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Contamination and Wildlife Communities in Stormwater Detention Ponds in Guelph and the Greater Toronto Area, Ontario, 1997 and 1998. Part I — Wildlife Communities

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There is very little information about the wildlife utilization of stormwater detention ponds although such ponds often self-seed into wetland habitats. To inventory wildlife utilizing stormwater ponds, a study was performed in 1997 and 1998 of 15 stormwater ponds and one natural wetland varying in age from 3 to 22 years in the Guelph and the Greater Toronto Area (GTA) in Ontario, Canada. Seven of the stormwater ponds were primarily open water with the aquatic vegetation accounting for less than 50% of the surface area. However, 90% of the surface area of four ponds was covered in aquatic vegetation. The surface area of those ponds covered with vegetation was positively correlated with total organic carbon and copper concentrations in sediment. Invertebrate populations in the stormwater ponds were often dominated by a single taxon. The most abundant benthic animals were tubificid worms or chironomidae. The number of taxa in sweep-net samples ranged from 4 to 25 and correlated positively with the age of the pond and total organic carbon in sediment. The number of taxa in the benthos correlated negatively with oil and grease concentrations in sediment. The range in number of amphibian species was one to seven in Guelph and zero to four in the GTA. In total, 40 species of birds were observed in the GTA ponds and 71 species were observed in the Guelph ponds during April to November 1997. A mean of 1.6 to 1.7 bird species was observed per survey at stormwater ponds in Guelph and the GTA. The number of species of amphibians and birds did not correlate with water quality, sedimentology, contaminant concentration, percentage of surface area of the pond covered with plants, or any benthic community parameter measured. Four species of reptiles and eight species of mammals were noted at or adjacent to the stormwater ponds and six species of fish were found in the ponds. We concluded that wildlife made use of the ponds, but species richness at almost all sites was low to mod-

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erate, indicating that the ponds did not provide high quality habitat for wildlife.

Key words: wildlife communities, stormwater detention ponds, Guelph, Greater Toronto Area, aquatic vegetation, terrestrial vegetation

Introduction

Constructed wetlands for sewage treatment are often enhanced with wetland plants and are known to attract wildlife (Brennan 1985; Henley and Mannan 1999). Similarly, ponds designed to capture and hold stormwater may self-seed into wetlands and could attract wildlife. This aspect of stormwater detention ponds, however, has not been examined in the past despite the promotion of such sites as wetland habitats (Brennan 1985; Kadlec 1985; Wren et al. 1997). Stormwater ponds are designed to protect downstream areas by acting as a catchment basin for pollutants that could create undesirable conditions for aquatic life (Schiff and Stevenson 1996; Helfield and Diamond 1997; Skinner et al. 1999). The accumulation of contaminants within the ponds may pose a threat to local wildlife if they are using these facilities as habitat (Kadlec 1985; Wren et al. 1997). However, although thousands of such ponds have been created in North America, there are no published surveys of the wildlife communities that utilize the sites (Wren et al. 1997). Therefore, this two-part study was conducted in which contamination and wildlife communities in stormwater detention ponds were examined. In Part I, we report the wildlife communities found in 15 stormwater detention ponds in Guelph and the Greater Toronto Area of Ontario. In Part II (Bishop et al. this issue), we report the contaminant levels and biological effects of contamination found in the same stormwater ponds. Also, the Ontario Ministry of the Environment conducted a companion study of the toxicity of sediments to invertebrates and fish (Bedard 1999) and these data are referenced in the context of this study.

Because stormwater detention ponds are exposed water bodies and may be located in or near natural green spaces, we predicted that wildlife would be attracted to them even if the ponds were not enhanced as wildlife habitat. To test this hypothesis, the plant and invertebrate and vertebrate species present in stormwater detention ponds which had not experienced any wildlife habitat enhancement and one natural wetland were surveyed during April 1997 to August 1998 at 10 sites in Guelph and 6 sites in the Greater Toronto Area in Ontario, Canada.

Methods

Study Areas

In 1997 and 1998, stormwater detention ponds at six sites (T#1 to T #6) in the Greater Toronto Area (GTA) and nine sites (G#1 to G#9) and a natural wetland (C#1) in Guelph were surveyed using components of the monitoring protocol recommended for constructed wetlands as described in Wren et al. (1997). In a complementary study conducted at the same time at these ponds (see Part II in Bishop et al., this issue), sedimentology, nutrients and contaminant concentrations in sediment and water quality and effects on amphibians, fish and invertebrates were measured in the same ponds.

Some of the stormwater ponds contained small wetlands that had developed (self-seeded) but none had received any specific habitat enhancements. The stormwater ponds ranged in age from three to 22 years (Table 1). Nine of 15 sites were single ponds whereas one site in the GTA and five sites in Guelph were pond systems with forebays (Table 1). All stormwater ponds were located in residential areas except three which were located in commercial or industrial areas (Table 1). A natural wetland located in the Guelph Reservoir Conservation Area beside a two-lane road was also sampled in the invertebrate and vegetation surveys. The natural wetland site was assigned an age of greater than 30 years.

Vegetation Surveys

The ponds were surveyed in August 1998 by one observer. The occurrence of emergent and submergent plants was mapped to a scale of 1 cm:1m. The percentage of the surface area of the ponds covered by open water and emergent and submergent vegetation was estimated from the maps. The terrestrial vegetation was also evaluated in a 5-m wide zone surrounding the edge of each pond. Pond depths were measured from the water surface to the hard substrate of the pond with a 2-metre stick and with an error of +/–0.5 cm in depth measurements. Measurements were taken by hand while wading through the ponds. Measurements were made at approximately every square metre of the ponds up to depths of 1.2 m.

Invertebrate Surveys

The nine stormwater detention ponds and one natural wetland in Guelph were visited on 4 August 1998; the six stormwater detention ponds in the Greater Toronto Area were visited on 6 August 1998. Three samples of benthic invertebrates living in and on the sediments adjacent to the primary inflow were collected while wading using a pole-mounted Ekman grab (0.0225 m^2). Where the bottom was firm due to macrophytes or sand and gravel, closure of the jaws of the grab was assisted by applying pressure with a booted foot. The contents of each grab sample were washed through 243 μm aperture netting and preserved in 5% formalin. A qualitative sample of epibenthic animals was collected along the shore and among macrophytes by sweeping with a dipnet (243 μm aperture netting) for about 2 minutes. The contents of the net were washed to remove fine sediment, plants and large pieces of debris were discarded, and then about 400 ml of the material was preserved in 5% formalin.

Table 1. Physical characteristics of 15 stormwater detention ponds and one natural wetland studied during 1997–1998 in Guelph and the Greater Toronto Area, Ontario (measurements were taken in August 1998)

Site and identification number	Age of pond (years)	Approximate surface area (range in water depth)	Land use surrounding pond	Forebay present or not (Yes[Y] or No [N]) [approximate surface area of forebay]	Street location of pond
G#1	9	4752 m^2 (0.4–0.85 m)	Residential	N	Downey
G#2	10	2520 m^2 (0.2–0.4 m)	Residential	N	Brady
G#3	19	2340 m^2 0.5m–>1.2 m	Residential	N	Cole
G#4	22	3960 m^2 (0.25–>1.2 m)	Residential	Y [2178 m^2]	Shadybrook
G#5	16	5832 m^2 (0.2–0.5m)	Residential	Y [216 m^2]	Brookhaven
G#6	13	1932 m^2 (0.3–0.5m)	Residential	Y [384 m^2]	Kortright
G#7	11	4860 m^2 (0.2–1.1m)	Residential	Y [216 m^2]	Koch
G#8	15	2584 m^2 0.35m–1.2m	Residential	N	Ironwood
G#9	13	7728 m^2 (0.25–0.7m)	Residential	Y [720 m^2]	Crowe
T#1	3	2992 m^2 (0.2–1.2 m)	Commercial	N	Langstaff
T#2	6	3774 m^2 (0.1–1.2 m)	Residential	N	Vaughan Mills
T#3	7	7040 m^2[a]	Industrial	N	Weston 400/ Industrial Park
T#4	10	14784 m^2 (>1.2 m)	Residential	N	Heritage Estates
T#5	10	2250 m^2 (>1.2 m)	Residential	Y [135 m^2]	Harding Park
T#6	6	1728 m^2 (0.25–0.6m)	Residential/ Commercial	N	Ascot Village
C#1[b]	30+	625 m^2 (0.2–0.4m)	Natural wetland in Guelph	N	Victoria Road in Guelph

[a] <0.1 m; little to no standing water.
[b] Natural wetland.

