensure that habitats are not permanently lost and for minimal impact to wildlife. Harvesting during late fall and winter periods prevents waterfowl and songbird loss by avoiding the spring-nesting and fall-staging periods when bird use of wetlands is highest. However, both Red-winged, Yellow-headed blackbirds, and Marsh wrens use the standing above-ground dead material for nesting in the early spring before new plant growth is established; therefore removing standing plant litter could affect some nesting habitat. In most cases, only a certain percentage of the marsh could efficiently be harvested for biomass removal, leaving sufficient nesting habitat for marsh birds and waterfowl arriving in the early spring.

**Further questions on the use of harvesting cattails for bioenergy harvest:**

- How long will it take cattails to close in the opened areas?
- Will this biomass harvest pressure people to purposely grow or farm dense cattail stands?
- Could cattail biofuel harvest provide a new use for wet marginal farmland?
- What steps need to be taken to ensure harvesting does not transport and/or encourage invasive species?
- Any concerns that cattail harvesting could become too intensive on a wildlife area that it could conflict with public wildlife uses?

# Notes...