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CHEMICAL LIMNOLOGY AND WATERBIRD USE OF AN URBAN CONSTRUCTED WETLAND

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The Sackville Waterfowl Park is a 19-ha shallow freshwater constructed wetland located in Sackville, New Brunswick, Canada. The objectives of this ongoing study are to determine the relationships between chemical limnology, primary productivity, macroinvertebrate abundance and waterbird density in this urban wetland and if these change with increasing duration of flooding. Based on total phosphorous and chlorophyll-a, this wetland would be categorized eutrophic. Annual mean concentrations of total phosphorous, total organic carbon and chlorophyll-a, did not decline during 1992–1996, a period from four to eight years after the creation of this wetland. Total nitrogen concentrations did however decline during this time period. Associated with high nutrient availability there was an abundance of macroinvertebrates with mean dry weight per activity trap ranging from 7–560 mg. Six different species of fish were caught in minnow traps, with mean number of fish caught per trap increasing from 10 to 27 during 1993–1996. The urban setting of the park has not deterred wildlife from using it, with over 160 species of birds being observed. There have been 26 species confirmed breeding in the park. There was an average of 49 broods of waterbirds produced annually during 1993 – 96, one of the highest reported brood densities in Atlantic Canada. These results suggest that constructing wetlands in an urban environment can create excellent wildlife habitat.

Key words: constructed wetland, limnology, waterbird, habitat, waterfowl

INTRODUCTION

Constructing wetlands to mitigate destruction of wetland habitat is becoming more prevalent in North America, and globally, due to wetland protection laws and society's increased understanding of the beneficial functions of wetlands (MITSCH 2005, BOBBINK *et al.* 2006). The Sackville Waterfowl Park (hereafter referred to as SWP) is a 22-ha park owned by the Town of Sackville, in New Brunswick, Canada. The site of SWP was originally a salt marsh but had been used for agricultural purposes for hundreds of years until being reflooded in the spring of 1988 (HANSON & SMITH 1993). Building freshwater impoundments on the dykelands of the upper Bay of Fundy has been used to increase the amount of aquatic habitat in this landscape (HOWELL *et al.* 1991). There is however concern that the primary productivity and habitat value of these freshwater impoundments declines over time (WHITMAN 1976, MAILLET *et al.* 1999). Although the use of urban wetlands by some waterbird species, such as Mallard (*Anas platyrhynchos*; HEUSMANN 1981) and Canada Goose ((*Branta canadensis*; COLUCCY *et al.* 2001) is well documented, the habitat value of constructed wetlands in urban environments for a broad suite of species is less understood (FOX *et al.* 1994). The objectives of this ongoing study are to determine the relationships between chemical limnology, primary productivity, macroinvertebrate abundance, fish populations, and waterbird density in an urban wetland, and to determine if these relationships change over time. This paper provides an overview of the chemical limnology and waterbird use of this urban constructed wetland during the period 1992–1996.

MATERIALS AND METHODS

Study site

SWP consists of approximately 19 ha of freshwater wetland and 3 ha of adjacent uplands (HANSON *et al.* 1994). The wetland has a shoreline of 2.4 km and drains a 207-ha watershed. SWP has 2.8 km of boardwalks and trails, equipped with rest benches, viewing areas and interpretative signs. The trails of the park take visitors directly into the wetland where they can share the habitat with the native animals (HANSON & SMITH 1993). Lesser duckweed (*Lemna minor*), pondweed (*Potamogeton pusillus*), and algae are the dominant submergent vegetation, whereas, wild rice (*Zizania aquatica*), cattail (*Typha latifolia, Typha angustifolia*), burreed (*Sparganium eurycarpum*), and common arrowhead (*Sagittaria latifolia*) are the dominant species of emergent vegetation.

