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Macrophyte Surveys of Littoral Habitats in Great Lakes' Areas of Concern: The Bay of Quinte, Hamilton Harbour, and Severn Sound - 1988 to 1991

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MACROPHYTE SURVEYS OF LITTORAL HABITATS IN GREAT LAKES' AREAS OF CONCERN: THE BAY OF QUINTE, HAMILTON HARBOUR, AND SEVERN SOUND - 1988 TO 1991

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ABSTRACT

Minns, C.K., V.W. Cairns, R.G. Randall, A. Crowder, and A. McLaughlin. 1993. Macrophyte surveys of littoral habitats in Great Lakes' Areas of Concern: The Bay of Quinte, Hamilton Harbour, and Severn Sound - 1988 to 1991. Can. Tech. Rep. Fish. Aquat. Sci., 1936:viii+60p.

This report describes the survey methods, the results, and the analysis of littoral macrophyte surveys conducted in three Great Lakes' Areas of Concern (AOCs): The Bay of Quinte, Hamilton Harbour, and Severn Sound, between 1988 and 1991. The transects surveyed were selected from a large set of electro-fishing transects and the macrophyte surveys were done to provide quantitative measures of fish habitat. Different survey methods were employed at various times. The abundance and composition of macrophytes in the three AOCs is described. In general, the average abundance levels by location were consistent with the degree of eutrophication. Comparisons between survey methods and between years are reported. Repeat surveys in different years provided evidence of stability of plant cover. Percentage cover, stem density, and quadrat biomass methods show significant agreement. A regression model of percentage cover as a function of stem density, and mean and c.v. of plant height was highly significant. Percentage taxonomic composition of macrophyte assemblages was not a significant predictor of abundance. Various survey methods are assessed; percentage cover is recommended, given sufficient standardization and sampling. The results were used to determine sample size requirements for percentage macrophyte cover on transects. Further method tests and comparisons are suggested.

RÉSUMÉ

Minns, C.K., V.W. Cairns, R.G. Randall, A. Crowder, and A. McLaughlin. 1993. Macrophyte surveys of littoral habitats in Great Lakes' Areas of Concern: The Bay of Quinte, Hamilton Harbour, and Severn Sound - 1988 to 1991. Can. Tech. Rep. Fish. Aquat. Sci., 1936:viii+60p.

Ce rapport décrit les méthodes, les résultats et l'analyse des dénombrements de macrophytes littoraux faitu dans trois secteurs préoccupants des Grands Lacs, soit la baie de Quinte, le port d'Hamilton et le détroit Severn, entre 1988 et 1991. Les transects ont été choisis parmi un vaste réseau de transects de pêche électrique, et les dénombrements de macrophytes ont servi a recueillir des données quantitatives sur l'habitat du poisson. Différentes méthodes ont été appliquees à différents moments. Le rapport décrit l'abondance et la composition des macrophytes dans les trois secteurs préoccupants. En général, l'abondance moyenne notée a différents emplacements correspond bien au degré d'eutrophication. Il est fait état de comparisons entre les méthodes de dénombrement et entre les années. Des dénombrements répétés à différentes années ont permis de montrer la stabilité de la couverture végétale. Les méthodes de dénombrement par pourcentage de couverture, par densité des tiges et par biomasses sur des quadrats, concordent significativement. Un modèle de régression du pourcentage de couverture en function de la densité des tiges, ainsi que la moyenne et le coefficient de variation de hauteur des plantes sont dans un rapport très significatif. L a composition taxonomique, en pourcentage, des assêmblages de macrophytes ne s'est par révélée être une variable prédictive de l'abondance. Différentes méthodes de dénombrement sont évaluées: la méthode par pourcentage de couverture est recommandée pouvu que la normalisation et que l'échantillonnage scient adéquats. Les résultats ont servi à déterminer l'importance de l'échantillonnage requis pour mesurer le pourcentage de couverture par les macrophytes sur les transects. Il est recommandé de procéder à de nouvelles comparaisons et à de nouveaux essais des méthodes.

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INTRODUCTION

Understanding the linkages between fish and fish habitat is essential for the conservation and effective management of fishery resources. In Canada, fish and fish habitats are guarded by the provisions of the Fisheries Act and its principle policy instrument - 'A Policy for the Management of Fish Habitat' (DFO 1986). While every fisherman and fisheries scientist 'knows' of the 'importance' of 'structure', 'cover', vegetation (emergent and submerged), and other habitat features, to fish assemblages, there is a dearth of quantified, scientific data confirming the nature and strength of fish:habitat linkages. On the Great Lakes, many nearshore fish habitats have been damaged by human developments and expansion. This is particularly true in the Areas of Concern (AOCs), locations around the Great Lakes designated by the International Joint Commission as having suffered intensive and extensive ecosystem degradation.

Fisheries and Oceans is conducting a research program to interrelate measures of fish assemblages and fish habitats in three AOCs: (i) Severn Sound at the southern end of Georgian Bay, the northern entrance to the Trent-Severn Waterway; (ii) Hamilton Harbour at the western tip of Lake Ontario, a major shipping port for coal, iron, and steel; and (iii) The Bay of Quinte connecting to the eastern outlet basin of Lake Ontario, the southern entrance to the Trent-Severn Waterway (Figure 1). Part of the program involves sampling fish habitat features in the littoral zones of those areas, with attention focused on the occurrence, abundance, and composition of submerged macrophytes. There are many methods for assessing submerged vegetation but it is unclear which methods, if any, can provide measures appropriate to the quantification of fish habitat and of linkages with fish assemblages. Over a four year period, 1988-1991, we conducted a variety of habitat surveys at a subset of sites where the fish assemblages were sampled using an electro-fishing boat. The purposes of this report are to: (i) Describe the methodologies and results of those macrophyte surveys, (ii) Describe the submerged macrophyte assemblages found in a wide range of Great Lakes littoral fish habitats at three AOCs, (iii) Assess the relationships between different measures of littoral macrophyte assemblages, and (iv) Compare the logistics and utility of the different methods.

MATERIALS AND METHODS

Bay of Quinte, 1988-1989

In 1988, we established a set of transects in the upper Bay of Quinte including four types of habitat in the littoral zone, i.e. areas with less than 2-3 metres water depth. The four types were: a) sites with strong fetch and probably no submergent vegetation except filamentous algae, b) sites with moderate fetch and presumed to have sparse vegetation (such sites were to have, if possible, structures such as harbour walls or sea-walls), c) sites with moderate fetch and natural beaches with about 50 percent vegetation cover, and d) sites with low fetch and dense vegetation cover of 100 percent (such sites were to have, if possible, underwater structure such as fallen trees or piles of stones). All sites were to be located close to Belleville or Trenton within the operating range of the electro-fishing boat used to assess fish assemblages. In practice, the habitat categories were imprecise but ensured that a range of fish habitat types was obtained.

The studies required the coordination of contractors undertaking separate macrophyte and fishing surveys. In 1988, a macrophyte survey of 32 transects was completed but logistic problems prevented the electro-fishing survey work from being done. In 1989, both macrophyte and electro-fishing surveys were completed on 33 transects, 30 of which overlapped transects selected in 1988. Twenty of the transects were electro-fished three times in 1990.

Macrophyte Survey in August, 1988: In 1988, Dr. Adele Crowder organized and conducted a macrophyte survey as part of a contract (Ontario Ministry of Environment Project #126016) as part of on-going efforts to document changes on submerged macrophyte assemblages in response to nutrient load reductions. This activity was one of several projects directed to the development of the Remedial Action Plan. Alison McLaughlin, Nancy Child, and Dr. Michael Bristow performed the diving work.

At each site, a 100 metre transect was laid out parallel to shore. Depth, Secchi disc depth, and pH were measured. Primary and secondary bottom types were observed and recorded, and a sediment sample was taken at all sites except those near Trenton. Vegetation was recorded as percentage cover and identified to species either underwater or on the accompanying boat. When visibility was poor, all specimens had to be brought to the surface. On transects where cover was 100 percent, it was impossible to swim along the line and spot dives were used instead.

Macrophyte Survey in 1989: This survey work was conducted on a contract issued by Dr. C.K. Minns to Dr. A. Crowder and A. McLaughlin (Department of Supply and Services Contract No. FP-921-9-0475). At each site, a transect of 100 metres oriented parallel to the shore was set out in water which was 2-3 metres deep. Depending on the vegetation cover conditions, divers either swam the length of the transect or else made spot dives to sample vegetation and substrate. Temperature, Secchi disc depth and pH were measured. Plant species were observed and recorded, and two 0.5 m^2 quadrat samples were collected for biomass measurements. The type of bottom substrate was recorded for each transect. Later, the macrophyte quadrat samples were identified, sorted to species, and oven-dried to a constant weight. Biomass was recorded as grams dry weight per square metre.

Bay of Quinte, Hamilton Harbour, and Severn Sound, 1990

In August and September of 1990, teams of divers conducted intensive macrophyte surveys in all three AOCs. In the Bay of Quinte (BQ) and Hamilton Harbour (HH), the transects were selected from those surveyed and electro-fished in 1988-1989 (Figure 2 A,B). In Severn Sound, transects were sampled in three sub-areas, Penetang Harbour (PH), Hog Bay (HB), and Matchedash Bay (MB), from the larger set of electro-fishing transects (Figure 2 C,D,E).

The sampling design was as follows:

(a) A 100 metre floating line marked at 5 metre intervals was positioned along a transect (they mostly followed the 1.5 metre depth contour parallel to shore) (Figure 3A)
(b) The diver moved along the line to a mark, every 10 metres in most instances, and dropped a weight from the line to randomly select a starting point on the bottom (position X in Figure 3B)
(c) The diver then searched within a 100 cm radius of point X for the nearest plant stem
(d) If no plant was found a '>100 cm' entry was recorded on a data sheet and the diver proceeded to the next X mark along the transect and resumed at step (b)
(e) If a plant was found (point Y in Figure 3B), the diver identified the plant and measured the plant's height (cm) and the distance XY (cm)
(f) The diver then placed a right-angled cross on top of point Y laying one axis along the line XY,
(g) The diver then searched within a 100 cm radius for the plant nearest to point Y in each of the four quarter circles
(h) In each case, the diver either identified the plant and measured the plant height and the distance from Y (lines YA,YB,YC,YD in Figure 3B) or, if no plant was found within a quarter, the diver entered a '>100 cm'.

In most instances, the divers sampled at 10 metre intervals along the transects. Plants were identified to species where possible. In addition, a visual estimate of percentage plant cover along the whole transect was recorded and the depth measured at the start and end of each transect.

The data were analyzed as follows:

(a) Mean and coefficient of variation (C.V.) of plant height was calculated using all measured plants by transect.

(b) Percentage composition by macrophyte taxa was calculated by transect and area

(c) Mean and C.V. of stem density was calculated from estimates of area per stem. Given the centre plant at Y, the half radius to the nearest plant in each quarter (YA/2,YB/2,YC/2,YD/2) is the radius of a circle enclosing an area for plant Y (Figure 3B). The approach used was based on distance methods of density estimation described in Upton and Fingleton (1985). The area around Y was calculated as $\pi*(YA^2+YB^2+YC^2+YD^2)/16$. In some instances the distance to the nearest plant was >1 metre either initially from X or in one or more quarters from Y and these were all designated as >100 cm. In other instances, the distances between plants were short and difficult for the divers to measure and were designated as <1 cm. In those cases where the number of <1 and >100 cm values from a transect survey were less than 20 percent of the values available, we used a regression technique to estimate distance values at the average tails of a cumulative percentile distribution ($\log_e$ distance versus random normal deviate of percentile) (Helsel 1990). The regression was performed on the distance values between 1 and 100 cm and the resulting equation extrapolated for higher and lower percentile values, the mean percentiles of values above 100 cm or below 1 cm. In the few instances where there were too few values between 1 and 100 cm, we substituted either 1 for <1 or 200 for >100. In the <1 case, a measure of 1 cm represents a density of 10,000 stems.m^2. In the >100, the doubling was justified on the ground that using 100 cm and then halving it to calculate an area, would cause density to be overestimated when the sampling indicated densities less than 1 per $\pi.m^2$, the initial search area centred on X (Figure 3B). Under this calculation scheme, the stem density can only be 0 if all XY distances sampled along a transect are >100 cm, and can only reach a maximum of 10,000 where all quadrant distances (YA,YB,YC,YD) are <1 cm. Next, the areas estimated at each mark on a transect were inverted to give density values and the mean and C.V. calculated for each transect.

Bay of Quinte, Hamilton Harbour, and Penetang Harbour in 1991

In August and September of 1991, teams of divers again conducted macrophyte surveys in all three AOCs although only Penetang Harbour was visited in Severn Sound. Detailed transect sampling was done using the same procedures as in 1990 except that visual percentage cover was recorded on a spot basis every 10 metres along the transects by divers at the surface looking down through a face-mask.

Data management and statistical analysis

In the field, data were recorded on formatted water-proof sheets. The data were entered into tables using the RS/1 software package (BBN 1991). Calculations and preliminary analysis was also performed using RS/1. Statistical analyses were performed using the SYSTAT software package (Wilkinson 1990). Results were judged significant using the P = 0.05 threshold unless otherwise indicated. Groupings and designation of macrophyte taxa were based on descriptions and drawings in Fassett (1966). Percentage assemblage compositions were compared between years using the percent similarity index (Washington 1984).

Statistical analyses included correlation, contingency analysis, one-way analysis of variance, and regression modelling. Pearson correlations were used to assess agreement between pairs of macrophyte measures in all groupings of data. Contingency analyses were used to assess the agreement of bottom substrate categories in 1988 and 1989 surveys in the Bay of Quinte. One-way analysis of variance was used to assess the association between bottom type classes and macrophyte measures in the same surveys. Regression modelling was used to describe the relationship between transect values of coefficient of variation and mean for plant height. Step-wise multiple regression was used to build models of macrophyte measures (percentage cover, stem density, and plant height) using macrophyte abundance and composition measures.

RESULTS

Bay of Quinte, 1988-1989

Description of data: In 1988 and 1989 respectively, 32 and 33 transects were surveyed with 30 transects in common between the two years. Transects were concentrated in three clusters (from left to right in Figure 2B) at Trenton, Belleville, and Big Island. Combined taxon lists for the two years show that 9 taxa were found in both years out of 17 and 15 encountered in 1988 and 1989 respectively (Table 1). Combinations of primary and secondary bottom substrate types were assigned codes to facilitate grouping of the sites (Table 2). Bottom type codes 1 to 4 represent a gradient of particle size going from small (mud) to large (rock).

In 1988, depths ranged from 1-2 metres, Secchi disc depths from 55 to 120 cm, and pH values ranged 6.3-7.2 (Table 3). Nine transects were rocky and 3 partly rocky, 3 were stony and 2 partially stony, 2 were sandy and 6 partly sandy, 7 were muddy, 2 were predominantly organic, and 3 were mixed. (One site was noted as having a very sharp drop-off.) On transect 10, bottles and plastic bags littered the bottom. No structures such as break-walls or submerged piles were encountered, although 2 transects (5 and 6) were just to the south of the wall of the Murray Canal. There were 9 transects with no macrophyte cover (7 at Big Island - BI, 2 at Belleville - BE), 8 with <3 percent cover (3 Trenton - TR, 4 BB, 1 BE), 7 with 3-80 percent (2 TR, 3 BE, 2 BB), and 8 with 80-100 percent (7 TR, 1 BE). The sites in the different cover ranges were spaced unevenly around the shore and clustered in some places. Transects dominated by sandy or mud substrates accounted for most of the high cover values while rock or sand-rock dominated sites had low cover or none. Low cover sites were generally closer to shore, indicating that steeper shore profiles are less favourable for submerged vegetation.

Aside from filamentous algae, 17 species were found (Table 1). Mosses were not identified and *Chara* were not identified to species. *Megalonka beckii* was the only species found in this survey, not found in previous surveys from 1972 to 1982 (Crowder and Bristow 1986). Detailed macrophyte composition data showed that *Heteranthera dubia*, *Vallisneria americana*, *Myriophyllumm spicatum*, and *Elodea canadensis* were the four species most frequently encountered (Tables 1 and 4).

