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Evaluation of the aquatic habitat and fish assemblage in an urban reach of the historic Rideau Canal, Ottawa, Canada: Implications for management in an engineered system

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Abstract The historic Rideau Canal (built in the 1800s) in eastern Ontario, Canada is a heavily managed and engineered ecosystem, popular for recreational boating and sport fishing in the summer and ice skating in the winter. However, little is actually know about the fish and aquatic macrophyte communities, particularly in the urban reach in Ottawa between Hartwell's Lock and the outflow of Dows Lake. The objective of this study was to examine the extent to which fish and macrophytes varied among different natural and engineered habitat/substrate types across the period when the canal is at navigational water levels. Five gross habitat types were identified, consisting of gravel, silt/sand, rip-rap/ gabion basket, boulder and concrete wall habitats. Replicate transects were established in the littoral zone, representing the different habitat types. Snorkel surveys were conducted on a biweekly basis, where fish species and aquatic macrophytes within the transects were quantified. Supplementary data on fish populations was obtained through seine net sampling as well as angler interviews and visual observations. The fish community was characterized as a reasonably simple warmwater assemblage, dominated by centrarchids (e.g., pumpkinseed [*Lepomis gibbosus*], bluegill [*L. macrochirus*], and largemouth bass [*Micropterus salmoides*]). In fact, more than 90% of all fish encountered (snorkel surveys and seine netting) belonged to the centrarchid family. None of the 17 fish species encountered in the reach were considered "at risk" in Canada, although the system supports one of the few urban muskellunge (*Esox masquinongy*) populations in the world and provides a range of urban recreational fishing opportunities for sportsfish. Fish diversity metrics (e.g., diversity, richness, evenness) varied little among habitat types, perhaps reflecting the fact that vegetation communities were reasonably homogeneous, largely

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dominated by the exotic Eurasian water milfoil (*Myriophyllum spicatum*). This research provides managers with the first detailed information on the aquatic ecology in this engineered urban ecosystem which will enable relevant government agencies (e.g., Parks Canada) to better balance the iconic cultural values of national significance with their mandate to protect the ecological integrity of the canal ecosystem.

Keywords Fish habitat · Aquatic macrophytes · Canal · Natural heritage · Biodiversity · Environmental management · Urban ecology

Introduction

Since the construction of the first canal in eastern Ontario in the 1800s, Canada has used its canal systems as alternate routes for trade or as tools in the country's defense. Before the construction of extensive railroad lines, canals allowed movement of ships, troops, and supplies around the country. The Rideau Canal system in particular was an important tool in commercial shipping and national defense, providing a direct route between Ottawa and Kingston (Bumsted 2003). Built between 1826 and 1832, the canal spans 202 km and has 47 working locks and 52 dams. Since about 1849, however, the role of the Rideau Canal has changed dramatically (Parks Canada 2005). Instead of playing a role in commercial and military endeavors, it now plays a more social role and has been designated as a National Historic Site, managed by Parks Canada. The Rideau Canal is a popular waterway for recreational boat traffic and angling during the summer. In the winter months, one segment (in downtown Ottawa) is used as the Rideau Canal Skateway (one of the World's longest skating rinks). Although the canal is one of the most prominent tourist attractions in Ottawa and indeed the entirety of eastern Ontario, little is known about the ecology of the system. Parks Canada's stated goal is to "preserve the cultural and natural values of the Canal and its setting while allowing for sustainable development on lands bordering the Canal and recreational use of the Canal itself" (Parks Canada 2005). To realize this goal, it is necessary to have an understanding of the ecology of the Canal.

To date, there have been few attempts to understand the ecology of the Rideau Canal system (Levin 2006), particularly in the urban reach between Hartwell's Lock and the outflow of Dows Lake in Ottawa (Wachelka et al. 2000). Dows Lake is a large man-made lake (excavated wetland) that is essentially a lentic section of the Rideau Canal, located near downtown Ottawa. Perturbations from upstream (e.g., agricultural impacts, nutrient enrichment, and associated dense macrophyte beds and mats), shoreline alterations, urban stormwater runoff, boating, fishing, and the seasonal water-level management (i.e., fall draining and spring flooding to accommodate the skateway and protect canal infrastructure) all represent unknown risks to the canal's habitats and organisms. The water levels in this urban reach are lowered annually by ~1.2 m in mid October where they stay until spring when water levels are raised by ~1.2 m to reach summer levels that enable navigation. Parks Canada has a strong interest in the preservation of diversity and is actively inventorying the natural heritage features in all the systems in which they have jurisdiction. Several earlier studies have examined the fish community present in the Rideau Canal system as a whole (Phelps et al. 1999; Coad 2001). However, none have examined how the fish community changes on a seasonal basis, nor examined the relationship between fish species and habitat structure, particularly in urban areas of the canal. With potential redevelopment of some lands adjacent to the canal as well as ongoing maintenance and operation of the canal itself, it is becoming increasingly important to understand the state and dynamics of this urban ecosystem. Such information is essential to enable the development of management strategies that balance the desire to maintain or enhance diversity with the human uses of this engineered environment.

This study is the first comprehensive analysis of the fish community in the reach of the Rideau Canal between Hartwell's Lock and the outflow of Dows Lake. Specifically, we examined habitat type and water quality and their impacts on the fish and aquatic plant communities. Five different habitat types were monitored over the course of the 5 months during which the canal was filled to navigational water levels. At the outset of the study, we predicted that areas with more complex substrate, like boulder habitats, would contain more diverse and complex fish and macrophyte communities, whereas less complex habitats like those along the canal wall and silt/sand substrates would not encourage diverse assemblages. Although canal wall habitats are of little relevance to other systems, Parks Canada is mandated to protect ecosystem features in the Rideau Canal that relate directly to the construction of the canal because of their historic and natural value (Parks Canada 2005). Thus, information obtained from this study will enable Parks Canada to better manage this urban reach of the Rideau Canal and balance cultural, recreational, navigational, heritage, and ecosystem needs.

Material and methods

Study site and habitat assessment

For the purpose of this study, research efforts focused on the reach of the Rideau Canal between Hartwell's Lock (beginning immediately downstream of the lock) and extending downstream roughly 1 km to the outflow of Dows Lake (at the Bronson St. Bridge, Ottawa; a linear distance of approx. 1 km). Included in this analysis are all connected habitats including Agriculture Creek in the Agriculture Canada Arboretum, and Dows Lake. Because of safety concerns and the need to maintain open navigation channels, research activity was restricted to the littoral zone. The only littoral regions not surveyed were those within 10 m downstream of the Hartwell's Lock gates and the area near the marina that is in the northwest corner of Dows Lake. Most sites we sampled were de-watered in the winter months, desiccating and freezing the exposed substrate.

