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Canada

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Cover illustration
The dots on the map represent Agriculture Canada research establishments.

ABSTRACT

Control of nuisance aquatic vegetation in the Rideau Canal was achieved with herbicides until 1979 after which responsible agencies utilized mechanical harvesting procedures which have been preferred ever since. Harvested aquatic vegetation is provided to local farmers as green manure. In 1987, 35 aquatic macrophytes were recorded in 13 sites where macrophyte control is traditionally necessary. Diversity was relatively low with the number of vascular aquatics at a site ranging from 9 to 20. The dominant aquatic weeds were *Myriophyllum spicatum, Potamogeton pusillus* var. *tenuissimus,* and *Potamogeton crispus,* but some variation exists in percentage cover of the different species between the channel and adjacent areas and among the 13 sites. Other species contributing relatively high cover values, especially at some sites, were *Ceratophyllum demersum, Elodea canadensis, Hydrocharis morsus-ranae, Lemna trisulca, Myriophyllum sibiricum, Potamogeton illinoensis, P. richardsonii, P. zosteriformis* and *Vallisneria americana.* Two of the three dominant species: *M. spicatum* and *P. crispus* are introduced from Europe. These two species were more abundant in the navigation channel than in adjacent areas. The third dominant species, *Potamogeton pusillus var. tenuissimus,* is native to Canada. The major weed species, *Myriophyllum spicatum* is expected to decline within a few years as populations of grazing insects increase.

RÉSUMÉ

Jusqu'en 1979, on a réussi à limiter le développement de la végétation aquatique nuisible dans le canal Rideau grâce à l'emploi d'herbicides. Par après, les organismes responsables de ce programme se sont tournés vers des méthodes de récolte mécanique, qui se sont révélées préférables depuis. La végétation aquatique ainsi récoltée est distribuée aux fermiers des environs qui s'en servent comme engrais vert. En 1987, on a relevé 35 macrophytes aquatiques dans 13 sites où leur limitation est traditionnellement nécessaire. La diversité des espèces était relativement faible avec, pour un site donné, de 9 à 20 trachéophytes (plantes vasculaires) aquatiques seulement. Les espèces dominantes étaient le *Myriophyllum spicatum*, le *Potamogeton pusillus* var. *tenuissimus* et le *Potamogeton crispus*; le pourcentage de couverture des différentes espèces variait toutefois entre le canal et ses abords, ainsi que d'un des 13 sites à un autre. Les autres espèces qui contribuaient à des indices de couverture relativement élevés, plus particulièrement dans certains sites, étaient le *Ceratophyllum demersum*, l'*Elodea canadensis*, l'*Hydrocharis morsus-ranae*, le *Lemna trisulca*, le *Myriophyllum sibiricum*, le *Potamogeton illinoensis*, le *P. richardsonii*, le *P. zosteriformis* et le *Vallisneria americana*. Deux des trois espèces dominantes, le *M. spicatum* et le *P. crispus*, sont originaires d'Europe. Ces deux espèces étaient d'ailleurs plus abondantes dans le canal de navigation qu'à ses abords. Quant à la troisième espèce dominante, le *Potamogeton pusillus* var. *tenuissimus*, elle est indigène. La principale espèce de plante nuisible, le *Myriophyllum spicatum*, devrait se trouver en déclin d'ici quelques années, en raison de l'accroissement des populations d'insectes qui s'en nourrissent.

INTRODUCTION

Management of aquatic vegetation has become a concern of many groups of people including especially those involved with recreation management, wildlife management and irrigated agriculture. Economical and rapid control procedures have been frequently emphasized. Information regarding the species contributing to the problem in different areas is frequently lacking or at least unavailable in published form. With the rapid development of the field of restoration and management of aquatic systems (eg. Cooke *et al.* 1986), accompanied by environmental concerns, the need for more biological information and accurate documentation of aquatic weed problems has become increasingly evident. Basic information such as a priorized listing of the species contributing to weed problems in different areas is relevant to successful control procedures and important to understanding the biology of species concerned. Sometimes the composition of nuisance aquatic vegetation changes rapidly and such changes can be predicted and monitored, but only if data from an earlier period is available.

This study documents the composition of vascular aquatic vegetation at several localities in the Rideau Canal system in southeastern Ontario. These localities have been identified by Parks Canada as areas where aquatic vegetation controls are necessary.