In 1989, 33 transects, numbered 1-33, were surveyed. Thirty of transects were repeated from the 1988 survey except that the 1989 surveys took place in 2-3 metres of water. A summary of data by location is given in Table 5 and a brief description of the shoreline area is given in Appendix Table A. Substrate types included mud, organic, sand, gravel, stone, rock, and wood. Water temperatures ranged from 23-29 C, pH ranged from 6.7-8.9, and Secchi disc readings ranged from 80 to 300 cm.

All the major species identified in the 1988 transects were found in July 1989. Among the minor species, more *Bidens beckii* and *Ranunculus aquatilis* were recorded in 1989 but there was no *Potamogeton pectinatus* or *P. richardsonii* and very little *P. crispus*. *Utricularia vulgaris* was not recorded because the site near one of the sewage pumping stations was not surveyed in 1989. *Heteranthera dubia*, *Vallisneria americana*, *Myriophyllum spicatum*, and *Elodea canadensis* were the most common species with frequencies of occurrence of 63.6, 57.6, 57.6, and 54.6 percent respectively (Table 1). *Myriophyllum spicatum* dominated the biomass by comprising 56.7 percent of the total biomass sampled (Table 1). Average biomass ranged from 0.0 to 288.5 dry $g.m^{-2}$ and species richness in the quadrats ranged from 0 to 11 (Table 6). *Myriophyllum spicatum* accounted for much of the biomass sampled.

Statistical analyses: Relationships among variables within years and among variables between years were assessed. Where a range of percent cover was reported, the mid-point was used for analysis; where a less than value was given, half the threshold value was used. The percent cover values are transformed by taking the arcsine$\sqrt{}$. Biomass values for 1989 were transformed as $\log_e(X+1)$. In both 1988 and 1989, Percentage cover and species richness were significantly ($P = 0.05$) correlated in both 1988 and 1989 ($r = 0.67$ on 31 df; $r = 0.55$ on 32 df respectively). In 1989, total biomass was significantly correlated with species richness ($r = 0.82$

on 32 df) and with percentage cover (r = 0.56 on 32 df).

On 30 transects surveyed in both 1988 and 1989, percent cover values were significantly correlated between years (r = 0.62 on 29 df). Species richness values were also significantly correlated (r = 0.36 on 29 df) though values were generally higher in 1989 as a result of the more thorough survey method; biomass quadrats yielded more species than point-intercepts on a knotted line. Large increases in richness were recorded along the wall of the Murray Canal and on transect 7 in Trenton. Richness decreased at transect 9 in Trenton close to the inlet of Dead Man's Creek, and also at transects 31-33 off Big Island. Transect 9 is known locally as a dumping site, and had a pH of 6.7 more acidic than any other site tested. Percent cover values for the two years had a significant correlation, r = 0.60. The coefficient of contingency between bottom type groups was 0.594 between the two years; the χ^2 test was not significant (χ^2 = 16.38 on 9 df). The substrate categories did not agree and agreement may have been limited by the fact that transect descriptions were visual observations and that the 1989 transects were done in slightly deeper water.

The relationships of percentage cover and species richness to bottom type were assessed in a series on one-way analyses of variance, using bottom type groupings 1-4 (Table 2). In 1988 and 1989, ANOVA showed that percentage cover varied significantly with bottom type (F_{88} = 4.54, P = 0.008 s on 3,28 df; F_{89} = 9.69, P = 0.000 s on 3,29 df). In both years, mean percent cover declined going from bottom type 1 to 4. In 1988, means for types 1 and 4 were significantly different; in 1989, the type 1 mean was significantly different from the means of both types 3 and 4, and type 2 mean was significantly different from type 4 mean. The results for species richness were mixed: In 1988, there was no significant difference between bottom type (F_{88} = 1.91, P = 0.150 ns on 3,28 df) while, in 1989, richness changed significantly with bottom type (F_{89} = 3.98, P = 0.017s on 3,29 df). In 1989, mean richness declined along the range of bottom types 1 to 4 and mean for types 1 and 4 were significantly different.

Overall the analyses indicated a good level of agreement and consistency among the percentage cover, species richness, and association with bottom types for the two years of sampling in the Bay of Quinte.

Bay of Quinte, Hamilton Harbour, and Severn Sound, 1990

Description of data: Macrophyte surveys were conducted on 72 electro-fishing transects in late August and early September (Tables 7,8). Percentage cover was much lower on most transects in Hamilton Harbour and Bay of Quinte compared to those in the Severn Sound bays. A total of 2758 plants were identified and measured belonging to 18 plant taxa, of which 9 were *Potamogetons* (Table 9). *Vallisneria americana* was the most frequently encountered plant in four of the five area (33.3 to 53.4 percent frequency). In the Bay of Quinte, *Potamogeton gramineus* was more common (40.8 compared to 30.2 percent). The next two or three most frequent species were either *Myriophyllum spicatum*, *Elodea canadensis*, *P. gramineus*, or *P. foliosus*, depending on the area.

Mean stem density ranged from 0.0 to 7126.8 stems.m^{-2} and the coefficient of variation (C.V.) from 0.0 to 312.1%. Mean plant height ranged from 0.0 to 100.7 cm and the C.V. from 0.0 to 145.0%. Plants were sorted into 11 categories (Table 10). (In Matchedash Bay, transect 5 was not surveyed according the stated methodology because of logistic constraints. Instead, a diver swam along the total length of the transect counting all plants in a 2 metre swath and noting species composition.) Stem densities showed considerable variability reflecting the patchy nature of macrophytes. Hamilton Harbour and Bay of Quinte had average stem densities considerably lower than those found in Severn Sound, where average densities were highest in Penetang Harbour (1303 stems.m^{-2}) (Table 11). Levels of variability were similar across the 5 areas. Mean plant heights were similar across the 5 areas and the level of variability was lower than that obtained for stem density. Percentage cover estimated visually ranged from 0 to 100 with a mean of 42 %. Average percentage cover was lower in Hamilton Harbour and Bay of Quinte than in Severn Sound. Percentage macrophyte composition showed similar average patterns for the 5 areas (Table 12). Overall, *Vallisneria* was first dominant accounting for 35.2 percent, narrow-leaved *Potamogetons* were second with 20.1, and *M. spicatum* was third with 13.1. In the Bay of Quinte, narrow-leaved *Potamogetons* were dominant (44.2) followed by *Vallisneria* and *Myriophyllum*. In Hamilton Harbour, *Myriophyllum* was the second dominant (21.4 percent). In Severn Sound, Penetang Harbour and Hog Bay were similar to the average except that *Chara* were a third co-dominant in Hog Bay. In Matchedash Bay, *Vallisneria* and *Elodea* were much higher (averages of 56 and 19 percent respectively) and narrow-leaved *Potamogetons* contributed only a small percentage. Percentage occurrences of the 11 plant taxa varied from 2.8 (*Alisma* sp.) to 75 (*Vallisneria*) for the 72 sites.

Bay of Quinte, Hamilton Harbour, and Penetang Harbour, 1991

Description of data: Macrophyte surveys were conducted on 30 electro-fishing transects in 1991 (Table 13) and a total of 1331 plants were identified and measured (Table 14). Seventeen plant taxa were noted in the three sampling areas, of which 7 were *Potamogetons*. *Vallisneria* was the most frequently encountered plant in all three areas, ranging from 36.9 percent in the Bay of Quinte to 77.3 percent in Hamilton Harbour. *Myriophyllum spicatum* and

P. amphifolius were the second and third most frequent plants in all three areas. Penetang Harbour had the greatest diversity with 16 taxa while Hamilton Harbour had the lowest with 6 taxa and the Bay of Quinte did only slightly better with 8 taxa (Table 14).

Mean stem density ranged from 0.2 to 2351.1 $\#.m^{-2}$ with C.V.'s ranging from 24.2 to 236.1 percent (Table 15). Mean plant height ranged from 5.2 to 100.3 cm with a C.V. range of 22.5 to 118.6 percent. Mean percent cover ranged from 0.1 to 100.0 percent with a s.d. range of 0.0 to 37.8 percent (Mean and s.d. based on arcsine√ transformation of raw values and reverse transformation of the results). On average across transects within areas, Penetang has the highest stem density and percent cover and Hamilton Harbour the lowest values (Table 15). Plant heights were highest in the Bay of Quinte and lowest in Penetang Harbour.

The percentage composition data from the 30 transects revealed differences between the three areas (Table 16). While *Vallisneria* was the most frequently encountered taxon, that taxon only dominated on half the transects. In Hamilton Harbour, 5 of 8 transects were dominated by *Vallisneria* and the rest by *M. spicatum* with a range of 58 to 100 percent of occurrences accounted by the dominant species. In Penetang Harbour, *Vallisneria* was present on all transects but dominated only 7 of 11 with *M. spicatum* dominating 3 and *Chara* one. There dominance ranged from 36 to 74 percent. In the Bay of Quinte, the dominance, with a range of 35 to 88 percent, was spread among 5 taxa: *Vallisneria* 3, *M. spicatum* 2, *P. amphifolius* 4, and *Elodea* and *P. crispus* 1 each.

Analysis of Combined Results

Since the basic survey methods were the same in 1990 and 1991 and many of the transects were the same in both years, the two data sets were pooled prior to any statistical analysis. Wherever necessary, appropriate tests were performed to detect any inter-year differences in means and relationships.

Some consolidation and transformation of data was undertaken prior to performing statistical analyses. Taxon composition data from all surveys was grouped into nine categories based on overall frequency of occurrence patterns and the difficulty of identifying *Potamogeton* species (Table 17). Percentage cover (COVER) values were transformed using the arcsine$\sqrt{}$ form (ACOV) recommended for percentage data. Mean stem density (STMN) was $\log_e$-transformed after adding 1 to account for presence of zeroes (LNST). The biomass data in the 1989 Bay of Quinte survey was transformed in the same way (LNBIOM). In the 1991 surveys, the means and standard deviation of percent cover were obtained by reverse transformation of the results of statistical analysis on ACOV values. The remaining variables were not transformed: C.V. of stem density (STCV) and C.V. of plant height (HTCV).

Variability: Before looking at relationships between measures of the macrophyte assemblages, we examined the relationships between transect means and their variation. In both 1990 and 1991, the estimates of stem density and plant height were based on multiple observations along each transect. In 1991 only, we estimated mean percent plant cover from multiple observations of percent cover along transects.

With stem density, the transect-by-transect values of the percent coefficient of variation (C.V.) covered a wide range from 0 to 312 %. C.V. did not vary systematically with mean stem density (Figure 4) although, apart from a cluster of low values at zero or very low densities, there is a slight tendency for lower values to occur more frequently at intermediate densities. Such a pattern of variability is consistent with the difficulties divers might be expected to have when measuring inter-plant distances. At high densities, divers reported difficulty deciding which inter-plant distance to measure when so many stems were close together. At low densities, divers may have difficulty finding stems to measure distances against. At very low densities, plots with zero plants become very frequent and the variance is reduced.

With plant height, there is a relationship between the $\log_e$ of the percentage C.V. and the mean (Figure 5). Using all data, the Pearson correlation was non significant ($r = -0.19$ on 94 df). When 3 outlying points, in the bottom-left quadrant of the plot, were excluded, the correlation was significant ($r = -0.32$ on 91 df). The outlier points had no unusual features. A linear regression gave the following results:

Ln(C.V.+1) =	4.45	-0.0079*Mean Plant Height
s.d.	0.07	0.0012
T	62.45	-6.49

$F_{regression} = 42.2$ was significant at $P = 0.0001$ on 1,90 df. This result is consistent with the existence of a systematic measurement error, i.e. a minimum distance increment for measurements.

With both stem density and plant height, the variability was expected to be high as submerged macrophyte assemblages contain a mixture of species with different size characteristics and occurring with very patchy, contagious distributions.

In 1991, the multiple estimates of percent cover provided insight into the observation methods. Percentage cover values were transformed by taking the arcsine$\sqrt{}$. Means and standard deviations were computed, and the results were untransformed. Standard deviation expressed as percent cover was linked to mean percent cover in a dome-shaped relationship (Figure 6). The solid curve in the graph shows the expected values of standard deviation assuming that plant cover was observed as a binary, presence-absence, variable along transects; standard deviation = √(mean*(1-mean)/(n-1)) using mean percent cover and sample size as inputs. The agreement between estimated and predicted standard deviations indicates that recording simple presence-absence at multiple points along a transect would produce a similar value for percentage cover. Where the standard deviation was much higher on certain transects, it was evident from the run of point observations that the transect crossed an ecotone, passing from vegetated to unvegetated reaches of littoral habitat.

Reducing the variability inherent in the survey methods used to obtain estimates of mean stem density, plant height, and percent cover would require very large numbers of samples, numbers unwarranted by the nature of the research and unattainable with usual project resources.

Agreement between 1990 and 1991 transect pairs: 22 transects were visited in both 1990 and 1991 across the three area, Bay of Quinte, Hamilton Harbour, and Penetang Harbour. We assessed the agreement between the years using correlations of several measures and percent similarity of composition based on the 9 categories of plants. Measures of loge(stem density + 1), plant height, percent cover, arcsine(√percent cover), and species richness were all significantly correlated (Table 18) with correlations ranging from 0.41 to 0.81. Correlations for stem density (untransformed) and the C.V.s of stem density and plant height were not significant. Percent similarity values ranged from 0.00 to 0.94 with a mean of 0.60 (s.d.= 0.23). These results indicated a high degree of agreement between measures obtained in different years although the results do not allow us to distinguish between the uncertainty due to survey methodologies and the possibility of natural changes in macrophyte assemblages from year to year.

Agreement between 1988 through 1991 transect pairs in the Bay of Quinte: For percentage cover and species richness, we were able to assemble measures for transects visited in one or more of 4 years from 1988 to 1991. With sample sizes for paired years ranging from 6 to 30, all correlations of arcsine(√percent cover) were significant (Table 19) and ranged from 0.62 to 0.88. Except for the 1988-1989 pair, correlations of species richness were not significant for all other pairs of years (Table 19). In addition we examined the correlations between loge(plant biomass) in 1989 and loge (stem density +1) in 1990 and 1991. The correlations were significant: $r = 0.816$ and 0.790 on samples of 13 and 11 for 1990 and 1991 respectively. The agreement on measures of abundance was more important than the disagreement on species richness. In the 1990 and 1991 surveys, identifying all plant species was not a priority and most of the staff had less taxonomic knowledge than was available in the 1988 and 1989 surveys.

Analysis of percent similarity of assemblage composition for transects surveyed in various pairs of years showed mean similarity values were higher (0.58-0.59 vs 0.31-0.36) for the 1988-1989 and 1990-1991 pairs (Table 20). This result was not surprising as different sampling strategies were employed in the two pairs of years and in the earlier pair of years, the survey staff had a much higher level of knowledge of macrophyte taxonomy. Indeed, the surveys in 1988 and 1989 were trying to find as many species as possible. In the 1990 and 1991, species identification was only a secondary consideration and broad categories were considered more useful.

The comparisons of macrophyte abundance measures among 4 years of surveys showed a high level of consistency. Unfortunately replicate surveys were never conducted and thus the effects of temporal assemblage dynamics cannot be separated from measurement uncertainty.

Correlations, Regressions, and Associations: The modelling of the relationships among various measures of the macrophyte assemblages proceeded in four stages: (i) Correlations among measures and composition, (ii) Percent cover predicted by a model using density and size measures, (iii) Percent cover, stem density, and plant height predicted by models using percentage composition information, and (iv) Clustering of transects and measures.

There were few significant correlations (at a nominal P = 0.05 level) among the range of macrophyte measures derived from the 1990-91 surveys (Table 21). Among the nine percentage composition variables, all but one of the pair-wise correlations were not significant; *Elodea* (ELOD) and *Myriophyllum* (MYRI) had a significant negative correlation. Mean stem density, untransformed, was positively correlated with percent cover (COVER), $\log_e$(stem density + 1) (LNST), arcsine($\sqrt{}$percent cover) (ACOV), percentage ELOD and *Ceratophyllum* (CERA) composition. Mean plant height was positively correlated with COVER, ACOV, and percentage MYRI. COVER and ACOV had the highest correlation and both were correlated with LNST, having the next highest correlations, 0.75 and 0.79 respectively. Macrophyte species richness (MSPP) was positively correlated with C.V. of plant height, COVER, ACOV, and LNST.

