The Gananoque River Watershed Community Stewardship Project: Phase 2

A Partnership Project Led By The Algonquin To Adirondacks Conservation Association

2009-2010

Report prepared by:
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Algonquin to Adirondacks Conservation Association

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Executive Summary

The Gananoque River watershed is located in eastern Ontario in the Algonquin to Adirondacks region between Algonquin Provincial Park in Ontario and Adirondacks State Park in New York. This region is rich in biodiversity and represents a crucial pathway for wildlife between the two parks. Thus, maintaining and improving the ecological integrity of the area is of utmost importance for all organisms, including humans. People rely on healthy ecosystems for many reasons, including access to clean drinking water and recreational enjoyment of nature, such as fishing and hiking. Stewardship of lakes by local landowners is a vital part of achieving the goal of ecosystem health in this region.

This is the second year of the multi-year *Gananoque River Watershed Community Stewardship Project* led by the Algonquin to Adirondacks Conservation Association (A2A). The *Phase 2 Report* expands upon the knowledge gained in Phase 1 and encompasses the same three areas of study in the Gananoque River watershed: 1) fish and turtle inventory, with an emphasis on species at risk; 2) water quality data; and 3) shoreline surveys. The scientific data collected for this project contribute to a comprehensive baseline understanding of the state of the Gananoque River watershed, and allow A2A and its partners to identify opportunities for stewardship. In future years, A2A plans to extend the project to the remaining lakes in the Gananoque River watershed, with the exception of Charleston Lake, which has a lake plan already in place.

Fish Inventory in Gananoque Lake

During Phase 1, seine hauls were conducted at Lower Beverley Lake to inventory the fish species present. Data were also collected from turtle species caught as by-catch. In Phase 2, seine hauls were carried out at Gananoque Lake in partnership with the Ontario Ministry of Natural Resources, which also provided A2A with fish inventory data from a Nearshore Community Index Netting (NSCIN) program.

2822 fish, comprised of 14 species, were caught in 18 traps set by the NSCIN program. 58 turtles, representing 4 species, were also caught as by-catch. 4731 fish and 6 turtles were caught in the seine hauls. In analyses assessing fish-habitat associations, young-of-year fish were more likely to be found in areas of high vegetative cover, emphasizing the need for healthy aquatic vegetation in nearshore areas for fish habitat.

Nine individuals of two fish species at risk were caught: one American Eel (*Anguilla rostrata*) in the NSCIN program and 8 Grass Pickerel (*Esox americanus vermiculatus*) in the seine hauls. Three turtle species at risk were caught: Northern Map Turtle (*Graptemys geographica*), Snapping Turtle (*Chelydra serpentina*) and Stinkpot Turtle (*Sternotherus odoratus*).

The integrity of the fish community was also assessed. One invasive species, the Common Carp (*Cyprinus carpio*), was collected during the inventories. Common carp is detrimental to ecosystems, because it can replace native fish and reduce habitat quality.

Fortunately, only two Common Carp individuals were caught.

Shoreline Surveys of Gananoque Lake and South Lake

Healthy natural shorelines composed of native vegetation are particularly important for both water quality and habitat availability. The shoreline of Lower Beverley Lake was surveyed in 2008 for Phase 1. In 2009, 138 properties at Gananoque Lake and 38 properties at South Lake were assessed. Shoreline and upland characteristics were surveyed, and opportunities for restoration were identified. South Lake had a more natural shoreline than Gananoque Lake (93% vs. 77% natural shoreline). As well, South Lake had fewer built structures, less aquatic vegetation cover of invasive species, fewer groomed grasses and more canopy cover at the shoreline than Gananoque Lake. These data will be used to provide property-specific stewardship information packages for local landowners. Landowners will be encouraged to maintain a natural buffer strip of native plants at the shoreline to provide habitat for plants and animals, reduce erosion problems, and absorb run-off nutrients, such as phosphorus.

Water Quality of the Gananoque River watershed

A wide variety of historical water quality data was collected for the Gananoque River watershed in an effort to consolidate existing knowledge. In recent reports, the Cataraqui Region Conservation Authority and the Ontario Ministry of the Environment (OMOE) have indicated that the water quality in the watershed is generally good. The MOE 2010 report (see Online Appendix 3.1) suggests that elevated total phosphorus is the main problem affecting the watershed. Too much phosphorus can result in algal blooms, which can lead to a reduction in oxygen available to aquatic organisms. OMOE Lake Partners data also showed high levels of total phosphorus in the watershed. Five lakes in the watershed reported high levels of phosphorus (>20 µg/L) in at least 65% of years between 2002 and 2009. Unfortunately, none of these lakes were experiencing declining phosphorus levels during this time. Landowners can reduce phosphorus inputs to their lakes by ensuring that septic systems do not leak and by avoiding the use of phosphate-containing fertilizers.

Acknowledgements

The Algonquin to Adirondacks Conservation Association wishes to acknowledge and express thanks to the many volunteers from the community who helped with so many aspects of the projects and the following partnering organizations that provided volunteers, materials, expertise and good advice for the *Gananoque River Watershed Community Stewardship Project: Phase 2*:

Cataraqui Region Conservation Authority
Centre for Sustainable Watersheds
Charleston Lake Association
Department of Fisheries and Oceans
Elizabethtown-Kitley Township
Frontenac Arch Biosphere
Gananoque River Waterways Association
Griffin's Lakeside Cottages and Lodge
Leeds and the Thousand Islands Township
Leeds County Stewardship Council
Lower Beverley Lake Association
Mohawk Council of Akwesasne
Ontario Fur Managers
Ontario Ministry of the Environment
Ontario Ministry of Natural Resources
Ontario Nature
St. Lawrence Islands National Park
Shawmere
South Lake Association
Thousand Islands Community Development Corporation
Upper Beverley Lake Residents

A2A also wishes to gratefully acknowledge Environment Canada's Science Horizons Program in conjunction with the Township of Leeds and the Thousand Islands and the Thousand Islands Community Development Corporation, which helped to fund analysis and writing of this report, and the Evergreen Foundation, which provided funding for the planting workshop on Lower Beverley Creek. We also wish to thank the Gananoque River Waterways Association, the Leeds County Stewardship Council and the Lower Beverley Lake Association for their financial support, as well as individual donors who helped fund the project, particularly Ed Lowans of Lowans and Stephens, who made possible the hiring of a student to conduct the shoreline surveys and Chuck Shaw of Shawmere, who has volunteered his help, boats and motors to keep the project on the water.

Table of Contents

List of Figures and Tables

1. Fish and Turtle Inventory of Gananoque Lake

Introduction

Inventory data on species at risk can provide crucial information on the presence and abundance of species in previously unconfirmed or unknown regions. This information can then be used for implementing recovery and stewardship activities for these species. The Gananoque River watershed is deficient in recent inventory data, particularly for species at risk. An inventory of nearshore fish was conducted in Gananoque Lake in 2009 in an effort to provide these important data, as well as an assessment of the Gananoque Lake community. Turtles caught as by-catch were also noted. This information can then be used as a baseline for evaluation in future years, and to provide stewardship suggestions for the landowners on Gananoque Lake.

Methods

Field Methods

Two types of netting programs were conducted in the summer of 2009: 1) trap nets using the Nearshore Community Index Netting (NSCIN) protocol and 2) seine nets. Algonquin to Adirondacks Conservation Association (A2A) partnered with the Ontario Ministry of Natural Resources (OMNR) to carry out the seining program. The OMNR independently conducted the NSCIN program, and the data from this work have kindly been provided to A2A for analysis and inclusion in this report. All fish caught in these programs were released back into the lake.

The NSCIN program assesses the fish community in the nearshore zone of Ontario Lakes. Protocol followed the Ontario Ministry of Natural Resources' *NSCIN Manual* by Mark Stirling (1999). Trap nets were set 18 times in 18 different random locations between August 4 and August 12, 2009. Traps were set for 20 to 25 hours. For the first 20 fish of each species caught in each sample, fork length and weight were measured, and a scale was collected for determining age. Fish collected beyond the first 20 individuals were simply tallied. Mesh for the traps are a size such that the smallest fish caught was 91 mm in fork length. As well, particularly large fish would have been excluded, because the opening to the tunnel entrance is 25 x 25 cm. Local environmental conditions were noted for each sample, including air and water temperature, precipitation, and cloud cover. Substrate (e.g., sand, soft mix, bedrock, etc.) and cover categories (no cover, low, moderate or high cover for fishes) were also noted. More specific habitat details, such as percent vegetative cover or plant presence, were not described.

A total of 56 seine hauls were completed between July 2 and July 30, 2009. This netting protocol assesses small fish communities and critical fish nursery habitat. Fork length was measured for each of the first 20 fish of each species for each seine haul. Any additional fish were simply counted, as in the NSCIN program. Whether or not an individual was young-of-year (YOY) was also recorded. Young Bluegill (*Lepomis macrochirus*) and Pumpkinseed (*Lepomis gibbosus*) could not be distinguished from one another and so were combined into a "*Lepomis* species YOY" category. The type of seine (hand or boat seine), weather conditions, and air and water temperature were noted for each seine haul. Three habitat characteristics were also assessed: percent vegetative cover, plant species presence, and percent cover of each substrate type.

Turtles caught as by-catch in either netting program were identified and counted. The carapace and plastron of turtle species at risk were measured.

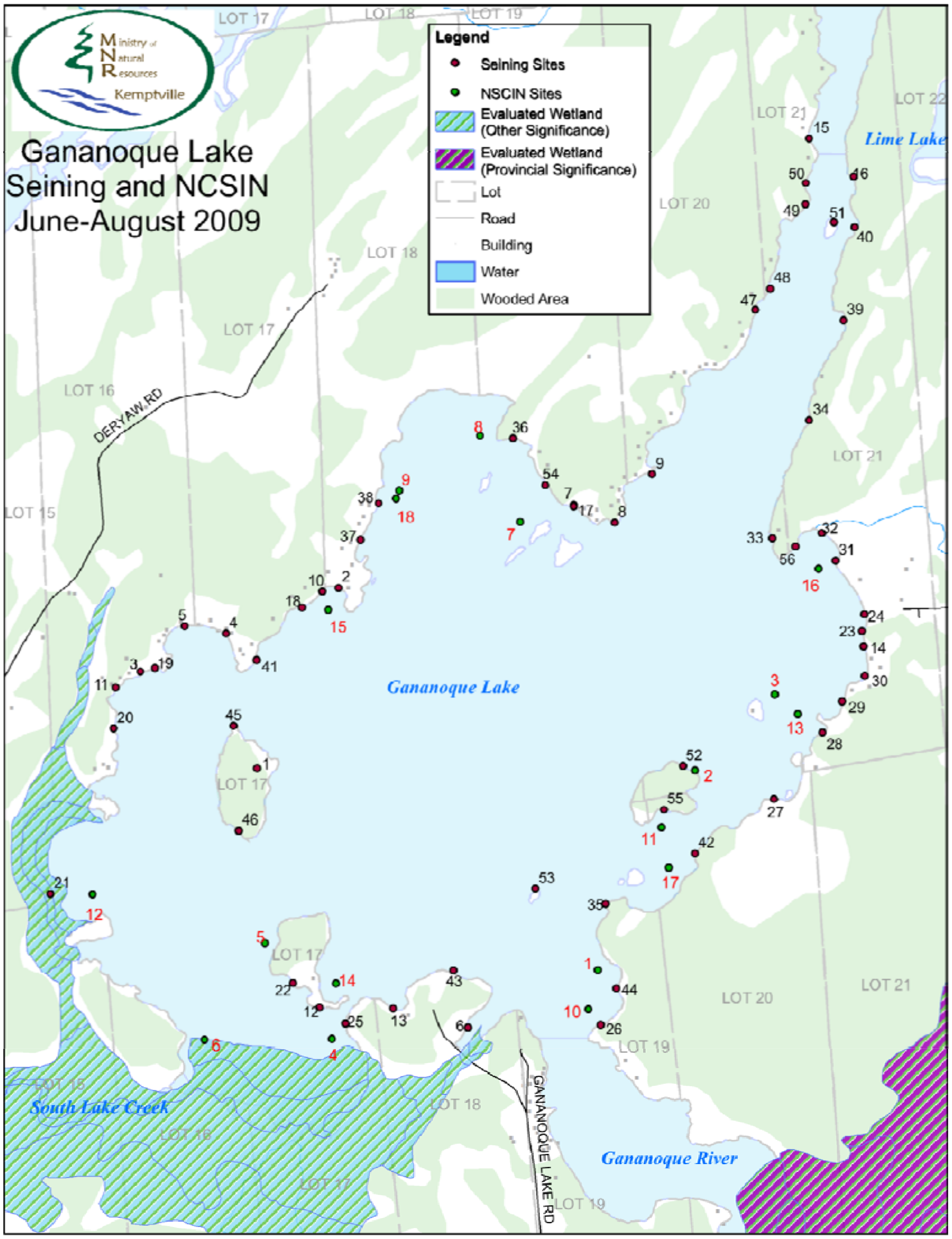


Figure 1.1: Seining and NSCIN sampling locations on Gananoque Lake.