THE STUDY AREA

The Rideau Canal system is comprised of a chain of lakes, rivers and canal cuts 198 km in length, extending from Kingston on Lake Ontario to Ottawa. It is one of Canada's 9 heritage canals maintained by Environment Canada. It is also one of the busiest recreational canals in the world with over 500,000 people using it each year. The Rideau canal, along with the connecting Trent-Severn waterway is within a one day drive of 60 million people.

In addition to preserving the canal's natural and historic features, Environment Canada is concerned with managing the canal in such a way as to provide a safe, pleasant and interesting environment where optimum recreational use is acheived without causing significant environmental damage. At 13 sites along the canal (Fig. 1, Table 1), vascular aquatic vegetation develops to the point where water-based traffic is impeded so that management is necessary to monitor and control excessive growth.

It was in the 1970s that problems with aquatic weeds became very serious in the Rideau-Trent-Severn System (Rideau Valley Conservation Authority 1979a,b,c,d), and the Rideau Valley Conservation Authority received numerous calls and letters of concern about the problem. In 1976 there were 4,000 ha of heavy weed growth in the major waterbodies comprising the Rideau System. The Authority had commenced experimental studies of control by chemicals in the late 1960s. These studies suggested that use of diquat provided temporary control and this herbicide was employed from 1972 to 1978 (Rideau Valley Conservation Authority 1974) in co-operation with Parks Canada who later took full responsibility for aquatic weed control. Aquatic weeds re-established six weeks after herbicide application and Tapegrass (*Vallisneria americana*)