Regression modelling was pursued on two fronts. First, as percent cover was considered to be the most integrative (and cheapest) measure of the macrophyte assemblages, we used other more complex measures to build a predictive model. Second, we used the percentage composition data as inputs to build regression models of abundance and size measures as a way of linking abundance and composition data.

The correlation results suggested that LNST, HTMN, and HTCV were good candidates for a regression model of percent cover. We fit a model and then did additional testing to ensure that the relationships were not artifacts of differences between years or locations. A graph of arcsine√(percent cover) versus $\log_e$(stem density + 1) revealed a sigmoid relationship across the five survey areas (Figure 7). A graph of mean plant height versus loge(stem density + 1) suggested two parallel groupings of points, one mostly drawn from HH and BQ sites where stem densities were lower for similar plant heights and the other from sites in Severn Sound (Figure 8). In a stepwise multiple regression, all three variables (LNST, HTMN, and HTCV) entered significantly (Table 22). Percent cover increased with both stem density (LNST) and mean plant height (HTMN) but decreased as the C.V. of plant height increased. The model indicates that percent cover is a measure of the volume occupied by plants in the water column. The regression model accounted for 78 percent of the variation in percentage cover (as ACOV). To ensure that there were no year or location effects confounding the regression result, we performed analyses of covariance on ACOV with the model variables as covariates. There were no significant differences among the five locations ($F = 1.54$ on 4,90 df, $P = 0.20$) or between years ($F = 2.69$ on 1,93 df, $P = 0.10$).

The proportion of variation accounted for in the regression model probably overstates the predictiveness of the model. Given a range of 0 to 1.57 for arcsine√(percent cover) where percent cover ranges from 0 to 100, a standard prediction error of 0.26 is 16.5 percent of the range, suggesting percent cover is a coarse indicator with categories such as absent, sparse, moderate, and dense.

In step-wise regression models of ACOV, LNST, and HTMN, with relative composition by taxon groups as independent variables, R values ranged 0.58-0.67 and all coefficients were positive (Table 22). Proportions of *Ceratophyllum*, *Elodea*, and *Vallisneria* entered all three models. *Najas* spp. entered the cover model, *Chara* spp. the stem density model, and narrow-leaved *Potamogetons* and *Myriophyllum* the height model. Since all nine composition variables were in the form of percentages, the regression coefficients give a measure of the relative weight of different taxa. *Ceratophyllum* had the highest coefficient value in all three models and *Vallisneria* the lowest. This result suggested there might be some relationship between abundance and composition in these macrophyte communities.

Clustering of sites: We used K-means clustering of the percentage taxon composition data to divide the sites into 3 groups (Table 23); after the formation of three groups, further groups tended to be singleton transects with unusual assemblages. The groupings were based on nearly discrete combinations of VALL, MYRI, and POTN which each showed a significant difference between groups (Table 23). Group 1 was dominated by VALL, group 3 by POTN, and, to a lesser extent, group 3 by MYRI. A similar attempt to produce groups using LNST, HTMN, and HTCV, the input variables for the percent cover model, yielded 4 groups but there was no correspondence between those groups and the ones based on composition.

We classified each site into the composition clusters and determined the group frequencies by location (Table 23). Groups 1 and 2 were co-dominant in Hamilton and Penetang Harbours. Group 2 was less frequent in the other 3 locations. Group 3 was more prevalent in the Bay of Quinte and Hog Bay but absent in Matchedash Bay. The pattern of group frequencies did not follow the gradient of eutrophication. Randall *et al.* (1993) used available AOC information to order the locations by degree of eutrophication from greatest to least: Hamilton Harbour, Bay of Quinte, Penetang Harbour, Hog Bay, and Matchedash Bay.

All attempts using clustering to show a linkage between abundance measures and composition failed. This suggested that assemblage composition is not a primary determinate of abundance, at least when using density data.

DISCUSSION

These surveys of macrophyte assemblages in the littoral zones of three Great Lakes' Areas of Concern were not primarily intended to provide insight into the ecology of aquatic macrophytes but to aid characterization of littoral fish habitat. Farmer and Adams (1989) provided a hierarchical view of research studies ranging from physiological to ecosystemic levels of organization. Our studies are positioned at the ecosystem level with emphasis on the linkages between the gross features of macrophyte assemblages, as a main constituent of fish habitat, and the abundance and composition of the fish assemblages which occupy the habitats. Papers like that of Duarte and Kalff (1990a) point to the wide range of factors drawn from different spatial scales (whole ecosystem, e.g., alkalinity, Secchi depth; and site-specific, e.g., depth, slope, exposure) which influence the extent, composition, and abundance of macrophytes. The survey designs in our studies were restricted to 100 metre transects along the 1.5 metre depth contour, to match the constraints of electro-fishing surveys. However, the surveys do provide some insights into the ecology of submerged macrophytes and the selection of survey methodology.

Abundance and composition of macrophytes in three Areas of Concern:

The macrophyte surveys of Crowder and Bristow (1986) (C&B) from 1972-82 in the Bay of Quinte provide the primary reference point for comparisons of composition as there are no published quantitative studies of macrophytes in Hamilton Harbour and Severn Sound. The dominant macrophyte taxa in our surveys were similar with *Myriophyllum*, *Vallisneria*, *Elodea*, and *Najas* taxa being prominent. C&B also found a lot of *Heteranthera*. It was common in the

1988-89 surveys in the Bay of Quinte but uncommon in the 1990 surveys in all areas and unrecorded in the 1991 surveys. C&B noted this set of dominant species was often found at eutrophic sites in Ontario with *Myriophyllum spicatum* being a recent invader which has displaced or overwhelmed many native species.

There are marked composition differences between the three AOCs. *Potamogetons* were very common in the Bay of Quinte and moderately common in Penetang Harbour and Hog Bay. *Vallisneria* and *Myriophyllum* predominated in Hamilton Harbour. *Elodea* was common in Severn Sound and inversely related to the gradient of eutrophication across the five survey areas, being highest in Matchedash Bay and lowest in Hamilton Harbour (Table 9).

Mean stem density and percent cover in the five survey areas also followed the eutrophication gradient while mean plant height showed no discernible pattern. The means and ranges of stem density, plant height, and biomass were similar to those reported for a range of littoral macrophyte stands in Quebec and New York lakes (Duarte and Kalff 1990b).

Relationships among macrophyte measures:

Two results stood out in the analysis of our macrophyte surveys: A) The high degree of agreement between the measures of abundance, and B) The high degree of similarity between years. The significant correlations among percentage cover, stem density, and biomass was obtained despite the relatively high levels of uncertainty surrounding the mean values obtained for stem density. The sample sizes, typically 9-11 per transect, were insufficient to attain usual levels of accuracy (10-20 percent) for exact determination of stem density. However, the uncertainty associated with percentage cover, measured in 1991, was much lower, and the agreement between percentage cover and stem density, obtained after transformation, was high.

Given the patchiness of macrophyte assemblages, substantially narrower confidence limits for stem density would require unreasonably large sample sizes. For percentage cover, the situation is less harsh. Hofmann and Ries (1990) estimated sample sizes for measuring percentage ground cover on North Dakotan prairie using various formulae. They showed that smaller sample sizes were required when a binomial or poisson distribution assumptions were invoked. Using their equation, we find that for a $P = 0.2$ level of significance and mean percentage cover levels ranging from 10 to 50, we need sample sizes of 4-10 and 15-40 for accuracy levels of 0.2 and 0.1. This indicates that a sample size of 20, one measure every 5 metres, would be preferable to the protocol we used although there is frequent possibility that a transect crosses an ecotone, thereby inflating the sample size required. In an analogous situation, estimating percentage cover by taxa on rocks, Meese and Tomich (1992) showed that visual estimation, when complemented by digitization to provide a reference for standardization and by observer training, provided a reliable and very cost effective survey method.

The single most important result was the regression model allowing percentage cover to be predicted from stem density, and the mean and C.V. of plant height. This result provided both a validation of percentage cover as an integrative measure of macrophyte assemblages and an explanatory model of the measure. Intuitively, it makes sense that percentage cover is a measure of the degree to which plant growth occupies the water column volumetrically. Stem density expresses the areal coverage, mean plant height expresses the depth occupancy, and the C.V. of plant height captures the 'openness' of the plant canopy. This result has not been reported in the freshwater ecological literature previously. Lillie and Budd (1992) presented a complex index, with horizontal and vertical components, based on the architecture of *Myriophyllum spicatum* individuals. Their method, only developed for one taxon so far, maybe suitable for detailed site surveys but would be unsuitable for extensive surveys of fish habitat. Kinsolving and Bain (1990) presented an alternate approach to measuring cover, based on counting vertical and horizontal surfaces along line transects. They summarized criticisms of percentage cover under three items: i) the multi-dimensional nature of the measure, ii) difficulty of working with percentage and categorical measures of cover when other habitat measures are continuous variables, and iii) the statistical and distributional difficulties associated with percentage data. The results obtained here contradict those limitations. That percentage cover is multi-dimensional measure, as shown here, means an integrative measure has been obtained which can be efficiently and cheaply obtained. The difficulties of percentage and categorical variable types with non-normal statistical distributions are illusory and overstated. After a simple transformation and with reasonable sample sizes, reliable measures can be obtained. Perhaps the problem, in many past applications of percentage cover to assessment of fish habitats, is that insufficient attention has been given to the measurement methodologies for habitat measures when fish or other biota have been the main focus of study.

The other main result was the degree of similarity between pairs of years obtained in all three AOCs. This result suggest a high degree of stability of habitat conditions site by site. Longer-term and spatially more extensive studies (Blindow 1992; Scheffer et al. 1992) indicate that aquatic vegetation can vary considerably from year to year on local and ecosystem level scales. In Veluwemeer, in the Netherlands, the percentage of the lake surface occupied by Potamogeton pectinatus, the dominant taxon, varied between 5 and 45 during 1969-1989 (Scheffer et al. 1992). Predictive logistic regression site models had maximum probabilities of occurrence below 1. The authors indicated that spatially concentrated browsing by overwintering flocks of swans might account for the low level of temporal and spatial stability in macrophyte occurrence at the ecosystem scale which is more relevant to our studies. Given the recent origin of these lakes, reclaimed from the sea, long-term plant successional changes and ecosystem development factors may be influential. Blindow (1992) presented results for two Swedish lakes covering the period 1983-1991. In Lake Takern vegetation covered about 50 percent of the lake surface for the entire period while coverage rose from low values over 2 years and then covered about 50 percent of the surface in Lake Krankesjon. Changes in the taxon composition of the macrophyte assemblages in both lakes were attributed to water level fluctuations. Lake Krankesjon changed from being a turbid lake in the 1982-86 period to be a clear lake in the later period. Blindow suggested that once established macrophyte assemblages exert a 'stabilizing influence' in the whole lake ecosystem, including themselves. Except where major changes in controlling ecosystem and local factors occur, we conclude that we should expect a high degree of 'stability' in aggregate measures of macrophyte occurrence and abundance on the scale of our transects, 100 metres.

Alternative methods for surveying macrophyte assemblages:

Over the course of these macrophyte surveys, four types of surveys were used; (i) Percent cover (COVER), (ii) Quadrat biomass (BIOMASS), (iii) Point intercept (POINT), and (iv) Inter-plant distance/plant height (DISTANCE). To this set, we can add the combination of echo-sounding and digitization (ECHO-DIG) which will be evaluated in future study. The methodologies can be evaluated using several criteria; types of measure, skills required for the work, labour needed to complete the work, and the applicability of the method (Table 24). Three types of measure were identified: abundance, plant size, and composition. Only DISTANCE and ECHO-DIG can give plant height. COVER and ECHO-DIG cannot give composition and POINT does not measure abundance. Three types of staff skills were identified: taxonomic, scuba, and computing (data processing and analysis). Macrophyte taxa can be difficult to identify, especially in the field. Taxonomic know-how is not important for COVER and ECHO-DIG but essential for the other methods. Scuba activity is necessary in three methods: BIOMASS, POINT, and DISTANCE. Scuba work takes time, requires special training, and increase the staff numbers if safety is properly considered. DISTANCE and ECHO-DIG data require considerably more knowledge in the analysis phase. Labour requirements must be considered regardless of the purposes of the sampling program. COVER has minimal labour needs both in the field and afterwards while ECHO-DIG is simple in the field but requires a lot of labour for data-processing. The other methods have moderate to high labour needs in both stages of the work. All methods may be applicable in a survey or research context, depending on the objectives of the project. Only COVER, and possibly ECHO-DIG, can be considered suitable for assessment work in support of operational habitat management work. This conclusion is similar to that of Meese and Tomich (1992) discussed above.

The above comparison of methods (Table 24) and the earlier assessment of statistical needs (transformation and sample sizes) strongly suggest that percentage cover is the most suitable choice for most fish habitat assessment work in the littoral zones. The ECHO-DIG method assessment will be described in a later study and a final evaluation should be deferred. Future work can be directed to (i) further simplifying the assessment of percentage cover, perhaps using a categorical scheme with multiple samples at each transect, and (ii) finding a simple way of gathering some composition information about the macrophyte assemblages, perhaps by assigning a dominant taxon from a limited list at each point estimate of percentage cover.

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Table 1 List by macrophyte taxa found, percentage frequency of occurrence by taxon in 1988 and 1989, and percentage of total biomass by taxon in 1989, in the Bay of Quinte.

Code	Group	Taxon name	% frequency of occurrence		% biomass
			1988	1989	1989
HET	9	*Heteranthera dubia*	17.4	63.64	8.81
VAL	1	*Vallisneria americana*	21.4	57.58	9.81
MYS	2	*Myriophyllum spicatum*	12.6	57.58	56.70
ELO	3	*Elodea canadensis*	11.7	54.55	1.82
POP	6	*Potamogeton pusillus* (N)	-	36.36	2.27
NAG	8	*Naja guadalupensis*	7.8	24.24	0.47
NAF	8	*Naja flexilis*	-	21.21	0.23
MYE	2	*Myriophyllum exalbescens*	0.9	15.15	3.06
CHB	5	*Chara braunii*	-	15.15	6.05
CER	4	*Ceratophyllum demersum*	5.8	12.12	9.73
BID	9	*Bidens beckii*	-	9.09	0.24
RAN	9	*Ranunculus aquatilis*	-	9.09	0.02
POF	6	*Potamogeton friesii* (N)	4.8	6.06	0.05
POZ	6	*Potamogeton zosteriformes* (N)	-	6.06	0.73
POC	7	*Potamogeton crispus* (B)	0.9	6.06	0.01
CHA	5	*Chara* spp.	4.8	-	-
MOS	9	Mosses	2.9	-	-
PPE	6	*Potamogeton pectinatus* (N)	0.9	-	-
POR	7	*Potamogeton richardsonii* (B)	1.9	-	-
POZ	6	*Potamogeton zosterifolius* (N)	1.9	-	-
MEB	9	*Megalodonta beckii*	0.9	-	-
UTV	9	*Utricularia vulgaris*	1.9	-	-
LET	9	*Lemna trisulca*	0.9	-	-
		Number of transects	32	33	
		Species richness	17	15	
		Total biomass (N and sum)	-	66	1288.15

Table 2 Assignment of bottom substrate type to groups based on primary and secondary dominant substrates observed on transects in the Bay of Quinte, 1988-1989.

	Secondary substrate							
Primary substrate	Mu	Or	De	Ma	Sa	Gr	St	Ro
Mu (Mud)	1	1	1	1	1	1	1	1
Or (Organic)	1	1	1	1	1	1	1	1
De (Detritus)	1	1	1	1	1	1	1	1
Ma (Marsh)	5	5	5	5	5	5	5	5
Sa (Sand)	2	1	1	1	2	2	3	3
Gr (Gravel)	2	2	2	2	2	2	3	3
St (Stone)	6	6	6	6	3	3	4	4
Ro (Rock)	6	6	6	6	3	3	4	4

Table 3 Coordinates, distance from shore, and depth of 32 transects surveyed in the Bay of Quinte in 1988, along with Secchi depth, pH, percentage vegetation cover, and bottom type data.