In the laboratory, the samples were washed in water to remove most of the formalin, and invertebrates were sorted from the preserved material with the aid of a dissecting microscope. Quantitative samples which contained very large numbers of animals were subsampled: the preserved material was washed into a conical net and drained thoroughly to form a compact pellet. The pellet was then repeatedly cut in half to yield subsamples of one-eighth, and invertebrates were sorted from at least two of these subsamples. Qualitative samples were washed and all animals were removed from small, randomly selected portions until at least 200 individuals were found. Any remaining material was scanned for additional, larger, rare taxa. All invertebrates were identified to the lowest practical taxonomic level, largely following Clarke (1981), Weiderholm (1983), Brinkhurst (1986) and Merritt and Cummins (1996). Most animals were identified to the level of genus or species, but some only to family, so individual entities will be called "taxa" in this report. Three indices were used to summarize the data: number of taxa (pooled for Ekman samples), percentage contribution of the most abundant taxon (% dominance) and percentage similarity to the reference pond C#1 (PSC).

Amphibian Surveys

The calls of frogs and toads can be identified to species and these animals conduct their maximum calling activity in the evening at predictable months of the year, usually April to July (Weeber et al. 1997). Therefore, auditory surveys of amphibian calls were conducted between 15 April and 16 June 1997. Because one observer conducted all the surveys, and due to the large number of sites and the distance between Guelph and Toronto, all sites could not be monitored within a single night. Sites were grouped into two routes which were surveyed separately: one route comprised the nine stormwater sites in Guelph and the second route comprised the six stormwater sites in Toronto. Surveys began 0.5 h after sunset and were completed by 01:00 h. Because of the effect of ambient climate on calling behaviour, a flexible sampling regime was used; this allowed sampling under the best possible survey conditions (see Weeber et al. 1997). Inter-sample intervals were generally 7 to 10 days. Call surveys consisted of 3-minute point counts from fixed points from the edge of the ponds. It was occasionally necessary to conduct count surveys along with a circuit of the pond to confirm if frogs and toads were calling from the detention pond versus any adjacent natural wetlands. The number of calling individuals was counted or estimated according to the amphibian call survey protocol used by the Marsh Monitoring Program (MMP) (Weeber et al. 1997), except that the survey was restricted to areas within the shoreline boundaries of each pond while the standard for the MMP surveys is an unlimited distance from a survey point on a shoreline.

Visual encounter surveys for amphibians were also conducted. These were made during daylight hours on weekly visits to each site between April 27 and June 23 and monthly visits between July 6 and November 27. During each visit, a single circuit of the pond was made at a slow walk approximately 1 to 2m from the water's edge. Adult and subadult frogs and toads were identified to species. Larvae were noted and samples were collected with a dip net for identification. Egg masses were identified to species and notes were made of their condition.

Bird Surveys

The species and numbers of individual birds were identified and counted at each stormwater pond in the Greater Toronto Area during 30 April to 30 September 1997 while avian surveys were conducted from 29 April to 31 October 1997 at the Guelph stormwater ponds. Avian censuses were conducted once per week from April to the end of August and twice per week in September. Survey times alternated between mornings (06:00 h to about 09:00 h) and evenings (19:00 to about 22:00 h or sunset, whichever was earlier) from April to August, and mornings only in September and October. Censuses consisted partly of observations from one or more vantage points on shoreline surrounding the ponds. This technique was combined with observation while walking along the dyke in order to flush cryptic, non-vocalizing species. Birds were identified by sight with binoculars and by vocalization. Surveys were not conducted in adverse conditions such as poor light, rain and strong winds while mist and light fog were acceptable.

In Toronto, morning visits began at the easternmost stormwater pond site and ended with the westernmost study site. Evening visits were conducted in the reverse order. The length of the visit varied from 5 to 15 min. In Guelph, each pond visit consisted of exactly 15 min of observation.

Two other censuses were conducted at each pond according to the Marsh Monitoring Program protocol (Weeber et al. 1997). The MMP protocol consists of selecting a vantage point which afforded the best overall view of the pond system. The survey period was 10 min, during the first 5 min of which a tape recording was broadcast of the calls of six cryptic marsh bird species. All birds seen within 100 m of the survey point on the edge of the ponds were counted. Among all sites, the Marsh Monitoring censuses were conducted on 8, 9 and 26 June 1997 in the Greater Toronto Area. Among Guelph ponds, MMP surveys were conducted on 10 and 11 June and 2, 4, 6 and 11 July 1997.

Fish

Minnow traps were used to capture fish during late June (Guelph: 25 June 1997; GTA: 27 June 1997), and again in late August (Guelph: 19 August 1997; GTA: 25 August 1997). Two minnow traps per pond were baited with dry cat food and set in shallow water at dusk. Traps were checked the following morning.

Reptiles and Mammals

Specific surveys were not conducted for reptiles and mammals. However, observations of reptiles and mammals, including tracks, burrows and scat, were noted during the course of the bird, fish and amphibian surveys.

Statistical Analysis

Data were log-transformed, where necessary, to meet normality and homogeneity of variance requirements for parametric analysis. If those criteria could not be met or the sample size was too small for parametric analysis, non-parametric tests were used (Sokal and Rohlf 1981).

Correlations among characteristics of water and sediment and contaminant levels in sediments and the species diversity of the ponds were assessed using Spearman rank correlations. To examine correlations among diversity of each of the invertebrates and plants, the chemical and physical parameters used in the analysis were: age of the pond, surface area of the pond and the total organic carbon concentration, and percentage of organic carbon in sediment, and in water, pH and concentrations of total phosphorus, nitrite (NO_2) and nitrate (NO_3), and total Kjeldahl nitrogen (mean concentrations used were based on sampling from April 1997 to August 1998— see Part II of this study in Bishop et al., this issue) and trace metals, total PAHs and oil and grease concentrations in sediments. Organochlorine concentrations in sediment were deemed too low and not variable enough among sites to be utilized in statistical analyses (contaminant concentrations are reported in Part II of this study in Bishop et al., this issue).

For amphibians and birds, correlations were tested between the number of species observed in each pond and age of the pond, total organic carbon concentration in the sediment, pH, water concentration of nitrite (NO_2) and nitrate (NO_3), total Kjeldahl nitrogen, total phosphorus, surface area of the ponds, percentage of surface area of the ponds covered with emergent or submergent vegetation, and the species occurrence and density of invertebrate populations. Data were only collected for amphibians and birds from the 15 stormwater ponds. All statistical analyses were considered significant at $p \leq 0.05$ and the scatterplot of each correlation was examined to determine if credible linear trends existed (Sokal and Rohlf 1981). All data were analyzed using STATISTICA for Windows (StatSoft 1997).

Results

Vegetation Surveys

The terrestrial vegetation was relatively sparse with pond edges of 13 ponds dominated by grass due to regular lawn maintenance conducted by municipalities. While shrubs and some trees were present, few pond edges contained herbaceous vegetation (Table 2). Seven ponds were primarily open water and aquatic vegetation accounted for less than 50% of the pond surface area. While 70% of the surface area of T#6 was open

Table 2. Aquatic and terrestrial plants occurring in 15 stormwater detention ponds and one natural wetland (C1) in Guelph and the Greater Toronto Area, 1998

	Site															
Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	C1	T1	T2	T3	T4	T5	T6
<u>Aquatic</u>																
Common Cattail (*Typha latifolia*)	x	x	x			x				x	x	x	x	x	x	x
Water Plantain (*Alisma plantago-aquatica*)		x	x								x	x			x	
Water Milfoil spp. (*Myriophylum* spp.)		x	x	x	x	x	x	x	x	x	x				x	x
Lake Cress (*Armoracia lacustris*)											x					
Pondweed spp. (*Potamogeton* spp.)			x				x			x						
Bladderwort spp. (*Utricluaria* spp.)		x								x						
Pickerelweed (*Pontederia cordata*)										x	x					
Arrowhead spp. (*Sagittaria* spp.)									x	x	x	x				
Bulrush spp. (*Scirpus* spp.)		x			x	x	x	x	x			x		x	x	x

(continued)

Table 2. *(continued)*

	Site															
Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	C1	T1	T2	T3	T4	T5	T6
Spikerush spp. (*Eleocharis* spp.)		x						x	x			x				
Sedge spp. (*Carex* spp.)	x	x		x		x	x	x	x	x		x		x		
Common Reed (*Phragmites australis*)														x	x	
Purple Loosestrife (*Lythrum salicaria*)			x		x									x	x	x
Water Smartweed (*Polygonum amphibium*)							x	x		x					x	
Spotted Joe-Pye Weed (*Eupatorium maculatum*)															x	
Algae spp. (*Algae* spp.)					x	x	x		x	x						x
Duckweed spp. (*Lemna* spp.)		x	x	x												x
Common Burreed (*Sparganium emersum*)																x
Manna Grass spp. (*Glyceria* spp.)	x		x		x				x	x			x			x
Bulbiferous Water Hemlock (*Cicuta bulbifera*)										x						

(continued)

Table 2. *(concluded)*

Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	C1	T1	T2	T3	T4	T5	T6
	Site															
Nodding Beggar's Ticks (*Bidens cernua*)		x							x							
Shoregrass (*Littorella americana*)						x										
% open water[a]	98	0	50	85	30	10	65	50	10	20	55	40	0	95	70	70
% submergent plants[a]	0	30	20	15	68	85	35	50	85	35	20	0	0	0	10	10
% emergent plants[a]	2	70	30	0	2	5	0	0	5	45	25	60	100	5	20	20
Terrestrial																
Willow (*Salix* spp.)													x	x		x
Shrub spp.	x	x		x	x	x	x	x	x	x	x			x	x	
Tree spp.			x		x		x			x					x	
Unidentified Herbaceous spp.							x	x		x	x	x	x	x	x	x
Grass spp.	x	x	x	x	x	x	x	x	x	x		x	x		x	x
Vegetation zone >1m[b]		x					x	x[c]		x	x	x[c]	x	x	x	x

[a] Describes the percent of pond surface area that is covered by submergent, emergent plants, or open water.
[b] Vegetation, other than mowed grass, occurring within 1 m of the pond edge.
[c] Approximately one-half of pond was surrounded by herbaceous vegetation while the other side had mowed grass up to the edge of the pond.

water, a thick layer of algae covered almost 100% of the pond for much of the summer. The presence of large algal blooms may have reduced light penetration, which prevents growth of submergent plants. Four ponds had a surface area that was covered with at least 90% aquatic vegetation (Table 2). Submergent vegetation dominated in three ponds (G#5, G#6, G#9) where 68 to 85% or more of the surface area was covered in submergent plants (Table 2).