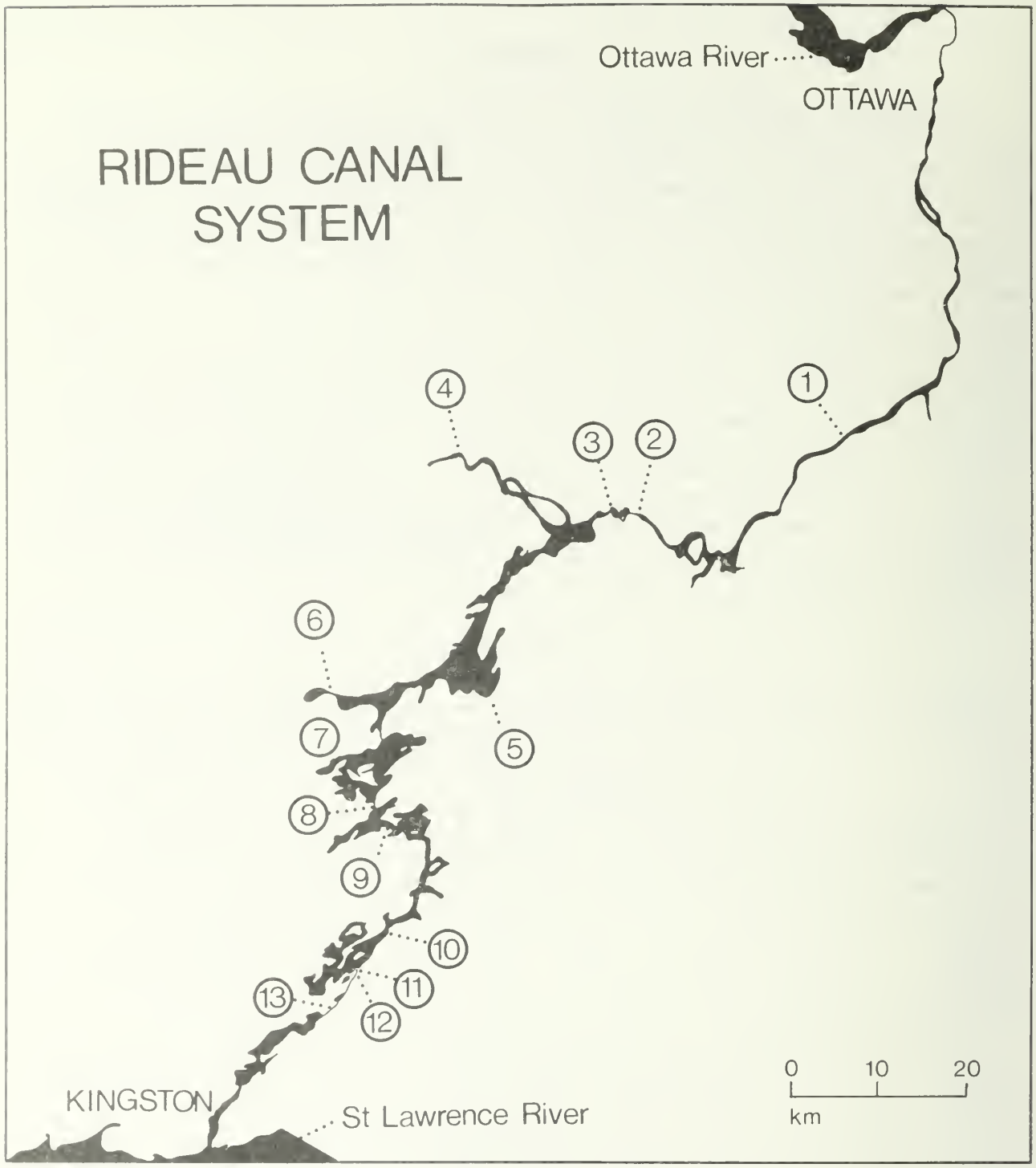

Figure 1. The Rideau Canal System showing the approximate location of the 13 study sites where aquatic weeds are harvested annually.

was not effectively controlled and accelerated its growth rate after herbicide removed competing species (Rideau Valley Conservation Authority 1971). The herbicide program was not expanded from 1972 to 1978 because of the feeling that herbicide is not appropriate for large scale aquatic plant control and undesirable side effects were associated with it. Mechanical harvesting methods became the object of intensive study in the late 1970s (Wile and Hitchin 1977, Rideau Valley Conservation Authority 1979a,b,c), and mechanical methods soon gained support (Rideau Valley Conservation Authority 1979d). From 1979 to present the responsible government agencies have advocated mechanical harvesting methods alone. A questionaire was circulated in 1980 to people involved with areas where aquatic weeds had been traditionally controlled. The majority preferred mechanical harvesting methods despite a very poor mechanical control program that year (Rideau Valley Conservation Authority 1980). Since 1980 harvested aquatic vegetation has been provided to local farmers for use as green manure.

METHODS

At the 13 sites along the Rideau Canal where aquatic plant growth reaches nuisance levels each year, Parks Canada has to make arrangements annually for aquatic plant harvesting. Problems develop as a result of both dense growth in the channel and as a result of vegetation from adjacent sites rafting in. Since the channel and the adjacent areas represent different habitats with different disturbances, they are described separately. In late June and early July 1987 (prior to harvesting), at each of the 13 sites, we sampled 25 $5m^2$ plots along the edge of the navigation channel and another 25 $5m^2$ plots 10

Table 1. Sites studied along the Rideau canal where vascular aquatic plants regularly develop to nuisance levels.

Site	lat.	long.	UTM
1. Burritts Rapids	44°59'N	75°47'W	361804 - 380811
2. Smiths Falls (east)	44°53'N	76°01'W	198718 - 205711
3. Smiths Falls (west)	44°53'N	76°01'W	188718 - 194718
4. Perth	44°54'N	76°15'W	012721 - 013723
5. Portland	44°42'N	76°11'W	055501
6. Westport	44°41'N	76°26'W	894480 - 894482
7. Newboro	44°39'N	76°19'W	947449 - 954443
8. Chaffeys Lock	44°34'N	76°18'W	952366 - 953371
9. Davis Lock	44°34'N	76°17'W	974349 - 979345
10.Seeleys Bay	44°29'N	76°14'W	010262 - 017257
11.Cranberry Lake	44°25'N	76°18'W	959199 - 969221
12.Brewers Mills	44°25'N	76°18'W	954183 - 957187
13.Joyceville	44°21'N	76°23'W	901121 - 918130