Analyses

Figure 1.1 displays the locations of the seining and NSCIN sampling sites on Gananoque Lake. The number and percentage of all fish captured for both types of netting, as well as the young-of-year (YOY) fish collected during seine hauls, were summarized by species (Tables 1.1 and 1.2; Figures 1.2 and 1.3). The numbers of turtles caught were also included in Tables 1.1 and 1.2. The number of seine hauls in which a particular plant species was identified is depicted in Table 1.3.

All statistical tests were conducted using SAS statistical software. These analyses were used to provide an assessment of young-of-year fish and habitat relationships using the seine haul data. In particular, a variety of tests were used to determine whether vegetative cover, plant species richness (i.e., the number of species in a sample), and substrate cover was associated with the abundance, presence, and species richness of young-of-year (See Appendix 1.1a Methods for statistical details).

The species at risk found in the two netting programs are given particular attention in this report and an effort was made to assess their associations with other fish and plant species where possible (See Appendix 1.1b Methods for statistical details). Low sample sizes resulted in a reduced ability to use or interpret statistical analyses in most cases, particularly for the American Eel.

The integrity of the fish community was also investigated using a number of indicators that were suggested by recent studies (e.g., Trebitz et al. 2009a and Brazner 2007). Statistical techniques, however, could not be used for this area of inquiry, given that no baseline data were available for this lake. A list of the characteristics of each fish species caught is depicted in Table 1.4. Trebitz et al. (2009a) provided the information in Table 1.4 of each species.

Results and Discussion

Nearshore Community Index Netting (NSCIN) Program

In 18 trap nets set for the NSCIN program, 2822 fish were caught, representing 14 fish species (See Table 1.1; Figure 1.2). Four turtles species were collected (58 turtles in total). Bluegill (*Lepomis macrochirus*) and Pumpkinseed (*Lepomis gibbosus*) made up the majority of the fish caught (57.1 and 26.6%, respectively). The fish scales had not been assessed for age at the time of the writing of this report. In the future, this information can be used to assess the age structure of this community.

Table 1.1: Fish and turtles caught in NSCIN program.

Common name	Latin Name	# of individuals caught	Percentage of total catch (fish)	# of traps
Fish				
American Eel	*Anguilla rostrata*	1	0.03	1
Brown Bullhead	*Ameiurus nebulosus*	187	6.6	14
Black Crappie	*Pomoxis nigromaculatus*	50	1.8	17
Bowfin	*Amia calva*	68	2.4	14
Bluegill	*Lepomis macrochirus*	1612	57.1	18
*Common carp	*Cyprinus carpio*	2	0.07	1
Common White Sucker	*Catostomus commersoni*	3	0.1	2
Largemouth Bass	*Micropterus salmoides*	95	3.3	16
Northern pike	*Esox lucius*	18	0.6	9
Pumpkinseed	*Lepomis gibbosus*	750	26.6	17
Rock Bass	*Ambloplites rupestris*	14	0.5	7
Smallmouth Bass	*Micropterus dolmieu*	3	0.1	3
Yellow Bullhead	*Ameiurus natalis*	4	0.1	3
Yellow Perch	*Perca flavescens*	15	0.5	6
Turtles				
Northern Map Turtle	*Graptemys geographica*	16	.	9
Painted Turtle	*Chrysemys picta marginata*	5	.	4
Snapping Turtle	*Chelydra serpentina*	5	.	3
Stinkpot Turtle	*Sternotherus odoratus*	32	.	5

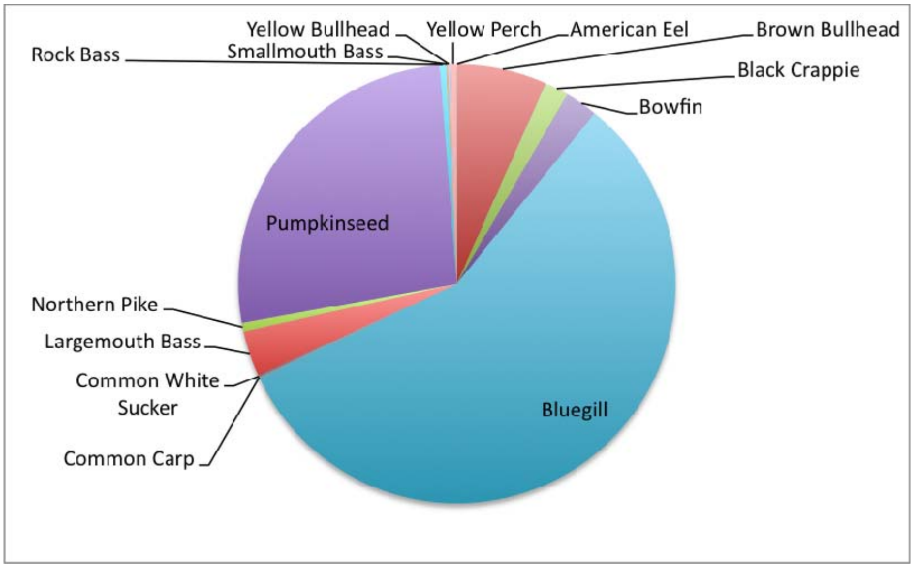


Figure 1.2: Proportion of fish caught by species in 18 NSCIN traps.

Seine Hauls and Nursery Habitat

4731 individuals were caught of 14 species in 56 seine hauls (see Table 1.1; Figure 1.3). Two turtle species were caught as by-catch: Painted Turtle (*Chrysemys picta*) and Stinkpot Turtle (*Sternotherus odoratus*). The most abundant species were Bluntnose Minnow (*Pimephales notatus;* 25.2% of fish caught), Bluegill (*Lepomis macrochirus*; 20.7%), Pumpkinseed (*Lepomis gibbosus;* 18.3%), and Yellow Perch (*Perca flavescens;* 10.3%).

Ten YOY species were caught in the seine hauls (presumably both Bluegill and Pumpkinseed YOY were caught at some point in the *Lepomis* spp category in this study; see Table 1.1; Figure 1.4). YOY comprised 23% of the total catch. The majority of YOY that were caught were Largemouth Bass (*Micropterus salmoides*; 46% of YOY) and Bluntnose Minnow (29.6% of YOY). Most of the Largemouth Bass and Northern Pike (*Esox lucius*) caught were YOY (89.2% and 72.7% of the catch of each species, respectively).

Detailed vegetative habitat features, including cover and plant species presence, were only assessed in the seine hauls. 20 plant groups were noted during seine hauls (14 were identified to the level of species; Table 1.4). Non-native plant species present included: European Frogbit (*Hydrocharis morsus-ranae*) and Eurasian Milfoil (*Myriophyllum spicatum*). Wild celery (*Vallisneria Americana*) was found in 95% of the seine hauls.

Vegetative cover and richness were positively associated with YOY presence and the number of YOY species (See Appendix 1.1a Results for further details). This finding is a common result with most other fish habitat studies (Bryan and Scarnecchia, 1992). Vegetation is essential for YOY because it provides protection from predators and areas for feeding, particularly through the increase in macroinvertebrate densities associated with aquatic plants (Pratt and Smokorowski, 2003). Vegetation also provides spatial isolation, which limits inter- and intra-specific competition and predation. The removal of nearshore vegetation can result in the reduction of YOY survival, which will in turn affect future recruitment (Bryan and Scarnecchia 1992). This information emphasizes the importance of stewardship of the shoreline, through actions such as maintaining nearshore aquatic vegetation.

Silt and detritus cover was the only substrate that was positively associated with YOY abundance (See Appendix 1.1a Results for further details). Silt and detritus cover was also positively associated with four YOY species separately (Banded Killifish, *Fundulus diaphanous;* Johnny Darter, *Etheostoma nigrum;* Largemouth Bass, and Yellow Perch).

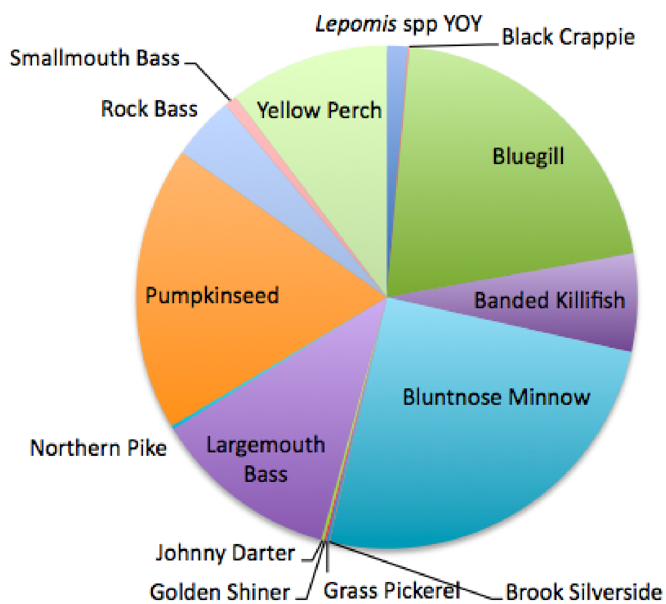


Figure 1.3: Proportion of fish caught by species in 56 seine hauls (includes all fish).

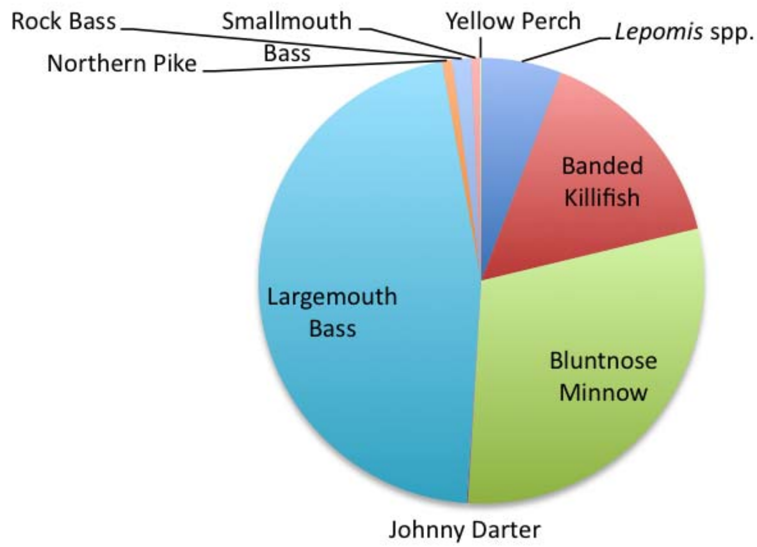


Figure 1.4: Proportion of young-of-year (YOY) fish caught by species in 56 seine hauls.

Table 1.2: Fish and turtle species caught in 56 seine hauls.

Common Name	**Latin Name**	***All Fish and Turtles***			***Young-of-Year***		
		# of individuals caught	**Percent of total catch (fish)**	**# of seines**	**# YOY caught**	**% of species YOY**	**% of total catch YOY**
Fish							
Black Crappie	*Pomoxis nigromaculatus*	5	0.11	3	0	0	0
Bluegill	*Lepomis macrochirus*	981	20.74	51	*Lepomis* spp. YOY	*Lepomis* spp. YOY	*Lepomis* spp. YOY
Banded Killifish	*Fundulus diaphanous*	299	6.32	30	169	56.52	15.36
Bluntnose Minnow	*Pimephales notatus*	1191	25.17	39	329	27.62	29.64
Brook Silverside	*Labidesthes sicculus*	2	0.04	2	0	0	0
Grass Pickerel	*Esox americanus vermiculatus*	8	0.17	6	0	0	0
Golden Shiner	*Notemigonus crysoleucas*	6	0.13	2	0	0	0
Johnny Darter	*Etheostoma nigrum*	9	0.19	7	1	11.11	0.09
Largemouth Bass	*Micropterus salmoides*	567	11.98	51	506	89.24	46.00
Northern pike	*Esox lucius*	11	0.23	8	8	72.73	0.73
Pumpkin-seed	*Lepomis gibbosus*	868	18.35	52	*Lepomis* spp. YOY	*Lepomis* spp. YOY	*Lepomis* spp. YOY
Rock Bass	*Ambloplites rupestris*	194	4.10	39	15	7.73	1.36
Smallmouth Bass	*Micropterus dolmieu*	37	0.78	18	7	18.92	0.64
Yellow Perch	*Perca flavescens*	489	10.34	50	1	0.20	0.09
Lepomis spp. YOY*	.	64	1.35	15	64	100	5.82
Turtles							
Painted Turtle	*Chrysemys picta marginata*	1	.	1	.	.	.
Stinkpot Turtle	*Sternotherus Odoratus*	5	.	4	.	.	.