In late April 2006, before the water levels in the Rideau Canal were raised (~1.2 m) to summertime levels, the littoral zone of Dows Lake and the canal near Hartwell's Locks were assessed to determine the shoreline habitat, littoral zone structure, and littoral zone substrate, all gross habitat elements that can influence fish distribution and community structure. The shoreline was divided into 100 m reaches. Throughout each 100 m reach we quantified the number of littoral structural elements (boulders, fixed woody debris, stumps). At the 50 m mark, each substrate type was quantified with a gravelometer and categorized using a modified Wentworth (1922) scale (silt [<62.5 um], sand [2 mm–62.5 um], gravel [64 mm–2 mm], cobble [256 mm–64 mm, rounded], riprap (256 mm–64 mm, broken rock added as riprap or round coble held within a gabion basket), boulder [>256 mm]) and expressed as a percentage of total substrate in three 1 m^2 quadrats. Based on these initial surveys, we separated the reaches in the littoral zone into five primary habitat categories according to dominant substrate composition and shoreline; boulder, silt, gravel/cobble, riprap/gabion baskets, and canal wall. These initial classifications reflected a combination of natural and engineered habitats and were used to establish transects (1 m×25 m) for snorkel surveys. For each primary habitat type, there were between three and five replicate transects.

Snorkel surveys

Snorkeling surveys were conducted beginning in early May 2006 and continued throughout the summer months on a biweekly basis, ending in late September 2006. Twenty-three sites, each dominated by one of the five primary habitat types (described above) were selected and 1 m×25 m transects were established (Fig. 1). Each transect was marked using coloured flags, with flags placed every 5 m dividing the transect into five 5 m sections. Depth of transects ranged from ~50 cm to ~150 cm. The snorkel surveys were conducted to observe fish spatial ecology and community structure as well as macrophyte dynamics. All snorkeling was conducted by one of two individuals that were both trained in fish and macrophyte identification. Snorkellers wore 6 mm wetsuits to provide buoyancy so that the transects could be swum at a slow but steady pace. All snorkel surveys occurred between 10 am and 3 pm.

Fish snorkeling surveys

Every 2 weeks, snorkeling surveys were conducted. The 23 transects were swum by snorkellers and the type and abundance of fish in each 5 m section of transect were

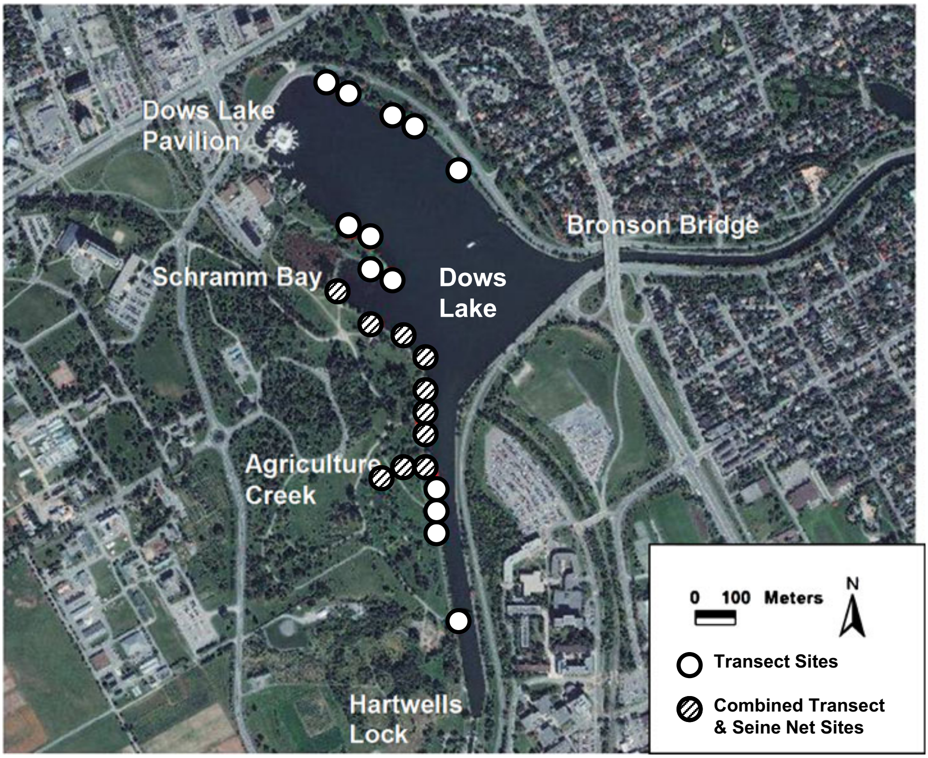

Fig. 1 Aerial view of Dows Lake study area showing location of transects (*open circles*) including those that were also sampled with seine nets (*circles filled with black angular lines*). Hartwell's lock is visible in the canal to the west of the Lake. The bridge (Bronson Street) at the east end of the Lake represents the downstream extent of the study area. Water flows downstream from Hartwell's Lock towards Dows Lake and onwards to the Ottawa Lockstation, some 6 km downstream

recorded. The time taken to swim each transect was standardized, with each transect taking between 5 and 7 min to complete. Snorkellers carried plastic slates onto which they recorded data into a matrix of species/transect sections. Data was transcribed at the end of a snorkeling session. Two repeated measures (with site as the repeated variable) analyses of variance (ANOVA) followed by multiple comparisons (Tukey's HSD *post hoc* test) were employed to determine differences in species diversity indices (see "Diversity metrics" below for information on diversity indices) between the sampling periods (with location as the repeated variable) and between habitat types (with sampling period as the repeated variable) (Day and Quinn 1989). All analyses were performed using JMP v 6.0 (SAS Institute).

Aquatic macrophyte assessment

Macrophyte snorkel surveys were conducted biweekly at the same times as the fish snorkel surveys (see above) with snorkellers randomly placing a 0.25 square meter quadrat in each 5 m section of each transect. Once the quadrat had been placed, species within the quadrat were identified, as well as the percent of the quadrat covered by each species. Identification was aided by the use of regional field guides including Spicer and Catling (1990). This sampling technique was conducted to determine seasonal patterns in macrophyte growth and assemblage structure. Repeated measures ANOVA were used to determine the differences in plant diversity and abundance between habitat types (with sampling period as the repeated variable) and over time (with location as the repeated variable). These tests focused on diversity indices (see below for calculations) and were completed in the same way as the fish data analyses.

Water quality assessment

Measurements of water quality were collected biweekly, coinciding with the swimming of the transects. Readings were taken, when possible, at the middle of each transect. For each transect the percent dissolved oxygen (and dissolved oxygen in mg per liter), conductivity and temperature were quantified using a handheld meter (YSI Model 85 Handheld Oxygen, Conductivity, Salinity and Temperature system). Turbidity readings were obtained using a turbidity meter (LaMotte 2020 turbidity meter). Water quality trends were analyzed across the ten snorkel survey periods and in the five primary habitat types. Repeated measures ANOVAs were used to assess differences in water quality between habitat types and over time (same analyses as for the plant and fish data).

Seine net sampling and other fish observations

Seine netting was used to identify different fish species that may not have been seen during snorkel surveys. A seine net measuring 4′ deep × 40′ long with a 4′ pocket and ¼ inch mesh was used bi-weekly at 10 different sites along the north side of the canal to capture fish (Fig. 1). The seine pulls covered a variety of habitat types so habitat specific analyses were not conducted. Generally the seine pulls were conducted between 8:00 am and noon. However, three seine sets were completed in the evening (starting at 9:00 pm) to ensure that we were not missing nocturnal species. After a seine pull, each fish captured was identified prior to release. Other observations such as reproductive status were also recorded when appropriate. In addition, we interviewed recreational anglers, conducted "research angling", and conducted visual surveys (i.e., looking through the air-water interface with polarized glasses) to supplement snorkeling and seine data, including one assessment in early April 2006 when we observed a winterkill event.

