iisd International Institute for Sustainable Development | Institut international du développement durable

IISD REPORT

Advancing Netley-Libau Marsh Restoration Efforts

Cattail biomass and nutrient survey of Netley-Libau Marsh

Richard E. Grosshans
with Henry David Venema
Bryan Oborne

April 2012

iisd.org

Published by the International Institute for Sustainable Development.

International Institute for Sustainable Development

The International Institute for Sustainable Development (IISD) contributes to sustainable development by advancing policy recommendations on international trade and investment, economic policy, climate change and energy, and management of natural and social capital, as well as the enabling role of communication technologies in these areas. We report on international negotiations and disseminate knowledge gained through collaborative projects, resulting in more rigorous research, capacity building in developing countries, better networks spanning the North and the South, and better global connections among researchers, practitioners, citizens and policy-makers.

IISD's vision is better living for all—sustainably; its mission is to champion innovation, enabling societies to live sustainably. IISD is registered as a charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Government of Canada, provided through the International Development Research Centre (IDRC), from the Danish Ministry of Foreign Affairs and from the Province of Manitoba. The Institute receives project funding from numerous governments inside and outside Canada, United Nations agencies, foundations and the private sector.

Head Office
111 Lombard Avenue, Suite 325, Winnipeg, Manitoba, Canada R3B 0T4
Tel: +1 (204) 958-7700 | Fax: +1 (204) 958-7710 | Website: www.iisd.org

Advancing Netley-Libau Marsh Restoration Efforts
Cattail biomass and nutrient survey of Netley-Libau Marsh

April 2012

Written by Richard E. Grosshans with contributions from Henry David Venema and Bryan Oborne

Acknowledgements

IISD acknowledges the financial support of Environment Canada through the Lake Winnipeg Basin Stewardship Fund, in partnership with Manitoba Water Stewardship, and Manitoba Hydro, as well as the continuing in-kind support from Ducks Unlimited Canada, Manitoba Water Stewardship, Manitoba Conservation, the University of Manitoba, and Dr. Dennis Anderson.

Executive Summary

Lake Winnipeg is one of the largest freshwater lakes in the world and drains a watershed area of 1,000,000 square kilometres. Overloading of phosphorus in the lake has caused an increasing frequency of algal blooms. The Red River contributes almost 60 per cent of the phosphorus entering the lake. Netley-Libau Marsh is the largest coastal wetland on Lake Winnipeg, comprised of shallow lakes, channels and wetland areas through which the Red River flows on its way to the lake. Over the past several decades, EGS benefits from Netley-Libau Marsh have been compromised by drainage, dredging, and water management. The result has been a gradual loss of plant communities, erosion of channels and islands, amalgamation of water bodies, and subsequent decline in wildlife habitat and populations. Netley-Libau Marsh is not currently functioning as a healthy coastal wetland, and many benefits to Lake Winnipeg that the marsh could provide have been severely degraded. Restoration and management of this important coastal wetland could help restore degraded environmental benefits.

The purpose of this study was to improve our understanding of how this freshwater coastal wetland—and wetlands throughout the watershed—reduce nutrient loading and ultimately improve water quality in Lake Winnipeg. Emergent plants play a critical role in physical marsh structure and in water quality improvement. A healthy marsh plant community captures and stores nitrogen and phosphorus in the sediment, litter, roots and accumulated biomass. Cattail (Typha spp.) is one of the dominant plant species in Netley-Libau Marsh.

New site research was conducted in August and September of 2009, collecting samples and survey information throughout Netley-Libau Marsh. Samples were collected of plants, roots, litter, and sediment as well as water and analyzed for a suite of elements and parameters.

Total phosphorus (TP) is the total amount of inorganic and organic P that is found in the water. Manitoba Water Quality Guidelines state TP should not exceed 0.025 mg/L in water bodies. Average TP concentrations in Netley-Libau Marsh during August 2009 ranged between 0.39 and 3.53 mg/L, significantly above the guideline.

Total stored phosphorus and nitrogen is estimated to be 525 tonnes and 1,965 tonnes in the plants (plants, roots, and litter) and 230 and 305 tonnes in sediment respectively. Restoration of the cattail and other marsh plants by 25% could increase phosphorus and nitrogen storage potential in the marsh by 130 and 500 tonnes respectively.

Table of Contents

List of Tables

List of Figures

1.0 Introduction: The need for knowledge

Netley-Libau Marsh lies at the mouth of the Red River along the south end of Lake Winnipeg, Manitoba (Figure 1). At 250 square kilometres, it is one of the largest freshwater coastal wetlands in Canada. This wetland provides an array of diverse ecological goods and services (EGS), functioning as a filter sequestering nutrients from the eutrophic Red River and Lake Winnipeg. Nutrient capture is an important and overlooked function of the marsh that is increasingly understood as a key component of a Lake Winnipeg basin management strategy aimed at reducing nutrient loadings to Lake Winnipeg.

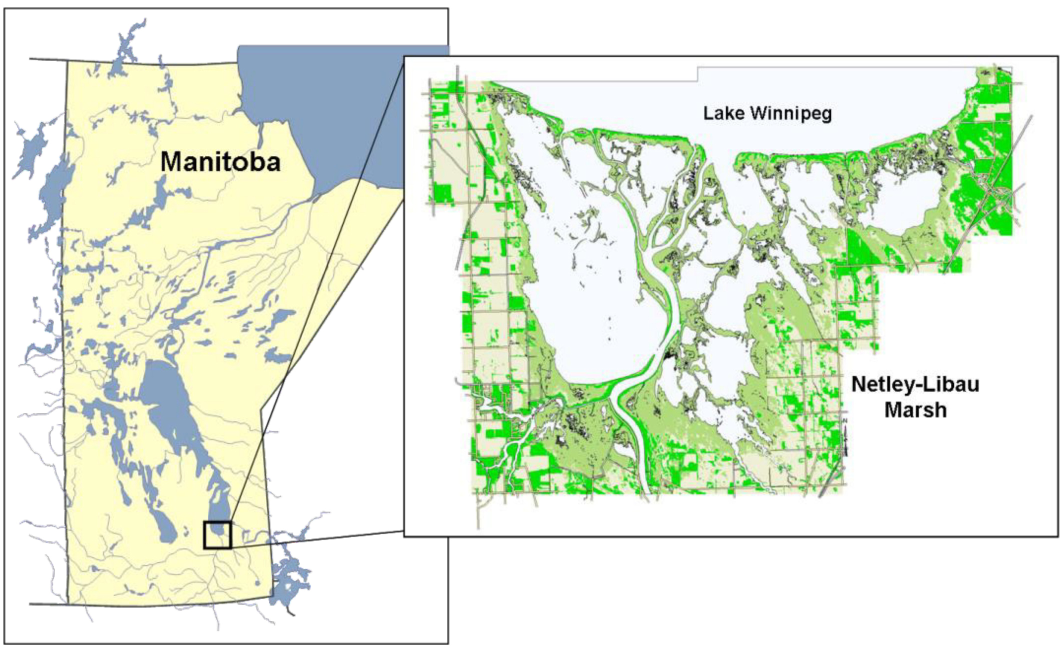


FIGURE 1. LOCATION OF NETLEY-LIBAU MARSH AT THE SOUTH END OF LAKE WINNIPEG IN MANITOBA, CANADA

Source: Grosshans et al. (2004).

There is a critical need to understand and quantify the hydrological and nutrient components of this large coastal wetland of Lake Winnipeg. Equally, there is the need to build public, organizational, governmental, and corporate support for restoration of the marsh and its future potential associated with reducing nutrient loading into Lake Winnipeg via the Red River. The focus of this research study was to measure the current state of nutrients in Netley-Libau Marsh, and to evaluate potential phosphorus storage with Netley-Libau Marsh restoration efforts while simultaneously building public support.

The overall goals of this project were:

1. To expand current research associated with IISD's Netley-Libau Nutrient-Bioenergy project to better understand the flow of nutrients through the marsh and evaluate how much additional benefit marsh restoration could have towards reducing current nutrient loading to Lake Winnipeg.
2. To implement sustained and consistent outreach communications focused on key audiences as a means of building support for future efforts to restore ecosystem integrity to Netley-Libau Marsh.

2.0 Background

2.1 Lake Winnipeg: An indicator of nutrient stress and prairie sustainability

Lake Winnipeg is one of the largest freshwater lakes in the world, and drains a watershed area across Canada and into the United States of almost 1,000,000 square kilometres. This other "great lake" is important to the province of Manitoba both economically and recreationally, and is critical to the livelihood and survival of many First Nations communities. Evidence has shown the significant degree to which this lake has become eutrophic over the past several decades from overloading of phosphorus from the surrounding watershed (Lake Winnipeg Stewardship Board, 2005). The largest contributor of nitrogen and phosphorus loads into Lake Winnipeg is the Red River, even though it has a relatively minor hydrologic input into the lake compared to that of the Winnipeg River system and the Saskatchewan River watershed (Figure 2).

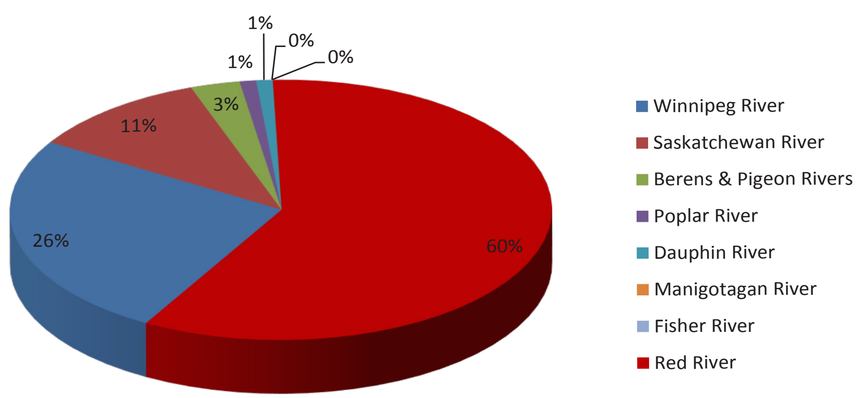


FIGURE 2. PHOSPHORUS LOADING TO THE RED RIVER.
Data source: Bourne et al. (2003).

The Red River contributes almost 60 per cent of the phosphorus entering the lake; 14 per cent of which comes from agriculture and 11 per cent from wastewater effluent from Manitoba sources (Lake Winnipeg Stewardship Board, 2005). Overloading of phosphorus in the lake has caused an increasing frequency of algal blooms—which can have serious health risks—in the lake. The Red River valley is a highly populated and productive agricultural region of Manitoba, with agricultural crops and fertilizer application, livestock operations, and large urban centres. This has a compounding effect of numerous point and nonpoint sources, contributing nutrients such as phosphorus to Lake Winnipeg. Agriculture and urbanization dominate the large geographic area within the watershed that drains into the Assiniboine River and Red River from the United States and Canada, contributing high levels of nutrients (Figure 3). The Red River supports several large urban centres, and as a result is the outlet for treated municipal wastewater. Proper watershed management is thus critical to maintaining water quality and sustainability in the Lake Winnipeg Basin (Gabor et al., 2001), emphasizing the importance of understanding the fundamental components of this watershed.