**The category "*Lepomis *species young-of-year (YOY)" consists of Bluegill and Pumpkinseed YOY because YOY of these two species could not be distinguished.*

Table 1.3: Plant species found in seine hauls

Common Name	Latin Name	# of seines
Algae		46
Broad-leaved Arrowhead	*Sagittaria latifolia*	4
Arum	*Arum* spp.	3
Common Bladderwort	*Utricularia vulgaris*	13
Bulrush	*Scirpus* spp.	2
Giant Bur-reed	*Sparganium eurycarpum Engelmann*	15
Stonewort	*Chara* spp.	9
Coontail	*Ceratophyllum demersum*	25
Lesser Duckweed	*Lemna minor*	20
Canadian Waterweed	*Elodea canadensis*	23
Fern		1
European Frogbit	*Hydrocharis morsus-ranae*	1
Eurasian Milfoil	*Myriophyllum spicatum*	44
Pickerel Weed	*Pontederia cordata*	7
Pondweed	*Potamogeton* spp.	40
Flowering Rush	*Butomus umbellatus*	18
Common Cattail	*Typha latifolia*	16
White Water Lily	*Nymphaea odorata*	23
Yellow Pond Lily	*Nuphar lutea*	3
Wild Celery	*Vallisneria americana*	53

Species at risk

Species at risk are those species in danger of becoming extirpated from a particular region (i.e., no longer present in that region) or extinct. The following are the specific levels of designation that a species at risk can receive and their definitions:

- Extirpated: No longer existing in the wild in Ontario (or Canada), but still exists elsewhere
- Endangered: Facing extinction or extirpation
- Threatened: At risk of becoming endangered
- Special Concern: Sensitive to human activities or natural events which may cause it to become endangered or threatened" (OMNR 2010)

The lists of species at risk may differ federally and provincially. The designations of species presented in this report are the same both federally and provincially unless otherwise indicated.

Two fish and three turtle species at risk were caught in Gananoque Lake. The following fish species were collected: one American Eel (*Anguilla rostrata*; endangered provincially and special concern nationally) in the NSCIN program and eight Grass

Pickerel (*Esox americanus vermiculatus*; special concern) in the seine hauls. The three turtle species at risk noted were:

- Northern Map Turtle (*Graptemys geographica*; special concern; 16 in the NSCIN program)
- Stinkpot Turtle (*Sternotherus odoratus*; threatened; 32 in the NSCIN program and 5 in seine hauls)
- Snapping Turtle (*Chelydra serpentina*; special concern; 5 in the NSCIN program)

Grass Pickerel was not previously known to inhabit Gananoque Lake. The eight Grass Pickerel were found in 6 of the 56 seine hauls, all with high species richness (6 or 7 other species). Bluegill, Pumpkinseed, Largemouth Bass, and Yellow Perch were found in each of the six seine hauls with Grass Pickerel. Rock Bass was found in 5 out of the 6 seine hauls (See Appendix 1.1b Results for further details).

Other studies have shown that Grass Pickerel is usually found in shallow, abundantly vegetated areas in lakes, with both emergent and submergent plants. The loss or degradation of habitat has been proposed to be an important factor affecting the survival of this species. Specific causes of habitat loss may include the removal of aquatic vegetation, and increases in turbidity and nutrients in the water (Beauchamp et al. 2009).

The American Eel was found in a net that also contained 11 other fish and turtle species (the second highest species richness): Largemouth Bass, Pumpkinseed, Bluegill, Rock Bass, Black Crappie, Yellow Perch, Brown Bullhead, Bowfin, and Stinkpot turtle, Map turtle, and Painted turtle. American Eels can live in a variety of habitats; however, the quantity of available habitat can be reduced by the construction of dams. The American Eel spawns in the Sargasso Sea, after which juveniles migrate to continental waters and inhabit them until returning to spawning locations as adults. Therefore, dams adversely affect the American Eel by inhibiting migration (COSEWIC 2006). The American Eel was known to inhabit Gananoque Lake in 1975 (OMNR). It is encouraging news that an eel still exists in the lake and, thus, the species has not been extirpated from the Gananoque River watershed.

Stinkpot Turtles and Northern Map Turtles were not associated with other fish species in analyses (See Appendix 1.1b Results for further details). Snapping turtles were not included in analyses because of the small number caught. Turtle species at risk are vulnerable to nest predation, being killed on roads by vehicles, and habitat destruction both on land and in the water.

There are many activities that landowners with shorelines can do to improve the quality of habitat for species at risk, such as maintaining wetland and natural aquatic vegetation, instituting a shoreline buffer of native terrestrial plants, and leaving basking sites for turtles (e.g., logs and rocks). An excellent resource describing these activities and many other ways of helping turtle species at risk, specifically, is the *Community Strategy for Turtle Recovery: Grenadier Island, Tar Island and Associated Mainland* by Bellemore and Kelly (2009). Other resources on species at risk include:

- Ontario Ministry of Natural Resources Species at Risk Program (http://www.mnr.gov.on.ca/en/Business/Species/index.html)
- Government of Canada's Species at Risk Registry (http://www.sararegistry.gc.ca/default_e.cfm)
- Ontario Turtle Tally (http://www.torontozoo.com/adoptapond/TurtleTally.asp)
- Eastern Ontario Model Forest Herpetofaunal Atlas (http://eomf.on.ca/atlas/list_e.html)

Fish Community Integrity

A common indicator used to assess ecosystem health is the number and abundance of invasive species (Seilheimer and Chow-Fraser 2007; Uzarski 2005). Common Carp (*Cyprinus carpio*) was the only non-native fish species found in Gananoque Lake, with two individuals caught in the NSCIN program. This species accounts for only 0.07% of the catch of the NSCIN program. Non-native invasive species are commonly associated with native fish extinction (the second most common cause after habitat loss; Hughes 1998). Common Carp inhabit turbid, disturbed waters, and actually increase turbidity because of feeding behaviour, which removes aquatic vegetation and re-suspends sediments (Chow-Fraser 2005; Wolfe et al. 2009). These behaviours, in turn, can lead to a reduction in zooplankton abundance and deterioration in habitat conditions (Lougheed et al. 1998). The low number of Common Carp sampled is a positive sign that they are likely not particularly invasive in this community at the present time and that the biotic community has not been severely degraded by them.

Habitats with larger populations of Common Carp have been shown to have lower densities of Grass Pickerel than habitats with reduced Common Carp numbers. Also, Eurasian Milfoil, which was found in 78% of seines, is a non-native invasive plant species that may negatively impact Grass Pickerel though the alteration of habitat and exclusion of native plant species. Thus, monitoring non-native species, such as Common Carp and Eurasian Milfoil, is suggested to be beneficial to the recovery planning of Grass Pickerel in the species' Management Plan (Beauchamp et al. 2009).

Nearly half of all species caught in both NSCIN program and in seine hauls are nest-guarding species. Trebitz et al. (2009a, b) found that nest-guarding species were associated with natural, less stressed watersheds in the Great Lakes, and Brazner (2007) noted that nest-guarding fish were indicative of decreased row-crop agriculture in a watershed.

Four omnivorous species were collected in total: two species in the NSCIN program (Common Carp and Common White Sucker), and two species during seining (Bluntnose Minnow and Golden Shiner). Omnivory is indicative of a more generalized diet, meaning that a fish may be able to adapt to anthropogenic (i.e., human-caused) stress more easily (Hughes 1998), and is usually a common trait of invasive species. A large proportion of omnivorous species in a community is associated with more disturbed habitats (Trebitz et al. 2009).

The baseline data described here can be used as a comparison in future years to show, for example, whether invasive species or omnivorous species are increasing or decreasing. This information can then help describe any changes in the state of Gananoque Lake's aquatic community.

Table 1.4: Characteristics of fish caught. Turbidity tolerance, spawning behaviour and diet from Trebitz et al. 2009a.

Common Name	Family	Turbidity Tolerance	Spawning behaviour	Diet	Type of net
*American Eel	Freshwater Eel (Anguillidae)	.	Outside of Canada	Carn	NSCIN
Banded Killifish	Sunfish (Centrarchidae)	.	Veg	.	seine
Bluntnose Minnow	Bowfin (Amiidae)	.	Guard	Omni	seine
Brook Silverside	Sunfish (Centrarchidae)	T	.	.	seine
Brown Bullhead	Bullhead Catfish (Ictaluridae)	.	Guard	Carn	NSCIN
Black Crappie	Sunfish (Centrarchidae)	.	Veg, guard	Carn	both
Bowfin	Bowfin (Amiidae)	T	Veg, guard	Carn	NSCIN
Bluegill	Sunfish (Centrarchidae)	.	Lyth, guard	Carn	both
**Common carp	Carp (Cyprinidae)	T	Veg	Omni	NSCIN
Common white sucker	Sucker (Catostomidae)	.	Lyth	Omni	NSCIN
*Grass Pickerel	Carp (Cyprinidae)	.	NA	NA	Seine
Golden Shiner	Sucker (Catostomidae)	.	Veg	Omni	Seine
Johnny Darter	Sunfish (Centrarchidae)	.	Guard	.	Seine
Largemouth Bass	Sunfish (Centrarchidae)	.	Veg, guard	Carn	both
Northern pike	Pike (Esocidae)	.	Veg	Carn	both
Pumpkinseed	Sunfish (Centrarchidae)	.	Veg, guard	.	both
Rock Bass	Sunfish (Centrarchidae)	.	Lyth, guard	Carn	both
Smallmouth Bass	Sunfish (Centrarchidae)	.	Lyth, guard	Carn	both
Yellow Bullhead	Bullhead Catfish (Ictaluridae)	T	Veg, guard	Carn	NSCIN
Yellow Perch	Perch (Percidae)	T	.	Carn	both

Legend: Turbidity Tolerance: T = tolerant; Spawning Behaviour: nest guarding, vegetation spawning, lythophilic spawning; and Diet: omnivore, carnivore.
*Denotes a species at risk (Grass Pickerel and American Eel)
**Denotes a non-native species (Common Carp)
“NA” denotes data that were not provided in Trebitz et al. 2009a
“.” denotes unavailable data

References

Beauchamp, J., Edwards, A.L., Hardy, D., Jarvis, P.L., Staton, S.K. 2009. Management plan for the Grass Pickerel (*Esox americanus vermiculatus*) in Canada [Draft]. *Species at Risk Act* Management Plan Series. Fisheries and Oceans Canada, Ottawa.

Brazner, J.C., Danz, N., Trebitz, A.S., Niemi, G., Regal, R., Hollenhorst, T., Host, G., Reavie, E.D., Brown, T., Hanowski, J., Johnston, C., Johnson, L., Howe, R.W., Ciborowski, J. 2007. Responsiveness of Great Lakes wetland indicators to human disturbances at multiple spatial scales: a multi-assemblage assessment. *Journal of Great Lakes Research* 33:42–66.

Bryan, M.D., Scarnecchia, D.L. 1992. Species richness, composition, and abundance of fish larvae inhabiting natural and developed shorelines of a glacial Iowa lake. *Environmental Biology of Fishes* 35: 329–341.

Chow-Fraser, P. 2005. Ecosystem response to changes in water level of Lake Ontario marshes: lessons from the restoration of Cootes Paradise Marsh. *Hydrobiologia* 539:189–204.

COSEWIC 2006. COSEWIC assessment and status report on the American eel *Anguilla rostrata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Hughes, R.M., Kaufmann, P.R., Herlihy, A.T., Kincaid, T.M., Reynolds, L., Larsen, D.P. 1998. A process for developing and evaluating indices of fish assemblage integrity. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1618–1631.

Kelly, M., Bellemore, C. 2009. Community Strategy for Turtle Recovery: Grenadier Island, Tar Island and Associated Mainland. Prepared on behalf of The Leeds County Stewardship Council and St. Lawrence Islands National Park.

Lougheed, V.L., Crosbie, B., Chow-Fraser, P. 1998. Predictions on the effect of common carp (*Cyprinus carpio*) exclusion on water quality, zooplankton, and submergent macrophytes in a Great Lakes wetland. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1189–1197.

Ontario Ministry of Natural Resources (OMNR). 2010. *What is a species at risk?* Accessed online at: http://www.mnr.gov.on.ca/en/Business/Species/index.html

Pratt, T.C., Smokorowski, K.E. 2003. Fish habitat management implications of the summer habitat use by littoral fishes in a north temperate, mesotrophic lake. *Canadian Journal of Fisheries and Aquatic Sciences* 60:286–300.

Seilheimer, T.S., Chow-Fraser, P. 2007 Application of the Wetland Fish Index to northern Great Lakes marshes with an emphasis on Georgian Bay coastal wetlands. *Journal of Great Lakes Research* 33 (Special Issue 3):154–171.

Trebitz, A.S., Brazner, J.C., Danz, N.P., Pearson, M.S., Peterson, G.S., Tanner, D.K., Taylor, D.L., West, C.W., and Hollenhorst, T.P. 2009a. Geographic, anthropogenic, and habitat influences on Great Lakes coastal wetland fish assemblages. *Canadian Journal of Fisheries and Aquatic Sciences* 66:1328–1342.