Transect #		Coord 1	Coord 2	Shore	Depth	Secchi	pH	Cover	Bottom type	
1988	1989			m	cm	cm		%	Desc.	Code
1	1	86.2	96.1	-	150	65	6.8	<3	Mu-Or	1
2	2	94.0	81.2	33	150	55	6.8	90	Mu-Ma	1
3	3	96.8	83.7	8	150	65	6.8	30	Ro	4
4	4	94.5	83.0	8	150	65	6.8	<3	Ro	4
5	5	93.0	81.6	5	150	65	7.2	100	Mu	1
6	6	93.2	81.3	33	150	65	7.0	100	Mu-Ma	1
7	7	93.5	84.3	50	175	65	7.0	<3	St	4
8	34	96.5	86.4	5	150	80	6.6	50	Sa-Ro	3
9	35	94.8	86.0	10	200	70	6.9	100	Sa-Ro	3
10	8	93.9	83.8	50	200	80	6.6	100	Sa-St-Or	3
11	9	91.9	82.2	33	150	75	6.5	100	Sa-Or	1
12	10	92.2	83.1	16	150	70	6.3	100	Sa-De-Rb	1
13	20	25.0	90.0	100	150	85	6.9	0	Sa-Rb	3
14	21	25.2	89.5	50	180	85	6.9	0	Sa-Ro	3
15	26	24.2	89.9	16	150	85	6.9	0	Sa-Ro	3
16	11	11.1	89.8	150	150	100	6.9	0	Sa-Ro	3
17	12	10.9	89.7	150	200	-	6.9	50	Mu	1
18	13	10.3	89.4	-	100	-	-	100	Mu	1
19	15	10.1	90.2	6	150	-	6.9	0	Mu-Rb	1
20	14	10.2	90.2	-	150	-	6.9	<3	Mu-Rb	1
21	16	9.4	91.2	100	150	90	6.8	50	Sa-Rb	3
22	17	9.2	91.2	100	150	90	6.8	50	Sa-Rb	3
23	22	24.7	89.3	-	160	120	6.3	40	Mu	1
24	23	24.7	89.3	-	160	120	6.3	30	Mu	1
25	24	23.6	89.4	80	170	120	6.3	0	Sa-Mu	2
26	25	23.6	89.4	80	170	120	6.3	0	Ro	4
27	28	22.1	89.1	8-16	150	120	6.3	0	Ro	4
28	29	22.1	89.1	8-16	150	120	6.3	0	Ro	4
29	30	21.1	89.1	10	150	120	6.3	<3	Ro	4
30	31	21.1	89.1	10	150	120	6.3	<3	Ro	4
31	32	19.0	88.3	3-8	150	-	-	<3	Ro	4
32	33	19.0	88.3	3-8	150	-	-	<3	Ro	4

Bottom type descriptors - See table 2 except for Rb-rock below, Wo-wood.

Table 4 Percentage composition of macrophyte assemblages observed on 32 transects in the Bay of Quinte, 1988 (Taxon names are matched to the 3-letter acronyms given in Table 1).

Trans.#	Species composition																					#
(1989)	HET	VAL	MYS	ELO	POP	NAG	NAP	MYE	CHB	CER	BIB	RAN	POF	POZ	POC	POR	PPE	LET	UTV	MEB	Oth.	Spp.
1	-	T	T	T	-	-	-	-	T	-	-	-	-	-	-	-	-	-	-	-	B+F	4
2	35	10	35	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
3	60	20	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
4	60	20	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
5	50	30	10	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
6	40	30	10	10	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	5
7	80	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
8	T	20	20	20	-	T	-	-	-	20	-	-	T	T	-	-	-	-	T	-	-	9
9	65	10	T	T	-	T	-	T	T	T	-	-	-	-	-	-	-	-	-	-	-	8
10	10	10	50	T	-	-	-	10	T	20	-	-	-	-	-	-	-	-	-	-	-	7
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
12	-	20	20	20	-	20	-	-	-	T	-	-	T	-	-	-	-	-	-	-	-	6
13	20	50	-	20	-	-	-	-	T	-	-	-	-	-	-	T	-	-	-	T	-	6
14	30	30	10	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
16	50	T	T	20	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
17	50	T	T	20	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
22	-	50	35	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
23	-	50	40	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
30	80	20	-	-	-	-	-	-	-	-	-	-	T	-	-	-	-	-	-	-	-	3
31	80	20	-	-	-	-	-	-	-	-	-	-	T	-	-	-	-	-	-	-	-	3
32	80	20	-	-	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
33	70	20	-	-	-	T	T	-	-	-	-	-	-	-	-	-	T	-	-	-	-	5
34	20	20	20	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B+F	4
35	T	T	50	T	-	T	-	-	-	30	-	-	T	T	-	T	-	T	-	-	M	10

B+F,Bryophytes and filamentous algae; M, Moss; T, Trace; -, absent.

Table 5 Coordinates of 33 transects surveyed in the Bay of Quinte in 1989, along with Secchi depth, pH, percentage vegetation cover, temperature, and bottom type data.

Trans.	Coord	Coord	Secchi	pH	Cover	Temp.	Bottom type	
#	1	2	cm	*	%	C	Desc.	Code
1	86.2	96.1	150	8.4	15	27	ro-sa	3
2	94.0	81.2	200	8.1	100	25	mu	1
3	96.8	83.7	250	8.0	<1	27	sa-ro	3
4	94.5	83.2	300	-	15-20	26	sa-st	3
5	93.2	81.6	150	7.8	100	27	mu	1
6	93.2	81.3	250	7.8	90	27	sa-mu	2
7	93.5	84.3	250	-	85-90	27	sa	2
8	93.8	85.7	250	8.8	95	27	sa-ro-wo	3
9	91.9	82.4	250	6.7	85	27	sa-mu	2
10	92.3	83.0	270	-	100	29	or-sa	1
11	11.1	89.9	150	8.0	90	28	or	1
12	10.9	89.7	150	7.1	35	26	sa	2
13	10.6	89.3	150	8.2	90	26	or	1
14	10.2	90.2	200	8.1	15	28	ro-sa	3
15	10.1	90.2	150	7.4	0	27	ro	4
16	9.4	91.3	200	7.7	75	27	sa-st	3
17	9.2	91.3	150	7.7	20	27	or-st	1
18	7.6	90.6	125	7.5	5	28	sa-ro	3
19	6.3	89.9	125	-	55	-	sa	2
20	25.5	90.0	100	8.7	<1	24	or	1
21	25.2	89.6	100	8.6	<1	24	sa-ro	3
22	24.7	89.3	80	8.7	95	24	sa-or	1
23	24.7	89.3	120	8.9	90	24	or-sa	1
24	24.5	89.7	100	8.9	<1	24	sa-gr	2
25	24.5	89.7	120	8.4	<1	23	ro-gr	3
26	24.2	89.9	140	8.9	<1	24	ro	4
27	24.2	89.9	100	8.7	0	25	st-sa-ro	3
28	22.1	89.1	125	8.7	0	26	ro-st-sa	4
29	22.1	89.1	125	8.7	<1	26	ro-st-sa	4
30	21.2	89.1	110	8.7	5	26	sa-ro	3
31	21.2	89.1	125	8.7	5	26	sa-st	3
32	19.2	88.4	120	8.4	5	-	st-sa	3
33	19.2	88.4	200	8.4	5	-	st-sa	3

Table 6 Macrophyte biomass, g.m^{-2} oven-dried, by species and transect, and species richness for 33 transects surveyed in the Bay of Quinte, 1989 (Taxon codes are matched to names in Table 1).

Trans	HET	VAL	MYS	ELO	POP	NAG	NAF	MYE	CHB	CER	BID	RAN	POF	POZ	POC	Sum	Spp #
1	-	7.09	0.04	0.01	-	-	-	-	-	1.34	-	-	0.42	-	-	8.90	5
2	-	7.60	251.27	0.01	-	-	-	3.07	-	-	-	-	-	-	-	261.95	4
3	0.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19	1
4	0.83	-	-	0.11	0.02	-	0.11	-	-	-	-	-	-	-	-	1.07	4
5	26.90	0.02	98.11	1.83	0.20	-	-	15.97	-	3.86	0.15	0.08	0.17	-	0.09	147.38	11
6	0.16	3.74	23.90	0.54	-	-	-	0.12	44.23	-	-	0.03	-	-	-	72.72	7
7	9.87	4.25	9.80	0.17	12.31	0.02	-	-	-	-	-	0.11	-	0.17	-	36.70	8
8	0.01	0.74	1.31	3.41	0.17	0.81	0.11	1.36	0.16	0.86	-	-	-	-	-	8.94	10
9	-	2.13	0.11	-	-	-	-	-	30.95	-	-	-	-	-	-	33.19	3
10	3.40	1.71	135.65	0.26	0.01	-	-	18.95	-	119.25	-	-	-	9.27	-	288.50	8
11	0.38	6.10	48.21	3.67	1.97	3.64	1.47	-	0.83	-	-	-	-	-	-	66.27	8
12	0.04	19.50	23.39	0.16	0.68	0.55	-	-	-	-	0.61	-	-	-	-	44.93	7
13	52.94	26.02	5.37	0.10	-	0.68	-	-	1.73	-	2.27	-	-	-	-	89.11	7
14	5.69	0.78	0.51	1.03	0.02	0.11	0.71	-	-	-	-	-	-	-	-	8.85	7
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0
16	0.10	0.25	0.72	0.01	12.36	-	0.28	-	-	-	-	-	-	-	-	13.72	6
17	5.22	-	3.94	10.73	1.43	0.05	0.08	-	-	-	-	-	-	-	0.09	21.54	7
18	4.86	-	0.34	0.30	-	0.13	-	-	-	-	-	-	-	-	-	5.63	4
19	0.03	0.88	-	-	-	-	0.14	-	-	-	-	-	-	-	-	1.05	3
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0
22	0.02	27.52	63.59	0.74	-	-	-	-	-	-	-	-	-	-	-	91.87	4
23	-	10.15	63.95	-	-	-	-	-	-	-	-	-	-	-	-	74.10	2
24	-	-	0.10	0.05	0.02	-	-	-	-	-	-	-	-	-	-	0.17	3
25	-	-	0.05	0.32	-	-	-	-	-	-	-	-	-	-	-	0.37	2
26	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	1
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0
30	0.58	1.54	-	-	0.09	-	-	-	-	-	-	-	-	-	-	2.21	3
31	0.35	4.83	-	-	-	-	-	-	-	-	-	-	-	-	-	5.18	2
32	2.00	1.58	-	-	-	-	-	-	-	-	-	-	-	-	-	3.58	2
33	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	1

Table 7 Description of electro-fishing transects surveyed in Bay of Quinte and Hamilton Harbour, in 1990.

Location Code name	Transect Number	Sampling Date	Depths (m) Start	End	Divers[1]	Percent Cover	Survey[2]
BAY OF QUINTE							
MBQ011	11	05/09/90	M	M	A & B	70	
MBQ013	13	05/09/90	M	M	A & B	87	
MBQ014	14	04/09/90	M	M	B & A	M	
MBQ015	15	04/09/90	1.8	M	A & B	<1	
MBQ016	16	05/09/90	M	M	B	87	
MBQ019	19	06/09/90	M	M	A	2	
MBQ021	21	06/09/90	M	M	A & B	3	
MBQ023	23	06/09/90	M	M	A & B	3	
MBQ025	25	06/09/90	1.5	0.75	A & B	<1	
MBQ027	27	06/09/90	M	M	A & B	<1	
MBQ029	29	05/09/90	M	M	A & B	2	
MBQ031	31	06/09/90	M	M	A & B	2	
MBQ032	32	06/09/90	M	M	A & B	2	
HAMILTON HARBOUR							
MHH002	2	30/08/90	1.8	1.8	A & C	5	
MHH004	4	30/08/90	1.8	1.8	A & C	0	
MHH006	6	30/08/90	1.9	1.9	A & C	<1	
MHH008	8	30/08/90	2.0	2.0	A & C	0	x
MHH010	10	30/08/90	2.0	1.9	A & C	2	
MHH012	12	30/08/90	M	M	A & C	0	x
MHH014	14	30/08/90	M	M	A	0	x
MHH016	16	30/08/90	M	M	A	0	x
MHH018	18	30/08/90	1.5	1.5	D	27	
MHH020	20	30/08/90	1.5	1.5	D	79	
MHH022	22	30/08/90	1.5	1.5	B	3	
MHH024	24	30/08/90	1.5	1.5	B	5	
MHH026	26	30/08/90	1.5	1.5	B	35	
MHH028	28	30/08/90	1.5	1.5	D	27	
MHH030	30	31/08/90	1.2	1.2	B & D	0	x
MHH032	32	31/08/90	1.2	1.2	B & D	0	x
MHH034	34	31/08/90	M	M	C & A	7	
MHH036	36	31/08/90	M	M	A & C	5	
MHH038	38	31/08/90	1.5	1.5	D	23	
MHH040	40	31/08/90	1.5	1.5	B	6	

[1] Divers: A/V.W. Cairns, B/J.C.Fitzsimons, C/T.Heiman, D/B.Grey.
[2] x=Density was based on total stems in a 2 metre band along the whole transect.

Table 8 Description of electro-fishing transects surveyed in three bays of Severn Sound, Hog Bay, Matchedash Bay, and Penetang Harbour, in 1990.

Location Code name	Transect Number	Sampling Date	Depth (m) Start	Depth (m) End	Divers[1]	Percent Cover	Survey[2]
HOG BAY							
MHB001	1	28/08/90	1.5	1.5	B	5	
MHB002	2	28/08/90	1.5	1.5	B	10	
MHB003	3	28/08/90	1.5	1.5	B	5	
MHB004	4	28/08/90	1.5	1.5	B	80	
MHB006	6	28/08/90	1.5	1.5	B	80	
MHB007	7	27/08/90	1.0	1.5	B	75	
MHB010	10	28/08/90	1.5	1.5	B	99	
MHB012	12	27/08/90	1.5	1.5	B	75	
MHB013	13	29/08/90	1.5	1.5	B	70	
MHB014	14	28/08/90	1.5	1.5	D	80	
MATCHEDASH BAY							
MMB001	1	29/08/90	2.0	2.0	A & C	66	
MMB002	2	29/08/90	1.8	1.8	C & A	100	
MMB003	3	29/08/90	1.0	1.0	B	80	
MMB004	4	29/08/90	1.0	1.2	B	80	
MMB005	5	28/08/90	M	M	A	100	x
MMB006	6	28/08/90	1.3	1.0	A & C	100	
MMB007	7	28/08/90	1.8	1.8	C & A	M	
MMB008	8	27/08/90	1.6	1.6	A & C	30	
MMB010	10	28/08/90	M	M	A & C	5	
MMB011	11	29/08/90	M	M	A & C	100	
MMB012	12	29/08/90	1.4	1.3	C & A	100	
PENETANG HARBOUR							
MPH001	1	21/08/90	M	M	A	70	
MPH002	2	21/08/90	1.5	2.0	A	100	
MPH003	3	21/08/90	1.8	0.7	C & A	100	
MPH005	5	21/08/90	2.0	2.0	B	100	
MPH006	6	22/08/90	1.8	1.5	A & C	80	
MPH007	7	27/08/90	2.0	1.5	C & A	100	
MPH009	9	22/08/90	2.0	1.5	A & B	50	
MPH011	11	23/08/90	M	M	A & C	5	
MPH014	14	24/08/90	M	M	A & B	26	
MPH015	15	24/08/90	1.3	2.0	B & A	95	
MPH016	16	24/08/90	1.3	2.0	A & B	20	
MPH018	18	24/08/90	1.5	2.0	B & A	22	
MPH019	19	23/08/90	M	M	A & B	100	
MPH021	21	23/08/90	M	M	A & B	M	
MPH023	23	23/08/90	1.6	1.6	B	80	
MPH027	27	23/08/90	0.6	M	A & B	M	
MPH028	28	24/08/90	2.2	M	A & C	30	
MPH029	29	24/08/90	2.0	2.0	C & A	70	

Table 9 Percentage composition of plant taxa encountered on transects surveyed in five areas in 1990.