Sampling and surveys

Two 500-ml surface water samples were collected by hand every two weeks, from five points within the wetland during summer (1 May–30 August), and from the inflows (n = 2) and outflow throughout the year during 1992–1996. One of these duplicate water samples was submitted to the Environment Canada Lab in Moncton, New Brunswick for analyses. This lab is accredited by the Canadian Society of Chemists/Canadian Association of Environmental Laboratories (CSC/CAEL). Standard methods were used for analysis of total nitrogen, total phosphorous, and total organic carbon (ENVIRONMENT CANADA 1982). Other parameters including major ions, and pH were measured but are not reported herein. The other duplicate sample collected during the summer was filtered using vacuum pump filters with 4.8 micron glass-fibre filters. Methanol based extraction of chlorophyll-a, corrected for phaeophyton, was done using the techniques of MARKER *et al.* (1980).

Macroinvertebrates were sampled using bottle activity traps (n = 5) (WHITMAN 1976, HANSON *et al.* 2000) and fish populations were sampled using standard wire mesh minnow traps (n = 5) every two weeks during the summer during the years 1994–1996. Traps were deployed for 24 hours. Waterbirds surveys were conducted weekly at dawn during May 1–October 1, 1993–1996. Surveys were done by quiet observation from elevated (5 m) viewing platforms by two persons who communicated using hand-held radios to reduce double counting of individuals. Waterbird surveys recorded species, age, and sex of all waterbirds seen or heard. Waterbirds were assigned to the following social status categories: single pair, single male, single female, group pairs, group males, group females, mixed sex groups, female with brood, and broods. Unique broods were determined based on the location, number and age of ducklings observed during the surveys (BELLROSE 1980, GOLLOP & MARSHALL

1954). The identification of unique broods was facilitated by conducting weekly surveys and thus being able to observe broods less than 7 days old (Class 1A).

Statistical analysis

Water chemistry variables were log-transformed prior to analyses. Shapiro-Wilk statistics indicated that transformed variables had normal distributions (PROC UNIVARIATE). This study is being conducted only on SWP, with no replication among study sites; therefore the variables of year and the age of the impoundment are confounded. To determine the relative importance of year compared to age of impoundment a mixed-effects analysis of variance (ANOVA) was conducted in which yearly variation (*i.e.*, 1992, 1993, 1994, 1995, and 1996) was considered a random effect and age of impoundment was considered a continuous variable (PROC MIXED). A separate ANOVA was conducted for each water chemistry parameter. Significance was determined at alpha = 0.05.

RESULTS

The annual mean total phosphorous concentration in surface water samples was greater than 0.05 mg L^{-1} in most years during 1992–1996 (Fig. 1). Mean annual total organic carbon ranged from 3.95 to 5.95 mg L^{-1} (Fig. 2), whereas total nitrogen ranged from 0.394 to 0.625 mg L^{-1} (Fig. 3). The concentration of chlorophyll-a in surface water samples was consistent with the eutrophic nutrient status of the wetland and annual means ranged from 9.0 to 30.0 µg L^{-1} (Fig. 4). There was no significant effect of either duration of flooding or month on total phosphorous (Table 1). In contrast there were significant effects of both duration of flooding and

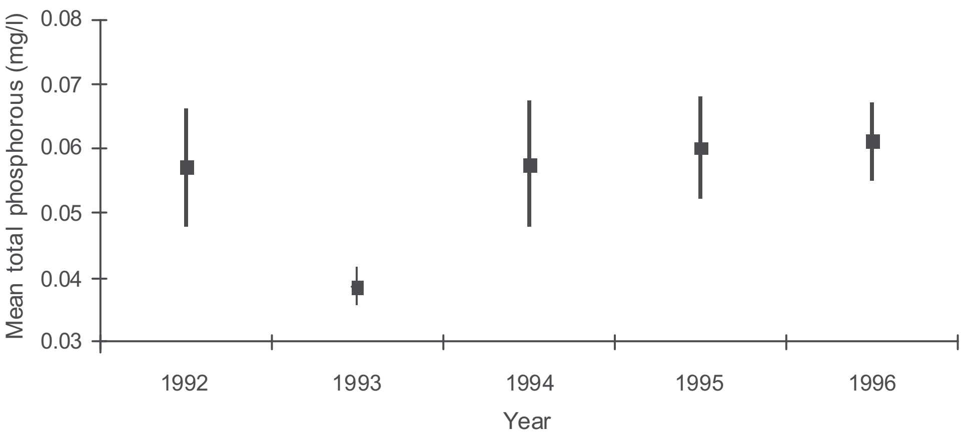

Fig. 1. Mean (±SE) total phosphorous concentration of surface water samples from Sackville Waterfowl Park during 1992–1996