The most commonly occurring aquatic plants were cattail (*Typha latifolia),* water milfoil (*Myriophylum* spp.), bullrush (*Scirpus* spp.), sedge (*Carex* spp.), and manna grass (*Glyceria* spp.) which occurred in greater than or equal to 50% of the ponds (Table 2). The percentage of the surface area of the pond covered by emergent and submergent plants was correlated with the percentage of total organic carbon in sediment (R_s=0.55; p= 0.033) and copper in sediment (R_s = 0.77; p = 0.0006). However, copper and total organic carbon concentrations in sediments were not correlated.

Invertebrate Surveys

Of the 114 taxa of benthic macroinvertebrates collected from the 16 ponds, most were insects (69 taxa), annelids (6 Hirudinea and 17 Oligochaeta) and molluscs (12 taxa). Crustacea (the amphipod *Hyalella azteca* and the isopod *Caecidotea racovitzai*) were abundant in a few ponds (Tables 3 and 4).

The number of taxa in sweep-net samples from stormwater ponds ranged from 4 (T#3) to 25 (G#3)(Table 3). The control pond (C#1) yielded 29 taxa. The 16 sweep-net samples yielded a total of 95 taxa, and 82 taxa were found in the 48 Ekman grab samples. There was no relationship between the numbers of taxa caught using the two methods (R^2 = 0.083), although pond T#3 had the lowest diversity in both sweep and grab samples.

While the same major groups of invertebrates were found with sweep-nets in most ponds, the relative proportions and dominant taxa varied from pond to pond. Insects were of greatest relative importance in 11 ponds; snails dominated the fauna in 3 ponds; and the amphipod *Hyalella azteca* and the oligochaete *Dero nivea* were the most abundant animals in samples from one pond each. The proportion of the collection represented by the single most abundant taxon ranged from 12.7% in pond G#4 to 71.4% in pond T#3. Relative to the control pond C#1, ponds G#6 and G#3 were most similar in overall faunal composition, T#3, G#1 and T#1 were most different (Table 3).

The number of taxa in Ekman dredge samples from stormwater ponds ranged from 5 (T#3) to 27 (G#3). (Table 3). The control pond (C#1) yielded 27 taxa. The total density of benthic invertebrates in grab samples ranged from less than 5000/m^2 in ponds T#6 and G#5 to more than 34,000/m^2 in G#3 and T#3 (Table 4). The most abundant animals in most ponds were either tubificid worms (9 ponds) or Chironomidae (4 ponds). The fingernail clam *Pisidium* was dominant in two ponds, and isopods were the most numerous single taxon in pond C#1. Percent dominance was greatest in ponds T#6 and T#3. In terms of percentage composition of

Table 3. Summary of the epibenthic fauna collected in sweep-net samples from 15 stormwater ponds and one natural wetland

Site	No. of taxa	Dominant taxon (DT)	% DT of total	PSC[a] to C#1	Chironomidae (%)	Other Insecta (%)	Oligochaeta (%)	Mollusca (%)	Crustacea (%)
G#1	18	*Dero* (i)	40.1	5.6	39	9.3	50.6	0	0
G#2	12	*Physa* (i)	58.6	12.7	0	29.7	0	65.6	4.7
G#3	25	*Physa* (i)	28.4	18.1	3.7	35	16.9	32.5	7.4
G#4	24	*Dicrotendipes* (i)	12.7	9.2	41.4	14.1	44.1	0	0
G#5	18	*Callibaetis* (i)	36.5	11	14.2	71.6	0	0.7	13.5
G#6	22	Coenagrionidae	17.2	21.6	55.2	40.1	0	0	4.2
G#7	16	*Oxyethira* (i)	23.7	7.3	44.1	26.3	24.6	0	0
G#8	20	Coenagrionidae	57.1	6.3	3.3	95.8	0	0.5	0.5
G#9	20	Coenagrionidae	20	11.5	6.5	72.4	0	17.3	2.2
T#1	14	*Chaoborus* (i)	31.5	5.9	0.9	97.2	0	1.9	0
T#2	18	*Hyalella* (i)	41.8	15.3	2	30.6	2	16.3	41.8
T#3	4	*Pseudosuccinea* (i)	71.4	2.2	0	9.5	19	71.4	0
T#4	17	Coenagrionidae	41.6	15.6	20.2	49.4	6.7	1.1	19.1
T#5	14	*Callibaetis* (i)	33.7	13.3	4.2	70.5	0	9.5	15.8
T#6	17	*Callibaetis* (i)	38.5	12.4	9.2	58.7	5.5	19.3	0
C#1	29	*Pantala* (i)	23.3	100	17.8	47.8	6.7	18.9	4.4

[a] PSC, percent similarity of community.

Table 4. Summary of the epibenthic fauna collected in Ekman dredge samples from 15 stormwater ponds and one natural wetland

Site	No. of taxa	Density[a]	Dominant taxon (DT)	% DT of total	PSC[b] to C#1	Chironomidae[a]	Other Insecta[a]	Oligochaeta[a]	Mollusca[a]	Crustacea[a]
G#1	10	13512	Tubificidae	45.2	9.7	2353	74	11085	0	0
G#2	20	10774	Tubificidae	47.3	15	474	1421	5091	3552	118
G#3	18	37118	Pisidium	24.1	15.1	3966	178	14504	17938	0
G#4	8	12195	Tubificidae	44.7	12	592	0	11544	0	0
G#5	27	4810	*Procladius* (i)	22.8	25.2	2620	814	1006	0	252
G#6	14	7341	Tubificidae	40.7	21	3330	163	3818	0	0
G#7	13	13853	*Chironomus* (i)	52.1	19.2	8998	296	4262	0	0
G#8	11	13971	Tubificidae	34.2	13.3	5476	326	7859	0	0
G#9	24	10893	*Chironomus* (i)	34.4	19.3	6719	178	3892	44	30
T#1	16	6394	*Chironomus* (i)	18.5	21.7	1894	2250	592	1717	0
T#2	25	19196	Tubificidae	25	21.4	2486	577	11899	1672	1051
T#3	6	34647	Tubificidae	57.4	9.5	0	0	29393	0	0
T#4	25	6379	Tubificidae	29	18.9	2131	44	3730	15	0
T#5	21	14800	Tubificidae	19.6	25.8	2842	4262	3434	3966	178
T#6	5	3552	Pisidium	71.7	13.8	178	533	355	2664	0
C#1	27	6216	*Caecidotea* (i)	19	100	1954	710	770	1362	1184

[a] Number per square metre.
[b] PSC, percent similarity to community.

the fauna, ponds G#5 and T#5 were most similar to the control (C#1), and G#1 and T#3 were most different (Table 4). There was little similarity between benthic and epibenthic communities in the stormwater ponds: there was no meaningful relationship between the two types of samples in number of taxa ($R^2 = 0.083$), % Dominance ($R^2 = 0.064$) or percentage similarity to the reference community ($R^2 = 0.195$). This suggests that the two components of the bottom-dwelling invertebrate fauna are controlled by different environmental parameters, except perhaps in pond T#3 (Table 3, 4) which had the lowest diversity in both sweep and grab samples.

The density and diversity of invertebrates were correlated with several sediment and water quality parameters and contaminant concentrations in sediments (Table 5). As the total organic carbon concentration increased in the sediment, the number of taxa captured and the percentage of Mollusca in sweep-net samples increased. Similarly, age of ponds and total organic carbon concentrations were correlated positively ($R_s = 0.56$; $p = 0.02$), and as pond age increased, so did the number of taxa in sweep-net samples (Table 5). Among all significant correlation coefficients, those for total organic carbon and age of ponds accounted for the highest percentage of variation in invertebrate populations although the R_s values for these variables were only 0.65–0.69 (Table 5).