Code Name	Group	Species name[1]	Penetang Harbour	Matchedash Bay	Hog Bay	Hamilton Harbour	Bay of Quinte	Total
Val	1	Vallisneria americana	33.3	52.0	41.5	53.4	30.2	40.8
Myr	2	Myriophyllum spicatum	11.4	12.4	9.6	30.4	5.7	13.7
Elo	3	Elodea canadensis	14.1	20.9	10.4	1.2	4.5	10.8
Cer	4	Ceratophyllumm demersum	7.9	2.9	2.4	0.8	0.5	3.7
Naj	8	Naja flexilis	2.1	5.2	-	-	9.0	2.9
Het	9	Heteranthera dubia	1.8	-	-	1.2	0.5	0.9
Char	5	Chara sp.	3.4	0.9	10.0	4.5	-	3.8
Alis	9	Alisma sp.	0.2	-	-	-	-	0.1
Unk	9	Unknown sp.	0.8	-	0.2	0.4	0.7	0.5
PotG	6	Potamogeton gramineus (N)	12.1	1.6	5.1	4.9	40.8	12.3
PotF	6	Potamogeton foliosus (N)	9.3	0.2	20.1	-	2.6	7.1
PotP	6	Potamogeton pectinatus (N)	-	0.7	-	1.2	1.7	0.6
PotA	6	Potamogeton amphifolius (N)	-	2.7	-	0.2	-	0.5
PotC	7	Potamogeton crispus (B)	-	-	-	0.2	3.8	0.6
PotR	7	Potamogeton richardsonii (B)	2.4	0.2	0.8	1.4	-	1.2
PotB	7	Potamogeton 'broadleaved' (B)	0.3	-	-	-	-	0.1
PotS	6/7	Potamogeton sp. (p)	1.0	0.2	-	-	-	0.4
PotQ	6/7	Potamogeton sp. (p)	-	-	-	-	0.2	0.0
		No. of plants	911	444	492	487	424	2758
		No. of transects	18	10	10	20	13	71
		No. of taxa	14	12	9	12	12	18

[1] Potamogetons assigned to broadleaved (PotB) or narrowleaved (PotN) types with those labelled p being assigned according to the proportions of B and N types by transect.

Table 10 Stem density and plant height statistics, and percentage composition of plant types by transect and area for surveys conducted in 1990.

Transect	Stem density #.m^{-2}			Plant height cm			Percentage composition by type										
	N_s	Mean	CV%	N_p	Mean	CV%	Elo	Val	Cer	Naj	Myr	PotN	PotB	Het	Unk	Char	Alis
HAMILTON HARBOUR																	
002	10	2.0	198.2	27	29.8	52.9	0.0	74.1	0.0	0.0	0.0	11.1	7.4	0.0	7.4	0.0	0.0
004	11	0.0	71.1	5	34.6	58.5	0.0	0.0	0.0	0.0	20.0	0.0	0.0	80.0	0.0	0.0	0.0
006	10	1.4	312.1	5	41.8	55.3	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
008	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
010	8	0.5	28.5	22	84.2	82.7	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
012	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
014	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
016	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
018	10	36.2	76.3	50	46.0	65.5	0.0	94.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
020	10	170.1	83.0	50	84.6	37.4	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
022	10	6.0	89.3	33	33.2	81.2	0.0	87.9	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0
024	10	18.0	155.9	48	40.1	92.4	0.0	85.4	0.0	0.0	10.4	0.0	0.0	4.2	0.0	0.0	0.0
026	10	50.7	136.9	44	63.3	61.1	2.3	84.1	0.0	0.0	11.4	2.3	0.0	0.0	0.0	0.0	0.0
028	10	34.2	192.3	45	39.0	72.3	0.0	71.1	0.0	0.0	20.0	8.9	0.0	0.0	0.0	0.0	0.0
030	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
032	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
034	10	15.4	245.5	48	82.3	68.1	0.0	8.3	0.0	0.0	72.9	18.7	0.0	0.0	0.0	0.0	0.0
036	9	4.9	146.6	38	100.7	61.1	0.0	0.0	0.0	0.0	92.1	7.9	0.0	0.0	0.0	0.0	0.0
038	10	7.2	122.2	43	79.0	62.8	7.0	0.0	2.3	0.0	39.5	4.7	11.6	0.0	0.0	34.9	0.0
040	10	0.3	66.8	29	100.2	46.1	6.9	0.0	10.3	0.0	55.2	0.0	3.4	0.0	0.0	24.1	0.0
BAY OF QUINTE																	
011	10	105.0	56.0	50	76.5	35.2	0.0	58.0	0.0	24.0	4.0	14.0	0.0	0.0	0.0	0.0	0.0
013	10	97.6	71.7	49	84.5	31.0	0.0	65.3	0.0	0.0	0.0	34.7	0.0	0.0	0.0	0.0	0.0
014	10	17.3	146.4	46	80.2	41.3	0.0	32.6	0.0	0.0	30.4	37.0	0.0	0.0	0.0	0.0	0.0
015	10	0.3	0.0	3	28.3	12.4	33.3	33.3	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0
016	10	54.7	70.6	50	75.7	32.4	0.0	52.0	0.0	0.0	2.0	46.0	0.0	0.0	0.0	0.0	0.0
019	10	1.0	124.9	33	22.8	45.6	0.0	0.0	0.0	9.1	0.0	84.8	0.0	6.1	0.0	0.0	0.0
021	10	0.1	46.4	36	30.9	85.5	38.9	5.6	5.6	22.2	0.0	27.8	0.0	0.0	0.0	0.0	0.0
023	10	2.4	170.5	19	17.8	63.4	0.0	0.0	0.0	0.0	10.5	0.0	84.2	0.0	5.3	0.0	0.0
025	10	0.0	70.5	13	37.2	34.5	23.1	0.0	0.0	0.0	7.7	69.2	0.0	0.0	0.0	0.0	0.0
027	9	0.3	10.7	4	41.7	20.5	0.0	0.0	0.0	0.0	25.0	75.0	0.0	0.0	0.0	0.0	0.0
029	10	1.8	301.6	22	44.6	75.6	0.0	27.3	0.0	22.7	0.0	50.0	0.0	0.0	0.0	0.0	0.0
031	10	5.9	106.9	49	62.9	47.6	2.0	8.2	0.0	4.1	2.0	83.7	0.0	0.0	0.0	0.0	0.0
032	10	4.7	73.1	50	57.2	46.0	0.0	26.0	0.0	16.0	2.0	52.0	0.0	0.0	4.0	0.0	0.0

Table 10 Continued.

Transect	Stem density #.m^{-2}			Plant height cm			Percentage composition by type										
	N_s	Mean	CV%	N_p	Mean	CV%	Elo	Val	Cer	Naj	Myr	PotN	PotB	Het	Unk	Char	Alis
PENETANG HARBOUR																	
001	11	2359.6	217.4	43	50.9	74.2	27.9	2.3	16.3	0.0	4.7	48.8	0.0	0.0	0.0	0.0	0.0
002	10	7126.8	88.2	43	81.7	48.9	14.0	14.0	53.5	0.0	0.0	18.6	0.0	0.0	0.0	0.0	0.0
003	15	4237.8	126.2	75	85.3	67.1	26.7	9.3	6.7	12.0	41.3	2.7	0.0	1.3	0.0	0.0	0.0
005	11	3435.3	135.8	55	55.0	81.4	36.4	0.0	27.3	5.5	21.8	0.0	9.1	0.0	0.0	0.0	0.0
006	10	546.5	157.5	50	49.4	89.5	34.0	0.0	0.0	0.0	20.0	16.7	3.3	26.0	0.0	0.0	0.0
007	10	1120.2	104.3	50	84.5	55.0	38.0	24.0	0.0	0.0	22.0	8.0	6.0	0.0	2.0	0.0	0.0
009	11	334.1	283.3	48	90.4	54.2	25.0	12.5	2.1	0.0	45.8	14.6	0.0	0.0	0.0	0.0	0.0
011	10	140.4	71.9	48	13.7	96.4	0.0	58.3	0.0	0.0	4.2	37.5	0.0	0.0	0.0	0.0	0.0
014	10	297.0	85.7	50	21.3	145.0	0.0	34.0	0.0	0.0	0.0	28.0	0.0	0.0	4.0	32.0	2.0
015	10	1116.1	98.1	50	67.0	53.5	22.0	20.0	0.0	0.0	10.0	32.0	16.0	0.0	0.0	0.0	0.0
016	12	238.7	83.0	60	13.7	74.7	0.0	76.7	0.0	0.0	0.0	23.3	0.0	0.0	0.0	0.0	0.0
018	10	79.9	58.0	50	10.1	52.9	2.0	56.0	0.0	0.0	2.0	24.0	0.0	0.0	2.0	12.0	2.0
019	10	406.0	79.5	50	16.4	59.8	2.0	64.0	0.0	0.0	0.0	8.0	4.0	0.0	6.0	16.0	0.0
021	10	323.7	78.3	50	53.9	69.2	12.0	52.0	0.0	4.0	4.0	22.0	6.0	0.0	0.0	0.0	0.0
023	11	1052.9	119.9	55	85.0	43.7	1.8	27.3	0.0	0.0	3.6	61.7	3.7	0.0	0.0	1.8	0.0
027	11	243.4	175.8	35	78.9	64.0	0.0	8.6	60.0	14.3	2.9	11.4	0.0	2.9	0.0	0.0	0.0
028	11	162.0	94.9	45	18.0	105.7	2.2	84.4	0.0	0.0	2.2	8.9	2.2	0.0	0.0	0.0	0.0
029	12	241.6	76.0	54	27.4	71.6	1.9	51.9	0.0	0.0	3.7	40.7	0.0	1.9	0.0	0.0	0.0
HOG BAY																	
001	10	184.1	149.5	50	6.6	92.8	0.0	18.0	0.0	0.0	0.0	34.0	4.0	0.0	0.0	44.0	0.0
002	10	346.7	77.1	49	11.9	78.1	0.0	63.3	0.0	0.0	0.0	32.7	4.1	0.0	0.0	0.0	0.0
003	10	164.4	119.3	43	7.4	73.3	0.0	4.7	0.0	0.0	0.0	39.5	0.0	0.0	0.0	55.8	0.0
004	10	314.2	57.3	50	34.7	95.9	20.0	34.0	0.0	0.0	0.0	38.0	0.0	0.0	2.0	6.0	0.0
006	10	724.7	84.1	50	29.3	55.3	0.0	34.0	0.0	0.0	0.0	66.0	0.0	0.0	0.0	0.0	0.0
007	10	120.5	80.9	50	56.7	46.9	34.0	50.0	8.0	0.0	6.0	2.0	0.0	0.0	0.0	0.0	0.0
010	10	65.8	124.1	50	74.0	36.3	16.0	48.0	4.0	0.0	32.0	0.0	0.0	0.0	0.0	0.0	0.0
012	10	125.7	67.9	50	27.9	61.3	14.0	62.0	0.0	0.0	6.0	18.0	0.0	0.0	0.0	0.0	0.0
013	10	47.4	65.9	50	87.6	47.9	2.0	56.0	0.0	0.0	28.0	14.0	0.0	0.0	0.0	0.0	0.0
014	10	73.2	42.8	50	45.4	61.9	16.0	40.0	12.0	0.0	22.0	10.0	0.0	0.0	0.0	0.0	0.0

Table 10 Continued.

Transect	Stem density #.m^{-2}			Plant height cm			Percentage composition by type										
	Na	Mean	CV%	Np	Mean	CV%	Elo	Val	Cer	Naj	Myr	PotN	PotB	Het	Unk	Char	Alis
MATCHEDASH BAY																	
001	11	625.2	128.6	51	61.4	52.7	33.3	54.9	3.9	2.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0
002	10	3145.4	161.4	50	80.5	33.0	56.0	42.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
003	10	49.0	48.2	50	60.5	34.9	4.0	64.0	0.0	2.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
004	10	26.0	45.9	50	52.4	44.0	14.0	32.0	8.0	0.0	44.0	2.0	0.0	0.0	0.0	0.0	0.0
005*	0	400.0	0.0	0	0.0	0.0	0.0	60.0	0.0	30.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
006	10	719.5	228.3	50	63.2	35.4	2.0	48.0	2.0	14.0	4.0	28.0	0.0	0.0	0.0	2.0	0.0
007	10	7.8	222.4	32	34.7	43.2	3.1	93.8	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0
008	10	60.9	179.9	40	58.9	39.9	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
010	9	9.3	213.7	21	34.6	50.0	28.6	71.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
011	10	672.8	198.3	50	40.5	46.7	12.0	24.0	2.0	26.0	24.0	6.0	0.0	0.0	0.0	6.0	0.0
012	10	279.0	131.1	50	54.6	35.0	50.0	26.0	8.0	2.0	8.0	4.0	2.0	0.0	0.0	0.0	0.0

* Not sampled according to the protocol described.

Table 11 Summary statistics for stem density m^{-2} and plant height for 72 transects in five parts of three Areas of Concern in 1990.

Measure	Stems density N	Stems density Mean	Stems density C.V.	Plant height N	Plant height Mean	Plant height C.V.	Percent Cover	Depth m
Minimum	0	0.00	0.0	0	0.00	0.0	0.0	0.6
Mean	9	448.08	107.4	38	46.45	53.3	42.2	1.6
Maximum	15	7126.84	312.1	75	100.71	145.0	100.0	2.2
Sample	72			72			68	48
Zeros	7			7			7	0
Mean where present	10	488.81	119.0	42	51.45	59.1		
	#Transects							
By Area:								
Bay of Quinte	13	22.39	96.1	33	50.80	43.9	21.6	1.5
Hamilton Harbour	20	17.34	96.2	24	42.93	44.9	11.2	1.6
Severn Sound:								
Penetang Harbour	18	1303.46	118.5	51	50.15	72.6	65.5	1.7
Hog Bay	10	216.67	86.9	49	38.14	65.0	57.9	1.5
Matchedash Bay	11	544.98	141.6	40	49.22	37.7	76.1	1.5

Table 12 Average percentage composition of macrophyte assemblages on 72 transects in 5 parts of 3 Areas of Concern in 1990.

Measure	ELO	VAL	CER	NAJ	MYR	PON	POB	HET	UNK	CHA	ALI
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	9.2	35.2	3.2	2.9	13.1	20.1	2.3	1.7	0.5	3.3	0.1
Maximum	56.0	100.0	60.0	30.0	100.0	100.0	84.2	80.0	7.4	55.8	2.0
Mean where present	18.5	46.9	13.0	13.1	21.5	28.4	11.1	17.5	4.1	21.3	2.0
%Occurrence by transect	50.0	75.0	25.0	22.2	61.1	70.8	20.8	9.7	11.1	15.3	2.8
Stem density by species where present	205.8	134.8	318.3	74.1	84.1	108.8	45.7	30.1	8.4	39.8	3.8
By Area:											
Hamilton Harbour	0.8	30.2	0.6	0.0	21.4	8.3	1.1	4.2	0.4	3.0	0.0
Bay of Quinte	7.5	23.7	0.4	7.5	9.0	44.2	6.5	0.5	0.7	0.0	0.0
Severn Sound:											
Penetang Harbour	13.7	33.1	9.2	2.0	10.5	22.6	2.8	1.8	0.8	3.4	0.2
Hog Bay	10.2	41.0	2.4	0.0	9.4	25.4	0.8	0.0	0.2	10.6	0.0
Matchedash Bay	18.5	56.0	2.4	6.9	10.9	4.5	0.2	0.0	0.0	0.7	0.0

Table 13 Description of transects surveyed at 3 Areas of Concern: Bay of Quinte, Penetang Harbour, and Hamilton Harbour, in 1991.