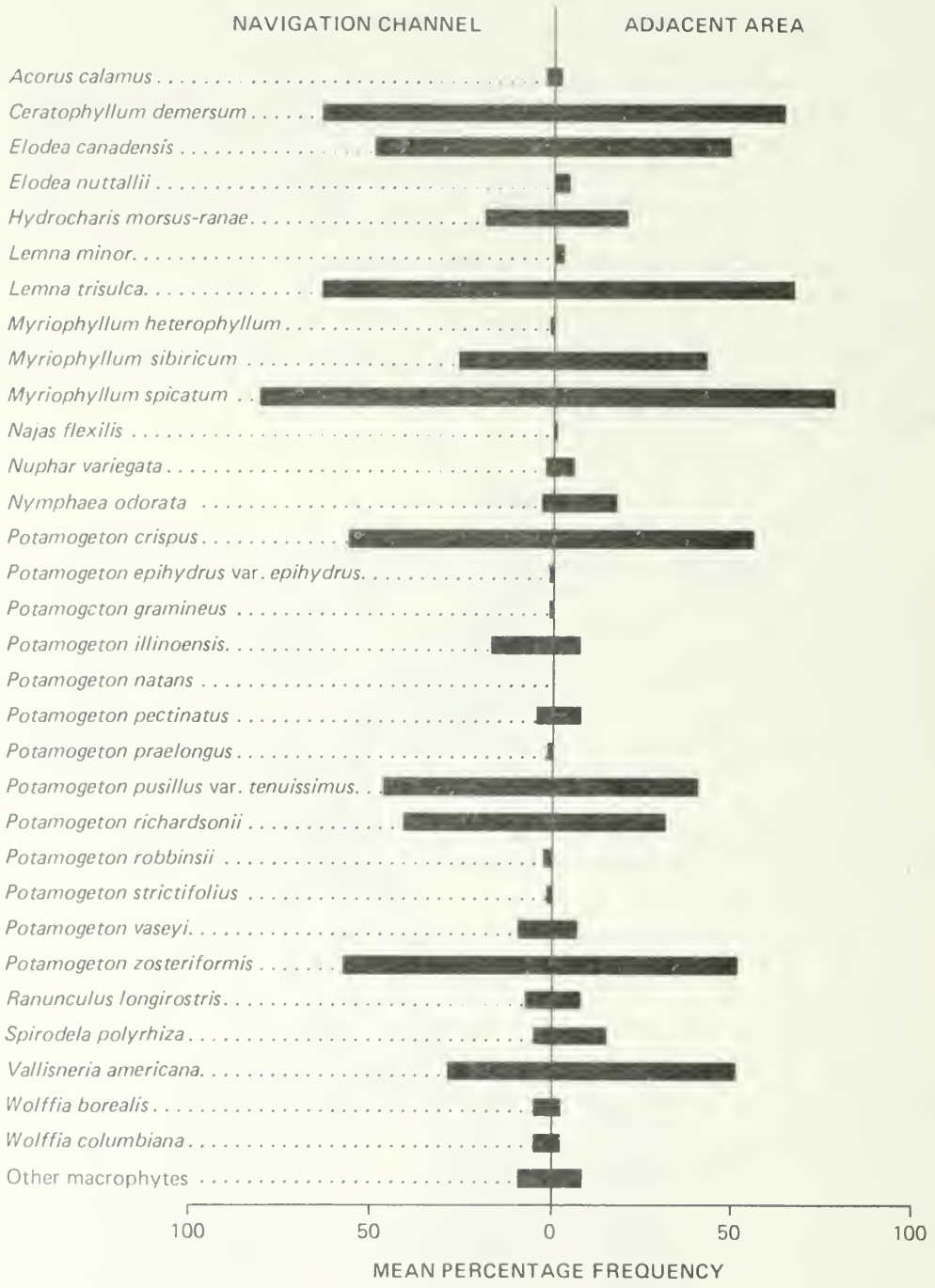

Figure 2. Histograms of mean percentage frequency for 31 vascular aquatics and other macrophytes at 13 sites along the Rideau Canal.

Figure 3. Histograms of mean percentage cover for 31 vascular aquatics and other macrophytes at 13 sites along the Rideau Canal.

to 20m from the edge of the navigation channel. The percent frequency and cover of each species present was estimated for each plot. A hand rake was used in deeper turbid water to ensure that all material present in each plot was recorded. The size of the problem areas varied from site to site (Table 1), but the sample plots were distributed evenly throughout each site. Data on percent frequency and percent cover for each species was summarized for each site.

Since the aquatic vegetation was harvested in late July, it was necessary to conduct the inventory in late June and early July but most of the species present were well developed and in a flowering or fruiting stage at this time. Additional but non-quantitative observations were made in August 1987, after the harvesting.

RESULTS AND DISCUSSION

1. DIVERSITY

A strong domination by one or a few species (see below) and a relatively low species diversity seem to be characteristic of many sites that are identified as requiring management of aquatic vegetation. The number of species at the sites managed along the Rideau Waterway ranges from 9 to 20 (Table 2). Few descriptions of the composition of nuisance aquatic vegetation in Canada are available to compare with the results of the present study, and those that are available are not very detailed. Although differences in area and geography are not adequately accounted for, there is some general information on aquatic plant diversity, mostly from non-nuisance aquatic vegetation (table 3). It is clear from this table that 9 to 20 species is relatively low in terms of diversity of aquatic plant communities.

Table 2. Size of study areas and number of species recorded at each site.