Mean nitrite and total Kjeldahl nitrogen concentrations in water correlated positively with the density of Insecta and correlated negatively with the density of oligochaetes in Ekman samples (Table 5). Marginal correlations between TKN and the density of Insecta, and nitrite and the density of Mollusca were also found but the correlations may be spurious because the trends were driven by a few outlier points. The percentage of Mollusca in sweep-net samples also correlated positively with total phosphorus concentration in water, and the TKN marginally correlated positively with Insecta and Mollusca in Ekman samples (Table 5). As pH of the water increased, the density of chironomids also increased (Table 5).

Among contaminants, as oil and grease concentration in sediment increased, the number of taxa found in Ekman samples declined (Table 5). Conversely, as oil and grease and copper concentrations in sediment increased, the density of oligochaetes increased (Table 5). There was a tendency for molluscs to replace chironomids in sweep samples as nickel concentrations increased. As cadmium concentrations increased, the number of taxa in sweep-net samples also increased, but this was probably an artifact of the correlation between TOC and cadmium in these sediments (see Bishop et al., this issue). Mercury concentrations were also positively correlated with the density of Crustacea, but this trend was only significant due to two high values, suggesting this trend is probably spurious.

Amphibians

Seven stormwater ponds had two or fewer amphibian species while eight ponds had three to seven species. The species found were wood frog

(*Rana sylvatica*), American toad (*Bufo americanus*), northern leopard frog (*Rana pipiens*), green frog (*Rana clamitans*), gray treefrog (*Hyla versicolor*), spring peeper (*Pseudacris crucifer*), and western chorus frog (*Pseudacris triseriata*). The range in number of species found per pond was one to seven in Guelph and zero to four in the GTA (Table 6).

Site G#2 had the highest number of species, with G#6 having only one species, and T#3 did not contain any amphibian species. Seven sites had four species and four sites had only two species (Table 6). The most common species were the green frog and American toad, which were present at over 80% of the stormwater ponds. Spring peeper and northern leopard frog were found at 40 to 55% of the sites while wood frog, western chorus frog and gray treefrog occurred at one-third or fewer of the ponds (Table 6). There were no significant correlations among the total number of amphibian species in ponds and any water quality or sedimentology parameter or contaminant concentration, percentage of surface area of the pond covered with plants, or any benthic community parameter measured.

G#1 was a single pond located at the edge of town and was in close proximity to substantial tracts of undeveloped land. The diversity of amphibian species was relatively rich (Table 6) but intensity of calling by males was low despite a high level of amphibian activity in the adjacent wetland, and based on visual encounter surveys, no evidence of successful breeding was recorded for any species. Several dead and partially eaten frogs were found, as well as one dead leopard frog with no apparent wounds.

Site G#2 was a small pond which had the highest amphibian diversity among all ponds in the study (Table 6). There was extensive vegetation around much of the perimeter of the pond. Amphibian diversity was highest with seven species observed but only American toads and green frogs appeared to breed in the pond. The other species were calling in small numbers and probably represented the edges of choruses in the large natural wetland adjacent to the site.

Site G#3 was a single pond that was relatively deep and well vegetated with extensive stands of cattails at both ends and appeared to be excellent habitat for amphibians. Despite the apparent quality of the habitat, amphibian diversity was low (Table 6). The green frog population was large and because tadpoles were seen it was concluded that breeding success appeared to be reasonably high for both green frogs and toads. The low diversity may be attributed to the isolation of the site from other wetlands which could act as source populations.

Considering the size of G#4 and its proximity to extensive natural wetland, the diversity of amphibians was low with only three species found. Only the green frogs appeared to breed successfully. In G#5, amphibian diversity of five species was greater than average, but calling intensity was low for all species. Eggs of chorus frogs and northern leopard frogs were found (25 clutches of leopard frog eggs), but no larvae or transformants were found, which indicates that breeding may have been unsuccessful.

Table 5. Spearman rank correlations among invertebrate population parameters and water quality, sedimentology, age of ponds and contaminants in sediments from 15 stormwater ponds and one natural wetland[a,b]

	TOC	% TOC	Age of pond	pH	NO_2	TKN	TP	Cu	Ni	Cd	Oil & grease	Hg
Ekman												
Density	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-0.48 (.05)	NS
Total number of taxa	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Density Chironomidae	NS	NS	NS	0.54 (.03)	NS	NS	NS	NS	NS	NS	NS	NS
Density Oligochaeta	NS	NS	NS	NS	-0.56 (.021)	NS	NS	0.50 (.04)	NS	NS	0.53 (.03)	NS
Density Mollusca	NS	NS	NS	NS	0.55 (.02)	0.49 (.05)	NS	NS	NS	NS	NS	NS
Density Insecta	NS	NS	NS	NS	0.62 (.009)	0.50 (.04)	NS	NS	NS	NS	NS	NS
Density Crustacea	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

(continued)

Table 5. *(concluded)*

	TOC	% TOC	Age of pond	pH	NO_2	TKN	TP	Cu	Ni	Cd	Oil & grease	Hg
Sweep-Net												
Total number of taxa	0.65 (.05)	NS	0.69 (.003)	NS	NS	NS	NS	NS	NS	0.56 (.02)	NS	NS
Percentage of total Chironomidae	NS	NS	NS	NS	NS	NS	NS	NS	-0.63 (.008)	NS	NS	NS
Percentage of total Oligochaeta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Percentage of total Mollusca	NS	0.50 (.04)	NS	NS	NS	NS	0.56 (.02)	NS	0.54 (.03)	NS	NS	NS
Percentage of total Insecta	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Percentage of total Crustacea	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.61 (.01)

[a] Spearman rank correlation coefficient is shown with p value in brackets underneath.
[b] NS, no significant correlation.

Table 6. Species of amphibians observed during 15 April to 16 June 1997 at 15 stormwater detention ponds in Guelph and Greater Toronto Area[a]

	Site																	
Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	T1	T2	T3	T4	T5	T6	All Guelph ponds[b]	All GTA ponds[b]	All ponds[b]
Wood Frog (*Rana sylvatica*)	X	X														22.2	0	13.3
Spring Peeper[c] (*Pseudacris crucifer*)	X	X		X	X			X					X			55.6	16.7	40
Western Chorus Frog[c] (*Pseudacris triseriata*)		X			X											22.2	0	13.3
Northern Leopard Frog[c] (*Rana pipiens*)	X	X			X			X	X	X	X		X			55.6	50	53.3
American Toad (*Bufo americanus*)	X	X	X	X	X		X	X	X	X	X		X	X	X	88.9	83.3	86.7
Gray Treefrog (*Hyla versicolor*)		X								X	X					11.1	33.3	20
Green Frog (*Rana clamitans*)	X	X	X	X	X	X	X	X	X	X	X		X	X	X	100	83.3	93.3
Total species	5	7	2	3	5	1	2	4	3	4	4	0	4	2	2	NA[d]	NA[d]	NA[d]

[a] X, species was observed at least once.
[b] Percentage of ponds where a species occurred.
[c] Species indicative of high quality marsh habitat (Chabot et al. 1998).
[d] NA, not applicable.

There was very little vegetation or deadfall in the water to protect the leopard frog eggs, most of which were washed ashore during a storm.

Site G#6 comprised a two-pond system adjacent to a "green belt" containing a natural wetland. Amphibian use was confined to a single species (green frog) which did breed successfully in the previous year because two-year old larvae were found, although numbers of larvae were low. There was no evidence of successful breeding in 1997. G#6 was located beside a busy road with a raised median strip which separates the pond from a more natural habitat. In addition, several amphibians and one small turtle were found dead on the road.

G#7 was a large two-pond system with extensive vegetation along the margins of the larger pond. Despite the apparently high quality of the habitat and its proximity to a green belt containing natural wetland, only two species of amphibians (green frogs and American toads) were found at the site (Table 6). Both species were found in low numbers, and only the green frogs appeared to breed successfully. At site G#8, only the American toads bred successfully, but they were present in very large numbers (>80 males in the chorus, and many clutches of eggs and larvae). At G#9, there were only three species of amphibians present (northern leopard frog, American toad and green frog) and there was no evidence that any species reproduced successfully. Amphibians appeared to prefer the adjacent natural wetland as breeding habitat. There was an extensive algal bloom in the pond throughout the summer.

T#1 consisted of a single medium-sized pond adjacent to an extensive riparian area. In T #1, amphibian diversity (four species) was higher than average for the GTA ponds with American toads, gray treefrogs and green frogs all calling in reasonably large numbers, although successful reproduction was documented only for American toads and green frogs. Northern leopard frogs were seen occasionally, but apparently did not breed at the site.

T#2 was also adjacent to an extensive riparian area. It was less isolated than the T#1 site, and there was less vegetation surrounding the pond, but there was more emergent vegetation in the pond itself. Amphibian diversity (four species: northern leopard frog, American toad, gray treefrog and green frog) was higher than average for the GTA sites. All species present formed breeding choruses, and clutches of American toad, gray treefrog and green frog eggs were found. No leopard frog eggs were found, but the extensive emergent vegetation may have obscured them. This was one of the best sites overall in terms of amphibian use. However, during the summer, construction damaged the pond extensively, apparently contaminating the pond with oil early in the spring and finally filling in part of it and widening another part later in the summer. There appeared to be high mortality in American toad eggs, possibly due to large fluctuations in water levels. The fate of the eggs of the other species is unknown.