Location	Transect	Date	Depth		
Code name			Start	End	Operator[1]
BAY OF QUINTE					
MBQ002	2	27/08/91	1.5	M	E&B&F&C
MBQ004	4	27/08/91	M	M	E&B&F
MBQ009	9	27/08/91	1.5	M	E&F&C&B
MBQ010	10	27/08/91	1.5	M	C
MBQ013	13	28/08/91	M	M	C
MBQ014	14	28/08/91	M	M	C
MBQ016	24	28/08/91	M	M	-
MBQ023	23	28/08/91	M	M	C
MBQ025	25	28/08/91	M	M	C
MBQ027	27	28/08/91	M	M	-
MBQ029	29	28/08/91	M	M	-
PENETANG HARBOUR					
MPH001	1	03/09/91	1.5	1.5	E
MPH004	4	04/09/91	M	M	E
MPH006	6	04/09/91	0.9	M	E
MPH007	7	04/09/91	1.5	1.5	C
MPH013	13	04/09/91	1.5	1.5	D
MPH016	16	04/09/91	1.5	1.5	D
MPH018	18	04/09/91	1.5	1.5	D
MPH020	20	03/09/91	1.5	1.5	D
MPH021	21	03/09/91	1.5	1.5	D
MPH023	23	03/09/91	1.5	1.5	D
MPH027	27	03/09/91	1.5	1.5	E
HAMILTON HARBOUR					
MHH002	2	06/09/91	1.3	1.3	G
MHH006	6	06/09/91	1.5	1.5	G
MHH018	18	06/09/91	1.0	1.3	E
MHH022	22	06/09/91	M	M	G
MHH026	26	06/09/91	2.0	M	E
MHH028	28	06/09/91	1.5	1.4	E&B
MHH036	36	30/08/91	M	M	-
MHH040	40	30/08/91	M	M	-

[1] Operators: A/V.W. Cairns, B/J.C.Fitzsimons, C/T.Heiman, D/B.Grey, E/E.DeBruyn, F/K.Hill, G/B.Valere.

Table 14 Percentage frequency of plant taxa encountered on detailed transect surveys in three areas in 1991.

Code name	Group	Latin name	Penetang Harbour	Hamilton Harbour	Bay of Quinte	Total
Val	1	Vallisneria sp.	43.5	77.3	36.9	48.2
Myr	2	Myriophyllum spicatum	17.3	15.5	16.4	16.6
PotA	6	Potamogeton amphifolius (N)	9.3	1.8	28.6	14.7
Nad	8	Najas spp.	9.8	0.0	1.0	4.6
Char	5	Chara spp.	9.1	0.0	0.0	3.9
Elo	3	Elodea canadensis	3.1	1.8	4.1	3.2
PotC	7	P. crispus (B)	0.2	1.1	6.6	2.7
PotS	6/7	P. spp.(p)	0.0	1.8	3.9	1.8
Eri	9	Ericaulon septangulare	3.0	0.0	0.0	1.3
Cer	4	Ceratophyllumm demersum	2.3	0.0	0.2	1.1
Unk	9	Unknown	0.3	0.7	2.1	1.1
PotR	7	P. richardsonii (B)	0.5	0.0	0.0	0.2
Ppra	7	P. praelongus (B)	0.5	0.0	0.0	0.2
Nup	9	Nuphar spp.	0.5	0.0	0.0	0.2
PRob	6	P. Robbinsii (N)	0.2	0.0	0.0	0.1
PotB	7	P. broadleaved? (B)	0.2	0.0	0.0	0.1
Sagi	9	Sagittaria cristata	0.2	0.0	0.0	0.1
		No. plants	572	277	482	1331
		No. transects	11	8	11	30
		Species richness	16	6	8	17

Table 15 Stem density, plant height, and percentage cover statistics by transect and area for surveys conducted in 1991.

Area	Stem density.m^{-2}			Plant height, cm			Percent Cover		
Transect	n	mean	C.V. %	n	mean	C.V. %	n	mean %	s.d. %
Bay of Quinte									
MBQ002	10	39.8	189.9	48	35.0	96.5	9	16.0	3.2
MBQ004	12	30.4	123.4	60	100.3	25.7	12	75.5	3.8
MBQ009	10	33.2	142.2	47	90.6	38.9	10	96.7	5.8
MBQ010	13	524.8	133.5	65	98.1	26.5	13	97.9	3.8
MBQ013	11	386.8	77.3	55	87.8	31.3	11	100.0	0.0
MBQ014	11	89.2	202.9	51	83.7	22.5	11	77.0	30.5
MBQ016	11	55.1	117.7	55	63.3	30.4	11	61.6	9.1
MBQ023	11	17.4	185.0	42	61.5	84.8	11	36.5	37.8
MBQ025	11	1.7	236.1	23	44.7	118.6	11	0.6	1.1
MBQ027	11	0.3	25.2	11	41.8	59.5	11	0.1	0.2
MBQ029	11	0.2	24.2	25	23.1	48.7	11	0.2	0.5
Penetang Harbour									
MPH001	11	156.6	101.8	55	75.5	57.4	11	100.0	0.0
MPH004	11	200.2	108.0	55	75.9	55.3	11	100.0	0.0
MPH006	11	43.6	81.2	55	57.6	61.6	11	73.4	17.7
MPH007	11	105.3	135.3	55	75.1	41.2	11	99.3	3.5
MPH013	11	219.0	141.8	55	11.6	70.6	11	37.7	8.2
MPH016	11	155.3	196.5	32	6.6	70.4	11	2.7	3.2
MPH018	10	2351.1	190.2	50	5.2	86.7	10	14.3	7.8
MPH020	11	97.7	118.1	55	8.2	59.2	11	28.7	16.9
MPH021	11	170.6	123.0	55	65.5	57.6	11	99.7	3.0
MPH023	10	136.5	54.0	50	21.3	92.6	10	58.6	13.1
MPH027	11	954.6	168.1	55	16.0	101.3	11	87.2	12.1
Hamilton Harbour									
MHH002	10	5.5	193.2	19	30.7	48.2	10	1.7	2.9
MHH006	11	0.3	70.7	8	26.1	105.1	11	0.1	0.9
MHH018	11	129.5	73.7	55	68.2	26.8	11	95.0	2.2
MHH022	11	62.9	120.9	38	18.9	28.4	11	28.3	21.5
MHH026	11	156.8	114.1	54	71.2	33.0	11	88.5	9.1
MHH028	11	92.5	80.3	50	52.3	36.3	11	60.4	16.3
MHH036	11	0.4	25.9	19	46.7	51.4	11	0.2	0.3
MHH040	10	4.3	119.0	34	50.2	65.7	9	2.4	2.4
Area means									
Bay of Quinte	11	107.2	132.5	44	66.4	53.0	11	51.1	8.7
Penetang Harbour	11	417.3	128.9	52	38.0	68.5	11	63.8	7.8
Hamilton Harbour	11	56.5	99.7	35	45.5	49.4	11	34.6	6.9

Table 16 Percentage composition of plant taxa by transect for surveys conducted in 3 areas in 1991.

Xsect	Val	Myr	PotA	Naj	Char	Elo	PotC	PotS	Eri	Cer	Unk	PotR	Ppra	Nup	PRob	PotB	Sagi
Bay of Quinte																	
MBQ002	20.8	33.3	2.1	-	-	-	39.6	4.2	-	-	-	-	-	-	-	-	-
MBQ004	20.0	-	65.0	-	-	3.3	-	11.7	-	-	-	-	-	-	-	-	-
MBQ009	25.5	66.0	-	-	-	4.3	-	4.3	-	-	-	-	-	-	-	-	-
MBQ010	80.0	4.6	7.7	-	-	7.7	-	-	-	-	-	-	-	-	-	-	-
MBQ013	78.2	3.6	16.4	-	-	-	-	-	-	1.8	-	-	-	-	-	-	-
MBQ014	7.8	2.0	88.2	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-
MBQ016	61.8	1.8	23.6	7.3	-	5.5	-	-	-	-	-	-	-	-	-	-	-
MBQ023	21.4	45.2	2.4	-	-	-	31.0	-	-	-	-	-	-	-	-	-	-
MBQ025	4.3	26.1	8.7	-	-	34.8	-	4.3	-	-	21.7	-	-	-	-	-	-
MBQ027	9.1	-	72.7	-	-	-	-	9.1	-	-	9.1	-	-	-	-	-	-
MBQ029	-	-	60.0	-	-	-	-	24	-	-	16.0	-	-	-	-	-	-
Penetang Harbour																	
MPH001	29.1	7.3	25.5	18.2	-	9.1	-	-	-	10.9	-	-	-	-	-	-	-
MPH004	56.4	10.9	29.1	1.8	-	-	-	-	-	1.8	-	-	-	-	-	-	-
MPH006	14.5	50.9	12.7	1.8	-	10.9	-	-	-	-	3.6	-	-	5.5	-	-	-
MPH007	29.1	63.6	1.8	-	-	3.6	-	-	-	1.8	-	-	-	-	-	-	-
MPH013	61.8	1.8	-	14.5	7.3	-	1.8	-	-	-	-	5.5	5.5	-	-	1.8	-
MPH016	65.6	-	-	18.8	6.3	-	-	-	9.4	-	-	-	-	-	-	-	-
MPH018	58.0	-	2.0	6.0	8.0	-	-	-	26.0	-	-	-	-	-	-	-	-
MPH020	34.5	36.4	1.8	7.3	16.4	-	-	-	1.8	-	-	-	-	-	1.8	-	-
MPH021	50.9	9.1	18.2	3.6	5.5	7.3	-	-	-	5.5	-	-	-	-	-	-	-
MPH023	74.0	-	6.0	12.0	6.0	-	-	-	-	2.0	-	-	-	-	-	-	-
MPH027	18.2	-	-	27.3	49.1	1.8	-	-	-	1.8	-	-	-	-	-	-	1.8
Hamilton Harbour																	
MHH002	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHH006	-	62.5	-	-	-	-	37.5	-	-	-	-	-	-	-	-	-	-
MHH018	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHH022	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHH026	96.3	-	-	-	-	3.7	-	-	-	-	-	-	-	-	-	-	-
MHH028	98.0	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHH036	5.3	57.9	-	-	-	5.3	-	21.1	-	-	10.5	-	-	-	-	-	-
MHH040	-	76.5	14.7	-	-	5.9	-	2.9	-	-	-	-	-	-	-	-	-

Table 17 Macrophyte taxon groups used for multi-year percent similarity comparisons of assemblage composition; group memberships are given in Tables 1, 9, and 14.

Group	Code	Macrophyte taxon
1	VALL	Vallisneria spp.
2	MYRI	Myriophyllum spp.
3	ELOD	Elodea canadensis
4	CERA	Ceratophyllum demersum
5	CHAR	Chara spp.
6	POTN	Narrow-leaved Potamogetons
7	POTB	Broad-leaved Potamogetons
8	NAJA	Najas spp.
9	OTHR	Others

Table 18 Pearson correlations between macrophyte measures obtained on 20 transects visited in both 1990 and 1991 in the Bay of Quinte, Hamilton Harbour, and Penetang Harbour.

Macrophyte Measure	n	r	
Stem density	22	-0.036	
Loge(Stem density + 1)	"	0.744	**
C.V. of stem density	"	-0.254	
Plant height	"	0.411	*
C.V. of plant height	"	-0.096	
Percent cover	19	0.790	**
Arcsine(√Percent cover)	"	0.807	**
Species richness	22	0.643	**

Significance - * P = 0.05, ** P = 0.01

Table 19 Pearson correlations for percentage cover and species richness between pairs of years for macrophyte surveys conducted in the upper Bay of Quinte, 1988-1991.

Measure		1988	1989	1990	1991
Arcsine(√Percent cover)					
	1988	-	0.788 **	0.697 *	0.664 *
	1989	30	-	0.742 **	0.619 *
	1990	10	12	-	0.879 **
	1991	10	11	6	-
Species richness					
	1988	-	0.599 **	-0.015	-0.152
	1989	30	-	0.236	0.103
	1990	11	13	-	-0.154
	1991	10	11	7	-

Significance - * P = 0.05, ** P = 0.01

Table 20 Summary statistics for percent similarity values from transects visited in two or more years in the Bay of Quinte, 1988-1991.

Group	n	Mean	s.d.	Minimum	Maximum
1988-1989	30	0.58	0.25	0.08	1.00
1988-1990	11	0.36	0.20	0.08	0.54
1988-1991	10	0.34	0.20	0.10	0.61
1989-1990	13	0.31	0.17	0.08	0.50
1989-1991	11	0.31	0.20	0.05	0.59
1990-1991	7	0.59	0.18	0.42	0.82
All	82	0.44	0.24	0.05	1.00

Table 21 Pearson correlations among macrophyte measures and percentage composition values from 102 transects surveyed in 1990 and 1991. Significance was assessed at a nominal P = 0.05 level using a Bonferroni correction for multiple testing; significant values are underlined. The sample size for any correlation is the minimum of the sample values (diagonal) for each pair of variables.

	STMN	STCV	HTMN	HTCV	COVER	COVSD	LNST	ACOV	VALL	MYRI	ELOD	CERA	CHAR	POTN	POTB	NAJA	OTHR	MSPP
STMN	102	0.10	0.18	0.08	0.38	-0.01	0.57	0.41	-0.12	-0.08	0.37	0.57	-0.01	-0.06	-0.05	0.07	-0.01	0.24
STCV	-	102	0.23	0.34	0.04	0.28	0.25	0.09	0.07	0.04	0.10	0.06	0.05	0.08	0.11	0.12	0.01	0.26
HTMN	-	-	102	-0.11	0.51	-0.06	0.24	0.51	0.01	0.38	0.21	0.22	-0.23	0.07	-0.10	-0.11	-0.14	0.24
HTCV	-	-	-	102	-0.14	-0.04	0.23	-0.10	0.00	0.14	0.06	0.05	0.32	0.01	0.21	0.05	0.18	0.40
COVER	-	-	-	-	98	0.06	0.75	0.99	0.26	-0.06	0.31	0.31	-0.08	-0.11	-0.16	0.15	-0.19	0.45
COVSD	-	-	-	-	-	30	0.19	0.06	0.04	-0.01	-0.20	-0.22	0.13	-0.01	0.07	0.03	-0.18	-0.01
LNST	-	-	-	-	-	-	102	0.79	0.33	-0.21	0.27	0.29	0.14	-0.10	-0.14	0.17	-0.15	0.55
ACOV	-	-	-	-	-	-	-	98	0.28	-0.05	0.32	0.33	-0.06	-0.14	-0.15	0.17	-0.20	0.48
VALL	-	-	-	-	-	-	-	-	102	-0.38	-0.19	-0.19	-0.14	-0.31	-0.22	-0.03	-0.18	-0.10
MYRI	-	-	-	-	-	-	-	-	-	102	0.04	-0.04	-0.06	-0.26	0.14	-0.15	0.01	0.07
ELOD	-	-	-	-	-	-	-	-	-	-	102	0.20	-0.13	-0.14	-0.07	-0.03	0.00	0.29
CERA	-	-	-	-	-	-	-	-	-	-	-	102	-0.04	-0.07	-0.06	0.13	-0.06	0.22
CHAR	-	-	-	-	-	-	-	-	-	-	-	-	102	-0.02	-0.02	0.13	-0.01	0.24
POTN	-	-	-	-	-	-	-	-	-	-	-	-	-	102	-0.11	-0.02	-0.04	0.12
POTB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	102	-0.10	0.02	0.01
NAJA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	102	-0.04	0.32
OTHR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	102	0.00
MSPP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	102

Table 22 Multiple regression models of cover as a function of stem density, plant height and height variation, and of cover, stem density, and height as functions of percentage taxa composition.

Dependent (N)	Independent	Coefficients: Slope	se	$T_{b=0}$	P	Analysis of Variance: F_{regr}	P	R	s.e. Estimate
ACOV-Arcsine(√Percent cover) (98)									
	Intercept	0.038	0.079	0.48	0.263				
	LNST	0.177	0.012	15.06	0.000				
	HTMN	0.006	0.001	5.87	0.000				
	HTCV	-0.005	0.001	-4.79	0.000	113.01	0.000	0.89	0.26
ACOV-Arcsine(√Percent cover) (98)									
	Intercept	0.273	0.086	3.18	0.002				
	CERA	0.025	0.008	4.03	0.002				
	ELOD	0.013	0.004	3.37	0.001				
	NAJA	0.014	0.007	2.03	0.045				
	VALL	0.007	0.001	4.51	0.000	11.56	0.000	0.58	0.47
LNST-Log$_e$(Density + 1) (102)									
	Intercept	1.518	0.361	4.21	0.000				
	CERA	0.092	0.023	4.03	0.000				
	CHAR	0.066	0.019	3.39	0.001				
	ELOD	0.064	0.016	4.09	0.000				
	VALL	0.037	0.006	6.01	0.000	15.79	0.000	0.63	1.91
HTMN-Mean plant height (102)									
	Intercept	-2.641	6.919	-0.38	0.704				
	CERA	1.110	0.268	4.14	0.000				
	ELOD	0.640	0.183	3.50	0.001				
	MYRI	0.918	0.119	7.69	0.000				
	POTN	0.568	0.108	5.25	0.000				
	VALL	0.481	0.088	5.48	0.000	15.50	0.000	0.67	22.03

Table 23 Results of K-means cluster analysis of transects using the assemblage composition data as the basis for group separation.