Trebitz, A.S., Brazner, J.C., Pearson, M.S., Peterson, G.S., Tanner, D.K., Taylor, D.L. 2009b. Patterns in habitat and fish assemblages within Great Lakes coastal wetlands and implications for sampling design. *Canadian Journal of Fisheries and Aquatic Sciences* 66:1343–1354.

Wolfe, M.D., Santucci, V.J., Einfalt, L.M., Wahl, D.H. 2009. Effects of Common Carp on Reproduction, Growth, and Survival of Largemouth Bass and Bluegills. *Transactions of the American Fisheries Society* 138(5):975–983

Uzarski, D.G., Burton, T.M., Cooper, M.J., Albert, D.A., Ingram, J., Timmermans, S. 2005. Fish habitat use within and across wetland classes of the five Great Lakes. *Journal of Great Lakes Research* 31:171–196.

Appendix 1.1 Statistical Details for Methods and Results

a) General fish and habitat associations from seine hauls, including young-of-year

Methods: Regressions were conducted to assess the relationship of young-of-year fish richness and abundance with plant species richness and vegetative cover. Logistic regressions were performed to determine associations of young-of-year presence with plant species richness and vegetative cover. Correlations of each substrate cover category with total fish and young-of-year abundance were completed.

Results: Plant species richness was significantly positively associated with young-of-year presence, abundance, and richness (logistic regression with YOY presence: % concordant = 85.5, P = 0.009; regression with YOY abundance: $r^2 = 0.09$, P = 0.03; and regression with YOY richness: $r^2 = 0.12$, P = 0.009). Vegetative cover was not significantly correlated with young-of-year abundance, but was significantly associated with young-of-year presence and richness (logistic regression with YOY presence: % concordant = 94.1, P = 0.01; and regression with YOY richness: $r^2 = 0.12$, P = 0.01).

Silt and detritus cover was positively correlated with YOY abundance (correlation: $r^2 = 0.38$, $P<0.004$), but not total fish abundance. Four species of the total ten YOY species were significantly positively correlated with silt and detritus cover: Banded Killifish ($r^2 = 0.27$, $P<0.04$), Johnny Darter ($r^2 = 0.28$, P=0.03), Largemouth Bass ($r^2 = 0.28$, P=0.03), and Yellow Perch ($r^2 = 0.36$, P=0.007). The remaining substrate categories (e.g., sand, bedrock, gravel, etc.) were not significantly correlated with either total fish abundance or YOY abundance.

b) Species at Risk

Methods: Correlation analysis and backwards stepwise regressions were used to assess the relationship between the abundance of each species at risk and other fish and turtle species' abundances. Grass Pickerel was found in the seine hauls and so had additional habitat characteristics described. Thus, regressions of vegetative cover and plant species richness with Grass Pickerel abundance, as well as correlations with plant species presence with Grass Pickerel, were included in the analyses. Low sample sizes resulted in a limited ability to use or interpret statistical analyses in most cases, particularly for the American Eel.

Results: While Pumpkinseed abundance was significantly correlated with Grass Pickerel abundance, as well as being significantly associated with Grass Pickerel in the backwards stepwise regression, the species was also found in nearly 93% of seine hauls, and, therefore, is unlikely to be a very good predictor of Grass Pickerel presence/absence in this system. Grass Pickerel abundance was not associated with vegetative cover, plant species richness, or any plant species in the regressions and correlations. The low number of Grass Pickerel found makes confidence in statistical tests limited.

Stinkpot and Northern Map turtles were not significantly associated with any other fish species in the correlations or the backwards stepwise regressions. An increased number of sampling sites would provide more power to these and all species at risk conclusions.

2. Shoreline Surveys of Gananoque Lake and South Lake

Introduction

A lake shoreline represents a very important interface between the land and water. Natural shoreline areas contain a high diversity of species in a relatively small amount of space and provide essential habitat for both aquatic and terrestrial species (Wetzel 2001). Healthy shorelines with an abundance of native vegetation provide a wide range of ecosystem services in addition to offering habitat; these services include water purification, erosion protection, and nutrient processing (Schmeider 2004; Strayer and Findlay 2010). Nutrient processing encompasses actions such as the decomposition of biological matter, which frees nutrients for use by other organisms, and the capture of nutrients moving from the land to the water (and vice versa; Strayer and Findlay 2010).

Algonquin to Adirondacks Conservation Association (A2A) undertook shoreline surveys of two lakes in the Gananoque River watershed in 2009, which describe the current states of the shorelines. In addition to the analyses and discussion presented in this report, the survey data will be used to create personalized stewardship binders for each property owner on Gananoque Lake and South Lake. Each binder will contain information on the shoreline of each property, as well as possible restoration ideas. A2A and its partners at the Centre for Sustainable Watersheds (CSW) created such binders for all properties on Lower Beverley Lake in 2009.

Methods

Shoreline surveys were carried out on Gananoque Lake and South Lake in July and August 2009. 138 properties were assessed on Gananoque Lake and 38 properties on South Lake. A GPS device and a mini computer with GIS software were used to determine the position of the surveyor on the lake property map on the computer.

The shoreline survey followed the MAPLE Shoreland Classification Survey Protocol, prepared by the Rideau Valley Conservation Authority (RVCA 2008). This survey provides a large quantity of data for each property including information on the following (See Appendix 3.1a for blank data sheet):

- Shoreline classification: degraded, ornamental, regenerative, natural cover
- Built shoreline cover: structures, docks, retaining walls
- Natural shoreline cover: shoreline vegetation, aquatic vegetation, and abiotic cover (i.e., non-living cover, such as bedrock, sand, clay, etc.)
- Restoration opportunities

Additional information beyond the MAPLE protocol was also collected, including shoreline access and an upland survey (See Appendix 2.1b).

The Cataraqui Region Conservation Authority used ArcView GIS software to link the survey data for each property to its corresponding property on the lake property map, and provided the shapefiles to A2A. The shoreline length of each property was calculated in ArcView. The percentage of shoreline with a certain characteristic could then be determined (e.g., the percentage of lake shoreline that was natural). Some calculations were based on the number of properties on which a certain discrete feature occurred, such as the presence of docks or other structures. Note that with any study utilizing GPS devices, GPS points will contain some degree of error. Thus, any analyses using these data will likely have some minor degree of error associated with them.

Results and Discussion

Shoreline Classification

Four types of land were classified in the surveys: natural, regenerative, ornamental, and degraded. Natural shoreline is mostly natural with healthy, native vegetation and little development other than a small dock. An ornamental shoreline is one in which people have removed the natural vegetation and substituted it with lawn or non-native vegetation. Regenerative shorelines are reverting from an ornamental to a natural state or are minimizing impacts on the shoreline. Degraded shorelines have little vegetation, structures that are deteriorating, and active soil erosion. Therefore, degraded properties will negatively affect the lake environment (RVCA 2008).

Both Gananoque Lake and South Lake had high percentages of natural shoreline (Figures 2.1a, 2.2b, 2.2, and 2.3). Specifically, Gananoque Lake had 77% natural shoreline, with the remaining being ornamental. South Lake had an even higher quantity of natural shoreline at 93%. Most of the rest of the shoreline at South Lake was classified as ornamental, with a very small amount of regenerative shoreline (<1%). No degraded land was observed at either lake. As a comparison, the percentage of natural shoreline was higher at both South Lake and Gananoque Lake than the Rideau River between Ottawa and Smiths Falls. The Rideau Valley Conservation Authority found that the percentage of natural shoreline on the Rideau River was: 19% in 2002 between Ottawa and Kars; 21% in 2003 between Kars and Merrickville; and 61% between Merrickville and Smiths Falls (Schelenz, P. and A. Guertin 2002; Stephens 2004; Stephens 2005).

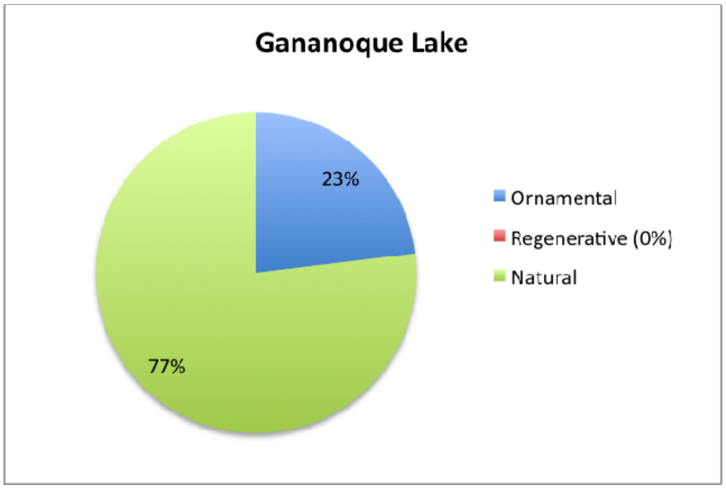


Figure 2.1a: Percentage of shoreline in each classification category at Gananoque Lake.

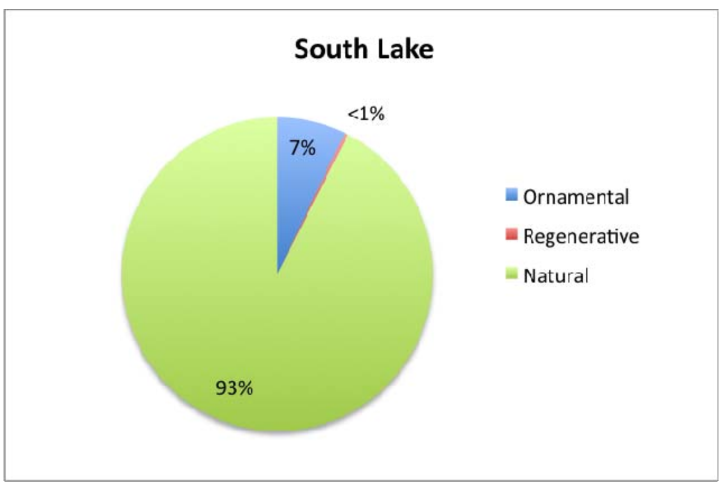


Figure 2.1b: Percentage of shoreline in each classification category at South Lake.

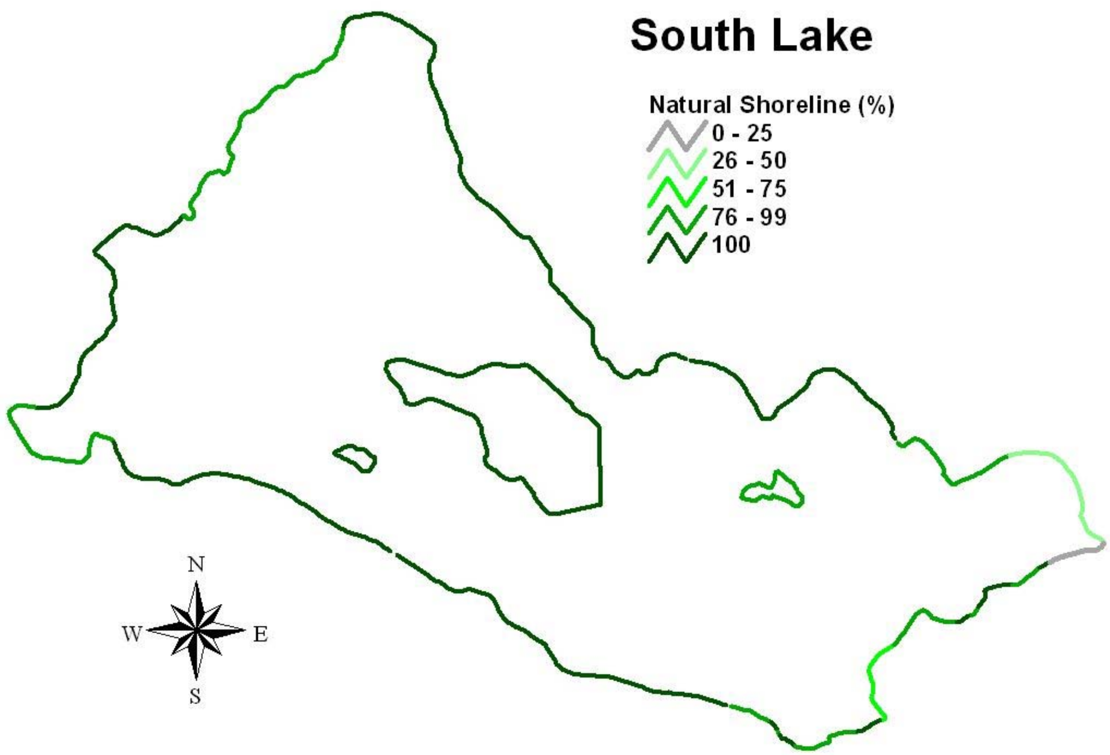


Figure 2.2: Map of the percentage of natural shoreline at South Lake by property.