There were no amphibians found at T #3 although there was extensive emergent vegetation (mostly cattails). The berm was in a poor state of repair and the water level was very low. Most of the site was dry, and the fraction that was not dry rarely held more than 5 to 10 cm depth of water. There were no amphibians found at this site at any time during the spring or summer, although there was a moderately large chorus of American toads breeding in a small, seasonal pond less than 100 m from the constructed wetland.

At T#4, species diversity was higher than average (four species: spring peepers, northern leopard frogs, American toads and green frogs), but only the American toads and green frogs appeared to breed. The population of American toads was very large (more than 75 males). Although large numbers of toad eggs were deposited in the water, no toad larvae or transformants were found.

T#5 was a small system with a forebay and very little vegetation around the margin and none at all in the ponds themselves. Amphibian diversity was low (American toads and green frogs) and no evidence of successful reproduction was found. Local people living in the area reported that transforming toads were common in some years. This site had very little access to larger wetlands that could act as source populations. Powerful lights used for night games at an adjacent baseball park may have contributed to the apparent unattractiveness of the site for amphibian breeding.

T#6 was a small shallow pond that had well-vegetated margins and once supported emergent vegetation (mostly cattails), although no living emergent vegetation was seen during the surveys. There was good access to an unmowed "green belt" and a nearby river. Amphibian diversity was low (American toads and green frogs) and only the green frogs appeared to breed successfully. There was a large and persistent algal bloom in this pond throughout the summer.

Bird Surveys

The highest number of bird species seen feeding or nesting at a pond was 38, while fewer than 10 species were seen at two ponds (Table 7a, b). In Guelph stormwater ponds, 71 species of birds were seen nesting or feeding at the stormwater ponds during the 6 months of surveys (Table 7a). During the MMP surveys, the average number of species was 5.7 in Guelph ponds and 1.0 in GTA ponds. The maximum number of bird species at any stormwater pond during the MMP surveys was eight. The maximum number of species seen per non-MMP survey among the Guelph ponds varied from five to ten while the maximum numbers ranged from three to seven among the GTA ponds (Table 7a, b). Similar to the findings for amphibians, there were no significant correlations among the total number of bird species in ponds and any water quality, sedimentology, contaminant concentration, percentage of surface area of the pond covered with plants, or any benthic community parameter measured. The number of species of amphibians and birds found among sites was not correlated.

The most common species in Guelph and GTA ponds was mallard (*Anas platyrhynchos*). Mallards were seen, on average, during 67.7% of surveys in Guelph. In Toronto, mallards were seen on 26% of the surveys.

Other species occurring on at least 20% of surveys in Guelph were song sparrow (*Melospiza melodia*), Canada goose (*Branta canadensis*), red-winged blackbird (*Agelaius phoenicius*) and American Robin (*Turdus migratorius*) (Table 7 a,b). In Toronto, the second most commonly observed species were only seen on 8 to 12% of surveys, and these species included song sparrow, red-winged blackbird, barn swallow (*Hirundo rustica*) and spotted sandpiper (*Actitis macularia*) (Table 7b).

Canada geese attempted to breed at all ponds in Guelph except two, G#3 and G#8. The nests at G#1 and G#2 were depredated during incubation, while at G#4, the entire brood was depredated shortly after hatching. At the remaining four sites, all of the young that hatched also fledged. Canada geese were not common at the GTA sites, occurring on average in less than 1% of surveys (Table 7a, b).

Mallards with young were seen at seven ponds in Guelph, with G#1 and G#4 being exceptions. The total for all ponds was at least 12 broods. Determining the success of mallard broods was difficult because, unlike goslings, when not in open water, mallard ducklings tended to forage in denser vegetation and could be missed on a particular survey. Mallards are also less faithful to a site than Canada geese and are often led away, particularly if there is suitable habitat nearby. One or more ducklings may also switch to another brood. However, a reasonable objective assessment of the success of mallard broods in the survey was made at the Guelph sites. At the GTA sites, mallard broods were noted at only two ponds (T#1and T#5) and one wood duck brood was seen at T#6, but reproductive success was not evaluated.

In Guelph, for the single-brood ponds, three ducklings at G#3 made it to fledging, but the brood may have been more numerous and well hidden earlier in the year. At G#2, nine tiny ducklings disappeared for a month, but the five that returned fledged successfully. At G#8, the hen of a brood of four disappeared and the brood was not seen soon after. At G#7, four ducklings were seen on one occasion only.

At G#6, two mallard broods were found. A brood of nine was soon reduced to five and then disappeared. The second brood of five was reduced to one. Brood reduction at G#9 was as follows: of a brood of eight, six fledged; of a brood of three, all fledged; while of a brood of five, none survived due to predation of the hen. At G#5, a brood of nine led to six fledging, a brood of six was finally reduced to one, and a brood of five was lost. It is evident that for Canada geese, once the period of incubation and early fledging is past, the success rate was very high. For mallards, the situation was very different, with ducklings being very vulnerable until almost full grown.

Fish, Reptiles and Mammals

Among all ponds in the study, four species of reptiles were found, including eastern garter snake (*Thamnophis sirtalis sirtalis*) and three species of turtles, common snapping turtle (*Chelydra serpentina serpentina*); midland painted turtle (*Chrysemys picta marginata*) and red-eared slider

Table 7a. Species and frequency of occurrence of birds observed during 29 April to 31 October 1997 at 15 stormwater detention ponds in Guelph (birds listed here were on the surface, on emergent vegetation, on the shore of pond, or foraging in the air above the pond; data are observations in percent surveys)

Species	Site									
	G1	G2	G3	G4	G5	G6	G7	G8	G9	All Guelph sites
Pied-billed Grebe (*Podilymbus podiceps*) [a]	9	0	0	2	0	0	0	0	0	1.2
Great Blue Heron (*Ardea herodias*)	11	11	2	29	27	16	4	2	29	14.6
Green Heron (*Butorides striatus*)	0	0	4	0	4	0	11	4	9	3.7
Black-cr. Night-Heron (*Nycticorax nycticorax*)	0	0	0	0	0	0	4	0	0	0.5
Mute Swan (*Cygnus olor*) [b]	0	0	0	0	0	0	0	0	0	0
Canada Goose (*Branta canadensis*)	16	4	2	24	51	42	42	9	44	26.2
Wood Duck (*Aix sponsa*)	0	0	0	2	0	0	2	0	0	0.5
Mallard (*Anas platyrhynchos*)	33	73	38	58	98	91	80	40	98	67.7
American Black Duck (*Anas rubripes*)	0	0	0	0	0	0	0	0	0	0
Blue-winged Teal (*Anas discors*)[a]	0	0	0	0	0	0	0	0	27	3.0
Sharp-shinned Hawk (*Accipiter striatus*)	0	0	0	0	0	2	0	0	0	0.2
Merlin (*Falco columbarius*)	2	0	0	0	0	0	0	0	0	0.2
Virginia Rail (*Rallus limicola*) [a]	0	0	0	0	0	11	0	0	0	1.2
Sora (*Porzana carolina*) [a]	0	0	0	0	0	0	0	0	0	0
Lesser Golden Plover (*Pluvialis dominica*)	2	0	0	0	0	0	0	0	0	0.2
Killdeer (*Charadrius vociferus*)	0	0	0	2	0	0	0	2	7	1.2
Lesser Yellowlegs (*Tringa flavipes*)	2	0	0	0	0	0	0	0	4	0.7
Solitary Sandpiper (*Tringa solitaria*)	0	0	0	2	0	2	2	0	2	1.0

(continued)

Table 7a. ***(continued)***

	Site									
Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	All Guelph sites
Spotted Sandpiper (*Actitis macularia*)	13	2	0	2	22	0	2	0	38	8.9
Common Snipe (*Capella gallinago*)	0	0	0	0	0	4	0	0	0	0.5
Ring-billed Gull (*Larus delawarensis*)	13	2	2	2	13	16	13	7	36	11.6
Herring Gull (*Larus argentatus*)	0	0	0	0	0	0	2	0	0	0.2
Caspian Tern (*Sterna caspia*)	0	0	0	0	0	0	0	0	2	0.2
Rock Dove (*Columba livia*)	0	0	0	0	0	0	0	2	0	0.2
Mourning Dove (*Zenaida macroura*)	2	9	0	2	4	4	0	2	2	3.0
Chimney Swift (*Chaetura pelagica*)	0	0	0	0	9	0	0	0	2	1.2
Belted Kingfisher (*Megaceryle alcyon*)	0	0	2	9	2	2	11	2	7	4.0
Downy Woodpecker (*Picoides pubescens*)	2	0	0	2	0	0	0	0	0	0.5
Northern Flicker (*Colaptes auratus*)	0	0	0	2	7	0	0	0	0	1.0
Alder Flycatcher (*Empidonax alnorum*)	0	0	0	0	0	0	2	0	0	0.2
Willow Flycatcher (*Empidonax traillii*)	0	0	0	0	0	0	0	2	0	0.2
Least Flycatcher (*Empidonax minimus*)	0	0	0	0	0	0	2	0	0	0.2
Eastern Phoebe (*Sayornis phoebe*)	0	2	0	0	4	0	0	0	0	0.7
Eastern Kingbird (*Tyrannus tyrannus*)	2	0	2	0	2	0	20	2	0	3.2
Tree Swallow (*Iridoprocne bicolor*)	9	2	0	16	11	2	2	2	2	5.2
N. Rough-winged Swallow (*Stelgidopteryx ruficollis*)	2	0	0	4	2	0	0	0	0	1.0
Bank Swallow (*Riparia riparia*)	0	0	0	0	0	0	0	0	0	0
Barn Swallow (*Hirundo rustica*)	29	0	0	16	2	0	0	4	0	5.7
Marsh Wren (*Cistothorus palustris*) [a]	0	0	0	0	0	0	0	0	0	0
Blue Jay (*Cyanocitta cristata*)	0	0	0	0	7	0	0	2	0	1.0