Diversity metrics

Raw data from fish and aquatic macrophytes (abundance of each species in each transect during each sampling period) was used to calculate diversity metrics. First, species richness, defined as the total number of different species present, was determined. Next, we calculated the Shannon-Wiener index of diversity (H) using the methods described by Krebs (1989). The Shannon-Wiener index incorporates species richness and the proportion of each species (Peet 1974). Additionally, we calculated evenness (E; Krebs 1989) which is a measure of the similarity of the abundances of different species (Washington 1984). We also determined the abundance of fish and macrophytes, which was a summation of the number of fish or macrophytes observed during a single sampling event. All diversity metrics were calculated using the MS Excel freeware program Diversity Tools (John Hanks, Texas, USA).

Results

Habitat assessment

Habitat mapping and assessment during low water periods (i.e., prior to canal filling) revealed that the littoral zone had 18.7±27.3% overhead cover (range of 0% to 100%). The majority of the overhead cover was provided by trees in the Agriculture Canada Arboretum. In-water cover (in the form of large woody debris or boulders) was reasonably sparse. Mean number of boulders and large woody debris per 100 m stretch of shoreline was 8.7±15.2 pieces (range 0 to 82). Wall habitats tended to have the least amount of in-water cover. Across all sites, the average percentage of different substrate types was as follows: 32% silt, 14% sand, 24% gravel, 17% cobble/riprap, and 13% boulder fields.

Water quality

The dissolved oxygen saturation and actual concentration of dissolved oxygen (i.e., mg/l) both varied throughout the study season (% Saturation, df=6, F-ratio=10.68, $P<0.001$; Dissolved Oxygen, mg/l, df=6, F-ratio=21.02, $P<0.001$) and by habitat type (% Saturation, df=3, F-ratio=9.29, $P<0.001$; Dissolved Oxygen, mg/l, df=3, F-ratio=5.67, $P=0.001$; Table 1) and there were no significant interactions (when analyzed by a repeated measures ANOVA). However, saturation was almost always above 100% throughout all habitat types and across all study periods, except during the seventh sampling period (early August). Generally, oxygen levels were highest in gravel habitats and were significantly lower in the silt habitats. There was a steady decreasing trend in conductivity throughout the study season, from approximately 650 microSiemens/cm in May to approx. 400 microSiemens/cm in late September (Table 1). The conductivity varied by habitat type (df=3, F-ratio=8.32, $P<0.001$) and by sampling period (df=6, F-ratio=71.07, $P<0.001$) and there were no significant interactions (when analyzed by a repeated measures ANOVA). Generally, conductivity was highest in boulder habitats and lowest in the rip-rap habitats. Turbidity was highly variable throughout the study period (Table 1). There was a significant interaction for turbidity between sampling period and habitat type

(F=1.66, $P<0.026$), with the highest turbidity readings occurring in areas with fine substrates like the silt/sand habitats. Turbidity was generally the lowest in gravel habitats. There is no overall temporal trend in turbidity, although turbidity in the silt/sand habitats increased over the study period. The water temperature varied by habitat type (df=3, F-ratio=10.33, $P<0.001$) and by sampling period (df=6, F-ratio=565.9, $P<0.001$) and there were no significant interactions (when analyzed by a repeated measures ANOVA). Water temperature was slightly higher in gravel habitats, but varied by less than 1°C between habitat types on any given sample date (Table 1). Temperature trends followed what would typically be expected, peaking around mid-summer then falling in late summer and early fall (Table 1). The highest water temperature was recorded on July 19, reaching 31.2°C.

Fish community dynamics

During snorkeling transects, 2,277 individual fish were encountered representing 12 species. In general, snorkel surveys and seine data showed a relatively simple fish community, dominated by centrarchids. The most common species encountered were bluegill and pumpkinseed. For the purpose of analysis, both species were combined as "lepomids" because juvenile bluegill and pumpkinseed are difficult to identify while snorkeling. There were 1,967 lepomids observed representing more than 86% of all observations. In fact, if one considers all centrarchids (i.e., lepomids, rock bass, smallmouth bass, largemouth bass, and black crappie) collectively, they represented 2,176 of all observations (95.5%). Most non-centrarchids were encountered infrequently and included brown bullhead (*Ameiurus nebulosus*), muskellunge (*Esox masquinongy*), yellow perch (*Perca flavescens*), log perch (*Percina caprodes*), golden shiner (*Notemigonus crysoleucas*), and common carp (*Cyprinus carpio*). Seine netting allowed smaller species to be caught and observed, however on several occasions larger species like common carp and northern pike *(Esox lucius*) were captured. Several species that were recorded during seine sampling were not seen at all during snorkel surveys, such as white suckers (*Catostomus commersoni*), northern pike, brook silverside (*Labidesthes sicculus*) and bluntnose minnows (*Pimephales notatus*), while other species like brown bullhead were observed several times during seine sampling, but only on one occasion during snorkel surveys (Table 2). Seine data was not analyzed for diversity metrics for this paper, but similar to snorkeling data, centrarchid fishes were the dominant fish species encountered (Fig. 2). In total, 2,068 fish were captured and enumerated during the 10 sampling days across 10 sampling sites. There were 15 species that were encountered during the sampling but their abundance/frequency of encounter varied substantially. Six of the species that were encountered were centrarchids (i.e., bluegill, pumpkinseed, black crappie, rock bass, smallmouth bass, largemouth bass) which dominated the overall catch (87.6% or 1,811 of 2,068 fish were centrarchids; Fig. 2). In fact, bluegill alone comprised more than 50% of the total catch with pumpkinseed comprising an additional 26% of the total catch (Fig. 2). None of the 17 fish species observed (see Table 2) in the study area are considered imperiled in Canada or offered any unique protection under the Species at Risk Act. A minor fish kill in winter 2006 (i.e., winterkill) was evident in April 2006 when conducting initial habitat surveys which provided an unique opportunity to obtain additional information on fish community composition (see Table 2).