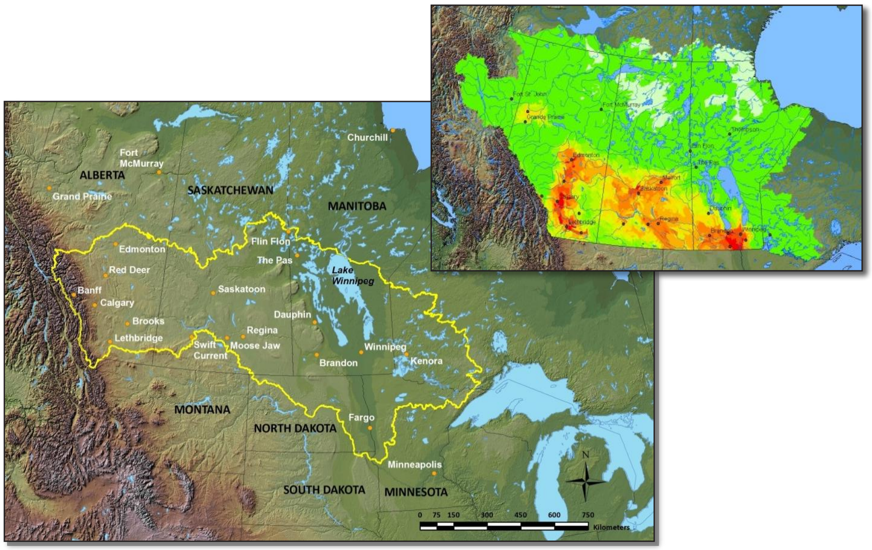


FIGURE 3. THE LAKE WINNIPEG WATERSHED STRETCHES ACROSS ALBERTA, SASKATCHEWAN, AND MANITOBA, AS WELL AS INTO ONTARIO AND THE UNITED STATES. THE INSET SHOWS THE CUMULATIVE WATER QUALITY STRESS MAP FROM GROSSHANS, VENEMA, AND BARG (2005), HIGHLIGHTING AREAS WITH HIGHER NUTRIENT LOADING RATES.

2.2 Wetlands: An important component of integrated watershed management

Wetlands are an important component of proper watershed management, and in their natural state they can effectively provide many economic and ecological benefits (Gabor et al., 2001). Wetlands improve the quality of water that flows through them by retaining, removing and assimilating nutrients (i.e., phosphorus and nitrogen), suspended sediments, pathogens, and other contaminants (Kadlec & Knight, 1996; Mitsch & Gosselink, 2007). The high biological activity of wetlands rapidly decomposes waste organic compounds, buries them in the sediments, or converts them into gases and harmless by-products. Wetland plants play a significant role in purifying this water by assimilating large amounts of nutrients from the sediment and organic layers into accumulated biomass. Plants also slow water and help retain nutrients by physical sedimentation into the organic and sediment layers where they are later taken up by the animal and plant communities. These transition areas between water and land provide a critical natural buffer between urban areas and freshwater rivers and lakes. Wetlands managed specifically for nutrient capture can significantly reduce downstream nutrient exports.

2.3 Netley-Libau Marsh: Lake Winnipeg's largest coastal wetland

Netley-Libau Marsh is the largest coastal wetland on Lake Winnipeg, comprised of shallow lakes, channels and wetland areas through which the Red River flows on its way to Lake Winnipeg (Figure 4). The river bisects the marsh into a western and eastern half, with nutrient-rich Red River water flowing primarily through the western portion out into the lake, and nutrient rich lake water cycling into the eastern marsh via lake currents, wind seiche, and wind setup. This wetland is designated an Important Bird Area by Bird Studies Canada and the Canadian Nature Federation, as it provides important habitat to waterfowl and furbearers, as well as spawning, nursery and feeding habitat for fish from

Lake Winnipeg and the Red River. It also provides significant additional environmental and economic EGS benefits—the area is also traditionally used for agriculture and recreation (i.e. boating, hunting, fishing, trapping and snowmobiling).

Over the past several decades, EGS benefits from Netley-Libau Marsh have been compromised by drainage, dredging, and water management. A study by Grosshans, Wrubleski, and Goldsborough (2004) documented the significant loss of emergent aquatic vegetation and erosion of separating upland habitats within the marsh over a 22-year period. Open water areas within the marsh had increased from 8,880 hectares (35 per cent) in 1979 to 13,125 hectares (51 per cent) in 2001, while vegetation cover had declined by almost 32 per cent (Figure 4). Several factors were attributed to these changes in the marsh, including flooding, prolonged periods with no low-water events, carp, and increased nutrient loads (Grosshans et al., 2004). The result has been a gradual loss of plant communities, erosion of channels and islands, amalgamation of water bodies, and subsequent decline in wildlife habitat and populations. A healthy coastal wetland can store and remove a significant amount of nitrogen and phosphorus (Neely & Baker 1989; Kadlec & Knight, 1996). Netley-Libau Marsh is not currently functioning as a healthy coastal wetland, and many benefits to Lake Winnipeg that the marsh could provide as wildlife and fisheries habitat, and in capturing and storing nutrients that would otherwise enrich the lake, have been severely degraded or lost (Grosshans et al., 2004). Nevertheless, restoration and management of this important coastal wetland could help restore degraded environmental benefits. Evidence from dry conditions and low water levels experienced during 2003 showed that marsh vegetation could be re-established in Netley-Libau Marsh.

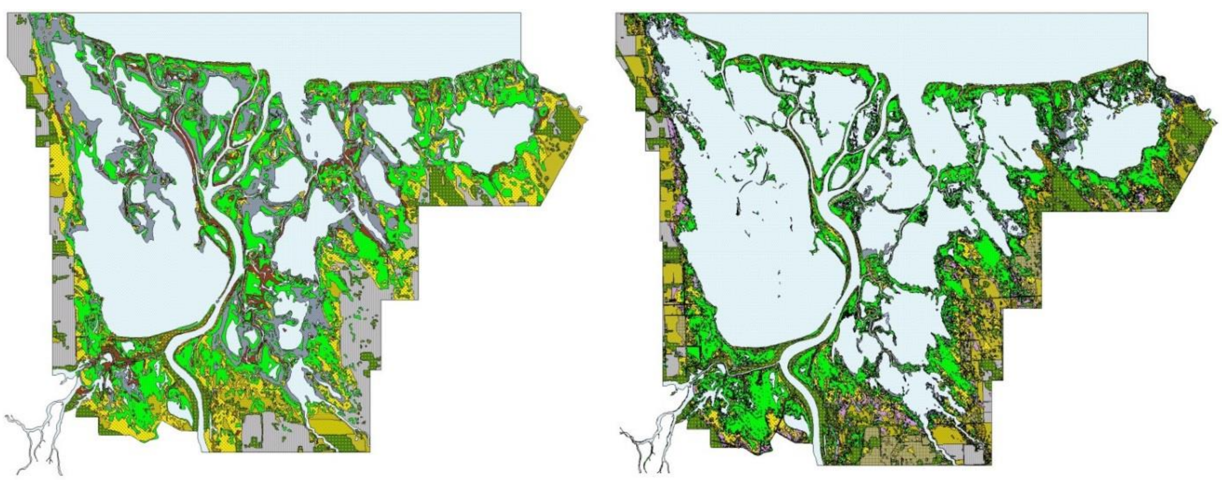


FIGURE 4. VEGETATION OF NETLEY-LIBAU MARSH IN 1979 (LEFT) AND 2001 (RIGHT). THE LOSS OF PLANT COMMUNITIES AND ISLAND AREAS SINCE 1979 IS CLEARLY EVIDENT (GROSSHANS ET AL., 2004).

2.4 Wetland nutrient cycling and phosphorus storage

Wetlands have been shown to be extremely effective in improving downstream water quality: in the form of natural wetlands, acting as filters on the landscape retaining nutrients from runoff water (Gabor et al. 2001); engineered wetlands, for improving river water (Mitsch et al., 2012); and constructed treatment wetlands for treating heavily loaded wastewater effluent (Kadlec & Knight, 1996). Cattail (Typha spp.) is a large emergent plant found in wetlands and waterlogged areas, and grows wherever standing water persists. It is found throughout North America and is often one of the dominant emergent plants in freshwater marshes. Emergent plants such as cattail play a critical role in wetlands for nutrient retention and breakdown. As shown in Figure 5, they take up nutrients almost exclusively from the organic litter layer and sediments (Smith et al., 1988; Noe et al., 2003; Mitsch & Gosselink, 2007). Dense stands of emergent plants act as permanent nutrient sinks in a wetland, with storage in the below-ground plant material, and in decaying plant litter (Kadlec & Knight, 1996, Mitsch & Gosselink, 2007). Mitsch and Wang (2000) found that 74 per cent of the phosphorus inflow into a series of constructed wetlands was effectively taken up by emergent plants from sediments, most of which cycled through the plants in the summer and was incorporated back into the organic layer and sediments during fall die-off. Decaying plant material releases considerable quantities of phosphorus to the water (Mitsch & Gosselink, 2007). Phosphorus entering a wetland settles out of the water column and moves into the litter layer quite rapidly (Noe et al., 2003). The litter and sediment pool of a wetland is the main storage site of dissolved nitrogen and phosphorus to surface and pore water, replacing nutrients taken up by aquatic plants. Phosphorus removal in wetlands is through permanent storage in the sediment and litter layers (Noe et al., 2003), which involves accretion of new sediments, or sorption to wetland substrate—there is no degradation route for phosphorus in a wetland. Gradually, phosphorus accumulation in the sediment occurs, affecting biogeochemical removal pathways and limiting the long-term phosphorus removal effectiveness (DeBusk, Newman, & Reddy, 2001; Noe et al., 2003). In some cases, phosphorus can accumulate in wetland sediments to the point where these wetlands can eventually become saturated, decreasing their ability to retain phosphorus.

Cattails can absorb a significant amount of phosphorus from sediment and litter, and research by IISD has shown that by harvesting and removing the nutrient-rich aboveground cattail biomass, a significant amount of stored nutrients (i.e., phosphorus) can be permanently removed from the aquatic system (Grosshans et al., 2011). In turn, this harvested biomass is a valuable biomass source as a feedstock for bioenergy and higher-value biomaterials (Grosshans et al., 2011). Phosphorus can be recycled from the biomass as a green manure fertilizer for crop production, extracted prior to processing for densification, biocoal, or cellulosic ethanol, or following energy production through use of the ash for soil amendment and fertilizer.