		Cluster group 1	2	3	$F_{B\text{-}W}$*
Statistics by plant taxon:					
VALL	Min.	34.0	0.0	0.0	164.0
	Mean	70.5	13.2	12.9	
	Max.	100.0	48.0	34.0	
MYRI	Min.	0.0	0.0	0.0	27.5
	Mean	4.3	31.1	2.8	
	Max.	30.0	100.0	25.0	
POTN	Min.	0.0	0.0	34.0	126.0
	Mean	12.0	7.6	65.4	
	Max.	46.0	37.0	100.0	
Frequency of groups by location:					
Hamilton Harbour		12	15	1	
Bay of Quinte		6	8	10	
Penetang Harbour		14	13	2	
Hog Bay		4	2	4	
Matchedash Bay		8	3	0	

*$F_{B\text{-}W}$ - F-ratio between vs. within on 2,99 df, all significant at P = 0.001

Table 24 Comparative evaluation of five alternate macrophyte survey methodologies.

Criteria	COVER	BIOMASS	POINT	DISTANCE	ECHO-DIG
Measures:					
Abundance	Y	Y	N	Y	Y
Size	N	N	N	Y	Y
Composition	N	Y	Y	Y	N
Skills:					
Taxonomic	L	M	H	H	L
Scuba	N	Y	Y	Y	N
Computing	L	L	L	H	H
Labour:					
Field	L	M	M	H	L
Lab/Office	L	M	M	H	H
Applicability:					
Research	Y	Y	Y	Y	Y
Assessment	Y	N	N	N	Y

Y=Yes, N=No, L=Low, M=Medium, H=High

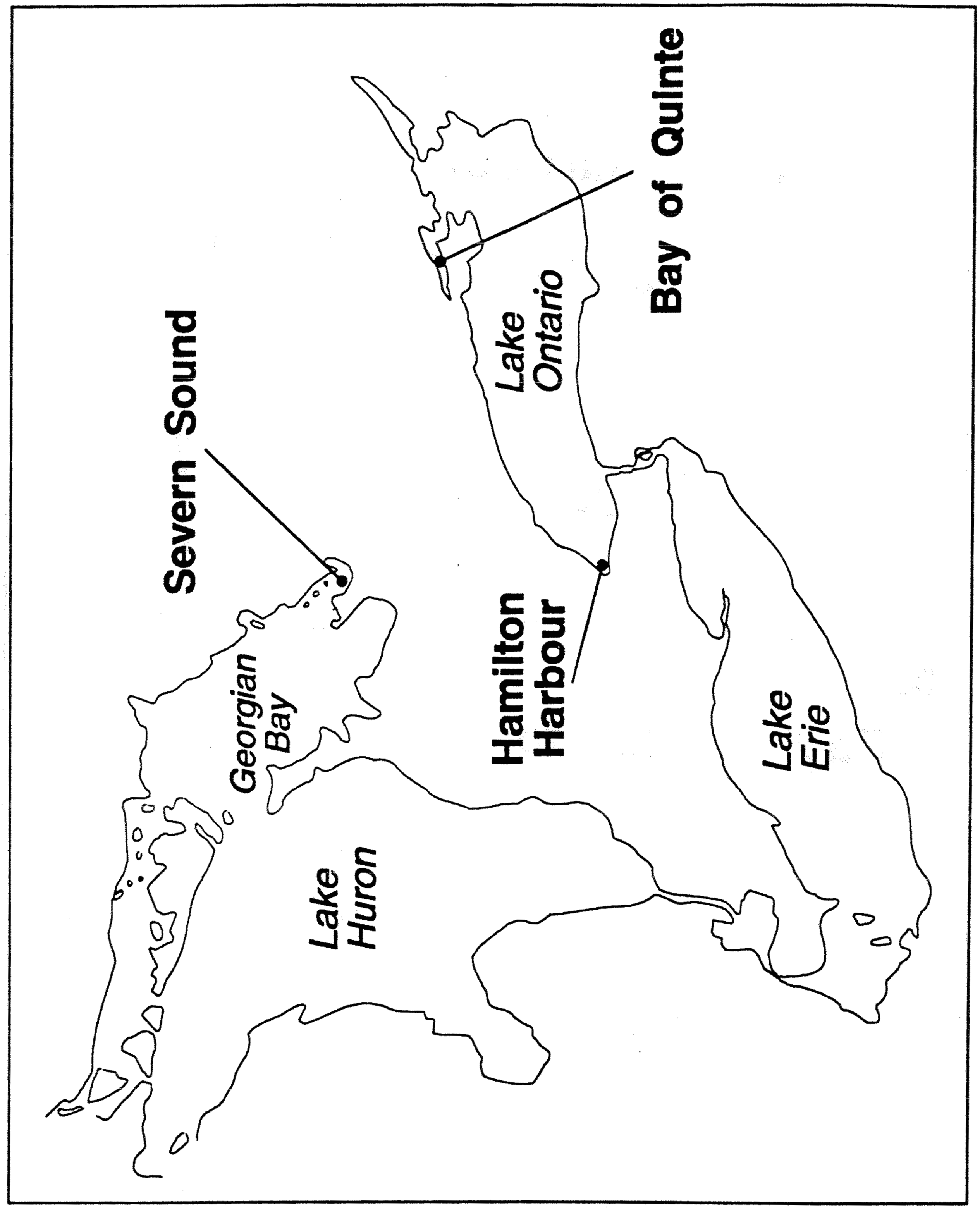


Figure 1. A map showing the locations of the three Areas of Concern.

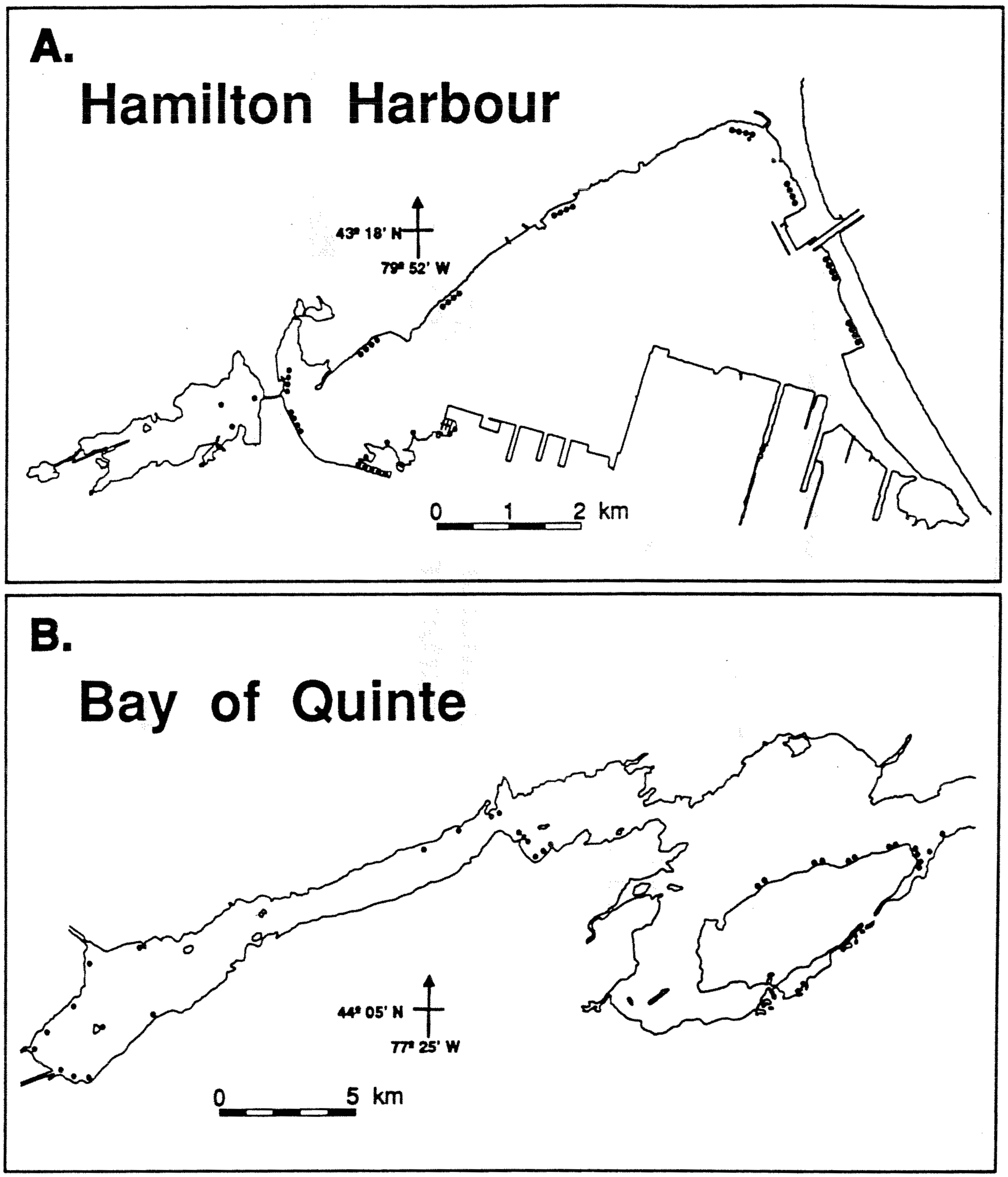


Figure 2. Maps showing the locations of the electro-fishing and macrophyte transects.

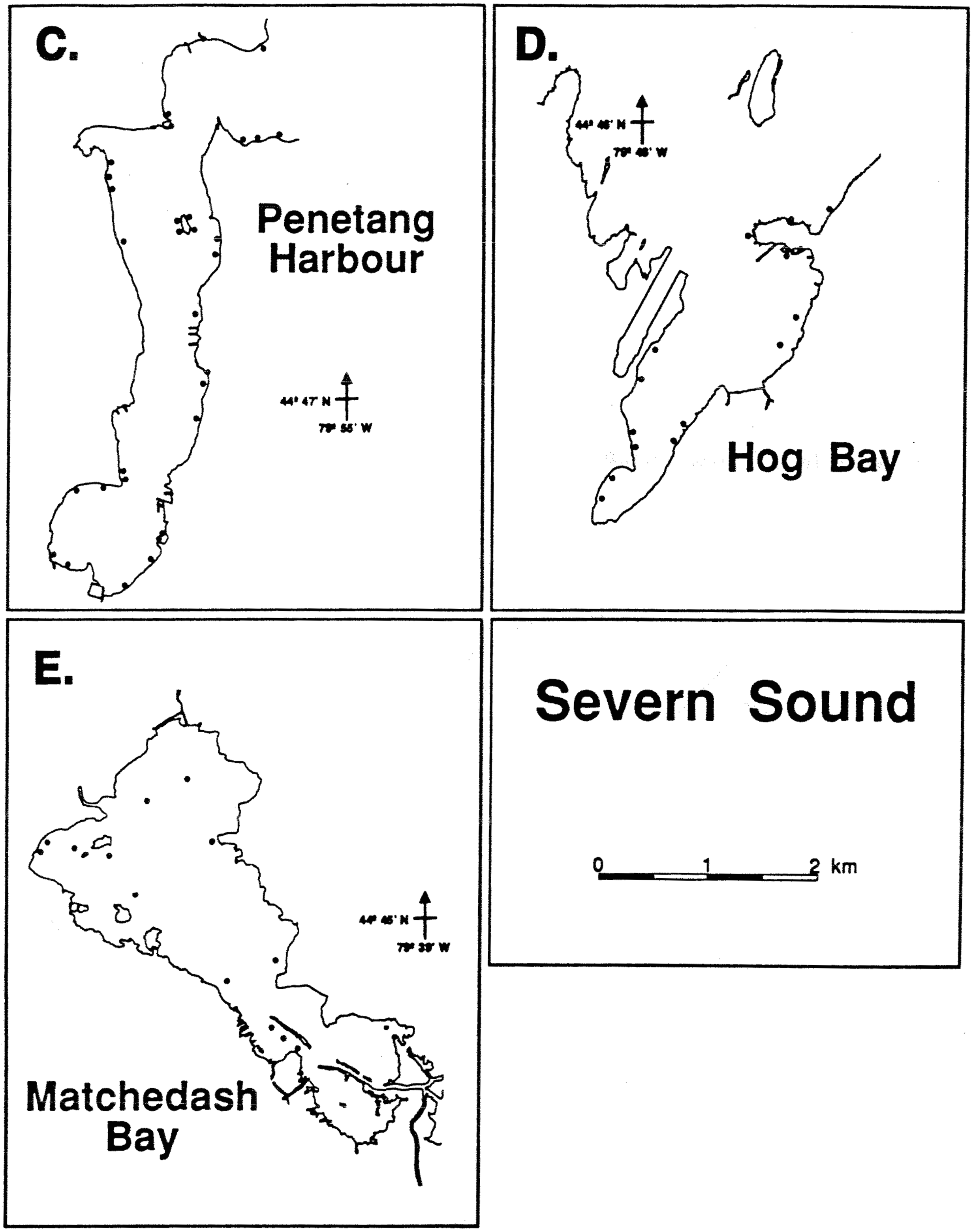
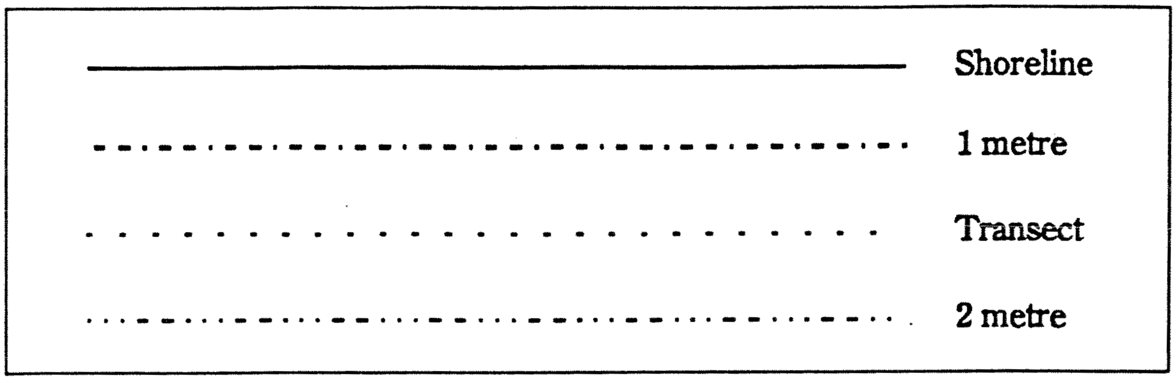


Figure 2 (continued). Maps showing the locations of the electro-fishing and macrophyte transects.