Site	Area in hectares	No. of species
1	13.20	16
2	.79	14
3	1.04	18
4	.53	9
5	.16	14
6	.91	14
7	9.86	17
8	1.82	19
9	6.73	20
10	9.93	11
11	32.83	12
12	1.96	11
13	21.21	16

Table 3. Number of vascular aquatic plants recorded at various locations in North America by different authors.

Location	Submersed Aquatic Macrophytes	All Aquatic Macrophytes	Reference
Lake Temagami		44	Dale 1986
Pelee Marsh		45	Maycock, Reznicek and Gregory 1978
St. Clair Marsh		35	Gow, Kelly and McLean 1982
St. Clair - Detroit River	18		Schloesser and Manny 1986
Cootes Paradise Marsh		36	Pringle 1969
Rouge River Marsh		27	Riley 1978 Riley, Varga and Oldham 1981
Oshawa Second Marsh		17	Cecile 1981
Lake Opinicon	29		Crowder, Bristow, King and Vanderkloet 1977
Bay of Quinte	15		Bristow, Crowder, King and Vanderkloet 1977
Gatineau Park Lakes		8-52	Aiken and Gillett, 1974
Eastern Ontario Lakes	5-33		Crowder, Bristow, King and Vanderkloet 1977
Canadian Prairie Lakes		3-19	Hammer and Heseltine 1988
Silver Lake, N.Y. (an acid lake)	11		Singer 1983
Manitoba ponds		1-11	Pip 1987
Lakes, Maine, U.S.A.		6-15	Hunter, Jones and Witham 1986
Muskoka Lakes, Ontario		17-32	Miller and Dale 1979
Nova Scotia Lakes		8-32	Catling, Freedman, Stewart, Kerekes and Lefkovitch 1986
Lake Superior Provincial Park	5-18		Fraser and Morton 1983

2. DOMINANT SPECIES

In the Rideau Canal navigation channels and adjacent areas there were three dominant species: *Myriophyllum spicatum, Potamogeton crispus* and *P. pusillus var. tenuissimus* (Table 4, Figs. 2 and 3). Of these three, *Myriophyllum spicatum* was by far the most important species with mean percentage frequencies of 81% and mean percentage cover values of 39% in the navigation channel. Apart from the three species mentioned above there were no others claiming more than 10% mean percentage cover. However, 10 other species claimed greater than 10% mean percentage frequency (i.e. *Ceratophyllum demersum, Elodea canadensis, Hydrocharis morsus-ranae, Lemna trisulca, Myriophyllum sibiricum, Nymphaea odorata, Potamogeton illinoensis, P. richardsonii, P. zosteriformis* and *Vallisneria americana*). At least 22 other species were present but were of minor importance.

3. DIFFERENCES BETWEEN THE NAVIGATION CHANNEL AND ADJACENT AREAS

The navigation channels and the adjacent areas had very similar aquatic plant composition. Even percentage frequencies of species were similar but there were substantial differences between the navigation channel and adjacent areas in the percentage cover of different species. *Potamogeton crispus* and *Myriophyllum spicatum* had higher cover values in the navigation channel, although overall percentage frequencies of these two species were similar in the two zones (Table 4). *Potamogeton pusillus* var. *tenuissimus* was approximately as frequent in the navigation channel as in adjacent areas but had higher cover values in adjacent areas. *Vallisneria americana, Myriophyllum sibiricum,* and many other species to a lesser degree, were much more frequent and had much higher cover values in areas adjacent to the navigation channel, than in the channel itself (Table 4). At some sites the navigation channel and the adjacent areas were quite similar in terms of dominant species. For example, at the eastern end of Smiths Falls, *Myriophyllum spicatum* was by far the dominant species and had percentage cover values of 48.48 in the navigation channel and 47.64 in the adjacent areas (Appendix Table 2). However, at some other sites there were substantial differences. For example, at Burritts Rapids (Appendix Table 1) *Myriophyllum spicatum* had a mean cover value of 66.12% in the navigation channel, but only 8.80% in adjacent areas. At the same site the reverse trend is apparent in *Potamogeton pusillus* var. *tenuissimus*.

4. VARIATION AMONG SITES

Most of the sites were similar in having relatively high frequencies and cover values of *Myriophyllum spicatum* and a much smaller contribution to frequency and cover from other species. The Portland site (Appendix Table 5) was remarkable in being dominated by *Potamogeton vaseyi* and *Hydrocharis morsus-ranae* and the aquatic moss *Amblystegium riparium,* with no

Table 4. Mean frequencies and mean cover of vascular aquatic plants and other macrophytes in and near the navigation channels at 13 locations along the Rideau Canal.