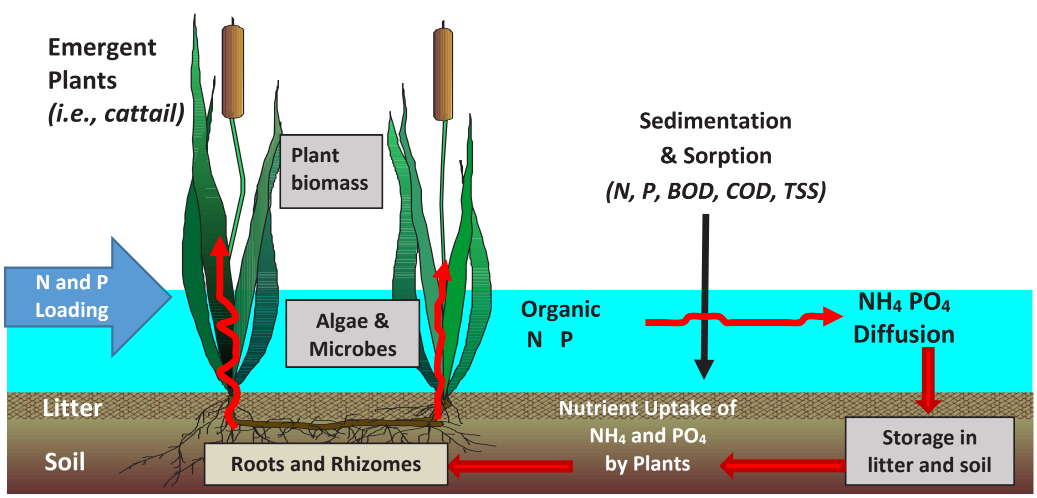


FIGURE 5. WETLAND BIOGEOCHEMISTRY—UPTAKE BY WETLAND PLANTS. WHITE HIGHLIGHTED AREAS SHOW REGIONS OF NUTRIENT STORAGE IN A WETLAND. (N=NITROGEN, P=PHOSPHORUS, BOD=BIOLOGICAL OXYGEN DEMAND, TSS=TOTAL SUSPENDED SOLIDS)

3.0 Netley-Libau Marsh Survey

3.1 Background and Purpose

The purpose of this study was to improve our understanding of the importance of Netley-Libau Marsh to the health of Lake Winnipeg, and how this freshwater coastal wetland—and wetlands throughout the watershed—can reduce nutrient loading and ultimately improve the water quality in Lake Winnipeg. The emergent plant community in a wetland such as Netley-Libau Marsh plays a critical role in both physical marsh structure (with the creation of islands and channels) and in water quality improvement. A healthy marsh plant community can capture and store nitrogen and phosphorus—elements that contribute to lake eutrophication—assimilating these nutrients from the sediment and litter into their accumulated biomass. Additionally, these plant communities provide valuable wildlife habitat, sediment reduction, and erosion control, as well as providing surfaces for algae and microorganisms that quickly take in and break down nutrients and toxins.

Cattail (Typha spp.) is one of the dominant plant species in Netley-Libau Marsh, covering nearly 50 square kilometres or 5,000 hectares (Grosshans, Wrubleski, & Goldsborough, 2004). It is an extremely competitive wetland plant characteristic of prairie marshes. Cattail can produce high biomass yields within a single growing season, and assimilate and store significant amounts of nutrients and carbon within its biomass (Martin & Fernandez, 1992; Grosshans et al., 2011). Research by IISD and the University of Manitoba evaluated the ability of cattail plant communities to capture, store, and reduce excess nutrients in aquatic systems, as well as the harvesting of this plant biomass for the combined benefits of nutrient removal and recovery, as well as the use of the biomass as a feedstock for bioenergy and biomaterials while gaining GHG emission offsets (Grosshans et al., 2011). The research showed that cattail biomass was a viable feedstock for use in pellet stoves and biomass stoker burners (Grosshans et al., 2011). IISD's current research explores the commercial-scale harvesting of cattail for phosphorus removal and recovery to reduce phosphorus loading to the Lake Winnipeg watershed, habitat restoration, carbon emission offsets, and higher-value biofuels and materials for cattail and other ecological biomass (IISD, 2012)

3.2 Funding and Scope

The Netley-Libau Marsh survey was funded under the Lake Winnipeg Basin Stewardship Fund, Manitoba Water Stewardship, Manitoba Conservation, and Manitoba Hydro, and assessed the nutrient storage and biomass accumulation within the cattail communities of Netley-Libau Marsh. This allowed estimation of current levels of phosphorus storage in this marsh system, potential biomass production, and the potential for additional phosphorus capture and reduction to Lake Winnipeg nutrient loading with Netley-Libau Marsh restoration efforts.

3.3 Objectives

- Sample emergent cattail plants, below-ground roots, litter and sediment throughout the marsh to estimate biomass accumulation, nutrient content, and stored phosphorus levels in cattail plant communities of Netley-Libau Marsh.
- Estimate current phosphorus levels and potential additional phosphorus capture with marsh restoration efforts.
- Increase our knowledge of this large coastal wetland's influence on the water quality of Lake Winnipeg by evaluating nutrient storage and cattail biomass content.
- Continue to develop materials and outreach to public and partners.

4.0 Activity and Methods: The 2009 Marsh Survey

4.1 Site Research

New site research was conducted in August and September of 2009, collecting samples and survey information throughout Netley-Libau Marsh. Sites were accessed either over land using an ARGO all-terrain vehicle or over water with the use of a canoe or Panther Airboat provided and operated by Manitoba Conservation (Figure 6). Equipment storage, day facilities, field equipment and repairs, and marsh access was granted by landowner Dr. Dennis Anderson, north of Libau, Manitoba. A total of 28 sites were sampled throughout Netley-Libau Marsh (Figure 7). At each sample location, GPS coordinates were collected, and photographs taken to allow these 28 sample locations to become part of a long-term monitoring program on Netley-Libau Marsh. There is significant value to revisiting these sites to monitor nutrient flux within the marsh ecosystem. Additionally, winter sampling of these sites could further identify long-term nutrient storage as part of a nutrient management strategy.

FIGURE 6. TRANSPORTATION OPTIONS FOR RESEARCH IN NETLEY-LIBAU MARSH.

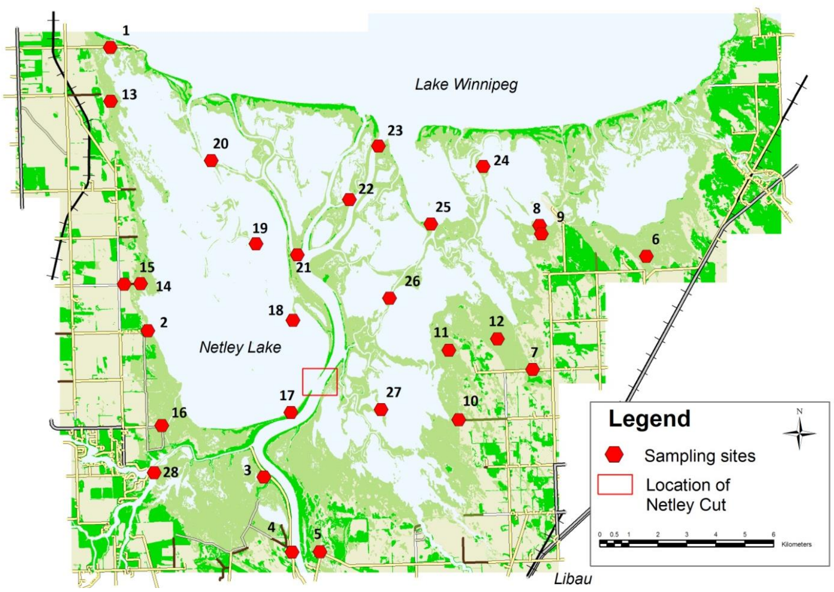


FIGURE 7. LOCATIONS OF 28 SAMPLE SITES IN NETLEY-LIBAU MARSH, SUMMER/FALL SAMPLING 2009.

4.2 Site Data and Sample Collection

At each site, information was recorded and samples collected of plants, roots, litter, and sediment from three randomly placed 1 metre x 1 metre sampling quadrats. All collected samples from the three quadrats were combined for a representative mixed sample. At each quadrat, information was noted on plant composition, plant density, plant height, water depth, litter accumulation, and water clarity. Water samples were also collected from each location. Samples of the emergent plant cattail (Typha spp.) and its roots were collected to examine nutrient storage and biomass accumulation within the cattail communities of Netley-Libau Marsh. From each quadrat, two individual plants were collected, for a total of six plants per site location (Figure 8). Roots were cut from the base of the cattail plant, washed in the water, and bagged separately.

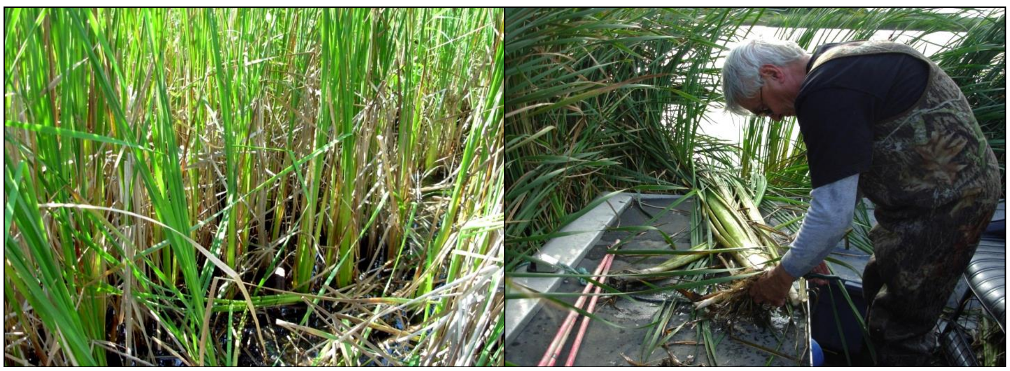


FIGURE 8. PLANT SAMPLING IN NETLEY-LIBAU MARSH. TYPICAL CATTAIL STAND INSIDE A 1M X 1M QUADRAT (LEFT); COLLECTING, CUTTING, AND BUNDLING CATTAIL SAMPLES (RIGHT).

At each quadrat sample site, soil cores were collected with a 5-cm diameter soil corer (Figure 9) and extracted from the corer using a plunger-type ramrod. The top litter layer was removed and bagged separately. Soil cores were combined and bagged in Ziploc storage bags, and all samples were stored on ice for transport to the lab for processing. Water samples were collected at each site using a 1-metre long, 5-cm wide plastic tube, which effectively collects a mixed sample from the entire water column. Each water sample was transferred to a 1-litre white plastic sample bottle, stored on ice, and analyzed within 24 hours for numerous water quality parameters.

FIGURE 9. SEDIMENT CORER SHOWN INSIDE A 1M X 1M QUADRAT (LEFT); A SUCCESSFUL 5-CM DIAMETER SEDIMENT CORE REMOVED FROM SEDIMENT CORER (RIGHT).

4.3 Sample Processing: Plant and root biomass

Plant and root samples were transferred to the University of Manitoba and dried in drying ovens at 65 degrees Celsius for 48 hours, then weighed to calculate moisture content and biomass accumulation. Dried samples were packed in brown paper bags and put in dry storage until processing. Stored plant and root samples were ground to fine dust using Wiley Mill grinders in the Department of Soil Science at the University of Manitoba (Figure 10) and stored in Ziploc storage bags. Samples of ground material were packed in sample containers for shipping and sent to Agvise Laboritories in North Dakota for complete nutrient analysis, which includes: total phosphorus, total nitrogen, potassium, calcium, magnesium, sodium, zinc, iron, manganese, copper, sulphur, and boron. Nutrient content is of interest to measure plant nutrient uptake with biomass accumulation of the marsh plant communities in order to estimate nutrient storage in Netley-Libau Marsh (Table 1).