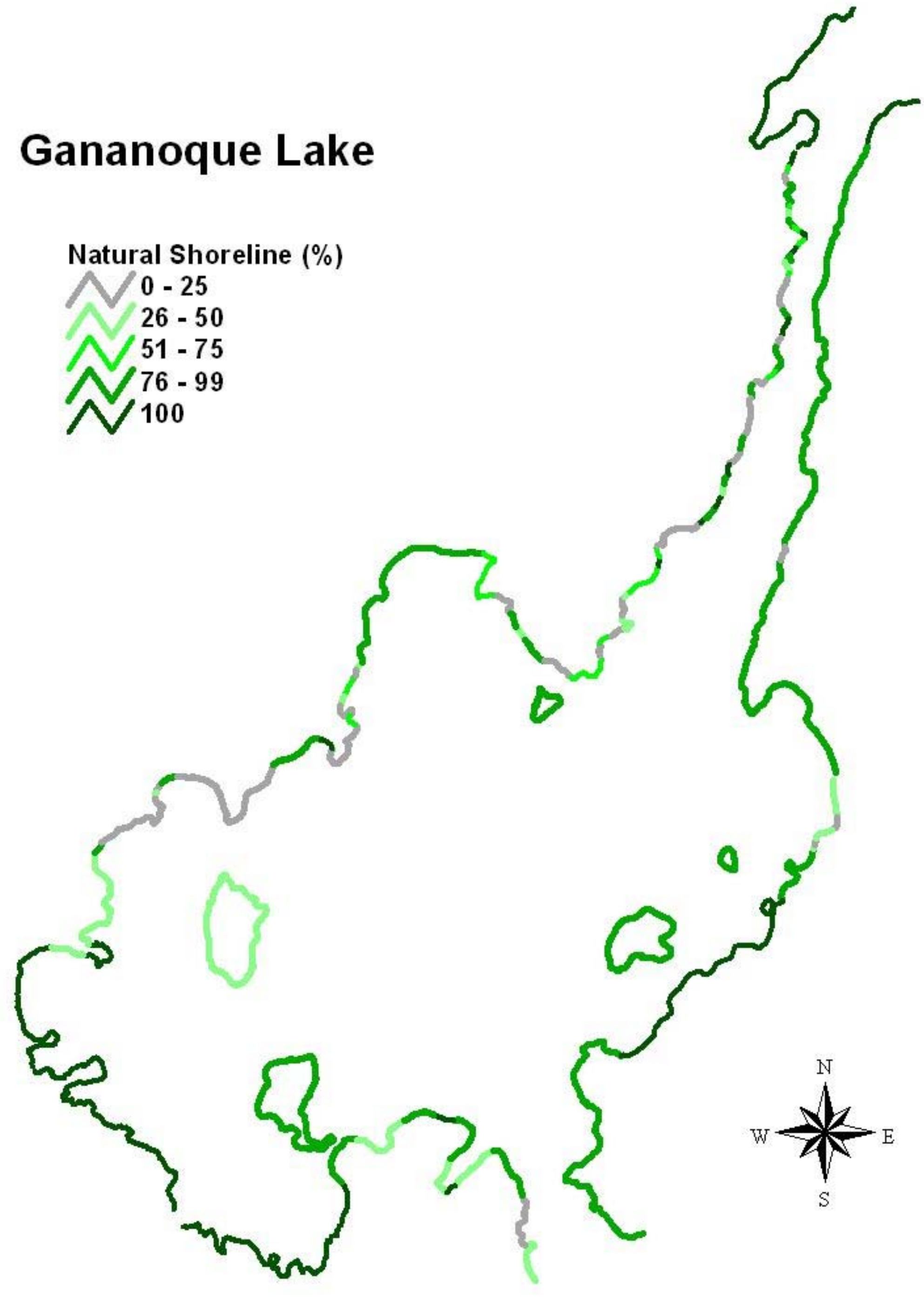
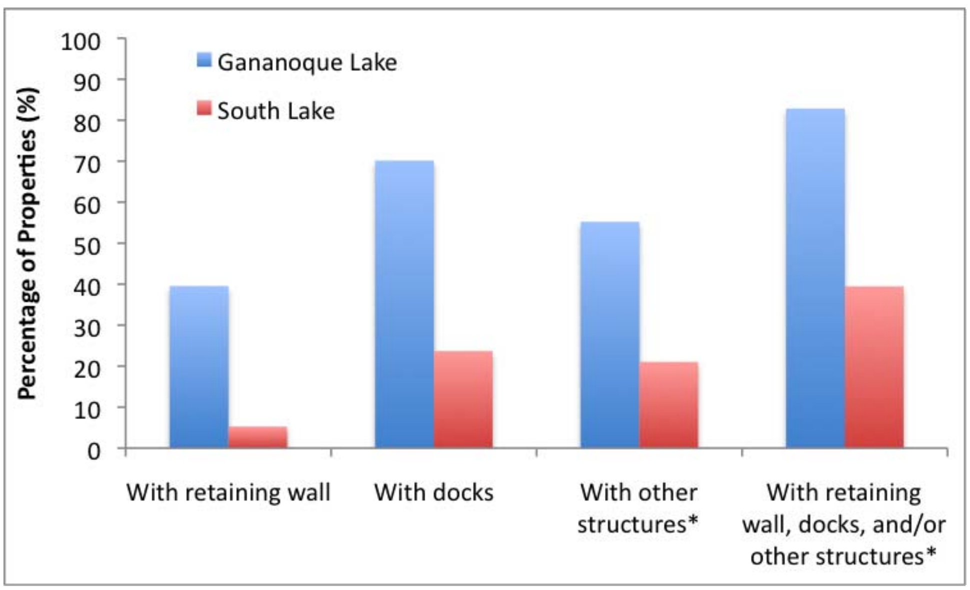


Figure 2.3: Map of the percentage of natural shoreline at Gananoque Lake by property

Built Shoreline Cover

People often alter the shorelines of lakes by creating docks, retaining walls, and other structures such as decks, boat ramps, boathouses, boat lifts, and buildings. Generally, a structure will reduce the available habitat for wildlife; however, some structures are less detrimental to wildlife than others. For example, cantilever, floating, and post docks are the best choices for minimizing impact on the shoreline, because they allow for movement under the dock and cause less disturbance to the lake bottom (A2A and CSW 2009; Schelenz, P. and A. Guertin 2002; Stephens 2004; Stephens 2005).

Gananoque Lake had a greater percentage of properties with retaining walls, docks, or other structures than South Lake (Figure 2.4). In fact 82% of properties had at least some form of built cover at the shoreline at Gananoque Lake (vs. 40% at South Lake). This is no surprise given the difference in the percentage of natural shoreline between the lakes noted above. Most properties at Gananoque Lake had a dock and, fortunately, the vast majority of those docks were floating or post docks. Only 3 properties at Gananoque Lake had crib docks, which have a larger impact on the shoreline than floating or post docks. Most of the built structures present at Gananoque Lake were boat ramps and decks.



* "Structures" refer to decks, boat ramps, boathouses, boat lifts, boat slips, and/or buildings.

Figure 2.4: The percentage of properties with a retaining wall, docks, other structures, or any of the aforementioned structures.

Natural Shoreline Cover

Shoreline vegetation is extremely beneficial for water quality and habitat. For example, vegetation at the shore can help stabilize the shoreline, prevent soil erosion, provide habitat for animals, and prevent pollutants from entering the water (Correll 2005;

Schmeider 2004). The composition of natural shoreline cover can impact the health of the lake and its inhabitants. Woody vegetation, such as trees and shrubs, supplies shade for fish, snags (i.e., a standing dead or partly dead tree) for wildlife habitat, and coarse woody debris. Coarse woody debris provides many benefits to animals, including shelter from predators and basking sites for turtles (Strayer and Findlay 2010). Natural native vegetation is preferred over ornamental vegetation, such as groomed grasses, because it provides better and more diverse habitat for native animals and is adapted to the local environment.

The natural shoreline was categorized as either canopy (i.e., with trees) or open (i.e., with shrubs, grasses, herbs, bedrock, etc.). South Lake had higher natural shoreline canopy cover than Gananoque Lake (84% vs. 69%). The tree canopy was 45% coniferous at Gananoque Lake and 52% coniferous at South Lake.

Groomed grasses, shrubs, and bedrock made up the majority of the open natural shoreline at Gananoque lake (Figure 2.5a and Figure 2.5b). This was similar to the open shoreline of South Lake with the exception of natural grasses and herbs, which also represented a significant portion of the shoreline.

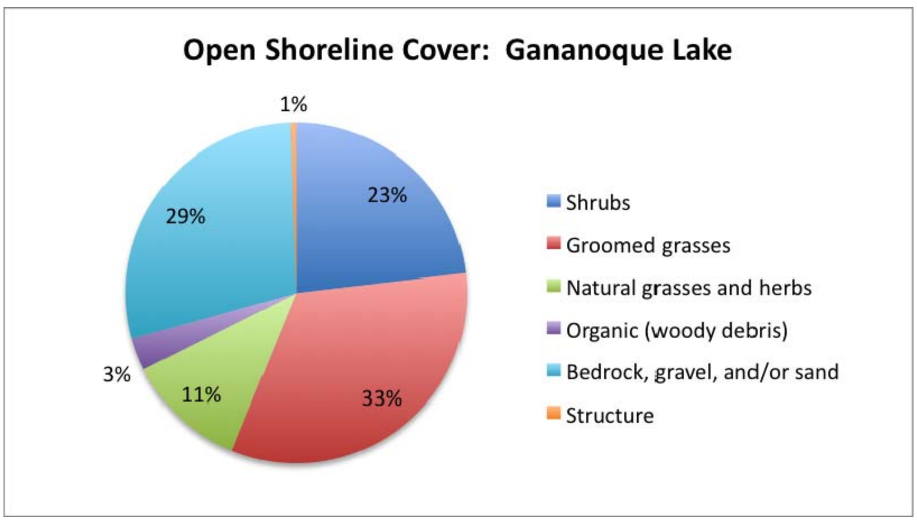


Figure 2.5a: Composition of open shoreline cover at Gananoque Lake.

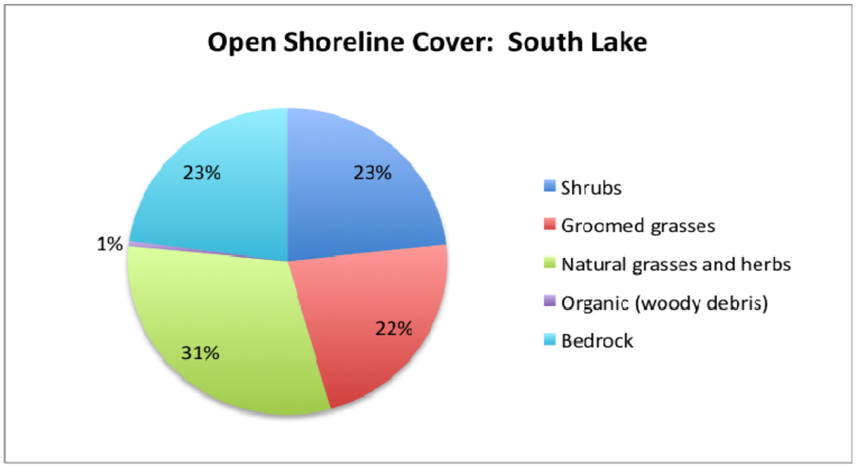


Figure 2.5b: Composition of open shoreline cover at South Lake.

Aquatic Vegetation Cover

As described in the *Fish and Turtle Species Inventory (1)* section of this report, aquatic vegetation is extremely important for habitat, particularly for young fish species. Three aquatic vegetation types were assessed: emergent (rooted below the water and extend above the surface of the water, e.g., Cattail); submergent (grow below the surface of the water, e.g., Canadian Waterweed); and floating plants (e.g., Yellow Pond Lily).

Gananoque Lake had a higher percentage of cover of all aquatic vegetation types than South Lake (Figure 2.6). Submergent vegetation covered almost 81% of the shoreline at Gananoque Lake and 56% at South Lake.