(continued)

Table 7a. *(continued)*

	Site									
Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	All Guelph sites
American Crow (*Corvus brachyrhynchos*)	2	2	2	0	16	0	0	0	4	3.0
Black-capped Chickadee (*Parus atricapillus*)	0	2	0	0	0	0	9	0	0	1.2
Ruby-crowned Kinglet (*Regulus calendula*)	0	0	0	0	0	0	2	0	0	0.2
American Robin (*Turdus migratorius*)	9	29	2	29	7	4	36	49	22	20.7
Gray Catbird (*Dumetella carolinensis*)	0	0	0	0	0	0	11	2	0	1.5
Brown Thrasher (*Toxostoma rufum*)	0	0	0	0	0	0	0	2	0	0.2
Water Pipit (*Anthus spinoletta*)	4	0	0	0	2	0	2	0	0	1.0
Cedar Waxwing (*Bombycilla cedrorum*)	0	4	0	0	2	0	2	0	4	1.5
European Starling (*Sturnus vulgaris*)[b]	18	2	4	13	2	0	2	2	2	5.2
Orange-crowned Warbler (*Vermivora celata*)	0	0	0	0	0	0	2	0	0	0.2
Nashville Warbler (*Vermivora ruficapilla*)	0	0	0	0	0	0	0	2	0	0.2
Yellow Warbler (*Dendroica petechia*)	0	9	4	7	0	0	2	2	0	2.7
Northern Waterthrush (*Seiurus noveboracensis*)	0	0	0	0	0	0	0	0	0	0
Yellow-rumped Warbler (*Dendroica coronata*)	0	0	0	0	2	0	9	0	0	1.2
Blackpoll Warbler (*Dendroica striata*)	0	0	0	0	0	0	2	0	0	0.2
Common Yellowthroat (*Geothlypis trichas*)	0	2	0	2	0	0	0	0	0	0.5
Scarlet Tanager (*Piranga olivacea*)	2	0	0	0	0	0	0	0	0	0.2
Northern Cardinal (*Cardinalis cardinalis*)	0	4	0	0	2	0	20	4	0	3.5
Indigo Bunting (*Passerina cyanea*)	0	0	0	0	0	0	0	0	2	0.2
Am. Tree Sparrow (*Spizella arborea*)	0	0	0	0	0	0	2	0	0	0.2
Field Sparrow (*Spizella pusilla*)	0	0	0	0	0	0	0	4	0	0.5
Savannah Sparrow (*Passerculus sandwichensis*)	7	0	0	0	0	0	0	0	0	0.7
Song Sparrow (*Melospiza melodia*)	9	62	2	24	47	9	76	76	47	39.0
Lincoln's Sparrow (*Melospiza lincolnii*)	0	0	0	0	0	0	0	0	0	0

(continued)

Table 7a. ***(concluded)***

Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	All Guelph sites
	Site									
White-throated Sparrow (*Zonotrichia albicollis*)	0	0	0	0	0	0	11	0	0	1.2
White-crowned Sparrow (*Zonotrichia leucophrys*)	0	2	0	0	0	0	2	0	0	0.5
Swamp Sparrow (*Melospiza georgiana*)	0	2	0	0	0	0	0	0	0	0.2
Dark-eyed Junco (*Junco hyemalis*)	0	4	0	0	0	0	4	0	0	1.0
Eastern Meadowlark (*Sturnella magna*)	2	0	0	0	0	0	0	0	0	0.2
Bobolink (*Dolichonyx oryzivorus*)	2	0	0	0	0	0	0	0	2	0.5
Red-winged Blackbird (*Agelaius phoeniceus*)	33	42	76	40	9	22	9	4	2	26.4
Common Grackle (*Quiscalus quiscula*)	11	18	27	20	16	0	18	20	13	15.8
Brown-headed Cowbird (*Molothrus ater*)	2	0	2	2	2	0	0	2	0	1.2
Baltimore Oriole (*Icterus galbula*)	0	0	0	0	0	0	2	0	0	0.2
House Finch (*Carpodacus mexicanus*)	0	9	2	0	0	0	0	0	0	1.2
Common Redpoll (*Carduelis flammea*)	0	0	0	0	0	0	2	0	0	0.2
American Goldfinch (*Carduelis tristis*)	13	13	0	0	2	7	9	9	11	7.2
House Sparrow (*Passer domesticus*) [b]	22	2	2	0	16	0	4	11	0	6.4
For the following variables, except total number of species, the average for each site is presented:										
Total number of species	29	25	17	24	29	15	38	28	25	71
Mean number of species per survey	1.4	1.6	1.1	1.6	2	1.2	2.2	1.4	1.6	1.6
Maximum number of species/any single survey	10	7	5	10	8	7	9	9	9	8.2
Minimum number of species/any single survey	0	0	0	0	0	0	0	0	0	0
Total number of species seen during MMP surveys	7	8	2	7	4	4	7	4	7	18

[a] Species indicative of high quality marsh habitat (Chabot et al. 1998).
[b] Non-native to Canada.

Table 7b. Species and frequency of occurrence of birds observed during 29 April to 31 October 1997 at six stormwater detention ponds in the Greater Toronto Area (GTA) (birds listed here were on the surface, on emergent vegetation, on the shore of pond, or foraging in the air above the pond; data are observations in percent surveys

Species	T1	T2	T3	T4	T5	T6	All GTA sites
Pied-billed Grebe (*Podilymbus podiceps*)[a]	0	0	0	22	0	0	3.7
Great Blue Heron (*Ardea herodias*)	0	0	0	29	0	4	5.5
Green Heron (*Butorides striatus*)	0	0	0	7	0	0	1.2
Black-cr. Night-Heron (*Nycticorax nycticorax*)	0	0	0	0	0	0	0.0
Mute Swan (*Cygnus olor*)[b]	0	0	0	4	0	0	0.6
Canada Goose (*Branta canadensis*)	0	0	0	4	0	0	0.6
Wood Duck (*Aix sponsa*)	0	0	0	0	0	12	1.9
Mallard (*Anas platyrhynchos*)	30	4	4	22	81	15	26.0
American Black Duck (*Anas rubripes*)	0	0	0	4	0	0	0.6
Blue-winged Teal (*Anas discors*)[a]	0	4	0	0	0	0	0.6
Sharp-shinned Hawk (*Accipiter striatus*)	0	0	0	0	0	0	0.0
Merlin (*Falco columbarius*)	0	0	0	0	0	0	0.0
Virginia Rail (*Rallus limicola*)[a]	0	4	4	0	0	0	1.2
Sora (*Porzana carolina*)[a]	0	4	7	0	0	0	1.9
Lesser Golden Plover (*Pluvialis dominica*)	0	0	0	0	0	0	0.0
Killdeer (*Charadrius vociferus*)	0	0	0	0	7	0	1.2
Lesser Yellowlegs (*Tringa flavipes*)	0	0	0	0	4	0	0.6
Solitary Sandpiper (*Tringa solitaria*)	0	4	0	0	0	4	1.3
Spotted Sandpiper (*Actitis macularia*)	0	4	7	7	30	4	8.7
Common Snipe (*Capella gallinago*)	0	0	7	0	0	0	1.2

(continued)