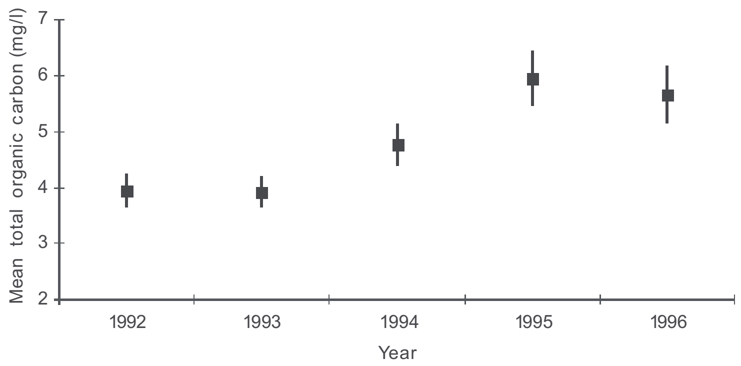

Fig. 2. Mean (± SE) total organic carbon concentration of surface water samples from Sackville Waterfowl Park during 1992–1996

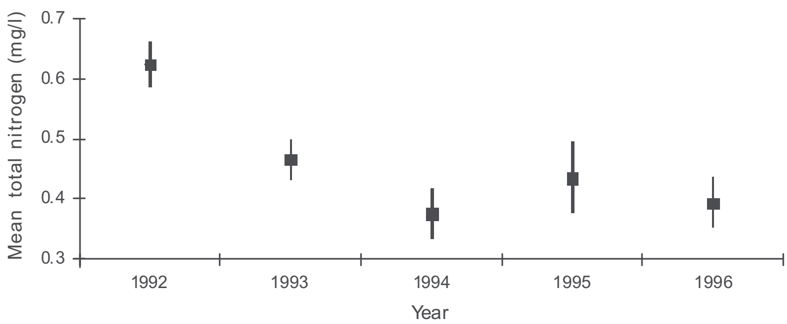

Fig. 3. Mean (± SE) total nitrogen concentration of surface water samples from Sackville Waterfowl Park during 1992–1996

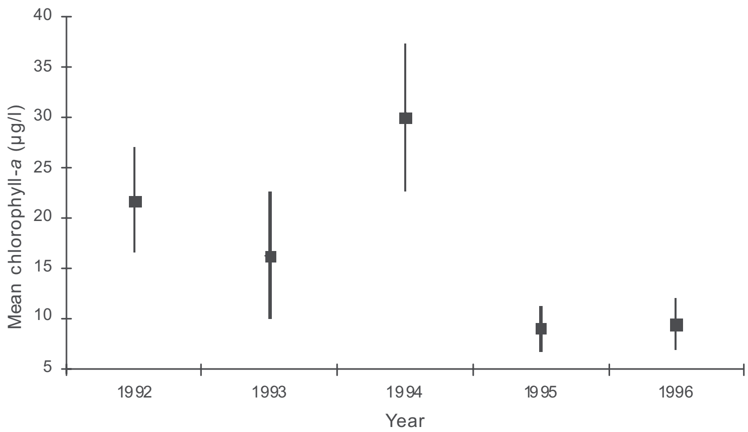

Fig. 4. Mean (±SE) chlorophyll-*a* concentration of surface water samples from Sackville Waterfowl Park during 1992–1996

Table 1. Results from mixed effects ANOVAs to test effects of duration of flooding and seasonal variation (month) on chemical limnology of Sackville Waterfowl Park. Year was considered a random variable in the models. The estimate and standard error of the slope for the effect of duration of flooding are also provided.