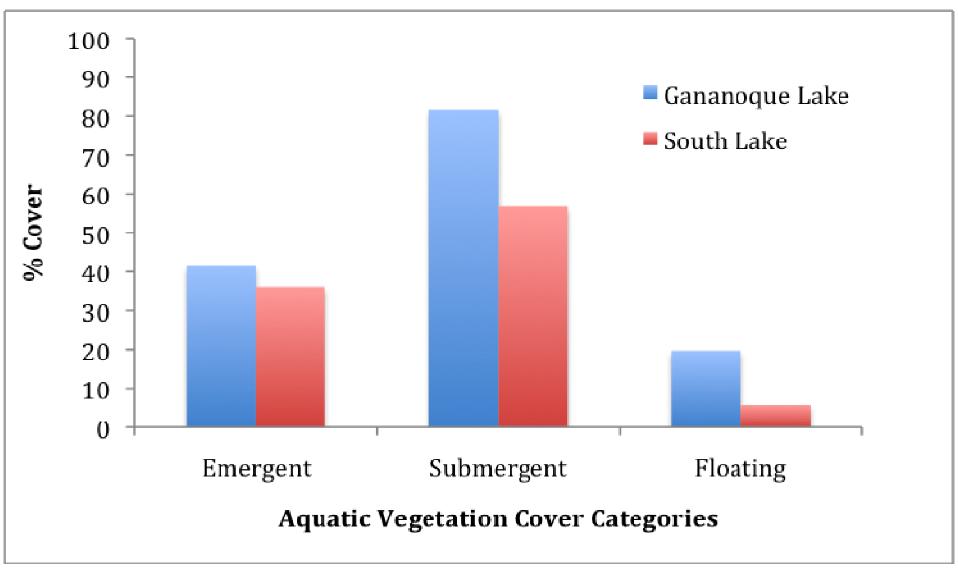


Figure 2.6: Percentage of aquatic vegetation cover in three categories (emergent, submergent, and floating cover) at Gananoque Lake and South Lake. See text for a description of each type.

Invasive aquatic plant species are a major concern in many lakes because exotic species have the capacity to negatively influence ecosystems by replacing native species, altering nutrient cycling, and reducing habitat quality (Wilson and Ricciardi 2009; Trebitz and Taylor 2007). At Gananoque Lake, 48% of properties had invasive aquatic plants present, covering 10% of the shoreline. Purple loosestrife (*Lythrum salicaria*) was the most common invasive species present, followed by Eurasian watermilfoil (*Myriophillum spicatum*) and European frog-bit (*Hydrocharis morsus-ranae*).

Gananoque Lake had a much higher number of invasive aquatic plant species present than South Lake, which might be part of the reason that Gananoque Lake exhibited greater aquatic vegetation cover than did South Lake. At South Lake, only six of 38 properties (16%) had invasive plants present and the percentage of shoreline with invasive plant cover was only 2%. As was the situation in Gananoque Lake, the most frequent invasive species at South Lake was purple loosestrife. European frog-bit was only found on one property, and Eurasian watermilfoil was not found on any properties.

Guidelines for Improving Shorelines

There are many ways for landowners with shorelines to improve the water quality of their lakes, as well as the aquatic and terrestrial habitat on their properties. Maintaining a buffer strip of native vegetation at the shoreline is recommended. Implementing such a buffer zone can reduce erosion, provide increased habitat for animals, and help reduce the amount of harmful chemicals that enter the lake from inland sources. Septic system re-inspections are recommended to ensure that leaks are not occurring. The following list contains links to more resources on the topic of shoreline improvement:

- Cataraqui Region Conservation Authority (http://www.cataraquiregion.on.ca/index.html)
- Living by Water Project; Centre for Sustainable Watersheds (http://www.livingbywater.ca/main.html)
- Rideau Valley Conservation Association: Shoreline information and reports (http://www.rvca.ca/watershed/aquatic_habitat/shoreline_overview.html#surveys)
- Information resources appendix from Lower Beverley Lake shoreline binders (A2A and CSW 2009) (http://www.a2alink.org/)

References

Algonquin to Adirondacks Conservation Association and Centre for Sustainable Watersheds (A2A and CSW). 2009. Gananoque River Watershed Community Stewardship Project: Appendix to the Lower Beverley Lake Shoreline Report. Algonquin to Adirondacks Conservation Association and Centre for Sustainable Watersheds.

Correll, D.L. 2005. Principles of planning and establishment of buffer zones. *Ecological Engineering* 24:433–439.

Rideau Valley Conservation Authority (RVCA). 2008. M.A.P.L.E. Shoreland Classification Survey: Field Sheet and Protocol. Rideau Valley Conservation Authority.

Schelenz, P., Guertin, A. 2002. Rideau River Shoreline Classification Survey: Kars Bridge to Mooney's Bay Summer 2002. Rideau Valley Conservation Authority. Accessed Online at: http://www.rvca.ca/watershed/aquatic_habitat/shoreline_overview.html#surveys

Schmeider, K. 2004. European lake shores in danger – concepts for a sustainable development. *Limnologica* 34:3–14.

Stephens, B. 2004. Shoreline Classification Project: 2003 Report. Rideau Valley Conservation Authority. Accessed Online at: http://www.rvca.ca/watershed/aquatic_habitat/shoreline_overview.html#surveys

Stephens, B. 2005. Shoreline Classification Project: 2004 Report. Rideau Valley Conservation Authority. Accessed Online at: http://www.rvca.ca/watershed/aquatic_habitat/shoreline_overview.html#surveys

Strayer, D.L., Findlay, S.E.G. 2010. Ecology of freshwater shore zones. *Aquatic Science* 72:127–163.

Trebitz, A.S., Taylor, D.L. 2007. Exotic and invasive aquatic plants in great lakes coastal wetlands: Distribution and relation to watershed land use and plant richness and cover. *Journal of Great Lakes Restoration* 33:705–721.

Wetzel, R.G. 2001. Limnology, 3rd edition. Academic Press. London.

Wilson, S.J. and Ricciardi, A. 2009. Epiphytic macroinvertebrate communities on Eurasian watermilfoil (*Myriophyllum spicatum*) and native milfoils *Myriophyllum sibericum* and *Myriophyllum alterniflorum* in eastern North America. *Canadian Journal of Fisheries and Aquatic Sciences* 66:18–30.

Appendix 2.1a: Front side of 2009 data sheet

Shoreline Survey Property Description Form (Field Sheet)

Property/ Pin Number	**Site Map Number**	**GPS UTM (NAD83)**	
	Sector Number	**E** **N** **Start of property**	**E** **N** **End of property**

Digital Photo Reference Number	
% Classifcation	
Degraded %	
Ornamental %	
Regenerative %	
Natural %	
Comments:	
Shoreline Profile	
Building Setback (m)	
Frontage (m)	
Slope Angle (degree)	5 10 15 20 30 40 50 60 70 80
Comments:	
Shoreline Cover (Built)	
Structures %	
☐ Decks	☐ Boat Lift
☐ Boat Ramp	☐ Boat Slip
☐ Boathouse	☐ Building(s)
Comments:	

Retaining Wall		
Height (m)	% Cover	State of Repair *Good Fair Poor*

Type	
☐ Wood	☐ Riprap
☐ Loose Rock	☐ Gabion Basket
☐ Armourstone	☐ Steel
☐ Concrete	☐ Other
Dock	
Number of docks	☐ Permanent
Type	☐ Not permanent
Comments:	
☐ Agricultural Active/Non Active	☐ Camp
☐ Seasonal Residence	☐ Marina
☐ Permanent Residence	☐ Road/Railway/Bridge
☐ Recreation/Open Space	☐ Other

% Shoreline Cover (Natural)	
Biotic	**Abiotic**
Canopy %	☐ Bedrock (exposed rock)
☐ Trees (Coniferous)	☐ Boulder (>25cm)
☐ Trees (Deciduous)	☐ Stone (8-25cm)
Open %	☐ Gravel (0.2-8cm)
☐ Shrubs	☐ Sand (0.05-0.10cm, gritty)
☐ Grasses Groomed	☐ Silt (<0.05cm, powdery)
☐ Natural Grasses/herbaceous	☐ Clay (0.01cm, greasy feel)
☐ Organic (woody debris)	
Comments:	

Erosion	
☐ Upland erosion	☐ Undercut bank erosion
☐ Mass movement erosion	☐ % lot frontage affected
Source	
Comments:	

% Aquatic Vegetation Covering	
Emergents %	**Floating %**
☐ Cattail	☐ Lily-Type Plants
☐ Sedges/Grasses/Rush	
☐ Other:	**Invasive Plant Species %**
Submergents %	☐ Purple Loosestrife
☐ Algae	☐ Eurasian Milfoil
☐ Grass-like	☐ European Frogbit
☐ Leaf-like	
Comments:	

% Aquatic Substrate/Cover		
Biotic	**Abiotic (measurements as above)**	
☐ Detritus (leaves, etc.)	☐ Bedrock	☐ Gravel
☐ Downed Woody Debris	☐ Boulder	☐ Sand
☐ Other	☐ Stone	☐ Silt
	☐ Muck (combo sand, silt, clay)	
Comments:		

Restoration Opportunities
Plant native shrubs/ trees along shoreline
Total re-vegetation recommended

Comments:		Leave natural	Limit shoreline access
		Retire retaining wall	Control invasive plant species
		Erosion control measures	Soften retaining wall
		Upland rainwater diversion	Other
Land Cover		Other:	
☐ Wetland	☐ Meadows		
☐ Woodland	☐ Farm Pasture		
☐ Farm crops (corn,hay)	☐ Other		
Comments:		**Other Observations**	
		Fish:	
		Wildlife:	
		Cattle:	
Surveyed By:		Other Significant Features:	
Survey Date:		Comments:	
Date Data Entered:			
Entered By:			

Appendix 2.1b: Back side of 2009 field data sheet:

Shoreline Survey Property Form (Field Sheet)

Building				
Structure	**Y/N**	**Description**	**Y/N**	**Comments**
Eaves		Rain Barrel		
		Infiltration Pit		
		Vegetative Area		**Recommendations**
		Ground		
Shoreline Access				
Structure	**Y/N**	**Description**	**Y/N**	**Comments**
Pathway		S-curve		
		Straight		
Stairway		Aboveground		
		Inground		
	Materials	Rail ties		
		Wood		
		Gravel forms		**Recommendations**
		Concrete		
		Other		
	Erosion	Major		
		Minor		
		Location		
Upland				
Structure	**Y/N**	**Description**	**Y/N**	**Comments**
Slope		Steep		
		Moderate		
		Flat		
		Erosion		
Vegetation		Overstorey:		
		% Coverage Coniferous		
		% Coverage Deciduous		
		Understorey:		
Leaf Litter		%Coverage		
Lawns		%Coverage		
Retaining Wall		Good Condition		
		Poor Condition		**Recommendations**
	Materials	Wood		
		Concrete		
		Loose Rock		
		Railroad Ties		
		Other:		
		Erosion		
Wildlife Habitat		Snags		
		Fallen Tree		
		Cavity Tree		
Bedrock		% Coverage		

3. Water Quality of the Gananoque River Watershed

Introduction

A wide range of historical and recent water quality data were gathered for the Gananoque River watershed to provide a picture of water quality in the region. The Ontario Ministry of the Environment and Cataraqui Region Conservation Authority provided most of these data to Algonquin to Adirondacks Conservation Association for this report. A complete list and description of these data is contained in Table 3.1. Many of these datasets are the result of one-time data collection sorties, which occurred on various lakes and rivers (and in various portions of a particular lake or river) and assessed a range of different variables, thus making it difficult to statistically assess trends in most cases.

MOE Report: The Water Quality of the Gananoque River Watershed (2010)

In 2008 and 2009, the Ontario Ministry of the Environment (OMOE) undertook a comprehensive water quality assessment of the Gananoque River watershed. Samples were collected from a number of lakes and locations in the Gananque River and tested for a multitude of metals and other water chemistry variables, including total suspended solids, specific conductivity, hardness, pH, and nutrients. Overall, the state of water quality in the watershed was deemed to be good, with the exception of phosphorus levels, which were found in elevated concentrations throughout the watershed. The topic of phosphorus is discussed in depth later in this report. The complete OMOE report is provided as an online appendix on the A2A website a2alink.org.

Cataraqui Watershed Report Card (2009)

The *2009 Cataraqui Watershed Report Card* by the Cataraqui Region Conservation Authority (CRCA) gave surface water quality in the Gananoque River watershed an "A" grade, indicating "very healthy watershed conditions" (CRCA 2009). The Gananoque River watershed was one of three watersheds in the Cataraqui Region to get an "A" grade, while the other seven watersheds in the region with sufficient data for analysis scored "B" grades. These grades were determined using surface water chemistry data (e.g., phosphorus and chloride data), as well as benthic invertebrates. Benthic invertebrates are organisms that live in or on the bottoms of lakes, rivers, and streams, and are useful indicators of water quality conditions.

Selected Historical Datasets

Lake Survey Data from 1981-1984 provide some of the most comprehensive historical data available, including 12 Lakes, 12 water quality variables and 4 years of data. The means of the 1984 data are provided in Table 3.4.

In addition, Lathem Group Inc. and Cumming-Cockburn and Associates Limited conducted a study from 1981 to 1983 entitled the *Gananoque Watershed Management Study*, which consisted of environmental and engineering information and data they collected from the watershed. In the final report, the consultants concluded that water quality issues needed to be tackled in the area. Specifically, they found high levels of phosphorus in streams in the bottom end of the watershed, which were likely caused by agricultural processes.

Note that some water quality data collection and analysis methods have changed over time. There is an increase in the accuracy of more current data which may make earlier data less comparable with newer data. This issue should be kept in mind when assessing the oldest datasets noted in this report (Table 3.1).