Table 7b. ***(continued)***

Species	T1	T2	T3	T4	T5	T6	All GTA sites
Ring-billed Gull (*Larus delawarensis*)	4	0	0	4	0	0	1.2
Herring Gull (*Larus argentatus*)	0	0	0	0	0	0	0.0
Caspian Tern (*Sterna caspia*)	0	0	0	0	0	0	0.0
Rock Dove (*Columba livia*)	0	0	0	0	0	0	0.0
Mourning Dove (*Zenaida macroura*)	4	0	4	0	7	0	2.5
Chimney Swift (*Chaetura pelagica*)	0	0	0	4	4	0	1.2
Belted Kingfisher (*Megaceryle alcyon*)	0	0	0	0	0	0	0.0
Downy Woodpecker (*Picoides pubescens*)	0	0	0	0	0	0	0.0
Northern Flicker (*Colapltes auratus*)	0	0	0	0	0	0	0.0
Alder Flycatcher (*Empidonax alnorum*)	0	0	0	0	0	0	0.0
Willow Flycatcher (*Empidonax traillii*)	0	0	0	0	0	0	0.0
Least Flycatcher (*Empidonax minimus*)	0	0	0	0	0	0	0.0
Eastern Phoebe (*Sayornis phoebe*)	0	0	0	0	0	0	0.0
Eastern Kingbird (*Tyrannus tyrannus*)	0	4	0	0	0	4	1.3
Tree Swallow (*Iridoprocne bicolor*)	0	0	0	7	4	0	1.9
N. Rough-winged Swallow (*Stelgidopteryx ruficollis*)	4	26	0	7	0	0	6.2
Bank Swallow (*Riparia riparia*)	0	26	0	0	0	0	4.3
Barn Swallow (*Hirundo rustica*)	4	7	19	19	11	0	9.9
Marsh Wren (*Cistothorus palustris*) [a]	0	4	0	0	0	0	0.6
Blue Jay (*Cyanocitta cristata*)	0	0	0	0	0	0	0.0
American Crow (*Corvus brachyrhynchos*)	0	0	0	0	0	0	0.0
Black-capped Chickadee (*Parus atricapillus*)	0	0	0	0	0	0	0.0

(continued)

Table 7b. *(continued)*

Species	T1	T2	T3	T4	T5	T6	All GTA sites
Ruby-crowned Kinglet (*Regulus calendula*)	0	0	0	0	0	0	0.0
American Robin (*Turdus migratorius*)	0	4	4	0	4	0	1.9
Gray Catbird (*Dumetella carolinensis*)	0	0	0	0	0	0	0.0
Brown Thrasher (*Toxostoma rufum*)	0	0	0	0	0	0	0.0
Water Pipit (*Anthus spinoletta*)	0	0	0	0	0	0	0.0
Cedar Waxwing (*Bombycilla cedrorum*)	15	7	0	0	4	19	7.5
European Starling (*Sturnus vulgaris*) [b]	0	7	0	0	0	0	1.2
Orange-crowned Warbler (*Vermivora celata*)	0	0	0	0	0	0	0.0
Nashville Warbler (*Vermivora ruficapilla*)	0	0	0	0	0	0	0.0
Yellow Warbler (*Dendroica petechia*)	0	0	0	7	0	0	1.2
Northern Waterthrush (*Seiurus noveboracensis*)	0	0	7	0	0	0	1.2
Yellow-rumped Warbler (*Dendroica coronata*)	0	0	0	4	0	0	0.6
Blackpoll Warbler (*Dendroica striata*)	0	0	0	0	0	0	0.0
Common Yellowthroat (*Geothlypis trichas*)	0	0	7	4	0	0	1.9
Scarlet Tanager (*Piranga olivacea*)	0	0	0	0	0	0	0.0
Northern Cardinal (*Cardinalis cardinalis*)	0	0	0	0	0	0	0.0
Indigo Bunting (*Passerina cyanea*)	0	0	0	0	0	0	0.0
Am. Tree Sparrow (*Spizella arborea*)	0	0	0	0	0	0	0.0
Field Sparrow (*Spizella pusilla*)	0	0	0	0	0	0	0.0
Savannah Sparrow (*Passerculus sandwichensis*)	0	0	11	0	0	0	1.9
Song Sparrow (*Melospiza melodia*)	4	11	44	0	7	0	11.1
Lincoln's Sparrow (*Melospiza lincolnii*)	0	0	7	0	0	0	1.2
White-throated Sparrow (*Zonotrichia albicollis*)	0	0	0	0	0	0	0.0

(continued)

Table 7b. ***(concluded)***

Species	T1	T2	T3	T4	T5	T6	All GTA sites
White-crowned Sparrow (*Zonotrichia leucophrys*)	0	0	0	0	0	0	0.0
Swamp Sparrow (*Melospiza georgiana*)	0	0	19	0	0	0	3.1
Dark-eyed Junco (*Junco hyemalis*)	0	0	44	0	0	0	7.4
Eastern Meadowlark (*Sturnella magna*)	0	0	0	0	0	0	0.0
Bobolink (*Dolichonyx oryzivorus*)	0	0	0	0	0	0	0.0
Red-winged Blackbird (*Agelaius phoeniceus*)	15	13	0	22	15	8	12.1
Common Grackle (*Quiscalus quiscula*)	0	11	4	11	4	0	4.9
Brown-headed Cowbird (*Molothrus ater*)	0	0	0	0	0	0	0.0
Baltimore Oriole (*Icterus galbula*)	0	0	0	0	0	0	0.0
House Finch (*Carpodacus mexicanus*)	0	0	0	0	0	0	0.0
Common Redpoll (*Carduelis flammea*)	0	0	0	0	0	0	0.0
American Goldfinch (*Carduelis tristis*)	0	0	3	0	0	0	0.6
House Sparrow (*Passer domesticus*) [b]	0	0	26	0	4	0	4.9
For the following variables, except total number of species, the average for each site is presented:							
Total number of species	8	18	18	19	14	8	40
Mean number of species per survey	0.6	2.3	2.9	1.8	1.8	0.7	1.7
Maximum number of species/any single survey	3	6	6	7	5	3	5.0
Minimum number of species/any single survey	0	0	0	0	0	0	0
Total number of species seen during MMP surveys	0	3	2	0	2	0	7

[a] Species indicative of high quality marsh habitat (Chabot et al. 1998)
[b] Non-native to Canada.

Table 8. Species of fish, mammals and reptiles observed during April to November 1997 at 15 stormwater detention ponds in Guelph and Greater Toronto Area (an 'X' indicates the species was observed at least once at the site)

	Site														
Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	T1	T2	T3	T4	T5	T6
<u>Reptiles</u>															
Common Snapping Turtle (*Chelydra serpentina serpentina*)				X											
Midland Painted Turtle (*Chrysemys picta picta*)		X	X	X		X	X	X			X		X		
Eastern Garter Snake (*Thamnophis sirtalis sirtalis*)		X	X												
Red-eared Slider turtle (*Trachemys scripta*)[a]				X									X		
<u>Fish</u>															
Pumpkinseed (*Lepomis gibbosus*)	X		X	X		X	X		X				X		
Bluntnose Minnow (*Pimephales notatus*)	X				X	X	X		X					X	
Brook Stickleback (*Culaea inconstans*)									X						
Spotfin Shiner (*Notropis spilopterus*)					X										
Spottail Shiner (*Notropis hudsonius*)					X										

(continued)

Table 8. *(concluded)*

Species	Site G1	G2	G3	G4	G5	G6	G7	G8	G9	T1	T2	T3	T4	T5	T6
Black-nose Shiner (*Notropis heterolepis*)					X										
White Sucker (*Catostomus commersoni*)	X														
Goldfish (*Carassius auratus*)[a]				X									X		
Mammals															
Meadow Vole (*Microtus pennsylvanicus*)	X														
Groundhog (*Marmota monax*)				X	X			X	X						
Muskrat (*Ondatra zibethicus*)	X		X	X	X	X	X	X	X	X	X			X	X
Eastern Cottontail (*Sylvilagus floridanus*)		X						X							
Striped Skunk (*Mephitis mephitis*)		X						X				X			
Raccoon (*Procyon lotor*)		X						X				X			
Red Fox (*Vulpes vulpes*)		X						X				X			
White-tailed Deer (*Odocoileus virginianus*)										X	X				X

[a] Non-native species in Canada.

(*Trachemys scripta*) (Table 8). The red-eared slider is an introduced species which is commonly kept as a pet and often released into local ponds. Eight species of fish, mainly minnows, as well as white sucker (*Catostomus commersoni*), pumpkinseed (*Lepomis gibbosus*) and non-native goldfish (*Carassius auratus*) were seen or trapped among all ponds (Table 8). In G#4, there was a small population of turtles seen basking (seven painted turtles, one red-eared slider and one snapping turtle) and a large population of goldfish, some of which were very large (e.g., approximately 20 cm snout-vent length). Eight species of native mammals were observed, including meadow vole (*Microtus pennsylvanicus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), eastern cottontail rabbit (*Sylvilagus floridanus*), groundhog (*Marmota monax*), muskrat (*Ondatra zibethicus*), white-tailed deer (*Odocoileus virginianus*), and red fox (*Vulpes vulpes*) (Table 8).

Discussion

Most stormwater ponds had developed at least a small wetland vegetation community, with the degree of plant growth being highest in ponds with the most organic carbon in sediment. The terrestrial vegetation surrounding most ponds was mainly limited to lawns. The diversity of invertebrate populations was also highest in ponds with high concentrations of organic matter in the sediments. Benthic invertebrate communities were moderately diverse but tended to be dominated by one or two species in ponds with high concentrations of oil, grease and copper in sediments. The diversity of amphibian and bird species at most ponds was also moderate to low, and few bird species were observed to be feeding or nesting at the ponds during individual surveys. The observed reptiles (Lamond 1994) and mammals were typical of urban environments.