Fish diversity metrics during snorkeling surveys showed some variation between habitat types (Table 3). There was a significant interaction in the Shannon-Wiener diversity index between time of sampling and habitat (F=1.80, $P=0.018$). In general, gravel and wall

Table 1 Seasonal water quality trends for dissolved oxygen (DO; in% saturation and mg/l), conductivity (cond. in mS), turbidity (turb. NTU), and water temperature (temp. °C) relative to different habitat types. Habitats were categorized as boulder (B), gravel/cobble (G), silt/sand (S), riprap/gabion baskets (R), and canal wall (W). Data represent means ± 1 SE

Date	Habitat type	N	Mean DO (% Sat)	SE DO (%)	N	Mean DO (mg/l)	SE DO (mg/l)	N	Mean Cond (mS)	SE Cond (mS)	N	Mean Turb (NTU)	SE Turb (NTU)	N	Mean Temp (°C)	SE Temp (°C)
May-11	B	5	118	3	5	11.4	0.1	0	NA	NA	5	2.7	0.3	3	16.0	0.1
May-11	G	6	123	5	6	11.8	0.3	0	NA	NA	6	1.9	0.2	6	15.9	0.1
May-11	R	4	125	1	4	11.8	0.2	0	NA	NA	4	3.3	0.2	1	15.9	NA
May-11	S	4	127	7	4	12.3	0.8	0	NA	NA	4	3.9	0.4	2	16.4	0.3
May-11	W	7	119	3	7	11.6	0.2	0	NA	NA	7	1.9	0.2	4	15.5	0.1
May-24	B	5	131	5	5	12.8	0.4	5	648	35	5	5.1	0.4	5	16.6	0.3
May-24	G	6	136	1	6	12.7	0.3	6	703	10	6	7.0	1.2	6	17.3	0.2
May-24	R	4	122	7	4	12.3	0.9	4	553	56	4	4.5	0.4	4	15.7	0.7
May-24	S	4	133	9	4	13.0	0.7	4	697	65	4	9.5	3.2	4	16.5	0.3
May-24	W	4	140	2	4	13.3	0.1	4	721	39	4	3.4	0.1	4	17.6	0.3
Jun-6	B	5	112	8	5	10.1	0.9	5	613	39	5	3.1	0.4	5	23.3	0.5
Jun-6	G	6	148	8	6	12.1	0.5	6	644	17	6	2.7	0.2	6	24.5	0.3
Jun-6	R	4	116	7	4	10.1	0.4	4	489	36	4	2.9	0.3	4	22.5	0.4
Jun-6	S	3	146	40	3	12.1	3.2	3	603	38	3	2.5	0.0	3	23.3	0.5
Jun-6	W	4	119	8	4	10.1	0.9	4	646	10	4	2.7	0.4	4	25.4	0.2
Jun-19	B	5	115	10	5	10.0	0.8	5	583	28	5	4.1	2.1	5	23.5	0.4
Jun-19	G	6	140	5	6	11.7	0.3	6	570	5	6	2.1	0.5	6	23.6	0.2
Jun-19	R	4	118	12	4	10.0	1.0	4	487	24	4	2.9	0.5	4	23.1	0.3
Jun-19	S	4	118	10	4	10.0	0.9	4	571	23	4	4.9	1.5	4	23.2	0.3
Jun-19	W	4	133	3	4	11.5	0.2	4	575	5	4	1.6	0.1	4	23.2	0.0
Jul-5	B	5	149	16	5	12.2	1.2	5	506	24	5	2.2	0.8	5	24.7	0.6
Jul-5	G	6	152	7	6	12.6	0.5	6	482	15	6	1.1	0.4	6	25.2	0.3

Jul-5	R	4	118	13	4	9.9	1.0	4	474	7	4	3.2	0.9	4	24.1	0.2
Jul-5	S	4	131	8	4	11.2	0.5	4	420	63	4	2.5	0.3	4	24.4	0.5
Jul-5	W	4	142	5	4	11.7	0.5	4	520	6	4	0.6	0.1	4	25.1	0.1
Jul-17	B	5	133	8	5	10.4	0.6	5	519	31	5	4.0	1.9	5	28.2	0.3
Jul-17	G	6	162	4	6	12.2	0.4	6	447	37	6	1.2	0.5	6	29.0	0.2
Jul-17	R	4	111	8	4	8.6	0.5	4	471	5	4	10.4	5.6	4	28.3	0.8
Jul-17	S	4	142	11	4	10.6	0.9	4	492	18	4	3.4	0.9	4	28.2	0.3
Jul-17	W	4	147	11	4	11.2	0.8	4	520	6	4	0.9	0.1	4	29.7	0.5
Aug-1	B	5	102	8	5	8.3	0.7	5	436	23	5	5.7	3.2	5	26.2	0.4
Aug-1	G	6	107	6	6	8.2	0.4	6	424	12	6	1.4	0.4	6	26.6	0.1
Aug-1	R	4	91	3	4	7.2	0.2	4	391	5	4	2.6	0.3	4	26.0	0.2
Aug-1	S	4	108	10	4	7.8	0.7	4	419	21	4	9.8	4.7	4	25.9	0.4
Aug-1	W	4	120	3	4	9.7	0.4	4	468	2	4	0.7	0.1	4	27.5	0.3
Aug-14	B	5	115	10	5	9.8	0.7	5	403	16	5	1.9	0.2	5	22.8	0.4
Aug-14	G	6	124	9	6	10.5	0.8	6	394	13	6	1.9	0.6	6	23.4	0.2
Aug-14	R	4	114	12	4	9.6	0.8	4	374	8	4	1.0	0.1	4	23.2	0.3
Aug-14	S	4	112	5	4	9.8	0.6	4	386	19	4	1.6	0.5	4	22.7	0.6
Aug-14	W	4	98	3	4	8.3	0.2	4	433	1	4	1.4	0.2	4	22.9	0.1
Aug-31	B	4	143	4	4	12.2	0.5	4	354	17	4	3.3	0.8	4	22.7	0.3
Aug-31	G	4	138	5	4	11.6	0.4	4	349	14	4	4.2	2.1	4	22.5	0.0
Aug-31	R	3	125	5	3	11.4	0.7	3	328	3	3	4.1	2.9	3	22.3	0.5
Aug-31	S	3	129	4	3	11.4	0.7	3	383	30	3	2.0	0.1	3	21.7	0.6
Sep-27	B	4	117	3	4	11.6	0.5	4	323	5	4	1.3	0.2	4	16.6	0.3
Sep-27	G	4	119	3	4	11.3	0.3	4	328	7	4	0.8	0.1	4	16.5	0.1
Sep-27	R	3	119	5	3	11.6	0.5	3	318	1	3	1.1	0.3	3	16.5	0.3
Sep-27	S	3	108	7	3	10.9	0.4	3	323	5	3	1.1	0.2	3	15.8	0.1

Table 2 Fish species observed in Dows Lake and the Rideau Canal through a variety of methods. Greyscale codes as follows; common (*black*), occasional (*dark grey*), rare (*light grey*), never (*white*)