A. Transect Layout



B. Sampling Configuration

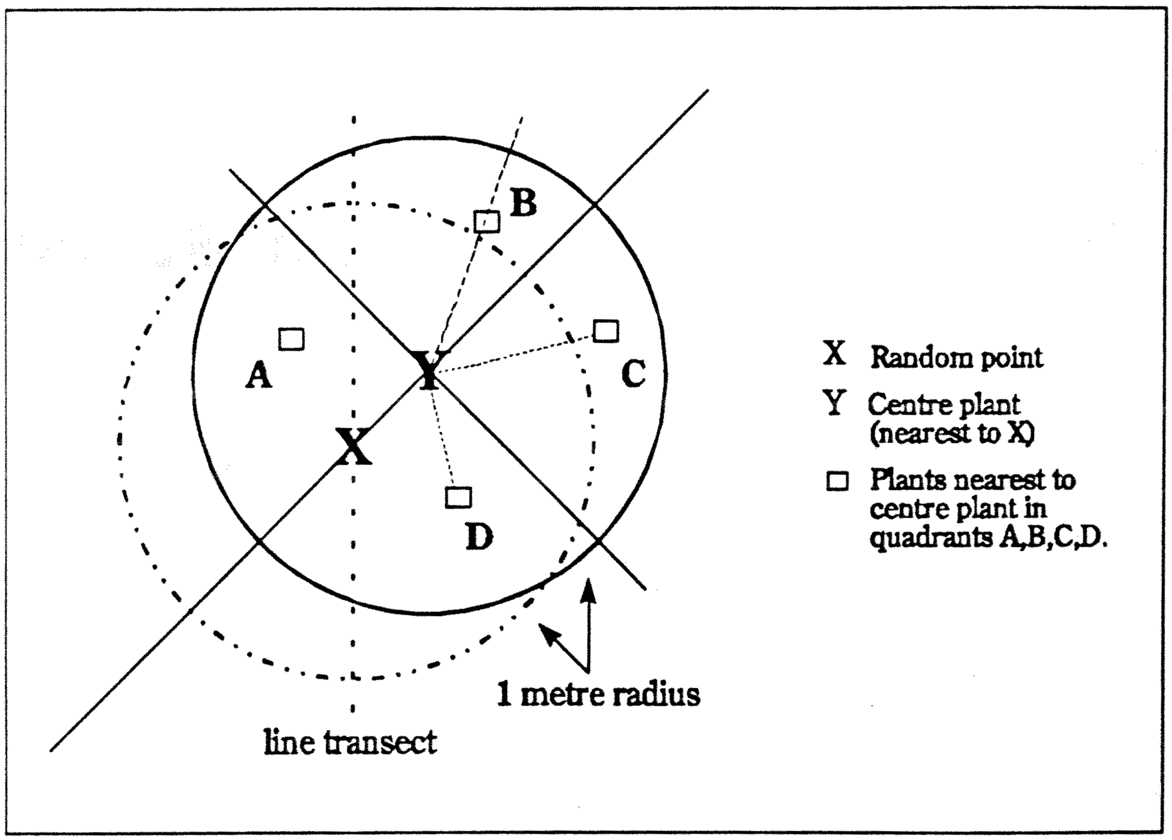


Figure 3. Diagrams showing the layout of a transect along the 1.5 metre contour and the configuration of the sampling method used to estimate stem density.

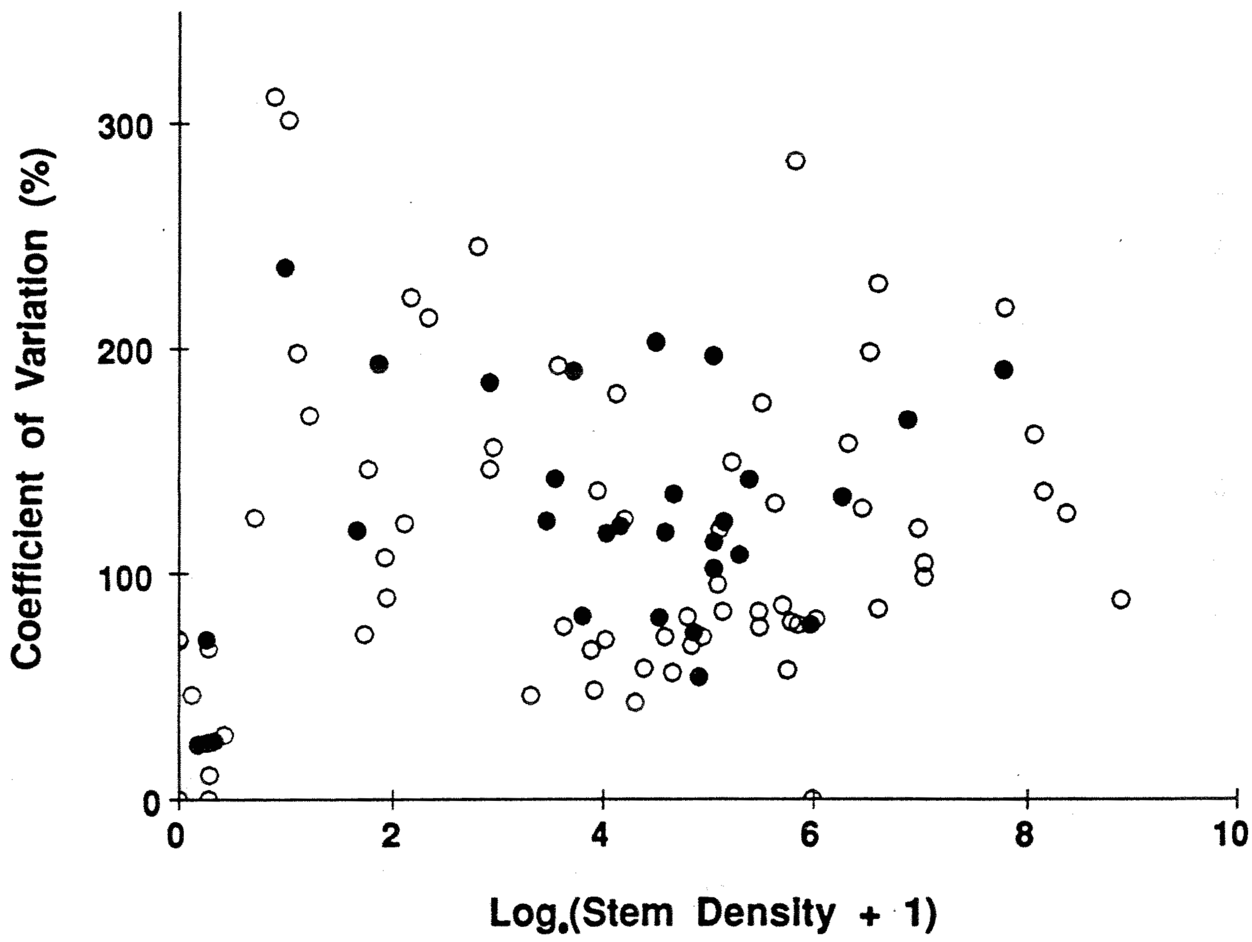


Figure 4. Semi-logarithmic relationship between the mean and percentage coefficient of variation of stem density on 102 transects surveyed in 1990 (O) and 1991 (●).

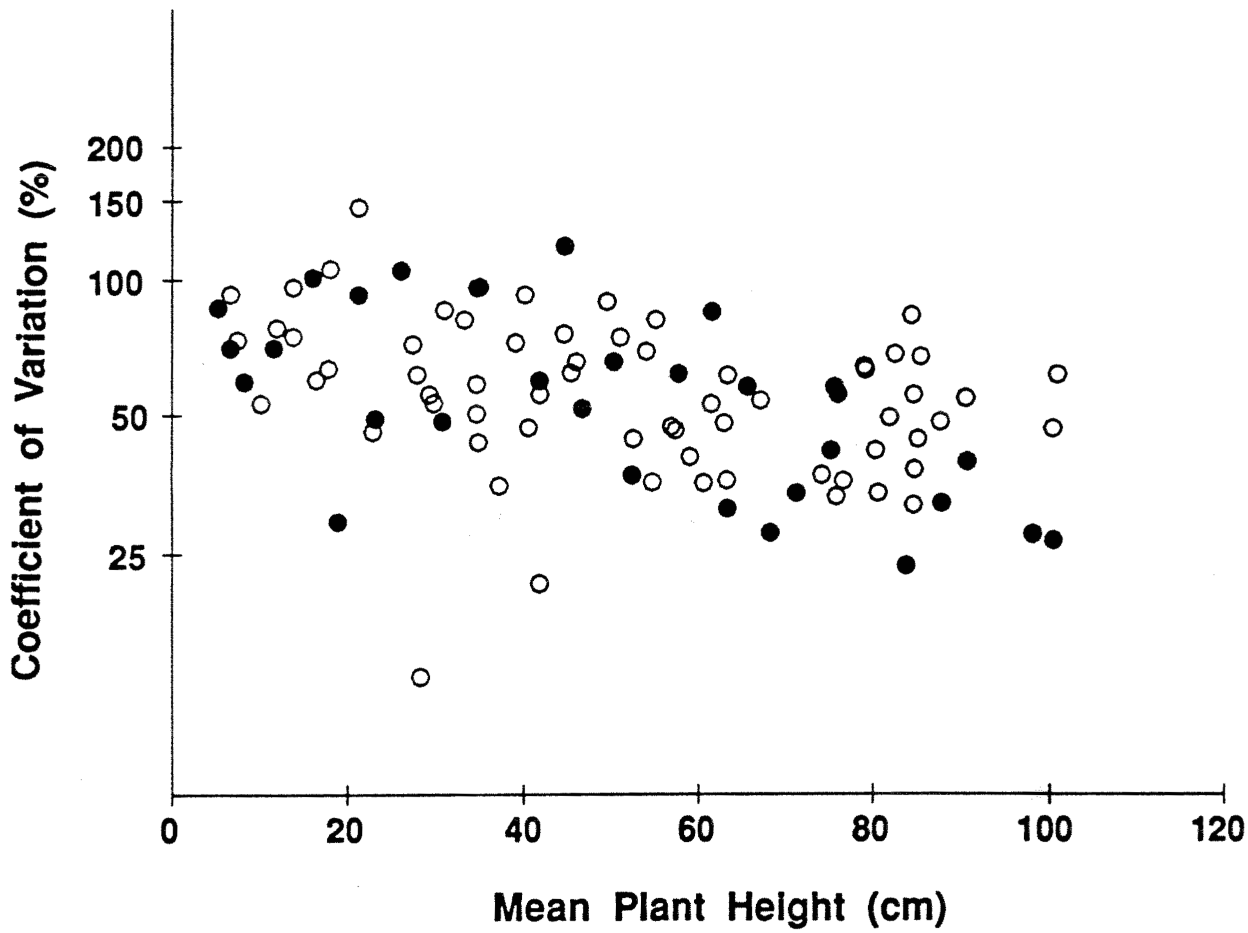


Figure 5. Semi-logarithmic relationship between the mean and percentage coefficient of variation of plant height on 102 transects surveyed in 1990 (O) and 1991 (●).

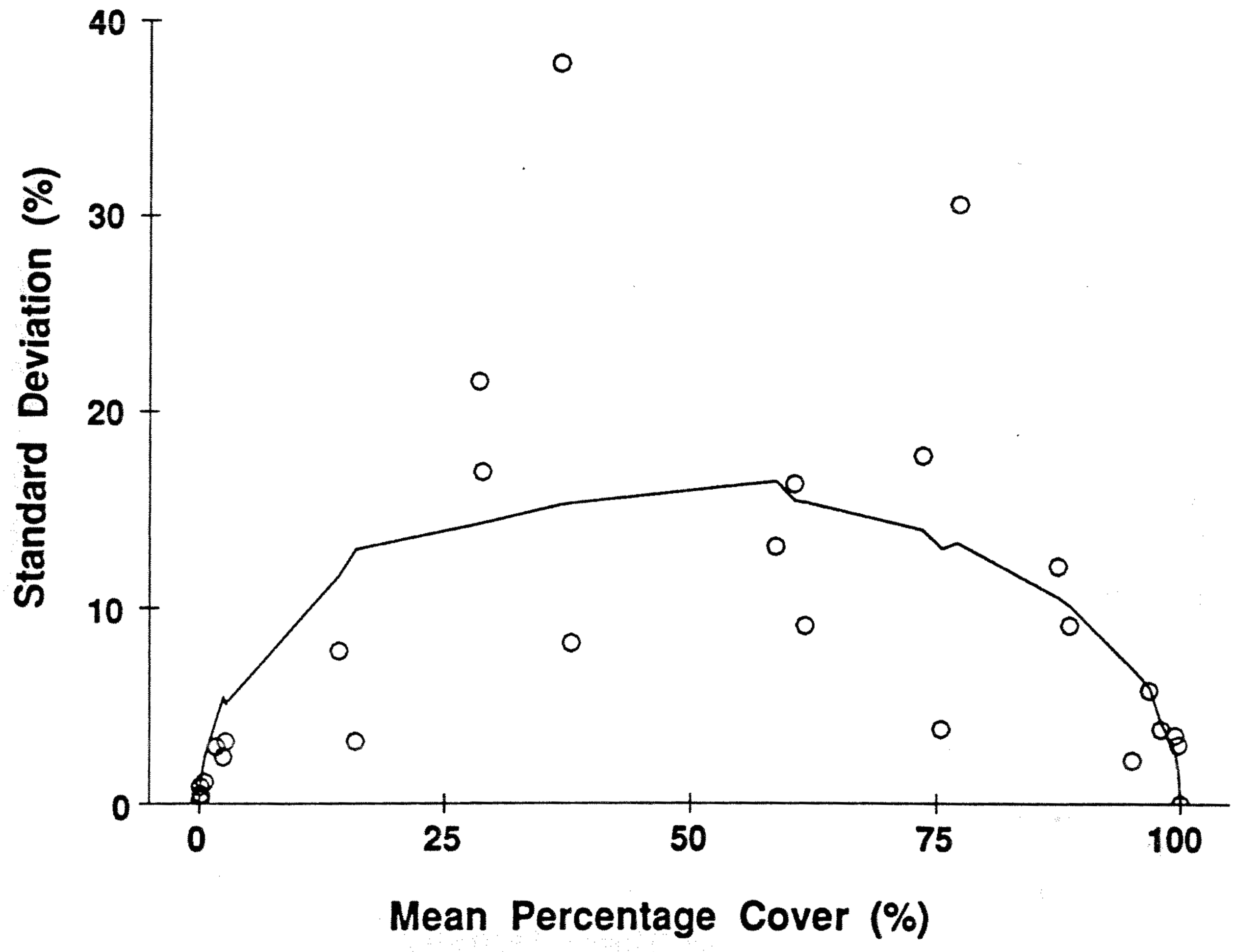


Figure 6. The relationship between the mean and standard deviation of percentage cover on 30 transects surveyed in 1991. The line represents the expected standard deviation given the mean and assuming the the data points on each transect were drawn from a biinomial population.

Appendix Table A Shoreline site descriptions of the macrophyte survey transects in the Bay of Quinte in 1988 and 1989.

Transect #	Log Book	Description
1	23	Spit from park, start from 2nd bridge going out towards lake
2	29	Along the front of the cat-tail mat, start near the toy bridge
3	28	Onderdonk Pt. east of red boat-house and canadian flag
4	26	Indian Island, hydro pole in line with tree, nb. red mark on rock
5	30	South side of canal, start at 2nd concrete pier, head in towards land
6	31	Along marsh front, start where old house with red roof can be seen between trees
7	25	Orange door of large factory, 100 m. west of door
8	24	In front of high red apt. bldg. near rail road tracks
9	32	On outside of offshore reed bed, near rail road track and road way, corner transect
10	33	Infront of white house with above grd. swim pool with red deck, 16 m from shore towards SW
11	1	Starts at astroturf boat launch, goes 100 m towards cat mat, away from island
12	2	Starts at property fence of 2-storey pink house, head toward cat mats
13	3	Start at corner of cat mats just below transects 11 and 12
14	4	Bay side of Rossmore point, follow shore line from tip into bay
15	5	Belleville side of Rossmore point, start at tip follow shore
16	6	100 m W of mouth of Moira, head W for 100 m Zwick Park
17	6/7	Continuation of transect 16, dredged area at W end of transect, nb. park bench
18	7	Overhanging willows W of bridge/old camper top on shore
19	8	200 m W of cemetery near park/large granite rock
20	11	Off tip of stone fill, near new houses, large grianite rock, 100 m offshore
21	12	Start off park wharf, head towards inlet
22	13	Start at last house before marsh, 100 m towards marsh
23	13/14	Continuation of transect 22, along marsh front, S of last house
24	15	From 1st house before marsh, north toward point (S transect)
25	15/16	Northern continuation of transect 24
26	17	W from green boat-house, 1st green boat-house W of Quinte Pt.
27	18	Continuation of transect 26, heading W
28	19	Start at road junction E of marina. Small cliff of rock, head E
29	20	Continuation of transect 28, heading E
30	21	Start opposite field of corn, heavy shore trees, no house behind, last house had no shore trees in front, with rocky shore
31	22	Continuation of transect 30 towards lone wharf with wagon wheels on it
32	9	Start of road junction W of marina, head W
33	10	Continuation of transect 32, heading W
34	-	Opposite white cottage with red roof 5 m from shore towards W
35	-	In front of bandshell where no trees at shore. 10 m from shore, towards W