Total Phosphorus

Phosphorus is a naturally occurring nutrient in lakes, and is essential for plant growth. Too much phosphorus in a lake, however, can cause excessive algal production. This process is called eutrophication. Oxygen is then depleted during decomposition of this additional organic material, meaning that the amount of oxygen available to fish is reduced. Thus, eutrophication reduces the water quality and the ability of a lake to support healthy populations of fish and other aquatic organisms. Additional phosphorus inputs by humans can come from agricultural run-off, leaking septic systems and lawn fertilizers. Local landowners can help decrease phosphorus in their lakes by:

- Ensuring septic systems are in good condition
- Using no or phosphorus-free fertilizers
- Creating a 30m buffer strip of natural vegetation at their shorelines

The 2010 report by the Ontario MOE (Online Appendix 3.1) indicates that elevated phosphorus levels are a widespread phenomenon in the Gananoque River watershed. Indeed, the report states, "Elevated and PWQO exceedances of total phosphorus is the single biggest water quality issue in the Gananoque River watershed."

The Ontario Ministry of the Environment's Lake Partners Program provides the tools for public participation in assessing the total phosphorus (TP) in lakes in Ontario. Water samples were collected by public volunteers between one and six times from May to October from 2002 to 2009 and sent to the Ministry of the Environment to determine the TP levels in the lab. The number of samples taken per year and the number of years in which the data was collected vary among lakes. Additional Lake Partners TP data are available from 1996-2001, but these data are less precise and, therefore, were not used in the analyses. A number of lakes in the Gananoque River watershed have not had people collecting data for the Lake Partners Program. People interested in learning about the water quality through monitoring of a lake are encouraged to participate in this program.
Data and information on how to get involved are available online: http://www.ene.gov.on.ca/en/water/lakepartner/index.php

The majority of lakes in the Gananoque River watershed were tested 6 times per year between May and October, while Upper Beverley Lake and Lower Beverley Lake were tested 3-5 times per year (Table 3.2). Fluctuations in total phosphorus are common during the ice-free period during which the samples were collected. Because of this issue, trends in TP were tested using the Kendall Seasonal test. This test addresses the issue of seasonality in the phosphorus data by testing for a trend through the years for each "season" (i.e., "month" in the case of this data) and then combining the results of each season together (Helsel and Hirsch 2002). Bass Lake and Higley Lake only had one sample taken per year and, thus, Mann-Kendall tests for trend were performed, as seasonality was not an issue for these data. Long lake and Singleton Lake were tested only once, and, therefore, no analyses could be performed. Means (i.e., averages) of TP for each year of each lake or lake section are presented in Table 3.2 and Figure 3.1. Note that the full range of TP concentrations in a given year can be quite variable (e.g., TP at Killenbeck Lake was 20.7 µg/L in May 2003 and 39.8 µg/L in September in the same year).

Lakes that have total phosphorus greater than 20 µg/L are considered to be eutrophic by the Lake Partners Program (OMOE 2005), and nuisance algal blooms may occur at such levels, as described in the Provincial Water Quality Objectives (PWQO; OMOE 1994). Mean TP was greater than 20 µg/L in at least 60% of years in the following lakes:

- Gananoque Lake (75% of years)
- Killenbeck Lake (62%)
- Lyndhurst Lake (100%)
- Lower Beverley Lake (25-100%, depending on the location in the lake)
- Temperance Lake (67%)

Excessive plant growth can occur in lakes with TP greater than 30 µg/L. Only Lower Beverley Lake's Oak Bay sampling site had a mean TP greater than 30 µg/L, and this occurred in 2008.

Total phosphorus averages (means) that were greater than 20 µg/L were also found in Gananoque Lake, Lower Beverley Lake, and Lyndhurst Lake in the MOE-CRCA Lake Survey Program in 1984 (Table 3.4). These three lakes also had high TP levels in the Lake Partners data. TP was high in Singleton Lake and Red Horse Lake in 1984, but were in the mesotrophic range (10-20 µg/L) in the newer Lake Partners data.

There was a significant downward trend in total phosphorus at Bass Lake, Charleston Lake (at 6 of the 7 sampling locations), and Upper Beverley Lake. Even as early as 2002, Bass Lake and Charleston Lake had TP in the mesotrophic zone, and thus, high phosphorus concentrations were likely not a concern. In fact, both Bass and portions of Charleston Lake have been in the oligotrophic range (<10 µg/L) in recent years. Upper Beverley Lake has gone from eutrophic to mesotrophic TP between 2002 and 2009, so this result is encouraging. The *Report on the Water Quality Survey for Charleston Lake* (Ontario Lake Assessments 2007) suggests that this phosphorus reduction in Charleston Lake may be caused by a reduction in TP inputs from local landowners and farmers, or an increase in the zebra mussel (*Dreissena polymorpha*) population.

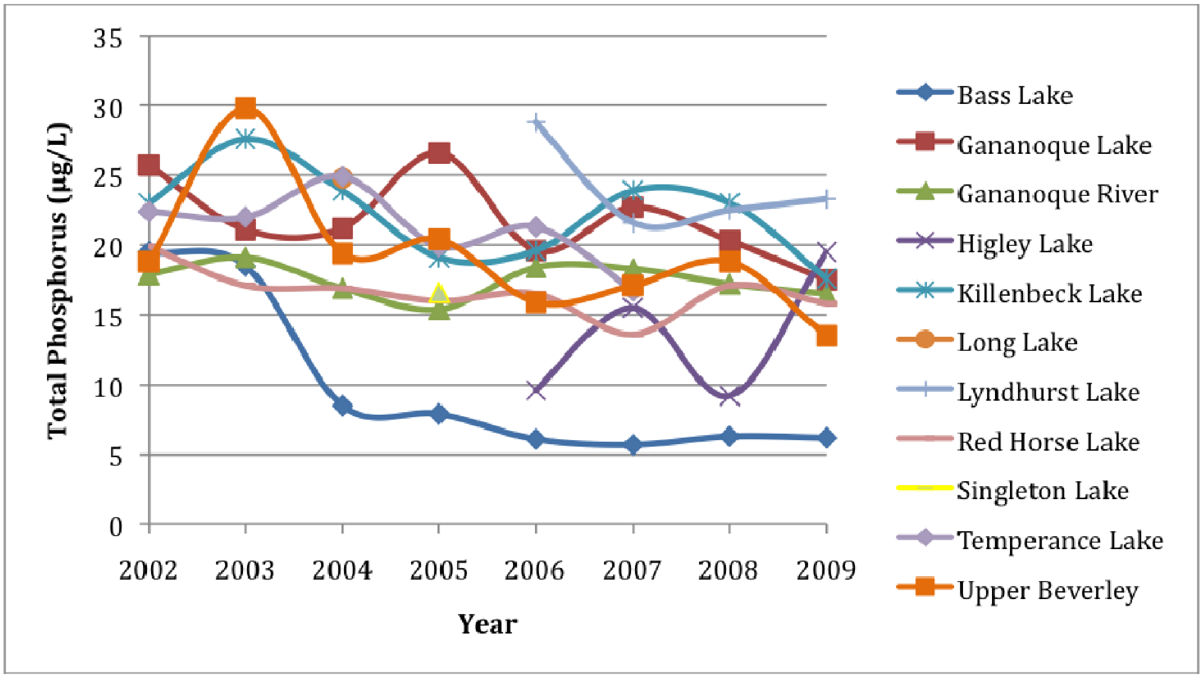


Figure 3.1: Yearly mean (average) total phosphorus concentrations of lakes in the Gananoque River Watershed between 2002-2009. The data are provided by the OMOE Lake Partners Program. Lower Beverley Lake and Charleston Lake are not included because of multiple sampling locations. Means for all sampling locations at those two lakes are provided in Table 3.2.

Secchi Disk Depth

Secchi disk depths provide a measure of water clarity. In the past, secchi depth (SD) has been used as an indicator for the nutrient status of a lake because increased phosphorus levels will lead to an increase in turbidity (i.e., a reduction in water clarity). The Lake Partners Program, however, does not suggest that SD should be used specifically for this purpose, as other causes can alter SD. For example, an improvement in SD in a lake may provide evidence for a proliferation of zebra mussels (*Dreissena polymorpha*), which is an invasive species. Zebra mussels intensively filter particles from water, and so have been shown to improve water clarity. Instead, the Lake Partners Program advises that SD readings can provide overall trends in water clarity over time (OMOE 2005).

Secchi depth data provided by the Lake Partners Program are located in Table 3.3. The Kendall-Mann test was used to check for changes in secchi depth over the years for each sample location for which there were at least three consecutive years of secchi depths available (Table 3.3).

Water clarity is quite good at Charleston Lake (6.1 - 7.5 m SD), Red Horse Lake (5.1 m SD), and Bass Lake (6.4 m SD) in 2009. Red Horse Lake and Charleston Lake, as well as Lower Beverley Lake, have exhibited increasing water clarity from 1996 to 2009 (not all sections of each lake include all years of data). The *Report on the Water Quality Survey for Charleston Lake* (Ontario Lake Assessments 2007) suggests that the increase in SD at Charleston Lake may be attributed to an influx of zebra mussels, as was the decrease in total phosphorus at this lake. Killenbeck also has a very high SD in 2009, but this should be treated with caution as all other years have SD measurements at least 4m lower at this lake. The remaining lakes have moderate water clarity.

Dissolved Oxygen

Fish and other aquatic organisms require oxygen dissolved in the water to survive, and low dissolved oxygen concentrations will stress or kill fish, depending on the severity of the decline. Aquatic plants produce oxygen through photosynthesis. Oxygen is also added to water from the air, which has a much higher concentration of oxygen than water. Oxygen concentrations vary throughout the year, and are often particularly low in the summer when water heats up, which makes oxygen less available. Additionally, in thermally stratified lakes no additional oxygen can enter the cold bottom layer of a lake (the hypolimnion) because mixing between the top and bottom water layers in the lake does not occur during the summer (BCMOE 1997). Eutrophication increases oxygen depletion (see above section on total phosphorus for details).

Dissolved oxygen has been assessed recently at both Red Horse Lake and Charleston Lake, the only two lake trout lakes in the Gananoque River watershed. Lake trout require even more dissolved oxygen than warmer water fish (MNR guideline: mean volume-weighted hypolimnetic dissolved oxygen concentration should be 7mg/L or greater in late summer; Evans 2005). The *Report on the Water Quality Survey for Charleston Lake (*Ontario Lake Assessments 2007) indicates that dissolved oxygen has been historically low in Charleston Lake, but has increased between 2002 and 2007 (up to 2 times). The authors stress that the zebra mussels may be instrumental in this positive trend, as the organisms consume organic matter, which is then not decomposed by bacteria that deplete oxygen from the hypolimnion. MOE data from 2005 indicate that Red Horse Lake maintains dissolved oxygen levels that are lower than the aforementioned MNR guideline.

Metals

Many metals are essential for the nutrition of plants and animals. These elements are called "micronutrients". Iron, for example, is an extremely important micronutrient for organisms, because it is used in many metabolic processes, including protein synthesis, respiration, and photosynthesis. Fortunately, iron is usually available in sufficient quantities in lakes (Wetzel 2001). Other micronutrients include zinc, copper, nickel, molybdenum, cobalt, and selenium.

Too much of some metals can be toxic to aquatic life. Metals that are commonly found in toxic levels in lakes as a result of anthropogenic (i.e., human-caused) enrichment are cadmium, lead, mercury, and aluminum. Very little metal chemistry data exist for lakes in the Gananoque River watershed other than the 2008 and 2009 data collected by the

Ontario Ministry of the Environment (Online Appendix). In 2008, the MOE found that cadmium, lead, and cobalt were at levels that exceeded Ontario's Provincial Water Quality Objective (PWQO) at some of the sampling sites. In 2009, however, no metal levels exceeded the PWQO. The report suggests that the difference between years may be the result of differing methods in the analysis, and that the 2009 data are much more precise. The MOE suggests that further testing needs to be conducted to determine whether the 2008 data are truly atypical (see Online Appendix 3.1 for details).

Additional Water Quality Resources

Additional information on ways landowners can minimize their impact on water quality can be found at:

- Cataraqui Region Conservation Authority: http://www.cataraquiregion.on.ca/index.html
- Living by Water Project (Centre for Sustainable Watersheds): http://www.livingbywater.ca/main.html
- Rideau Valley Conservation Association: Shoreline information and reports http://www.rvca.ca/watershed/aquatic_habitat/shoreline_overview.html#surveys
- Information resources appendix from Lower Beverley Lake shoreline binders (A2A and CSW 2009): http://www.a2alink.org/

Table 3.1: List and description of data collected in the Gananoque River watershed.