Name		Methods of observation					
Common	Species	Snorkeling	Observed from surface (live)	Observed from surface (dead)	Seine Net	Verified Angler Catch	Unverified Angler Catch
Black crappie	*Pomoxis nigromaculatus*	dark grey	black	black	black	black	white
Bluegill	*Lepomis macrochirus*	black	black	black	black	black	white
Bluntnose minnow	*Pimephales notatus*	white	white	white	light grey	white	white
Brook silverside	*Labidesthes sicculus*	white	black	white	black	white	white
Brown bullhead	*Ameiurus nebulosus*	light grey	light grey	white	dark grey	white	white
Common carp	*Cyprinus carpio*	black	black	black	dark grey	black	white
Golden shiner	*Notemigonus crysoleucas*	white	white	dark grey	black	black	white
Largemouth bass	*Micropterus salmoides*	black	black	white	black	black	white
Log perch	*Percina caprodes*	dark grey	white	dark grey	white	white	white
Muskellunge	*Esox masquinongy*	light grey	white	light grey	white	dark grey	white
Northern pike	*Esox lucius*	white	white	light grey	light grey	white	light grey
Pumpkinseed	*Lepomis gibbosus*	black	black	black	black	black	white
Rock bass	*Ambloplites rupestris*	black	black	black	black	black	white
Smallmouth bass	*Micropterus dolomieu*	black	dark grey	white	dark grey	dark grey	white
Walleye	*Sander vitreus*	white	white	white	white	light grey	light grey
White sucker	*Catostomus commersoni*	white	white	white	dark grey	white	white
Yellow perch	*Perca flavescens*	black	black	dark grey	black	black	white

habitats had the highest levels of diversity (Table 3). Diversity tended to be higher during the 4th and 6th sampling periods corresponding to mid June and mid July. For evenness, there was no interaction between date of sampling and habitat (F=1.52, $P>0.05$), however there were significant differences for both of these factors independently. Evenness varied

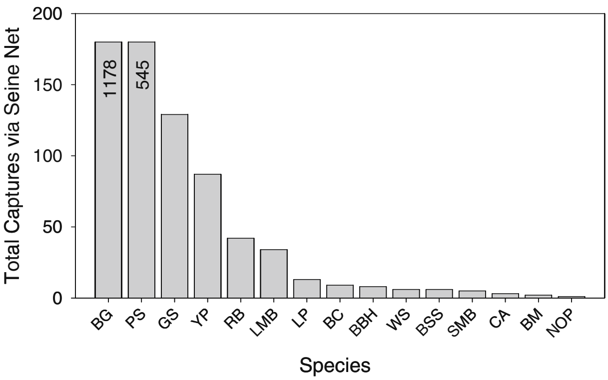

Fig. 2 Fish species encountered during seine net surveys across the study period. Seine net surveys were conducted at ten sites along the north side of Dows Lake (see Fig. 1). Species observed were bluegill (*BG*), pumpkinseed (*PS*), golden shiner (*GS*), yellow perch (*YP*), rock bass (*RB*), largemouth bass (*LMB*), log perch (*LP*), black crappie (*BC*), brown bullhead (*BBH*), white sucker (*WS*), brook silverside (*BSS*), smallmouth bass (*SMB*), common carp (*CA*), bluntnose minnow (*BM*) and northern pike (*NOP*)

among habitat types (F=3.014, P=0.031) with boulder and silt/sand substrates being the most even. There was also temporal variation in evenness (F=3.04, P=0.005) with evenness being highest early and late during sampling and lowest during the mid summer. There was no interaction between habitat type and time of sampling for total abundance (F=0.967, P>0.05) or a significant effect of time (F=1.72, P=0.102). However, abundance varied by habitat type (F=3.48, P=0.018) with highest fish densities observed in gravel and wall transect habitats. There was a significant interaction for the fish richness between time of sampling and habitat (F=2.30, P<0.0001). In general, gravel and wall habitats had the highest levels of richness (Table 3). Furthermore, richness was highest during the 4th, 5th, and 6th sampling periods corresponding to mid June through mid July.

Macrophyte community dynamics

At the beginning of the study season in early May, few plants were observed in the study areas. Young macrophytes and shoots began appearing in the middle of May, growing taller and thicker each week. The percent of each transect covered by macrophytes fluctuated throughout the study season, with silt/sand and gravel sites generally showing the most ground cover (Table 4). Percent cover in the silt habitats peaked drastically around July 10 with an average of 25.9% macrophyte coverage, declining as the season progressed. Wall habitats and rip-rap habitats showed a lot of fluctuation throughout the season. Both the gravel and boulder habitats showed peaks in plant coverage around the end of June (14.6% coverage and 10.7% coverage, respectively) and then again in the middle of September (7.9% coverage and 7.9% coverage, respectively), with lower levels between these times. These peaks correspond with the highest incidence of sago pondweed (*Potamogeton pectinatus*) at the end of June and Eurasian water milfoil (*Myriophyllum spicatum*) in mid-September.

Throughout the study season, the dominant macrophyte species fluctuated. From the middle of May to the end of June, the most common plant species found were needle spikerush (*Eleocharis acicularis*), which peaked in early June at an average of 11.3% coverage, and sago pondweed which peaked at an average of 21.3% coverage in mid-June (Table 4). Both species showed a decline in appearance after the middle of June. Between the end of June and the beginning of August, bushy pondweed (*Najas flexilis*) was common in many of the transects, with its occurrence peaking around July 10 with an average of 23.4% coverage. Eurasian water milfoil had a strong presence throughout most of the study season, but became especially prominent during the months of August and September, reaching on average 28.8% coverage across all habitat types (Table 4). This invasive species made up a large part of the vegetative cover in all study areas. Other species found in lower frequencies throughout the study areas were tape grass (*Vallisneria americana*), water stargrass (*Heteranthera dubia*), creeping spearwort (*Ranunculus flammula*), coontail (*Ceratophyllum demersum*), clasping-leaf (AKA Richardsons) pondweed (*Potamogeton richardsonii*), Canada waterweed (*Elodea canadensis*) and water bulrush (*Scirpus subterminalis*). None of the aquatic macrophytes observed in the study area are considered imperiled in Canada or offered any unique protection under the Species at Risk Act.

At the same time plant species began appearing, large algal blooms were observed in most of the study areas, covering the substrate and macrophytes as well as floating freely throughout most of Dows Lake. In early to mid-July, a thick layer of algae, small duckweed (*Lemna minor*) and dead, uprooted macrophytes consisting mainly of Eurasian water milfoil and sago pondweed covered a large area of Dows Lake. This thick, free-floating weed mat

Table 3 Diversity metrics for fish populations in Dows Lake and the urban reach of the Rideau Canal in Ottawa across different sampling periods and habitats. Habitats were categorized as boulder (B), gravel/cobble (G), silt/sand (S), riprap/gabion baskets (R), and canal wall (W). Diversity metrics include Shannon-Wiener diversity index (SW), evenness index (Even.), total abundance, richness, and% centrarchid fish. Data generated from snorkelling surveys conducted in different habitats. Data presented include means ± 1 SE