		F value	Pr>F	Slope estimate	Standard error
Total phosphorous	Duration	3.31	0.0741	0.036	0.020
	Month	1.16	0.3414		
Total organic carbon	Duration	18.84	0.0001	0.054	0.012
	Month	20.89	0.0001		
Total nitrogen	Duration	6.67	0.0124	–0.046	0.018
	Month	4.09	0.0007		
Chlorophyll-a	Duration	0.09	0.7679	–0.020	0.066
	Month	26.55	0.0001		

month on total organic carbon, with carbon increasing over time (Table 1). There was a significant negative relationship observed between duration of flooding and total nitrogen, with monthly variation also significant. There was no effect of duration of flooding on chlorophyll-*a*, but there was a large amount of monthly variation (Fig. 4, Table 1).

Samples collected from the inflow streams during the period 1994–1996 indicated that road salt was sometimes washed into the streams during winter and spring rainfall and snowmelt events. For example an event on December 10, 1996 resulted in chloride and sodium concentrations of 1611 and 1045 mg L^{-1} at the East Main Street inflow, 1048 and 611 mg L^{-1} at the King Street inflow and 69 and 38 mg L^{-1} at the outflow from the wetland. Although continuous sampling throughout an event was not done, and the residency time of water flowing into the park is unknown, available data and field observations suggest that dilution during these precipitation and snow-melt events minimizes the impact of road salt on this freshwater wetland. Maximum sodium and chloride concentrations and specific conductance of water samples collected from the outflow from the park were observed during the summer months and resulted from evapo-concentration of salts. Field observations and water quality parameters indicated that the inflow streams were not carrying large quantities of sediments or nutrients during storm events during 1994–1996.

High levels of available nutrients corresponded with high levels of chlorophyll-*a* as well as high diversity and abundance of macro-invertebrates. The mean number of macroinvertebrates captured in activity traps per sampling period ranged from 9 to 523 individuals, representing an ash free dry weight of 7–564 mg (Table 2).

Table 2. Mean ash-free dry mass (mg) of macroinvertebrates caught per activity trap (n = 5 per sampling date)

Date	1993	1994	1995	1996
5 May		56	7	51
19 May		32	28	38
02 June		105	66	14
16 June		54	79	27
30 June		205	35	66
14 July		185	124	65
28 July		564	189	260
11 August		163	271	71
25 August	138	127	45	185

Table 3. Mean number of fish caught in minnow traps (n = 5) per sampling date.

Year	1991	1993	1994	1995	1996
Fish species	Mean number per trap night				
Four Spine Stickleback (*Apeltes quadracus*)	0.00	1.00	0.60	2.36	0.87
Lake Chub (*Couesius plumbeus*)	0.00	0.80	0.23	1.91	0.18
Red-bellied Dace (*Chrosomus eos*)	0.17	5.60	0.33	0.27	0.07
American Eel (*Anguilla rostrata*)	0.00	0.00	0.00	0.02	0.00
Nine Spine Stickleback (*Pungitius pungitius*)	0.67	0.80	0.10	0.69	2.20
Golden Shiner (*Notemigonus crysoleucas*)	9.50	11.60	12.23	9.36	27.16

Table 4. Total number of waterbird broods observed in Sackville Waterfowl Park 1993–1996

Species	Total number of unique broods			
Year	1993	1994	1995	1996
American Black Duck (*Anas rubripes*)	2	1	1	1
American Coot (*Fulica americana*)	2	1	0	0
American Wigeon (*Anas americana*)	2	5	2	5
Blue-winged Teal (*Anas discors*)	6	7	4	3
Gadwall (*Anas strepera*)	4	7	7	6
Green-winged Teal (*Anas crecca*)	3	5	3	3
American Black Duck*Mallard Hybrid	2	0	0	0
Northern Shoveller (*Anas clyptea*)	3	1	2	2
Mallard (*Anas platyrhynchos*)	14	19	11	21
Pied-billed Grebe (*Podilymbus podiceps*)	6	8	6	8
Ring-necked Duck (*Aythya collaris*)	10	9	10	11
Total waterfowl broods	48	55	39	52

Six different species of fish were captured in minnow traps (Table 3), with the maximum mean number caught per trap night being 27 for golden shiner (*Notemigonus crysoleucas*) in 1996.