TABLE 1. COMPLETE PLANT NUTRIENT ANALYSIS

SYMBOL	ELEMENT	IMPORTANCE
Macronutrients		
N	nitrogen	Essential nutrient—cause of eutrophication in water
P	phosphorus	Essential nutrient—cause of eutrophication in water
K	potassium	Essential nutrient—readily exchangeable: plentiful in MB soils
Ca	calcium	Readily exchangeable—P retention capacity
Mg	magnesium	Readily exchangeable—P retention capacity
S	sulphur	Essential macronutrient
Micronutrients		
Fe	iron	Trace metal—very reactive with P
Zn	zinc	Trace metal
Mn	manganese	Trace metal
Cu	copper	Trace metal
B	boron	Essential micronutrient
Beneficial nutrients		
Na	sodium	Readily exchangeable

FIGURE 10. PLANT SAMPLE PROCESSING. WILEY MILLS GRINDERS GROUND PLANT MATERIAL TO DUST. SAMPLES WERE TRANSFERRED TO SAMPLE BOTTLES AND SENT TO AGVISE LABORATORIES FOR COMPLETE NUTRIENT ANALYSIS.

Plant samples were also collected in mid-December from half a dozen locations to evaluate winter storage in above-ground plant material (Figure 11). Early sampling at Netley-Libau Marsh during 2007 to 2009 has shown that nutrients continue to be lost over the winter months into spring due to freezing and thawing action on the dry frozen plant material. Nutrient content in plant samples during mid-winter is thought to be still significant compared to March or April following spring thawing (Grosshans et al., 2011).

FIGURE 11. SAMPLES WERE COLLECTED DURING DECEMBER 2009 FOR ANALYSIS OF NUTRIENT LOSS OVER THE WINTER.

4.4 Sample Processing: Litter and soil

Litter and soil samples were also transferred to the University of Manitoba and dried in drying ovens at 65 degrees Celsius for 48 hours, then weighed to calculate moisture content and bulk density. All dried litter and sediment samples were pulverized to dust in soil grinders in the Department of Soil Science at the University of Manitoba (Figure 12). All ground samples were bagged in AgVise soil bags and sent with the plant samples to Agvise Laboratories in North Dakota and analyzed for a suite of elements (Table 2), as well as percentage of organic matter, pH, salinity, and Cation Exchange Capacity (CEC).

TABLE 2. COMPLETE LITTER AND SOIL NUTRIENT ANALYSIS

SYMBOL	ELEMENT	IMPORTANCE
NH4	Ammonical nitrogen	Ammonical nitrogen—cause of eutrophication in water
P	Phosphorus	Available P form (P-Olsen)—cause of eutrophication in water
K	Potassium	Essential nutrient—readily exchangeable: plentiful in MB soils
Ca	Calcium	Readily exchangeable—P retention capacity
Mg	Magnesium	Readily exchangeable—P retention capacity
S	Sulphur	Essential macronutrient
Fe	Iron	Trace metal—very reactive with P
Zn	Zinc	Trace metal
Mn	Manganese	Trace metal
Cu	Copper	Trace metal
Cl	Chlorine	
Na	Sodium	Readily exchangeable
% O	% organic matter	Source of nutrient storage and release
pH	pH	Plant growth and nutrient storage
salts	Soluble salts	salinity
CEC	Cation Exchange Capacity	Ability of soil to hold onto nutrients

FIGURE 12. SOIL GRINDER AND SAMPLES AT THE UNIVERSITY OF MANITOBA, DEPARTMENT OF SOIL SCIENCE. SOIL SAMPLES WERE PULVERIZED, PACKED, AND SHIPPED TO AGVISE LABORATORIES FOR ANALYSIS.

4.5 Sample Processing: Water quality and nutrient analysis

All water samples were analyzed at the Environmental Engineering lab, in the Department of Biosystems Engineering (Dr. Nazim Cicek), at the University of Manitoba for a suite of water quality parameters, including: total reactive phosphorus (TRP) for fresh samples, turbidity, total phosphorus, ammonia, pH, alkalinity, dissolved inorganic carbon (DIC), and phytoplankton. All water samples were analyzed following the parameters found in *Standard Methods for the Examination of Water and Wastewater, 18th Edition* (American Public Health Association, 1998), and T*he Chemical Analysis of fresh water, 2nd edition* (Stainton, Capel, & Armstrong, 1977).

4.5.1 Total Reactive Phosphorus (TRP)

Total reactive phosphorus (TRP) methods employed the ascorbic acid and a molybdate color reagent method and determined using colorimetric analysis using an Ultrospec 400 UV/visible light spectrophotometer. Ammonia-N is measured following the hypochlorite method and also determined using colorimetric analysis using an Ultrospec 400 UV/visible light spectrophotometer.

4.5.2 Total Phosphorus (TP)

Total phosphorus was measured using HACH reagents and protocol, with total phosphorus by the PosVer 3 with acid persulfate digestion method (Hach Company 2009), followed by colorimetric analysis using a HACH visible light spectrophotometer.

4.5.3 Chlorophyll a

Phytoplankton biomass (chlorophyll a concentration) is measured by filtering 200 ml of sample. Algal pigments are extracted from the filter using 90 per cent methanol. Absorbance readings of the extract are used to calculate chlorophyll using the formulae of Marker, Crowther and Gunn (1980).

4.5.4 Alkalinity, pH, Conductivity and Temperature

Alkalinity is calculated by titration using 0.02 N hydrochloric acid to a clear end point (bromocresol green-methyl red indicator solution), pH determined using a pH meter, and conductivity, salinity, and water temperature area measured in the field using a conductivity/salinity probe.

5.0 Project Results and Discussion

5.1 Cattail Biomass Accumulation

Above- and below-ground biomass accumulation and moisture content of cattail (Typha spp.) was calculated for each study site (grams [g] per square metre [m^2]) and averaged to estimate an average cattail yield (kilogram per hectare) for Netley-Libau Marsh (Table 3). Cattail community characteristics and biomass data are summarized in Tables 3 and 4 respectively. Measurements from each sample site estimate average cattail density in Netley-Libau Marsh to be 43 plants per m^2 (Figure 13), with an average height of 260 to 290 centimetres (Table 3). The average cattail plant contained 84 per cent moisture content, with a dry biomass yield of 44 g per plant, or 1.9 kilograms (kg) per $m^{2.}$ Estimated total cattail biomass yield in Netley-Libau Marsh is 18,870 kg (18.9 tonnes) per hectare of cattail (Table 4).

Cattail Biomass Yield = 18.9 tonnes per hectare

Figure 14 highlights average dry biomass of cattails (g per m^2) in each of the study sites measured from samples collected during August peak growth. What is revealed is a wide range of cattail biomass yields, dependent on site location and cattail plant density at each given sample site. Understanding seasonal growth, biomass accumulation, and seasonal biomass yields (kg per hectare) of cattails is essential to understand biomass potential, nutrient storage, and phosphorus management.

TABLE 3. CATTAIL COMMUNITY CHARACTERISTICS AVERAGED FROM 28 SITES IN NETLEY-LIBAU MARSH.

SAMPLE	SPECIFICS	AVERAGE	COUNT	MEDIAN	STANDARD DEVIATION
Cattail	Height low (cm)	262.88	28	270.00	41.28
	Height hi (cm)	290.44	27	293.33	40.30
	# Collected	6	28	6.00	0
	% cover per m^2	55.12	27	56.67	6.78
	Density (total # per m^2)	42.91	27	42.00	9.01
	Seed heads per m^2	2.76	21	1.33	4.76
Deadfall	% cover per m^2	45.32	21	41.67	27.07
Water Level	depth (cm)	20.27	27	16.67	17.08

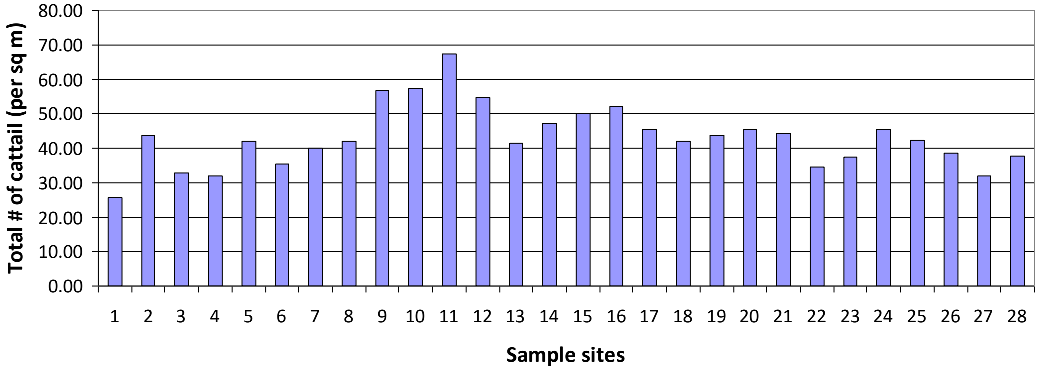


FIGURE 13. AVERAGE CATTAIL DENSITY (TOTAL # OF CATTAIL PLANTS PER M²) FOR EACH SAMPLE SITE.

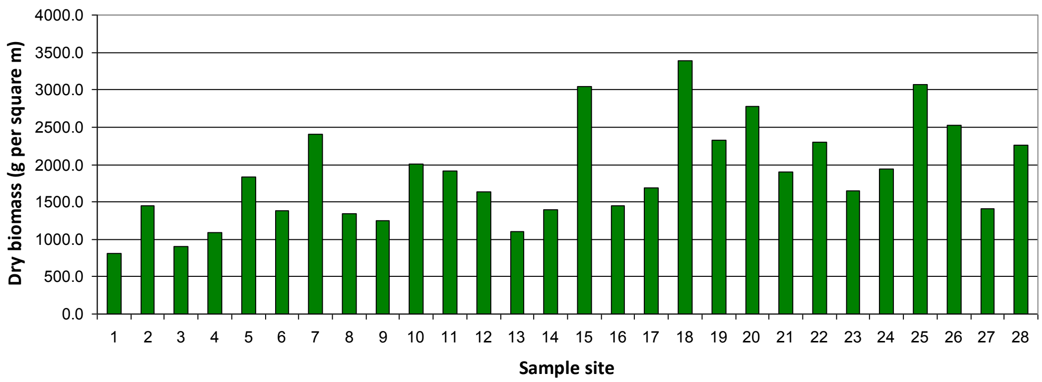


FIGURE 14. AVERAGE CATTAIL ABOVEGROUND DRY BIOMASS (G PER M²) FOR EACH SAMPLE SITE.

TABLE 4. PLANT CHARACTERISTICS AND AVERAGE BIOMASS YIELD AVERAGED FROM SAMPLES COLLECTED FROM 28 SITES IN NETLEY-LIBAU MARSH IN AUGUST 2009.