Date	Habitat	N	Mean SW	SE SW	Mean Even.	SE Even.	Mean Abund.	SE Abund.	Mean Richness	SE Richness	Mean% Centrarchids	SE% Centrarchids
May-11	B	5	0.094	0.094	0.886	0.114	2.20	1.46	1.00	0.32	75.0	25.0
May-11	G	5	0	0	1.000	0	3.40	2.42	0.80	0.20	100.0	0
May-11	R	4	0.212	0.212	0.973	0.027	2.00	1.35	1.00	0.41	100.0	0
May-11	S	3	0.604	0.174	0.702	0.083	6.00	0.58	2.33	0.33	93.3	6.7
May-11	W	4	0	0	1.000	0	3.75	3.09	0.75	0.25	100.0	0
May-24	B	5	0	0	1.000	0	4.00	2.02	1.00	0	100.0	0
May-24	G	6	0	0	1.000	0	9.83	8.07	0.67	0.21	100.0	0
May-24	R	4	NA	NA	NA	NA	0	NA	NA	NA	NA	NA
May-24	S	4	0	0	1.000	0	0.50	0.29	0.50	0.29	50.0	50.0
May-24	W	4	0.187	0.187	0.937	0.063	3.25	1.49	1.00	0.41	100.0	0
Jun-6	B	5	0.094	0.094	0.886	0.114	6.40	3.41	1.00	0.32	100.0	0
Jun-6	G	6	0.123	0.081	0.844	0.103	4.33	1.69	1.33	0.21	100.0	0
Jun-6	R	4	0.159	0.095	0.729	0.161	6.75	2.81	1.50	0.29	100.0	0
Jun-6	S	4	0.245	0.245	0.890	0.110	3.50	1.85	1.25	0.63	91.7	8.3
Jun-6	W	4	0	0	1.000	0	4.50	1.50	1.00	0	100.0	0
Jun-19	B	4	0.625	0.242	0.839	0.060	12.50	5.33	2.50	0.65	93.3	5.5
Jun-19	G	6	0.549	0.153	0.639	0.103	21.67	5.70	3.00	0.58	91.1	6.9
Jun-19	R	3	0.273	0.163	0.728	0.186	7.33	3.33	1.67	0.33	97.6	2.4
Jun-19	S	4	0.078	0.078	0.779	0.221	6.50	3.40	1.00	0.41	97.9	2.1
Jun-19	W	3	0.892	0.203	0.564	0.078	32.33	2.60	5.00	1.15	89.9	7.6
Jul-5	B	4	0.430	0.094	0.507	0.144	18.00	7.84	2.50	0.29	86.9	6.8
Jul-5	G	6	0.348	0.104	0.356	0.080	34.67	9.35	2.67	0.33	93.3	2.7

Jul-5	R	3	0.279	0.279	0.868	0.132	8.33	7.33	2.00	1.00	98.6	1.4
Jul-5	S	4	0	0	1.000	0	4.00	2.12	0.75	0.25	100.0	0
Jul-5	W	4	0.400	0.170	0.418	0.104	24.00	5.46	2.50	0.50	97.0	2.1
Jul-17	B	4	0.460	0.230	0.875	0.125	7.75	3.97	1.50	0.65	78.2	14.8
Jul-17	G	6	0.359	0.116	0.587	0.141	21.83	11.03	2.33	0.42	97.7	2.0
Jul-17	R	2	0.464	0.464	0.922	0.078	9.50	5.50	2.00	1.00	86.7	13.3
Jul-17	S	3	0.689	0.033	0.627	0.030	8.67	4.37	2.00	1.00	89.3	10.7
Jul-17	W	4	0.628	0.155	0.606	0.115	12.50	3.38	2.75	0.25	93.8	4.7
Aug-1	B	3	0	0	1.000	0	6.00	1.73	1.00	0	100.0	0
Aug-1	G	5	0.227	0.125	0.656	0.180	21.60	12.54	2.00	0.55	79.2	19.8
Aug-1	R	4	0.116	0.116	0.834	0.166	3.00	2.04	1.00	0.41	100.0	0
Aug-1	S	3	0.347	0.347	1.000	0	4.33	3.38	1.00	0.58	75.0	25.0
Aug-1	W	4	0.537	0.133	0.656	0.183	39.75	23.06	2.50	0.29	91.4	8.3
Aug-14	B	5	0.418	0.148	0.649	0.114	14.00	2.07	2.20	0.37	93.8	3.8
Aug-14	G	6	0.509	0.172	0.858	0.084	10.50	4.32	2.17	0.40	79.9	9.8
Aug-14	R	4	0.610	0.265	0.806	0.168	16.25	7.66	2.50	0.50	99.3	0.7
Aug-14	S	4	0.151	0.151	0.968	0.032	16.75	4.33	1.25	0.25	92.6	7.4
Aug-14	W	4	0	NA	1.000	0	2.75	0.85	1.00	0	100.0	0
Aug-31	B	3	0	NA	1.000	0	6.00	1.73	1.00	0	100.0	0
Aug-31	G	5	0.450	0.169	0.647	0.160	21.60	12.41	2.60	0.51	95.0	3.9
Aug-31	R	4	0.116	0.116	0.834	0.166	3.00	2.04	1.00	0.41	100.0	0
Aug-31	S	3	0.347	0.347	1.000	0	4.33	3.38	1.00	0.58	75.0	25.0
Aug 31	W	4	0.378	0.180	0.676	0.193	39.50	23.19	2.25	0.48	99.8	0.2
Sep-27	B	4	0.254	0.132	0.867	0.173	3.75	2.12	1.50	0.25	97.5	0.6
Sep-27	G	4	0.262	0.202	0.774	0.182	14.75	2.08	1.75	0.43	90.7	7.1
Sep-27	R	3	0	NA	1.000	0	2.60	1.10	1.00	0	100.0	0
Sep 27	S	3	0.316	0.155	0.791	0.169	7.00	1.78	1.66	0.33	73.3	8.4

Table 4 Summary of macrophyte presence (as mean% cover) in during snorkel surveys in Dows Lake and the urban reach of the Rideau Canal in Ottawa across different sampling periods and habitats. Habitats were categorized as boulder (B), gravel/cobble (G), silt/sand (S), riprap/gabion baskets (R), and canal wall (W)

Date	Habitat type	N	Mean total% cover	Mean% cover of primary species*								
				EM	SP	TG	WS	CS	BP	NS	CT	Other
May-11	B	5	0.3	0	0	0	0	0	0	0.32	0	0
May-11	G	6	1.3	0	0	0	0	0	0	1.30	0	0
May-11	R	4	0	0	0	0	0	0	0	0	0	0
May-11	S	4	1.7	0	0	0	0	0	0	1.75	0	0
May-11	W	4	0.6	0	0	0	0	0	0	0.65	0	0
May-24	B	5	0	0	0	0	0	0	0	0	0	0
May-24	G	6	0	0	0	0	0	0	0	0	0	0
May-24	R	4	0.1	0	0	0	0	0	0	0.05	0	0
May-24	S	4	0	0	0	0	0	0	0	0	0	0
May-24	W	4	0	0	0	0	0	0	0	0	0	0
Jun-6	B	5	3.6	0	0	0.72	0	0	0.16	2.76	0	0
Jun-6	G	6	3.7	0	0.23	0.07	0	0	0.07	3.37	0	0
Jun-6	R	4	3.6	0.05	0	0.05	0	0	0	3.50	0	0
Jun-6	S	4	15.7	0	14.60	0.80	0	0	0	0.30	0	0
Jun-6	W	4	5.5	0	0.35	0	0	3.75	1.00	0.40	0	0
Jun-19	B	5	10.7	0.24	2.12	1.84	3.92	0.08	2.28	0.08	0	0
Jun-19	G	6	14.5	3.77	5.33	0.23	1.70	0.37	3.17	0	0	0
Jun-19	R	4	2.1	0.2	0.05	0.55	0	0	1.35	0	0	0
Jun-19	S	4	20.9	0.05	16.35	4.45	0	0	0.05	0	0	0
Jun-19	W	4	2.6	0.05	0.20	0	0.05	1.1	1.15	0	0	0
Jul-5	B	4	8.0	2.00	2.25	1.05	0	0	2.60	0.05	0.05	0
Jul-5	G	6	10.3	1.17	1.10	0	0	0	8.13	0	0	0
Jul-5	R	4	4.7	0.45	1.10	0.05	0.50	0	2.50	0	0.10	0