Aquatic vegetation is relatively tolerant of trace metals and organic pollution in the water column and sediments of wetlands (Kadlec and Knight 1996). A key factor for growth and survival of wetland plants is the presence of adequate nutrients for growth (Kadlec and Knight 1996). This is consistent with the finding that organic carbon and copper in sediment correlated positively with the degree of vegetation coverage in the ponds. The amount of terrestrial vegetation was restricted by mowing, which probably did not enhance habitat for bird nesting or feeding.

Among all sites, seven of the nine species of amphibians that are known to occur in this region of Ontario (Francis and Campbell 1983; Weeber et al. 1997) were found. Although the amphibians were surveyed with higher frequency than is required for the Marsh Monitoring Program, the number of amphibians found per stormwater pond is still rated as low to moderate when compared to other MMP sites in the Great Lakes basin. The MMP rates wetlands with one to three amphibian species as "low" in terms of species richness and those with five to eight species as "medium" (Weeber et al. 1997). In the Guelph ponds, only three of five species of amphibians designated as representative of high quality marsh habitat by the Marsh Monitoring Program (Chabot et al. 1998) were found and only two of these five "designated" amphibian species were found in the GTA stormwater ponds.

Nonetheless, some of the stormwater ponds had a diversity of species similar to other ponds in and around Guelph and the GTA. In 1999, at three stormwater ponds in the Region of Waterloo (northwest of Guelph), five species of frogs and toads were found (Heaton and Brown 1999). At the Kortright Centre pond in the GTA, nine species of amphibians have been found (D. Stuckey, pers. comm.). In the GTA in the 1990s, a one-hectare pond at Colonel Sam Smith Park had only two species of amphibians while the Brickworks pond (5.0 hectare) had four (Toronto and Region Conservation Authority, unpublished data).

The low intensity of use and lack of successful breeding activity of amphibians in the stormwater ponds may have been due to a lack of suitable habitat within ponds (oviposition sites, refuges from predators and foraging habitat) and surrounding the ponds. Algal blooms were seen at ponds and such blooms may reduce oxygen availability and prevent development of submergent vegetation, which is important as food for tadpoles. Fish and turtles in some ponds may have been predators of amphibians and contributed to the low intensity of use by amphibians.

The birds that were seen most often at stormwater ponds were species that are typical of urban environments (Peck and James 1983; Cadman et al. 1987). On fewer occasions, a variety of other species were observed, suggesting that most were seasonal migrants or visitors foraging at the site during the breeding season. While there were no direct correlations between the number of bird species and water and sediment quality, and age of the ponds, the low number of bird species observed on each visit suggests the stormwater detention ponds do not offer particularly high quality nesting or feeding habitat perhaps due to lack of terrestrial and aquatic vegetation and a low diversity of invertebrate food sources in most ponds. For the two species that were monitored, the Canada geese had relatively high reproductive success while mallards did poorly.

Of the 142 species that occur annually in Wellington county where the Guelph ponds are located (Guelph Field Naturalists 1988), 42.9% of these species were seen in stormwater ponds at least once during this study. Of the 189 species that have occurred in the Greater Toronto Area (Smith and Coady 1999), 21.1% of those species were seen in the GTA stormwater ponds.

Breeding bird surveys conducted in 1998 at Chester Springs pond, a 0.25-hectare wetland in the GTA, found 28 species of birds using the site (Toronto and Region Conservation Authority, unpublished data), which is higher than the maximum of 19 species found in the GTA ponds but comparable to ponds in Guelph where 15 to 38 species were found. At the Kortright Centre, also in the GTA, water levels are maintained to create a 3.0-hectare pond, and 22 bird species are regularly found during the breeding season (D. Stuckey, pers. comm.). Seven stormwater ponds in Guelph, but none in the GTA, had more than 20 species of birds using them.

MMP surveys at Chester Springs pond revealed 15 species of birds, which is at least five times that seen during MMP surveys at the GTA stormwater ponds and twice that of all but one Guelph pond. According to MMP analysis, which rates species richness of one to seven as "low", eight to 14 as "moderate" and 15 to 22 as "high" (Weeber et al. 1997), the stormwater ponds would be rated as low in species richness at 14 sites and moderate at one site, while the Chester Springs pond would rate as a "high" species richness of marsh birds. Among all stormwater ponds in the GTA, only 5 of 11 species of birds designated as representative of high quality marsh habitat by the Marsh Monitoring Program (Chabot et al. 1998) were found and only four of these species were observed in the Guelph stormwater ponds. Clearly, some of the stormwater ponds can attract similar numbers of bird species as other small wetlands, but most sites in this study, especially in the GTA, did not. The marsh bird community, in particular, was depressed at the stormwater detention ponds.

Invertebrate communities of small ponds are notoriously variable in composition (Friday 1987), even in the absence of impacts from land use. Complete colonization i.e., the point at which number of taxa stabilizes, generally occurs within a few years (Street and Titmus 1979; Barnes 1983; Layton and Voshell 1991) and this seems to be the case in our set of stormwater ponds. There was no correlation between pond age and number of taxa living directly in the sediment, many of which have poor powers of dispersal relative to the insects which dominate the epibenthic fauna (Bronmark 1985; Jeffries 1989). All of the ponds have at least temporary surface connection to nearby streams, so colonization distances are not very great. Our data suggest that numbers of epibenthic species may take longer to reach equilibrium. This is unlikely to be a direct reflection of colonization rates, but rather the continuing accumulation of organic carbon, which leads to increasing habitat complexity. It seems unlikely that size or hydrologic regime varied sufficiently among ponds to influence colonization rates (Driver 1977; Jeffries 1989; Bazzanti et al. 1997). All ponds contained water in August of the second year of below average precipitation.

Some of the observed differences among stormwater ponds are associated with chemical contamination. Pond T#3 had very high concentrations of oil and grease and metals in the sediment (Bishop et al., this volume) and the fauna consisted almost entirely of tubificid worms in the sediment and the pulmonate snail *Pseudosuccinea columella* on cattails, the only aquatic vegetation in the pond. In a companion laboratory study, in which sediment samples were taken from the same stormwater ponds and assayed for their toxicity to invertebrates and fish (Bedard 1999; Bishop et al. 1999), sediments from T#3 were significantly toxic to growth of mayfly (*Hexagenia limbata*) and midge (*Chironomus tentans*) and to the survival of mayfly in acute toxicity bioassays.

Dominance by a single species or narrow taxonomic group of animals is characteristic of stressed aquatic habitats. This standard also suggests that conditions within the sediments of ponds T#3, T#6, G#2, G#1 and G#4 were less than ideal. Pond T#6 was also extreme in having the lowest standing stock of benthic animals, most of which were fingernail clams (*Pisidium*).

Bedard (1999) also reports that 21-day mayfly growth in Guelph sediments was negatively correlated with oil and grease concentrations in sediment, and mayfly survivorship declined as oil and grease and polycyclic aromatic hydrocarbon levels increased in sediments. Oil and grease, polycyclic aromatic hydrocarbons, copper, zinc and lead levels in sediments at these stormwater ponds are close to or well above concentrations expected to negatively effect sensitive species of benthos (Bishop et al., this issue; Bishop et al. 1999).

Another measure of relative environmental stress on invertebrates is the percentage similarity of the community to a reference pond (C#1). By this criterion, the benthic communities of ponds T#3 and G#1, and the epibenthic communities of T#3, G#1, T#1, G#8 and G#7 are most different from the natural wetland. With only a single reference pond, it is impossible to judge the significance of smaller or larger scores, but those ponds with the lowest values of PSC also tended to yield small numbers of taxa, and a single taxon accounted for at least 40% of the individuals in either grab or sweep-net samples. Taken together, the results for the wild populations and the laboratory bioassays of sediments from these ponds suggest that populations dominated by a few, tolerant species at most stormwater ponds were due to sublethal but chronic factors that maintain a low species diversity within the communities despite the likely availability of colonizing species through connections with other local streams. Our study and associated work in these ponds (Bedard 1999) indicates that sediment contamination is an important factor; however, other parameters such as habitat and food availability for individual species, both vertebrate and invertebrate, were not evaluated for the stormwater ponds and could also be important.

Although the stormwater ponds were never enhanced to attract wildlife, it is clear that communities of plants, invertebrates, fish, amphibians, reptiles and mammals utilized these areas. There was a lack of species richness for all biota examined and the dominant species were opportunistic, and stress-tolerant species representative of marginal, urban habitats. The accumulation of organic sediments in these ponds appears to have created conditions that allowed some invertebrate and plant populations to flourish, which is likely to have attracted vertebrates to the site. Contaminant levels in those organic-rich sediments sublethally impact the invertebrate community at most sites. This was supported in the findings of laboratory assays, which indicated acutely toxic effects at one site and trends to depressed survival and growth among all sites in conjunction with increasing contaminant exposures.

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