An average density of 2.5 waterfowl broods per hectare in the SWP was observed (Table 4), with Mallard (*Anas platyrhynchos*) being the most numerous species, followed by Ring-necked Duck (*Aythya collaris*) (Table 4). In addition to waterfowl there were also breeding Pied-Billed Grebes (*Podilymbus podiceps)* and during 1993–1994 there were breeding American Coots (*Fulica americana*) an uncommon species in Atlantic Canada. In addition to breeding waterfowl, high numbers of adult waterbirds used the wetland including post-breeding male Wood Duck (*Aix sponsa*) and American Wigeon (*Anas americana*) (Table 5).

Table 5. Total number of adult waterbirds observed in Sackville Waterfowl Park on survey dates 1993–1996

Date	Total number of adult birds observed			
	1993	1994	1995	1996
5 May			49	
12 May		48	36	46
19 May			49	35
26 May		54	48	47
2 June	46	60	54	77
9 June	43	52	50	51
16 June	86	70	38	77
23 June		88	50	69
30 June	118	139	97	123
7 July	162	104	69	111
14 July	148	105	108	104
21 July		106	106	115
28 July	87	116	132	105
4 August	162	105	93	122
11 August	254	148	94	131
18 August		89	116	153
25 August	207	50	107	198
1 September		63	116	311
8 September	146	80	62	316
15 September			100	206
21 September				158
28 September		99	48	94

DISCUSSION

Sackville Waterfowl Park, similar to other impoundments built on dykeland soils, had high levels of available nutrients (WHITMAN 1976, A. R. HANSON unpubl. data) and would be classified as eutrophic (VOLLENWEIDER & KEREKES 1980). During the period of study (1992–1996), SWP had relatively high amounts of available nutrients, and associated primary and secondary productivity. Suitable wetland habitat resulted in a high diversity of waterbird species using the wetland at high densities relative to other wetlands in the region (e.g. MAILLET *et al.* 1999). Over 160 species of birds have been observed in the SWP, with confirmed breeding records for 26 species (HANSON *et al.* 1994). Waterbirds in SWP, including diving duck species such as Ring-necked Duck, used SWP and habituated to the presence of people, in contrast to other species such as Pochard (*Aythya ferina*) in UK gravel pit wetlands (FOX *et al.* 1994).

Data indicated that there was annual and monthly variation in the various measures of chemical limnology. No significant effect of duration of flooding was observed on total phosphorous and chlorophyll-a, whereas a positive relationship with total organic carbon, and a negative relationship with total nitrogen was observed. The ability to statistical determine whether there was a decline in nutrient availability during the period 1992–1996, and the inferences that can be drawn from these results was limited because of the lack of replication and short time period of study. Water chemistry data collected during 2006 and 2007 will allow for an inter-decadal comparison and provide additional insight into changes in nutrient availability in relation to duration of flooding.

The abundance of aquatic macroinvertebrates caught in activity traps was similar to other dykeland freshwater impoundments on gleyic soils (WHITMAN 1976, A. R. HANSON unpubl. data) and impoundments on alluvial luvisols (HANSON *et al.* 1998) and high compared to inland freshwater wetlands on podzols (A. R. HANSON unpubl. data). A more thorough analysis of these data, including taxon specific comparisons was outside the scope of this paper but will be forthcoming. Considering that SWP was formerly a pasture, the number of fish in the Park has increased dramatically since its creation in 1988.

In 2003, the Town of Sackville (unpubl. report) estimated that SWP generated $1.28 million in economic benefits to the region through tourism, as well as providing recreational opportunities for the local population. Although some have questioned the value of created/restored urban wetlands because they do not replace all lost wetland functions (e.g. GRAYSON *et al.* 1999), the chemical limnology and waterbird data from 1992–1996 indicate that SWP provides good quality habitat for waterbirds. The support by people, communities, and governments to conserve, restore and create wetlands is dependant on the perceived value of the ecological goods and service provide by wetlands (ANDREWS & BURGESS 1991, KUSLER & OPHEIM 1996, MANUEL 2003). Whereas SWP has proven to be good for people and good for waterbirds, it has increased support for wetland conservation and restoration activities in the area. Water sampling and avian surveys were resumed in 2006 to determine current chemical limnology and waterbird use of SWP and relate this to change in the duration of flooding as well as land use change in the watershed.

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