SAMPLE	SPECIFICS	AVERAGE	COUNT	MEDIAN	STANDARD DEVIATION
Cattail	**Biomass Yield (kg per hectare)**	**18,871**	**28**	**17,554**	**6763**
	total wet weight (g)	1,439.38	28	1,386.53	417.65
	total dry weight (g)	263.84	28	245.39	96.23
	dry weight (g) per plant	43.97	28	40.90	16.04
	% dry matter	18.26	28	17.98	3.47
	% moisture	81.74	28	82.02	3.47
Cattail roots	**total wet weight (g)**	**509.37**	**27**	**429.37**	**317.74**
	total dry weight (g)	89.81	27	61.68	72.87
	dry weight of rhizomes (separated from root mass)	28.43	27	24.13	17.54
	dry weight (g) per rhizome	21.38	28	13.58	18.42
	% dry matter	15.94	27	14.91	4.53
	% moisture	84.06	27	85.09	4.53
River bulrush	**total wet weight (g)**	**232.75**	**5**	**232.75**	
	total dry weight (g)	79.23	5	79.23	
	dry weight (g) per plant	13.21	5	13.21	
	% dry matter	34.04	5	34.04	
	% moisture	65.96	5	65.96	

5.2 Soil and Litter Characteristics and Bulk Density

Soil and litter bulk density, moisture content, per cent organic matter, and pH were measured for soil and litter samples collected from each study site and averaged to estimate bulk density per m^2 for Netley-Libau Marsh (Table 5). Measurements from each sample site estimate average soil bulk density to be 257 kg per m^2, while average litter bulk density is 26 kg per m^2. Litter samples typically contained high levels of organic debris, dead plant material, plant roots, and a mix of organic soil with lower clay content. Average moisture content was 50 per cent and 70 per cent, and average per cent organic content at 10 per cent and 23 per cent for soil and litter respectively (Table 5). The pH levels for litter and soil samples in Netley-Libau Marsh were fairly neutral, with an average pH of 7.3 for litter with a range of 6.6 to 7.7, and an average pH of 7.4 for soil ranging from 6.6 to 7.8 (Table 5).

TABLE 5. SOIL AND LITTER CHARACTERISTICS AND AVERAGE BULK DENSITY, AVERAGED FROM SAMPLES COLLECTED FROM 28 SITES IN NETLEY-LIBAU MARSH IN AUGUST 2009.

SAMPLE	SPECIFICS	AVERAGE	COUNT	MEDIAN	STD DEV
Litter	Bulk Density (kg per m^2)	25.9	28	26.2	15.8
	total wet weight (g)	179.10	28	193.81	101.54
	total dry weight (g)	52.50	28	53.04	32.11
	% dry matter	30.61	25.00	30.17	12.32
	% moisture	69.39	25.00	69.83	12.32
	% organic matter	22.58	25	18.10	17.82
	pH	7.29	25	7.40	0.27
Soil	Bulk Density (kg per m^2)	257.0	28	262.1	112.9
	total wet weight (g)	1,026.86	28.00	987.62	412.46
	total dry weight (g)	521.35	28.00	531.73	228.99
	% dry matter	50.63	26.00	49.32	9.51
	% moisture	49.37	26.00	50.68	9.51
	% organic matter	10.25	26	6.95	9.90
	pH	7.41	26	7.40	0.30

5.3 Water Quality and Dissolved Nutrients in Netley-Libau Marsh

In natural aquatic systems, Phosphorus (P) and nitrogen (N) are two nutrients in shortest supply, with phosphorus expected to be the most limiting (Wetzel, 2001). Phosphorus naturally enters freshwater systems slowly and in low concentrations through erosion of soil, deposition from animal waste and plant decomposition. Human impacts have significantly accelerated the rate at which phosphorus enters aquatic systems through drainage, wetland loss, fertilizer application, livestock, and urban and rural wastewater. A small amount of fertilizer or sewage entering an aquatic system can greatly increase the concentration of phosphorus available for aquatic plant and algae production. Although nutrients in water are essential to biological life, too high of a nutrient concentration causes eutrophication and a rapid increase in plant and algae growth. Most nitrogen available for plants comes mainly from decaying organic matter, fecal matter, or bacteria that can "fix" the atmosphere's nitrogen into a form plants can utilize, but nitrogen is also readily obtained from fertilizer and human and animal waste. Lake Winnipeg—and consequently Netley-Libau Marsh—suffers from eutrophication due to an overabundance of phosphorus.

Water samples collected from Netley-Libau Marsh in August 2009 provide a snapshot of the water quality parameters during that time, and do not necessarily reflect overall water quality issues of the marsh and adjoining Lake Winnipeg—a much more comprehensive water quality sampling program would be necessary to gain a better understanding of seasonal water quality and nutrient input in Netley-Libau Marsh. Water quality parameters are summarized in Table 6.

TABLE 6. 2009 WATER QUALITY AND NUTRIENT PARAMETERS OF 28 SITES IN NETLEY-LIBAU MARSH (WITH TOTAL REACTIVE PHOSPHORUS [TRP], AND DISSOLVED INORGANIC CARBON [DIC]).

SITE	TRP (PO4) mg/L	AMMONIA -N (NH3) mg/L	TOTAL P mg/L	pH	ALKALINITY (mg/L)	(DIC) (mg/L)	CHLOROPHYLL-A (µ g/L)	PHEOPHYTIN (µg/L)	TOTAL (µg/L)
EC 1	0.2412	0.00000	1.260	7.510	320	83.0	7.4	0.0	7.4
EC 2	0.2604	0.02559	1.480	8.370	264	63.6	60.6	8.9	69.5
EC 3	1.2099	0.00000	9.560	7.320	360	97.3	56.9	13.2	70.1
EC 4	0.3260	0.08186	1.500	8.090	248	60.6	29.7	5.4	35.1
EC 5	0.0812	0.00000	0.790	7.460	264	69.1	11.1	1.1	12.2
EC 6	0.0364	0.00000	0.650	7.630	264	67.2	1.2	0.2	1.4
EC 7	0.0204	0.00000	0.390	7.440	288	75.7	4.9	0.0	4.9
EC 8	0.1964	0.00000	1.190	8.080	240	58.6	9.9	3.0	12.9
EC 10	0.0876	0.00000	0.800	7.500	312	81.1	4.9	0.1	5.0
EC 11	0.1020	0.00000	0.840	7.340	304	81.7	14.8	5.1	20.0
EC 12	0.0652	0.00000	0.760	7.290	256	69.8	2.5	3.9	6.4
EC 13	0.1388	0.00000	0.980	7.29	392	106.8	29.7	6.1	35.8
EC 14	0.4237	0.00000	1.780	7.29	440	119.9	6.2	1.7	7.9
EC 15	0.9182	0.00000	3.530	7.83	568	141.4	4.9	0.0	4.9
EC 16	0.3404	0.01354	1.720	7.49	360	93.7	11.1	3.9	15.0
EC 17		0.02961	1.200	8.13	272	66.3	61.8	0.0	61.8
EC 18		0.12807	1.850	8.2	264	64.0	75.4	11.2	86.7
EC 19		0.18902	2.440	7.9	264	65.1	39.6	8.4	47.9
EC 20		0.11601	1.450	8.0	264	64.8	30.9	2.8	33.7
EC 21		0.11333	1.540	8.1	264	64.6	59.3	5.9	65.2
EC 22		0.13946	1.990	8.1	208	50.7	18.5	6.4	25.0
EC 23		0.02760	1.290	8.4	264	63.6	47.0	0.0	47.0
EC 24		0.01421	1.660	7.8	288	72.0	37.1	7.3	44.4
EC 25		0.00416	1.200	8.4	256	61.6	33.4	1.1	34.5
EC 26		0.04770	1.640	8.3	272	65.8	50.7	3.1	53.8
EC 27		0.01421	1.300	7.7	288	72.9	8.7	3.5	12.1
EC 28		0.00081	0.890	8.3	368	88.8	22.3	2.1	24.4

TABLE 7. AVERAGE 2009 WATER QUALITY AND NUTRIENT PARAMETERS FROM 28 SITES IN NETLEY-LIBAU MARSH (WITH TOTAL REACTIVE PHOSPHORUS [TRP], AND DISSOLVED INORGANIC CARBON [DIC]).

	TRP (PO_4) mg/L	AMMONIA -N (NH_3) mg/L	TOTAL P mg/L	pH	ALKALINITY (mg/L)	(DIC) (mg/L)	CHLOROPHYLL-A (µg/L)	PHEOPHYTIN (µg/L)	TOTAL (µg/L)
Average	0.30	0.04	1.69	7.82	301.93	76.66	27.4	3.9	31.3
Count	15	27	27	27	27	27	27.0	27.0	27.0
Median	0.20	0.00	1.30	7.83	272.00	69.13	22.3	3.1	25.0
Std dev	0.34	0.05	1.69	0.39	74.21	20.36	22.2	3.7	24.5
Min	0.02	0.00	0.39	7.29	208.0	50.73	1.2	0.0	1.4
Max	1.21	0.19	9.56	8.38	568.0	141.4	75.4	13.2	86.7

5.3.1 Phosphorus—TRP and Total

It is important to measure total reactive phosphorus (TRP), because it is the amount of P in water that is readily available and can be taken up by algae and plants. Samples collected from Netley-Libau Marsh had an average 0.30 mg/L of TRP and ranged between .002 to 1.21 mg/L (Table 7). Some samples could not be analyzed for TRP due to length of storage (beyond 24 hours).

Total phosphorus (TP) is the total amount of inorganic and organic P that is found in the water. Manitoba Water Quality Guidelines (Manitoba Conservation, 2002) state TP should not exceed 0.025 mg/L, in any reservoir, lake, or pond, or in a tributary at the point where it enters such bodies of water. In other streams, total phosphorus should not exceed 0.05 mg/L, although the level of P in many water bodies of southern Manitoba is expected to be higher due to naturally higher nutrient levels in the surrounding soil. Average TP concentration in Netley-Libau Marsh during August 2009 was 1.69 mg/L, significantly above the guideline of 0.025 mg/L. Samples ranged between 0.39 and 3.53, with one site (EC 3) at 9.56 mg/L (Figure 15).

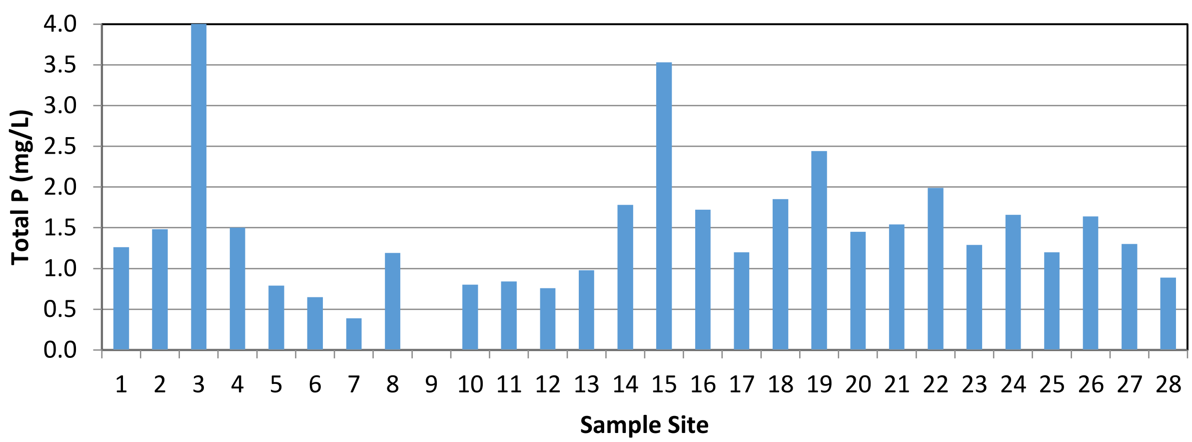


FIGURE 15. TOTAL PHOSPHORUS (MG/L) IN WATER SAMPLES AT ALL 28 SAMPLED SITES.