Jul-5	S	4	25.9	7.75	4.75	12.55	0	0.25	0.10	0	0.25	0
Jul-5	W	4	8.5	0.15	0.10	0	0	0	8.15	0	0.05	0
Jul-17	B	5	7.4	1.72	4.28	1.00	0.08	0	0	0	0.40	0
Jul-17	G	6	7.9	3.60	2.67	0.10	0.27	0	1.27	0	0	0
Jul-17	R	4	4.8	0.40	2.25	1.25	0.40	0	0.50	0	0.05	0
Jul-17	S	4	14.6	0.55	0.25	13.35	0.15	0	0	0	0.30	0
Jul-17	W	4	4.3	0.60	0.70	0	0.25	0	2.65	0	0.10	0
Aug-1	B	5	6.2	0.88	3.76	0.20	1.16	0	0.12	0	0.12	0
Aug-1	G	6	7.6	2.90	1.40	0	1.27	0	1.87	0	0	0.23
Aug-1	R	4	8.2	0.40	2.95	0.05	2.15	0	2.25	0	0.45	0
Aug-1	S	4	10.1	0.80	0.05	5.10	2.70	0.05	1.20	0	0.25	0
Aug-1	W	4	4.4	0.70	1.15	0	0.60	0	1.65	0	0.35	0
Aug-14	B	5	10.7	2.68	0.04	4.72	3.28	0	0	0	0.04	0
Aug-14	G	6	4.8	3.67	0.33	0.07	0.70	0	0	0	0.07	0
Aug-14	R	4	1.6	0.60	0.20	0.30	0.20	0	0	0	0.05	0.25
Aug-14	S	4	8.2	0.65	0	6.60	0.75	0	0	0	0.15	0.10
Aug-14	W	3	5.8	1.27	0.20	0	4.00	0	0.27	0	0.07	0
Aug-31	B	4	10.4	2.00	0.20	0.25	8.00	0	0	0	0	0
Aug-31	G	4	15.5	14.75	0	0.25	0.50	0	0	0	0	0
Aug-31	R	2	5.9	0.10	0.30	4.30	0.20	0	0	0	0	1.00
Aug-31	S	3	8.1	1.00	0	3.00	4.10	0	0	0	0	0
Sep-27	B	4	2.0	1.70	0	0.25	0.05	0	0	0	0	0
Sep-27	G	4	8.5	7.35	0	0.60	0.60	0	0	0	0	0
Sep-27	R	3	2.2	0.73	0.07	1.33	0.07	0	0	0	0	0
Sep-27	S	3	4.8	3.47	0.20	1.00	0	0	0	0	0	0.20

EM Eurasian milfoil (*Myriophyllum spicatum*), *SP* sago pondweed (*Potamogeton pectinatus*), *TG* tape grass (*Vallisneria americana*), *WS* water stargrass (*Heteranthera dubia*), *CS* creeping spearwort (*Ranunculus flammula*), *BP* bushy pondweed (*Najas flexilis*), *NS* needle spikerush (*Eleocharis acicularis*), *CT* coontail (*Ceratophyllum demersum*) obscured five of the transects, and a visible change was observed in the macrophyte populations beneath the mat over the weeks following its appearance. The macrophytes became scarcer and patchier, and the smaller plants seemed to disappear.

To assess changes in the plant populations throughout the season, we looked at indices of diversity, richness and evenness. The Shannon-Wiener diversity index shows an increase in species diversity over time ($F=7.21$, $P<0.001$) in all habitat types, with diversity peaking in early August. However, there were no significant variances in macrophyte diversity between habitat types. There were significant differences in evenness over the study period across all habitat types ($F=6.82$, $P<0.001$). Generally, evenness increased as the sampling season progressed, with a small decrease during the 6th sampling period near the end of July. Evenness did not show any significant differences between habitat types ($P>0.05$), and no one type showed any more consistency than the others. Richness showed significant variation over the study season within all habitat types ($F=41.47$, $P<0.001$), increasing in each habitat type as the season progressed. Macrophyte richness peaked around the beginning of August, with a small decline during the sample periods after that. No single habitat type consistently showed a higher degree of species richness than any other over the sample season.

Discussion

The Rideau Canal system may seem like an unsuitable habitat for fish species usually found in rivers, as the canal lacks a constant current and downstream flow and has relatively homogeneous substrate composition with many silty areas. However, studies done on other canal systems around the world indicate that canal habitats are very similar to lowland river habitats, and can in fact support a wide variety of species (Arlinghaus et al. 2002; Borcherding et al. 2002; Poulet et al. 2005). This was clear in our study, as we observed 17 of the 30 species of fish commonly found in the Ottawa region (Poulin 2001). Most of the fish species observed in our study were considered to be warm water species, and characteristic of lentic water bodies in eastern Ontario (McAllister and Coad 1975). The only invasive fish species to be found in reasonable numbers were common carp. We found no evidence of the invasive round goby (*Neogobius melanostomus*) which has become prevalent in the Trent-Severn Waterway (Lee Gutowski, Trent University, Unpublished Data), another warmwater canal system operated by Parks Canada in Ontario.

The littoral zones of lakes are generally known to contain many different habitat types or habitat patches, consisting of macrophyte beds, rocky substrates, gravel substrates or woody debris that may vary spatially and temporally (Brind'Amour and Boisclair 2006). As a result, it would be expected that fish communities would vary as well. It would also be expected that habitats with more complex or heterogenous substrate structures, such as woody debris, boulders or extensive macrophyte cover would have a greater species richness, diversity and abundance because they allow for better foraging, refuge, and spawning habitat (Bonaca and Lipej 2005; Brind'Amour and Boisclair 2006). However, our results indicated that species richness, diversity and abundance were generally higher in wall and gravel habitats which had a more homogenous substrate structure and generally less macrophyte cover. It is important to note, however, that turbidity was typically lowest in these habitats (i.e., wall and gravel), which provided greater visibility in these study areas (relative to silt habitats). Frequently during the sampling period, visibility was decreased to less than 0.75 m due to turbidity, making it nearly impossible to observe all species present within a transect. Turbidity was found to be greater in areas of high boat traffic (Walker and

Cooke, unpublished data) which can suspend fine sediments (Bauer 2002), or immediately following the filling of the canal in the spring or heavy rainfall. The invasive common carp may have also contributed to turbidity by resuspending fines in localized areas. High macrophyte density may have further decreased visibility for snorkelers and introduced some sampling error. It is possible that there were fish species present that were simply not observed due to the sheer amount of vegetation in some areas in which the fish could avoid detection. However, on days when turbidity was low across all habitat types, the pattern of fish diversity tended to mirror those during more turbid periods.