Data Source	Description of Water Quality Data	Year(s)	Lakes/Rivers in Gananoque River Watershed
1. 2010 Report on Water Quality of Gananoque River Watershed *- MOE (Online Appendix 3.1)*	- Multitude of water chemistry variables, including metals	2008 and 2009	Up to 24 sampling sites in rivers and lakes
2. Lake Partners Program *– MOE (Data available online. Means provided in Table 3.2 & 3.3)*	- Total phosphorus - Secchi disk depth	1996-2008	13 locations *
3. In-land water quality results for selected rivers and creeks in Gananoque River watershed *- CRCA*	- Summer: 13 variables - Fall: 28 variables	2007	- Gananoque River (3 sites) - Channel between Upper and Lower Beverley Lake - Lyndhurst dam area (2 sites) - Wiltse Creek (5 sites) - Leeders Creek
4. Provincial Water Quality Monitoring Network data (PWQMN) *– MOE and many partners*	Up to 16 variables	1964-2007	4 stations in Gananoque River*
5. Cottagers Data *– MOE*	- Chlorophyll a - Secchi disk depth	1973-1993	13 lakes and 1 sample site in Gananoque River*
6. Lake Survey *– MOE-CRCA (Table 3.4 contains 1984 means)*	12 variables and bacteriological surveys	1981-1984	12 Lakes
7. Gananoque Watershed Management Study (comprehensive 3-volume report on many aspects of watershed) *– Consultants for CRCA*	- Dissolved O_2 - Total P - Total Kjeldahl N - Chlorophyll a - P loadings	1982	13 lakes
Miscellaneous surveys:			
8. South Lake *– MOE*	18 variables	2007, 2008	South Lake
9. Gananoque River - MOE	- Temperature - Dissolved O_2 - Secchi disk depth - pH	2008	Gananoque River (3 locations)
10. Red Horse - *MOE*	17 variables and dissolved O_2 profiles	1998, 2001, 2005, 2008	Red Horse (East Basin, West Basin, and Long Reach)*
11. Report on the Water Quality of Charleston Lake by *Ontario Lake Assessments*	- Dissolved O_2 - Lake Partners data analysis	2007 (O_2)	Charleston Lake
12. Red Horse and Charleston Lake *- MNR*	Up to 8 variables	2002	- Red Horse Lake - Charleston Lake
13. Lower Beverley Lake Report by *Ontario Water Resource Commission*	- 13 variables - bacteriological surveys	1971	Lower Beverley Lake

*Data not always available in all years for each sample site or variable

Table 3.2: Mean total phosphorus (µg/L) per year from 2002-2009 and results from trend analysis (Ontario MOE Lake Partners data - available at http://www.ene.gov.on.ca/en/water/lakepartner/index.php).

Lake	2002	2003	2004	2005	2006	2007	2008	2009	Trend
Bass Lake - mid lake	19.5	18.5	8.5	7.9	6.1	5.7	6.3	6.2	↓
Charleston Lake:									
1. Big Water	16.5	12.4	13.1	11.6	12.3	10.9	10.8	9.2	↓
2. Deep Water	18.9	12.5	12.3	11.5	11.2	10.4	11.4	10.0	↓
3. Donaldson Bay	16.4	14.3	13.3	12.6	11.2	10.0	11.3	9.3	↓
4. Eastern Water	16.4	10.5	12.4	10.5	11.6	10.5	10.3	9.8	↓
5. North End, Goose Island	18.6	13.6	13.2	11.3	11.9	10.7	10.7	10.5	↓
6. Southern Water	15.5	12.6	13.7	12.3	12.0	11.0	13.3	13.4	~
7. Webster Bay	16.2	13.1	14.5	11.0	13.0	10.3	10.8	10.0	↓
Gananoque Lake - mid lake	25.7	21.1	21.2	26.6	19.6	22.7	20.3	17.5	~
Gananoque River - north end river	17.9	19.1	16.9	15.4	18.4	18.3	17.2	16.5	~
Higley Lake – mid lake	.	.	.	.	9.6	15.5	9.2	19.5	~
Killenbeck Lake – SW end	23.0	27.6	23.9	19.1	19.6	23.9	23	17.6	~
Long Lake – mid lake	.	.	24.8	.	.	.	.	.	N/A
Lower Beverley:									
1. Blackjack Island	29.8	20.9	19.7	23.4	21.6	18.0	21.2	18.7	~
2. Kendrick's Bay	19.8	21.8	18.2	18.0	18.3	16.5	20.5	17.4	~
3. Oak Bay	20.7	23.2	26.4	24.8	20.7	21.1	31.0	29.5	~
Lyndhurst Lake - mid lake	.	.	.	.	28.8	21.6	22.5	23.3	~
Red Horse Lake - W Basin	19.9	17.1	16.9	16.0	16.5	13.6	17.1	15.8	~
Singleton Lake – mid lake	.	.	.	16.6	.	.	.	.	N/A
Temperance Lake - mid lake	22.4	22.0	24.9	19.9	21.3	16.7	.	.	~
Upper Beverley - Outlet	18.8	29.8	19.4	20.4	15.9	17.1	18.8	13.5	↓

Kendall Seasonal tests, which account for seasonality, were used for all lakes to assess trends in total phosphorus (TP) over time, except in Bass Lake and Higley Lake where there was only one sample per year. In these cases the Kendall-Mann test was used. In addition, Singleton Lake and Long Lake had only one sample and, therefore, no analyses could be performed. Significant trends are expressed as arrows in the direction of the trend. The symbol "~" is used when there was no significant trend. Lakes that have mean TP greater than 20 µ/L are indicated by red text.

Table 3.3: Ontario MOE Lake Partners secchi disk depths (m) from 1996-2009 and results from trend analysis (http://www.ene.gov.on.ca/en/water/lakepartner/index.php).

Lake	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Trend
Bass	.	8.7	.	.	5.1	4.5	4.2	.	6.1	7.9	6.4	5.8	5.5	6.4	~
Charleston:															
1. Big Water	4.9	4.0	4.6	.	4.1	4.5	3.8	4.6	4.6	5.5	5.6	6.6	6.3	6.8	↑
2. Deep Water	.	.	.	.	4.9	4.7	4.0	4.7	4.8	5.5	5.6	7.1	6.9	7.3	↑
3. Donaldson Bay	.	.	.	.	3.9	4.6	4.1	4.4	4.3	5.3	6.1	6.6	5.7	7.5	↑
4. Eastern Water	.	.	.	.	4.2	4.4	3.9	4.2	5.0	5.5	5.5	6.8	6.7	7.0	↑
5. Goose Island	5.0	3.6	4.4	4.7	3.9	4.4	4.0	4.0	4.9	5.7	5.8	6.8	6.4	6.1	↑
6. Southern Water	.	.	.	.	4.1	4.4	3.6	4.3	4.7	5.4	5.3	5.7	5.3	6.2	↑
7. Webster Bay	.	.	.	.	4.0	4.3	3.8	3.9	4.5	5.9	5.7	6.8	5.8	6.6	↑
Gananoque	2.9	2.5	3.4	1.5	2.6	2.0	2.3	2.8	3.0	2.7	2.9	2.9	2.7	3.1	~
Gananoque River - North end	.	.	.	.	.	.	2.6	2.6	2.4	3.0	3.7	4.3	4.2	3.7	~
Grippen	2.7	3.0	.	3.0	.	.	.	.	.	.	.	.	.	.	N/A
Higley	.	.	.	.	.	.	.	.	.	.	4.2	.	.	2.9	N/A
Killenbeck–SW end	2.2	3.0	2.4	2.9	1.9	2.5	1.9	2.2	2.6	2.9	2.3	2.9	2.0	7.7	~
Lower Beverley:															
1. Blackjack Island	.	.	.	2.1	2.1	2.5	2.7	3.0	3.0	3.1	3.0	3.1	3.1	3.2	↑
2. Kendrick's Bay	2.8	2.6	2.2	2.1	2.3	2.4	2.8	2.7	3.0	3.4	3.1	3.4	3.4	3.3	↑
3. Oak Bay	2.3	2.6	2.0	2.0	2.0	2.5	2.9	3.1	2.6	2.7	2.9	3.2	2.6	2.8	↑
Lyndhurst	.	.	.	.	.	.	.	.	.	.	.	4.1	3.1	2.8	N/A
Red Horse - W Basin	3.6	3.6	3.5	3.6	2.8	3.7	3.1	3.4	4.1	4.8	4.9	5.6	4.7	5.1	↑
Temperance	.	.	.	1.7	2.3	2.2	1.8	2.0	1.4	1.5	1.7	2.2	.	.	~
Upper Beverley - Outlet	.	2.5	2.5	2.4	2.3	1.8	3.0	2.8	2.7	2.7	2.7	2.7	2.4	2.9	~

Kendall-Mann tests were used to assess trends in secchi disk depth over time. Significant trends are expressed as arrows in the direction of the trend. The symbol "~" is used when there was no significant trend.

Table 3.4: Surface water chemistry means and secchi disk depths from surface samples collected from May to August 1984 in the Gananoque River watershed (MOE-CRCA Lake Survey Program data).

Lake	Location of Multiple Samples per Lake	Secchi (m)	Chlorophyll a (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Total Dissolved Solids (mg/L)	pH	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Iron (mg/L)	Chloride (mg/L)	Dissolved O_2 Profile
Centre		2.1	2.8	90	100	131	8.1	20	614	0.08	8.0	F
Charleston	Eastern Water	3.6	3.1	98	113	141	8.2	18	479	0.07	6.0	E
	Big water	3.7	2.9	99	113	142	8.3	17	457	0.07	5.6	E
	Deep Water	3.7	2.8	98	113	141	8.2	18	438	0.06	5.8	E
Eloida		.	2.7	127	137	168	8.3	20	726	0.09	5.9	F
Gananoque	Station 17	2.9	4.4	121	132	166	8.3	22	581	0.05	7.2	C
	Station 18	4.4	5.1	118	131	164	8.2	25	618	0.05	6.9	C
Graham		2.7	3.6	73	92	120	8.1	18	508	0.08	6.3	F
Grippen		2.3	3.2	126	149	193	8.4	15	523	0.06	13.6	.
Lower Beverley		2.5	6.6	125	139	173	8.2	29	559	0.07	7.1	C
Lyndhurst		2.4	6.2	125	139	169	8.2	27	698	0.8	7.6	B
Red Horse	East	2.8	4.7	125	139	173	8.3	25	584	0.05	7.5	E
	West	2.7	4.9	124	139	173	8.4	21	566	0.16	7.3	E
	South	2.0	5.4	114	131	174	8.2	24	591	0.16	10.0	C
Singleton		2.6	5.3	126	139	175	8.2	25	614	0.06	6.9	C
Temperance		2.6	3.6	68	75	110	8.1	20	505	0.11	5.0	F
Upper Beverley		2.6	4.2	138	149	180	8.2	20	620	0.06	6.1	F

Dissolved Oxygen Profile Legend: B - clinograde without anerobic conditions; C - clinograde with anerobic conditions; E - negative heterograde; F - too shallow to permanently stratify

References

British Columbia Ministry of the Environment. 1997. Water Quality: Ambient Water Quality Criteria for Dissolved Oxygen. Water Management Branch, Environment and Lands Headquarters Division, Ministry of Environment, Lands and Parks. Publication available online at: http://www.env.gov.bc.ca/wat/wq/BCguidelines/do/index.html

Cataraqui Region Conservation Authority (CRCA). 2009. Cataraqui Region Conservation Authority Watershed Report Card 2009. Publication available online at: http://www.cataraquiregion.on.ca/.

Evans, D.O. 2005. Effects of hypoxia on scope-for-activity of lake trout: defining a new dissolved oxygen criterion for protection of lake trout habitat. Technical Report 2005-01. Habitat and Fisheries Unit, ARDS, ARDB, Peterborough.

Helsel, D.R., Hirsch, R.M. 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. U.S. Geological Survey. Publication available online at: http://pubs.usgs.gov/twri/twri4a3/

Lathem Group Inc. and Cumming-Cockburn and Associates Limited. 1982-1984. Gananoque Watershed Management Study. Reports on Year 1, 2, and 3. Prepared for the Cataraqui Region Conservation Authority.

Ontario Ministry of the Environment (OMOE; Formerly Ontario Ministry of Environment and Energy). 1994. Water Management: Policies, Guidelines, and Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen's Printer for Ontario. Publication available online at: http://www.ene.gov.on.ca/envision/gp/3303e.htm

Ontario Lake Assessments. 2007. Report on the Water Quality Survey for Charleston Lake. Ontario Lake Assessments. Harrowsmith, Ontario.

Ontario Ministry of the Environment (OMOE). 2005. Interpretation of TP and Secchi Results. Lake Partners Program, OMOE. Available online at: http://www.ene.gov.on.ca/en/water/lakepartner/index.php

Ontario Ministry of the Environment (OMOE). 2010. The water quality of the Gananoque River watershed 2008-2009. Available on the A2A website as Online Appendix 3.1.

Wetzel, R.G. 2001. Limnology. 3rd edition. Academic Press. London.