5.3.2 Ammonia-Nitrogen

Ammonia-N is the concentration of nitrogen in the water that is found in the form of ammonia (NH3). This form of nitrogen is a waste product of aquatic life, and in higher concentrations is toxic to living organisms. Ammonia toxicity varies depending on water pH and temperature. Manitoba Water Quality Guidelines state that at 20°C and pH of 9 ammonia levels should be < 0.3 mg/L (Manitoba Conservation, 2002). Ammonia levels were undetectable for most sample sites, and were at an average 0.04 mg/L, well below Manitoba Guidelines. Several sites along the Red River, however, (Sites EC17 to EC22) approached ammonia levels from 0.03 to 0.18 mg/L, suggesting higher ammonia inputs closer to the Red River.

5.3.3 pH

The level of pH is a measure of the number of hydrogen ions (H+) found in solution. It is very important in driving chemical reactions. The suggested pH range for aquatic life is between 6.5 and 9.0 (Manitoba Conservation, 2002). Water with pH of < 7 is considered acidic with an excess of H+, while water with pH of > 7 is considered basic and has more chemicals able to accept H+ than the concentration of H+ itself. The average pH of water in Netley-Libau Marsh was 7.82 and ranged between 7.29 and 8.38, well within the Manitoba Water Quality Guidelines.

5.3.4 Alkalinity

Alkalinity measures the buffering capacity of water, and refers to the concentration of dissolved chemicals (solutes) in water able to neutralize acids without the pH being changed. In natural systems the most common buffering solutes are bicarbonate and carbonate (Wetzel, 2001). The mean alkalinity of Netley-Libau Marsh in August 2009 was 302 mg/L, and ranged from 208 to 568 mg/L.

5.3.5 Chlorophyll a

Total chlorophyll analysis includes chlorophyll a pigments from both living and dead plant cells. Chlorophyll a is a green pigment found in all plants and often used as a measure of algal production in aquatic systems. High levels of algal production are undesirable because they can release toxins that cause health effects, and reduced oxygen concentrations and fish kills in water from decaying algae. Desirable limits of chlorophyll a are variable depending on natural levels in a given area. Water bodies with chlorophyll a concentrations between 56 and 155 μg/L are considered hyper eutrophic (i.e., high in nutrients) and characterized by dense algae and macrophytic growth. Average total chlorophyll a values in Netley-Libau Marsh were low, at 31.3 μg/L, and ranged from 1.4 to 86.7 μg/L (Figure 16).

5.3.6 Total Inorganic Carbon (DIC)

The total inorganic carbon (CT, or TIC) or dissolved inorganic carbon (DIC) is the sum of inorganic carbon species in a solution. The inorganic carbon species include carbon dioxide, carbonic acid, bicarbonate anion, and carbonate. Average DIC levels in Netley-Libau Marsh were 76.7 mg/L, and ranged between 51 and 141 mg/L.

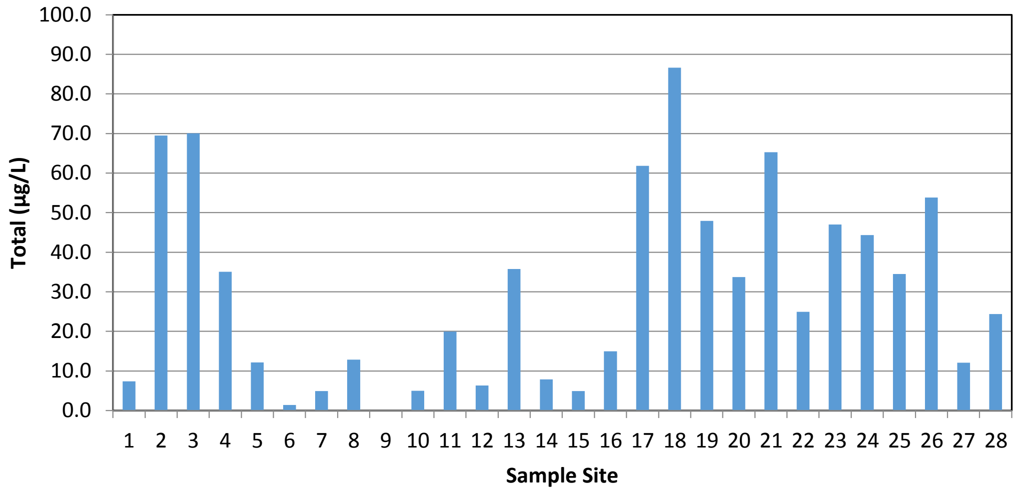


FIGURE 16. TOTAL CHLOROPHYLL IN WATER SAMPLES (MG/L) AT ALL 28 SAMPLED SITES.

5.4 Plant Nutrient Uptake and Stored Soil Accumulation

5.4.1 Plant and Soil Nutrient Content

During the growing season, nutrients are taken up by cattail roots and rhizomes from stored nutrients in the litter and sediment layers and incorporated within the above- and below-ground biomass. Averaged nutrient content for cattail plants and roots in Netley-Libau Marsh, from 28 sample sites, are given in Table 8, and for litter and soil in Table 9.

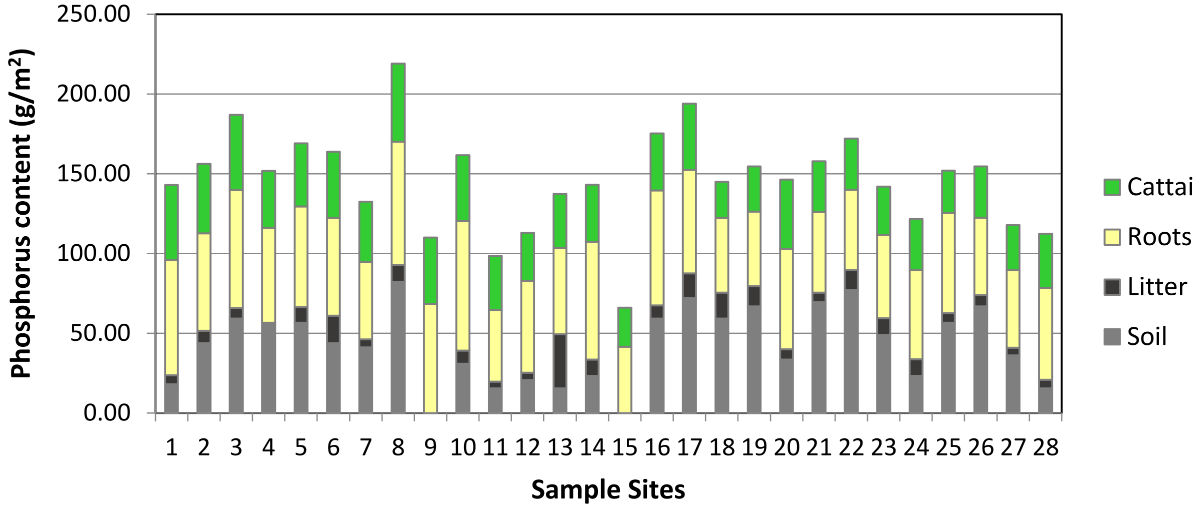
Figure 17 illustrates average phosphorus content (g of P per m^2) for each sample site surveyed in August 2009. Above-ground cattail plants take up phosphorus from the soil and litter layers. Typically, there is more phosphorus stored within the below-ground portion of the plant and within the soil layer than in the above-ground portions. Nutrients translocate to below-ground parts in the fall, allowing cattails to survive to the next growing season. Significant stored available phosphorus reserves were also found within the litter layer, which interacts more directly with the water column and plant communities (Figure 17). Phosphorus in the litter interacts with the surface water, and can be released over time as litter decomposes and is disturbed by fish (such as carp) and wind and wave action (Morris & Lajtha, 1986).

TABLE 8. PLANT NUTRIENT DATA AVERAGED FROM SAMPLES FROM 28 SITES IN NETLEY-LIBAU MARSH

SAMPLE	NUTRIENTS	AVERAGE (KG PER HA)	COUNT	MEDIAN	STD DEV
Cattail	N	234.80	28	227.39	36.53
	P	35.79	28	34.91	7.01
	K	332.59	28	336.84	85.53
	S	27.09	28	26.42	6.02
	Ca	171.59	28	168.89	26.04
	Mg	57.29	28	56.61	9.75
	Na	78.99	28	83.97	28.41
	Zn	0.24	28	0.23	0.06
	Fe	5.39	28	3.93	5.34
	Mn	9.79	28	9.22	3.23
	Cu	0.06	26	0.06	0.03
	B	0.23	28	0.23	0.02
Roots	N	149.27	28	152.85	29.13
	P	59.21	28	61.33	11.30
	K	247.50	28	249.09	53.99
	S	28.16	28	25.48	11.39
	Ca	127.61	28	133.98	39.80
	Mg	71.49	28	70.76	26.33
	Na	72.77	28	65.10	30.42
	Zn	0.73	28	0.65	0.58
	Fe	25.49	28	25.01	15.90
	Mn	4.82	28	4.61	1.63
	Cu	0.11	28	0.09	0.08
	B	0.22	28	0.23	0.03

TABLE 9. SOIL & LITTER NUTRIENT DATA AVERAGED FROM SAMPLES FROM 28 SITES IN NETLEY-LIBAU MARSH

SAMPLE	NUTRIENTS	AVERAGE (KG PER HA)	COUNT	MEDIAN	STD DEV
Litter	P (Olsen)	9.85	25	8.28	6.25
	K	54.11	25	57.98	17.86
	Ca	1,038.11	25	1,110.85	325.62
	Mg	241.02	25	232.68	72.34
	Na	42.50	25	40.12	19.61
	Sulfur	34.80	25	34.16	9.91
	Zinc	1.10	25	0.93	0.45
	Iron	37.32	25	36.05	12.98
	Mn	18.71	25	15.70	10.78
	Cu	1.80	25	1.94	0.84
	Cl	32.69	25	24.07	39.60
	NH4	8.87	25	8.64	2.51
	CEC (meq)	29.06	25	29.50	7.45
	Salts (mmhos/cm)	1.23	25	1.15	0.36
Soil	P (Olsen)	45.77	26	46.26	21.01
	K	635.35	26	588.59	290.58
	Ca	12,961.59	26	12,837.23	1,919.56
	Mg	3,510.20	26	2,995.65	1,741.82
	Na	385.05	26	345.70	141.62
	Sulfur	276.60	26	269.88	115.43
	Zinc	10.41	26	10.81	4.07
	Iron	366.31	26	329.89	154.36
	Mn	153.57	26	127.72	99.89
	Cu	21.92	26	21.73	6.22
	Cl	69.94	26	66.83	41.67
	NH4	60.73	26	55.39	19.31
	CEC (meq)	37.88	26	37.35	6.23
	Salts (mmhos/cm)	1.03	26	0.95	0.32