Water quality did not have a clear influence on fish and macrophyte populations. Dissolved oxygen levels remained generally high throughout the study season and were therefore, unlikely to have had a significant effect on fish populations. All fish observed during our sampling had minimum dissolved oxygen limits that were much lower than the lowest dissolved oxygen concentrations observed in this study (Davis 1975). Water temperature increased until mid-summer then decreased as is seasonally expected, and generally stayed within the known range of preferred temperatures for all species found in the study area (Wismer and Christie 1987; Coad 2007).

The fish species found throughout the study area were consistent with the type of fish usually found throughout this part of Ontario (McAllister and Coad 1975; Coad 2007). The system was dominated mostly by members of the family *Centrarchidae*, including bluegill sunfish (*Lepomis macrochirus*), pumpkinseed sunfish (*Lepomis gibbosus*), rock bass (*Ambloplites rupestris*), largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*). The bluegill and pumpkinseed sunfish were the most commonly seen during snorkel surveys, representing more than 86% of all observations. Collectively, centrarchids represented 95.5% of all individuals observed during snorkeling, while non-centrarchids were encountered infrequently. Pumpkinseed sunfish, bluegill sunfish and largemouth bass were commonly seen spawning during the study period, with many nesting sites observed within the transects. This centrarchid-dominated community structure is consistent with the shallow water and heavily vegetated sites observed in our study (Aday et al. 2009). In general, centrarchids tend to have little preference for substrate except during the reproductive period (Scott and Crossman 1973). Studies also show that centrarchids prefer areas where there is little current and relatively clear water (Theiling et al. 1997), which is also consistent with the Rideau Canal system. Other common fish in centrarchid-dominated systems are cyprinids (i.e., carp and minnows) and yellow perch which are all known to be lentic species (Leslie and Timmins 1997; Theiling et al. 1997; Wang et al. 2003). A study done by Arlinghaus et al. (2002) on fish communities in European canals indicated that many small fish species or younger individuals prefer habitats like bays or inlets that are more sheltered from outside disturbance, such as wakes from large boats or heavy currents flowing through straight portions of canals. These results are consistent with our observations that many fish species were found in areas of the lake where shorelines were not generally affected by boat traffic. Also, we observed many largemouth bass, pumpkinseed and bluegill nesting sites in Agriculture creek and Schramm Bay, two of the more sheltered areas in Dows Lake. Future studies should also sample fish in the deeper parts of Dows Lake where larger species like muskellunge (*Esox masquinongy*), northern pike (*Esox lucius*) and walleye (*Sander vitreus*) might routinely be found. Indeed, we observed these species on occasion but usually in angler creels (Table 2). The muskellunge that reside in Dows Lake and the Rideau Canal represent one of the few urban muskellunge fisheries in the world (Kerr 2007; Gillis et al. 2010). In fact, the reach that was studied here provides many urban angling opportunities in the City of Ottawa for a range of species that are appropriate for anglers with different levels of specialization and experience. Urban angling opportunities are regarded as providing important societal benefits (Manfredo et al. 1984) and increase the value of the Rideau Canal system.

Macrophyte composition did not vary significantly across habitat types, but varied temporally over the summer. The lack of relationship between substrate type and macrophyte community and diversity likely reflects the fact that some organic matter was present in all habitats providing opportunity for plants to root and grow (Aiken and Picard 1980). The dominant plant species changed several times over the study period, a trend previously documented in the adjacent Rideau River (Poulin 2001). In Dows Lake, smaller plant species were dominant throughout the spring and early summer, while larger macrophytes started appearing in early June. This shift in dominance of different sized species (i.e., progression from smaller to larger species) coincided with the appearance of a large weed mat over most of the study area, consisting mainly of uprooted Eurasian water milfoil, sago pondweed, small duckweed and filamentous green algae. The weed mat blocked sunlight from reaching the bottom of the lake, which apparently killed most of the small plant species (Walker, Personal Observation). The high density of aquatic macrophytes observed in the Rideau Canal may be reflective of the high phosphorus levels in Ottawa reach of the adjacent Rideau River (Poulin 2001) which feeds directly into the canal approx. 1.5 km upstream of our study site. Although we did not measure nutrients in this study, nutrient enrichment has previously been identified as one of the problems facing the Rideau Canal (Wachelka et al. 2000). One of the most abundant species found throughout the entire lake was Eurasian water milfoil. In fact, Eurasian water milfoil has previously been documented as the dominant aquatic macrophyte in a system-wide study in the Rideau in 1987 (Spicer and Catling 1990). Eurasian water milfoil is an invasive species that originated in Europe and Asia and has been in the Rideau system since the mid 1960s (Aiken et al. 1979) and has been known to out-compete local aquatic macrophyte populations (Aiken et al. 1979; Boylen et al. 1999). The dense weed beds and mats in the Rideau Canal can impede navigation and therefore, various agencies have attempted to control aquatic macrophytes in the Rideau Canal. Initially macrophyte control focused on herbicide application (until 1979; RVCA 1979) but more recently management agencies have relied on mechanical harvesting (Spicer and Catling 1990) and broader efforts to reduce nutrient inputs.

Overall, the fish community structure in Dows Lake and the urban stretch of the Rideau Canal was found to be relatively simple, and contrary to our prediction, fish diversity was reasonably consistent across all habitat types. Because much of the Rideau Canal in urban environments is characterized by distinct engineered wall habitats and other simple habitats (e.g., rip rap), there is opportunity to enhance structural diversity and potentially enhance biological diversity in the Canal. At present, the annual drainage of the canal, the need to maintain open navigation channels (and associated removal of woody debris), and manicured or urbanized riparian zones are all potentially limiting structural complexity in the littoral zone and represent a somewhat unique series of stressors compared to other centrarchid-dominated systems (Cooke et al. 2009). In addition, there is some evidence of winterkills (one in spring 2006 during this study) which are common phenomena in lentic systems in north temperate regions (Suski and Ridgway 2009). Obviously, any management activities intended to enhance diversity would need to be consistent with other Parks Canada objectives such as those dealing with culture, recreation, navigation, and heritage. Because Parks Canada is mandated to protect ecosystem features in the Rideau Canal that relate directly to the construction of the canal because of their historic and natural value (Parks Canada 2005), there is a need for creative techniques to enhance the complexity of these habitats without altering their historical value or engineering function. Another pressing issue in this reach of the canal is the dense macrophyte beds that impair navigation (Parks Canada 2005). The use of mechanical harvesting to control aquatic macrophytes and maintain open navigation channels is not a long-term solution. As such, there is a need to reduce nutrient inputs from upstream regions and from urban storm water infrastructure to reduce the density of aquatic macrophytes. Indeed, reductions of nutrient inputs and associated decreases in macrophyte biomass could also reduce the frequency and severity of fish kills (Suski and Ridgway 2009). Regular monitoring of the state of the Rideau Canal ecosystem, particularly in this urban reach, would be beneficial for evaluating long-term trends in ecosystem health and diversity. Considering the national significance of this historic Canal, there is need for more intensive study of the aquatic ecology of the Rideau Canal in its entirety including evaluations of different operational activities (draining, filling) and the connectivity of different reaches between the 47 locks.

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