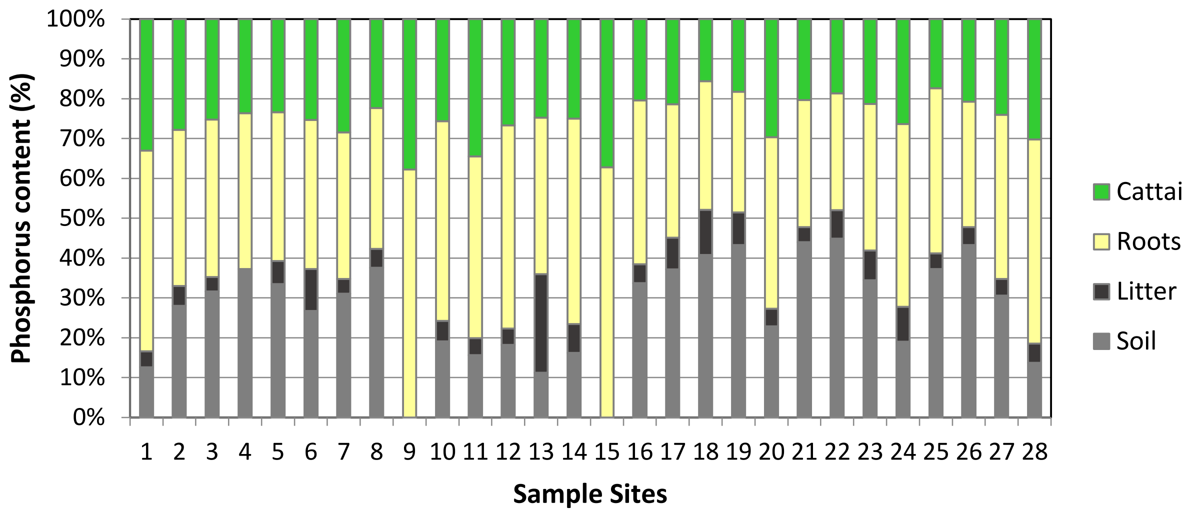


FIGURE 17. (TOP) AVERAGE PHOSPHORUS CONTENT (G OF P PER M²) FOR EACH OF THE 28 SAMPLE SITES SURVEYED IN AUGUST 2009. (BOTTOM) PERCENTAGE OF P PER SQUARE METRE FOUND IN EACH SAMPLE AREA.

5.4.2 Average Plant and Soil Nutrient Content in Netley-Libau Marsh

Average stored total nitrogen and total phosphorus was calculated for the cattail communities of Netley-Libau Marsh. Collected samples averaged 235 kg of nitrogen and 36 kg of phosphorus in the above-ground plants per hectare of cattail (Figures 18). The largest portion of nitrogen was found in the plant material (shoots and roots), with the greatest proportion in the above-ground plant material. For phosphorus, significant stored reserves are contained in the below-ground roots and the soil layer (Figure 18).

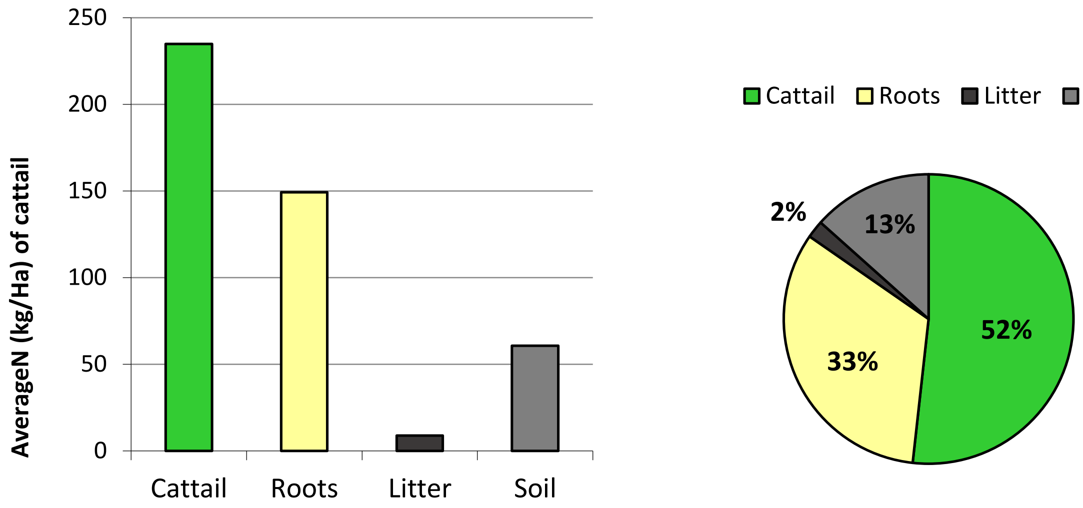


FIGURE 18. AVERAGE NITROGEN CONTENT IN THE CATTAIL COMMUNITIES OF NETLEY-LIBAU MARSH (KG PER HECTARE) AVERAGED FROM THE 28 SAMPLE SITES SURVEYED IN AUGUST 2009.

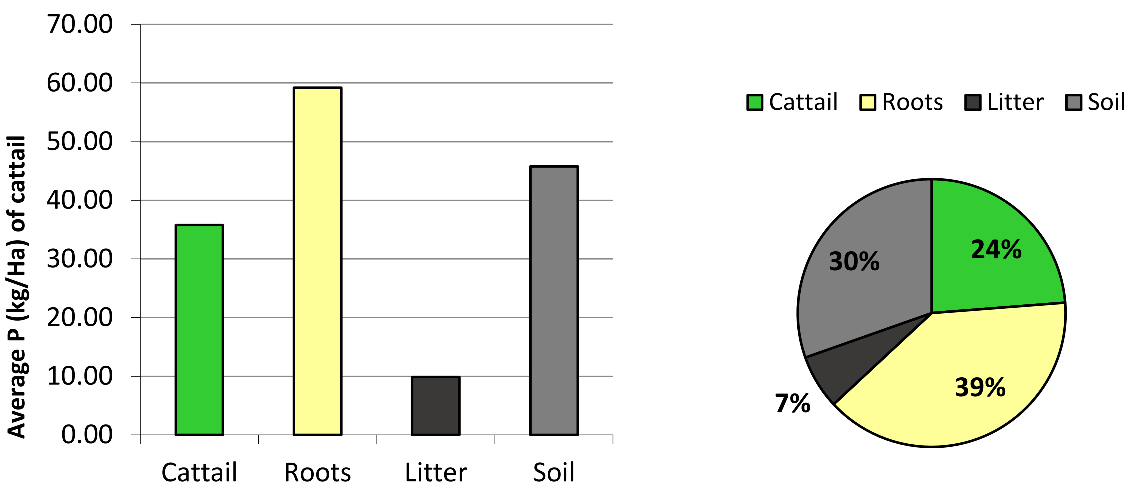


FIGURE 19. AVERAGE PHOSPHORUS CONTENT IN THE CATTAIL COMMUNITIES OF NETLEY-LIBAU MARSH (KG PER HECTARE) AVERAGED FROM THE 28 SAMPLE SITES SURVEYED IN AUGUST 2009.

5.5 Cattail Community Phosphorus Storage in Netley-Libau Marsh

5.5.1 Total Stored Phosphorus and Nitrogen in Netley-Libau Marsh

From the collected survey data of 2009, estimations were calculated for the total stored phosphorus and nitrogen in the cattail communities of Netley-Libau Marsh. Assuming averaged content measured and calculated per hectare of cattail from the collected samples in 2009 (kg per ha of cattail), and a total cattail area of 5000 ha as estimated by the habitat survey of 2001 (Grosshans et al., 2004), total stored phosphorus and nitrogen in the cattail community is estimated to be 525 tonnes and 1,965 tonnes respectively (Table 10). In addition, the soil layer was estimated to contain 230 tonnes of stored phosphorus, and 305 tonnes of nitrogen. Estimated is also the additional P and N storage potentially gained with 25 per cent restoration of the lost plant communities and associated organic litter layers in Netley-Libau Marsh.

TABLE 10. ESTIMATE OF TOTAL STORED PHOSPHORUS IN CATTAIL COMMUNITIES OF NETLEY-LIBAU MARSH.

	AVERAGE P KG/HA	AVERAGE N KG/HA	TOTAL P (TONNES IN 5000 HA OF CATTAIL)	TOTAL N (TONNES IN 5000 HA OF CATTAIL	ADDITIONAL P STORAGE WITH 25% RESTORATION	ADDITIONAL N STORAGE WITH 25% RESTORATION
Cattail emergent plants	36	235	180	1175	45	294
Cattail roots	59	149	295	745	74	186
Cattail organic litter (top 10 cm soil)	10	9	50	45	12	11
TOTAL	105 kg/ha	393 kg/ha	525 T	1965 T	131 T	492 T

5.5.2 Comparison to the Research

Research conducted in the eastern portion of Netley-Libau Marsh by IISD and the University of Manitoba since 2006 has revealed cattail yields on average of 15 to 20 tonnes of dry matter per hectare per year, with 20 to 60 kg of phosphorus being absorbed by cattails from litter and sediment per hectare per year (Grosshans et al., 2011, Cicek et al., 2006). This agrees with the 2009 survey results from samples collected throughout Netley-Libau Marsh, with average cattail biomass yields of 19 tonnes per ha (Table 4), and 36 kg of P taken up by the aboveground plants (Figure 18). Cattail harvesting experiments showed removal of this nutrient rich biomass prevents these nutrients from being released into the environment via natural decomposition (Grosshans et al., 2011; IISD, 2012). Additionally, cattail carbon sequestration research in California demonstrates cattails can annually sequester significant amounts of carbon per hectare, demonstrating how wetland restoration can be assessed for carbon storage (Meadows, 2009). Restoration of the plant communities in Netley-Libau Marsh would increase the capacity of this coastal wetland for phosphorus and nitrogen storage, while increasing carbon storage at the same time.

6.0 Communication and Outreach

6.1 Partnerships

In partnership with this project, research was also conducted on Netley-Libau Marsh during summer and fall 2009 by researchers from Environment Canada and the University of Manitoba. Environment Canada researchers conducted fish surveys, sampled invertebrates, and collected water samples as part of a pilot research study that continued in 2010. Researchers from the university's Department of Engineering measured flow estimates on the Red River, and various openings into and out of the marsh from 2009 to 2011. Measurements revealed that at least one-third of the Red River volume is now passing into the west marsh into Netley Lake through the "Netley Cut," an opening in the river bank between the Red River and Netley Lake, rather than through its historical channels into Lake Winnipeg (Haresign, 2012). The consequences of this input on marsh hydrology and the associated loading of nutrients and other chemicals are unclear, but the volume of water passing through the Cut helps explain the great extent of vegetation change over several decades in Netley Lake.

6.2 Outreach and Communications

IISD has been working with several key project partners as part of a Wetlands Working Group with Manitoba Conservation at the Department of Water Stewardship, emphasizing the renewed commitment towards research, future management and rehabilitation of this critical coastal wetland.

Communication material was developed in conjunction with this research project and other related research efforts within the Netley-Libau Nutrient-Bioenergy project. Numerous articles, videos, brochure, and publications are available on the IISD Netley-Libau Nutrient-Bioenergy project website (IISD, 2012). A publication is currently being produced on the history and significance of Netley-Libau Marsh as a coastal wetland of Lake Winnipeg, and as an important component of a larger Lake Winnipeg Basin Management Strategy required to reduce nutrient loadings to the lake. Communication material was also used to guide organized discussions through the Agricultural Wetland Research Network, accessed through IISD.org at http://www.waterinnovationhub.org/research/wetlands/awrn.asp.

7.0 Conclusions and Lessons Learned

This project attempts to better understand a marsh system about which we know very little, and yet is a key component of the Red River and Lake Winnipeg watershed. Netley-Libau Marsh is a critical component within a larger Lake Winnipeg basin nutrient management plan, and central to any attempt to address nutrient enrichment concerns of the lake. This project is evaluating the water quality and nutrient cycling of Netley-Libau Marsh; examining how this coastal wetland can reduce nutrient loading to Lake Winnipeg; enhancing the knowledge of how natural wetlands improve water quality by removing nitrogen and phosphorus; and examining the multiple co-benefits from restoration of this significant coastal wetland habitat. This study addresses objectives outlined by the Nutrient Management Strategy of Manitoba, the Lake Winnipeg Action Plan, and recommendations by the Lake Winnipeg Stewardship Board and the Government of Manitoba. This study, and the related research through IISD's ongoing Netley-Libau Nutrient-Bioenergy and Cattail Nutrient-Bioenergy projects, demonstrate innovative sustainable solutions that can be applied throughout the Lake Winnipeg watershed to reduce nutrient loading to Lake Winnipeg, while producing valuable economic and environmental co-benefits (IISD, 2012). For example, phosphorus, the noxious pollutant fouling Lake Winnipeg, is also a valuable strategic resource critical for agricultural fertilizer and global food security.

Preliminary results reveal that the cattail community of Netley-Libau Marsh contains significant levels of stored phosphorus, nitrogen, and other nutrients in the above-ground plants, and in the below-ground portions of the rhizomes, litter, and sediment. Estimates of phosphorus content in the cattail community of the marsh reveal 180 tonnes of phosphorus in the above-ground plants, and 750 tonnes of total stored phosphorus reserves. Restoration of cattail and other marsh plants would increase phosphorus storage potential in the marsh, thereby reducing nutrient loading to Lake Winnipeg. Ongoing harvesting experiments and bioenergy research by IISD demonstrate the significant co-benefits of wetlands for nutrient management. Continued monitoring of this significant coastal wetland habitat is needed to understand its importance within a larger Lake Winnipeg nutrient management strategy, and its multiple co-benefits to the lake and the Manitoba Bioeconomy.

FIGURE 20. CONTINUED MONITORING OF THIS SIGNIFICANT COASTAL WETLAND HABITAT OF LAKE WINNIPEG IS NEEDED TO UNDERSTAND THE MULTIPLE CO-BENEFITS IT PROVIDES TO THE LAKE, AND TO THE MANITOBA BIOECONOMY.

8.0 Achieving LWBSF Priorities

IISD's *Advancing Netley-Libau Marsh Restoration Project* directly addressed the Lake Winnipeg Basin Stewardship Funding Priorities as follows:

i. Reducing Nutrient Inputs from Rural and Urban Sources

The potential for functioning wetlands to reduce nutrient loads has been clearly documented (Mitsch & Wang, 2000). Netley-Libau Marsh is substantially degraded yet offers significant potential to reduce Red River nutrient loads before entering Lake Winnipeg. A functional marsh will help reduce nutrient loads generated from both rural and urban sources.

ii. Controlling Point and Nonpoint Sources of Pollution

While providing only 11 per cent of annual water flows into Lake Winnipeg, the Red River system contributes 30 per cent of annual loads of nitrogen and 60 per cent of annual phosphorus loads to the lake, making it the single largest contributor of excess nutrient loads to Lake Winnipeg. A functional marsh will help control point and nonpoint pollution sources contributed from throughout the Red River Basin.

iii. Rehabilitating Priority Aquatic Ecosystems for Nutrient Reduction

Section 36 of the final report prepared by the Lake Winnipeg Stewardship Board (LWSB) includes three recommendations focused on the concept of "Natural Wetlands as Nutrient Abatement Options," one of which is focused directly on the opportunities associated with Netley-Libau Marsh. A functional marsh will help rehabilitate the Lake Winnipeg ecosystem, specifically in terms of nutrient reduction. The Manitoba Government continues to support research and restoration efforts at Netley-Libau Marsh for Lake Winnipeg nutrient reduction.

iv. Enhancing Research and Monitoring Capacity to Assist Decision Making

LWSB Recommendation 36.3 states that "The Province of Manitoba should obtain a more complete understanding of the historic role of the Netley-Libau Marsh in reducing nutrient load from the Red River basin. Opportunities to recreate any natural historic nutrient reduction mechanisms with the Netley-Libau Marsh should be explored." This project will assist decision-makers in understanding the current state and cycles of nutrient loading in the marsh. The Manitoba Government continues to support research in the marsh.

v. Additional Public Awareness Benefit

This project and related ongoing IISD research will contribute substantially to increased public understanding and awareness regarding the nutrient loading of Lake Winnipeg, the importance of Netley-Libau Marsh and its potential to reduce loading to Lake Winnipeg, and further integrated surface water management, wetland restoration, biomass production, and nutrient capture throughout the watershed.

References

American Public Health Association (APHA). (2005). *Standard methods for the examination of water and wastewater, 21st Edition*. A.D. Eaton, L.S. Clesceri, E.W. Rice, A.E. Greenberg, and M.A.H. Franson (Eds.).

Bourne, A., Armstrong, N. & Jones, G. (2003). *A preliminary estimate of total nitrogen and total phosphorus loading to streams in Manitoba, Canada* (Manitoba Conservation Report No. 2002-04). Winnipeg, MB, Canada.

Cicek, N., Lambert, S., Venema, H.D., Snelgrove, K.R., Bibeau, E.L., & Grosshans, R. (2006). Nutrient removal and bio-energy production from Netley-Libau Marsh at Lake Winnipeg through annual biomass harvesting. *Biomass and Bioenergy, 30*(6), 529–536.

DeBusk, W. F., Newman, S., & Reddy, K. R. (2001). Spatio-temporal patterns of soil phosphorus enrichment in Everglades Water Conservation Area 2A. *Journal of Environmental Quality, 30*(4), 1438–1446.

Gabor, T.S., Kiers North, A., Ross, L.C.M., Murkin, H.R., Anderson, J.S., & Turner, M.A. (2001). *Beyond the pipe. The importance of wetlands & upland conservation practices in watershed management: Functions & values for water quality & quantity* (Ducks Unlimited Canada [DUC] report). Manitoba, Canada.

Grosshans, R.E., Venema, H.D., & Barg, S. (2005). *Geographical analysis of cumulative threats to prairie water resources: Mapping water availability, water quality, and water use stresses* (IISD Report). Winnipeg: IISD.

Grosshans, R.E., Venema, H.D., Cicek, N., & Goldsborough, G. (2011, January). Cattail farming for water quality: Harvesting cattails for nutrient removal and phosphorous recovery in the watershed. *Proceedings of the WEF-IWA Nutrient Recovery and Management 2011 Conference: Inside and outside the fence*. Miami, Florida, U.S.

Grosshans, R.E., Wrubleski, D.A., & Goldsborough, L.G. (2004). *Changes in the emergent plant community of Netley-Libau Marsh between 1979 and 2001* (Delta Marsh Field Station [University of Manitoba] Occasional Publication No. 4). Winnipeg, Manitoba.

Haresign, M. (2012). *Modelling river ice freeze-up on the Red River near Netley Cut.* (MSc. thesis). Department Of Civil Engineering, University of Manitoba. Retrieved from http://mspace.lib.umanitoba.ca//handle/1993/8865

International Institute for Sustainable Development (IISD). (2012). *Netley-Libau Marsh research project*. http://www.iisd.org/wic/research/wetlands/netleylibau.asp

Jones, G, & Armstrong, N. (2001). *Long-term trends in total nitrogen and total phosphorus concentrations in Manitoba streams* (Manitoba Conservation Report No. 2001-07).Winnipeg, Manitoba.

Kadlec, R.H., & Knight, R.L. (1996). *Treatment wetlands*. Boca Raton: CRC Press.

Lake Winnipeg Stewardship Board. (2005, January). *Our collective responsibility: Reducing nutrient loading to Lake Winnipeg. An interim report to the Minister of Water Stewardship for Manitoba*. http://gov.mb.ca/waterstewardship/questionnaires/surface_water_management/pdf/connected_docs/LWSBInterimReportJan05.pdf

Manitoba Conservation. (2002). *Manitoba water quality standards, objectives and guidelines, final draft* (Manitoba Conservation Report 2002-11).

Marker, A. F. H., Crowther, C. A., & Gunn, R. J. M. (1980). Methanol and acetone solvents for estimating chlorophyll a and phaeopigments by spectrophotometry. *Archiv für Hydrobiologie Beihefte, 14*, 52–69.

Martin, I. & Fernandez, J. (1992). Nutrient dynamics and growth of a cattail crop (*Typha latifolia L.*) developed in an effluent with high eutrophic potential— application to wastewater purification systems. *Bioresource-Technology, 42*(1), 7–12.

Meadows, R. (2009). UC scientists help California prepare for climate change. Research News. California Agriculture, 63(2). 56–58.

Mitsch, W.J. & Gosselink, J.G. (2007). *Wetlands*. 4th edition. New York: John Wiley and Sons Publishing.

Mitsch, W.J. & Wang, N. (2000). Large-scale coastal wetland restoration on the Laurentian Great Lakes: Determining the potential for water quality improvement. *Ecological Engineering, 15*. 267–282.

Mitsch, W.J., Zhang, L., Stefanik, K.C., Nahlik, A.M., Anderson, C.J., Bernal, B., Hernandez, M., & Song, K. (2012). Creating wetlands: Primary succession, water quality changes and self-design over 15 Years. *BioScience, 62*(3), 237–250.

Morris, J. T., & Lajtha, L. (1986). Decomposition and nutrient dynamics of litter from four species of freshwater emergent macrophytes. *Hydrobiologia, 13*1(3). 215–224.

Neely, R.K. & Baker, J.L. (1989). Nitrogen and phosphorus dynamics and the fate of agricultural runoff. In A.G. van der Valk (Ed.). *Northern Prairie Wetlands* (pp. 92–131). Ames: Iowa State Univ. Press.

Noe, G. B., Scinto, L.J., Taylor, J., Childers, D.L., & Jones, R.D. (2003). Phosphorus cycling and partitioning in an oligotrophic Everglades wetland ecosystem: A radioisotope tracing study. *Freshwater Biology, 48*(11), 1993–2008.

Smith, C.S., Adams, M.S., & Gustafson, T.D. (1988). The importance of belowground mineral element stores in cattails (Typha Latifolia L.). *Aquatic Botany, 30*, 343–352.

Stainton, M. P., Capel, M. J., Armstrong, F. A. J. (1977). *The chemical analysis of freshwater* (2nd edition). Fisheries and Environment Canada. Miscellaneous Special Publication No. 25.

Wetzel, R. G. (2001). *Limnology: Lake and river ecosystems* (3rd edition). San Diego: Academic Press.

Published by the International Institute for Sustainable Development.

International Institute for Sustainable Development
Head Office
111 Lombard Avenue, Suite 325, Winnipeg, Manitoba, Canada R3B 0T4
Tel: +1 (204) 958-7700 | Fax: +1 (204) 958-7710 | Website: www.iisd.org