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Acorus calamus	1.23	.62	-	-
Ceratophyllum demersum	64.92	64.62	3.57	4.19
Elodea canadensis	48.61	48.92	3.73	6.75
Elodea nuttallii	-	4.31	-	.08
Hydrocharis morsus-ranae	19.69	20.00	4.65	5.22
Lemna minor	.92	1.85	-	.02
Lemna trisulca	64.92	66.77	1.28	5.60
Myriophyllum heterophyllum	.31	-	-	-
Myriophyllum sibiricum	25.85	41.85	.53	3.24
Myriophyllum spicatum	80.92	78.77	39.40	2.64
Najas flexilis	1.54	1.54	-	-
Nuphar variegata	1.54	5.54	.35	.24
Nymphaea odorata	2.46	18.15	-	.67
Potamogeton crispus	62.15	45.23	10.21	4.54
Potamogeton epihydrus var. *epihydrus*	.31	-	-	-
Potamogeton gramineus	.31	-	-	-
Potamogeton illinoensis	16.31	8.00	1.80	.05
Potamogeton natans	-	.31	-	-
Potamogeton pectinatus	2.77	8.00	.34	2.45
Potamogeton praelongus	.31	-	-	-
Potamogeton pusillus var. *tenuissimus*	45.23	40.31	12.69	18.14
Potamogeton richardsonii	40.00	31.38	3.18	2.16
Potamogeton robbinsii	1.54	-	-	-
Potamogeton strictifolius	.31	-	-	-
Potamogeton vaseyi	8.31	7.69	5.69	5.96
Potamogeton zosteriformis	56.00	52.23	6.48	6.45
Ranunculus longirostris	6.46	9.54	.04	.36
Spirodela polyrhiza	4.62	16.00	-	.10
Vallisneria americana	28.00	51.08	1.52	5.71
Wolffia borealis	4.62	3.08	.04	-
Wolffia columbiana	4.62	3.08	.04	-
Other macrophytes:				
Amblystegium riparium	7.69	7.69	4.38	5.07
Chara globularis var. *globularis*	-	.31	-	-
Chara vulgaris var. cf. *vulgaris*	-	.31	-	-
Nitella flexilis	-	1.23	-	.04

Figure 4. *Myriophyllum spicatum*. A, habit showing submerged capillary leaf segments and emergent spike; B, leaves pinnately divided into capillary divisions; C, section of spike showing a pistillate flower and bracts; D, staminate flower from above; E, staminate flower from the side; F, pistillate flower from above; G, pistillate flower from the side.

Myriophyllum spicatum present at all and *Potamogeton pusillus* var. *tenuissimus* very scarce. All of the three dominants had frequency values of 100% and cover values exceeding 50%. *Potamogeton crispus* was dominant at Newboro and Joyceville (Appendix Tables 7 and 13) where *Myriophyllum spicatum* was quite frequent but had very low cover values. At these sites, *M. spicatum* may be declining and being replaced by *P. crispus* as has occurred in some of the Kawartha Lakes in the Trent-Severn system (Catling and Dobson 1985). Although *M. spicatum* is clearly the dominant weed overall, there is much variation from site to site.

5. HISTORY AND ECOLOGY OF THE DOMINANT SPECIES

Two species with very high cover values in the navigation channel, and almost as much in adjacent areas, are both newcomers of European origin. *Potamogeton crispus* has probably been present in the system since a little after 1900 (Catling and Dobson 1985), whereas *Myriophyllum spicatum* probably entered the system as recently as the mid-1960s (Aiken *et al.* 1979). Both of these species are characterized by a vegetative life cycle involving winter and early spring growth. This life cycle results in avoidance of adverse effects of (1) summer algal blooms, (2) competition with other species, and (3) periods of high turbulance from propellors. It also permits reproductive size to be reached by the time control is appropriate (i.e. just before the summer holiday period).

Myriophyllum spicatum was introduced to North America in the Chesapeake Bay area near Washington, D.C. in the 1800's (Reed 1977), quickly spreading and considered a weed species in the 1930's (Springer and Stewart 1959). Distribution in the United States by 1970 was shown by Reed (1970) and the invasion into Wisconsin and Michigan were recorded by Nichols and Mori (1971) and Coffey and McNabb (1974) respectively. The first record of *M. spicatum* in Canada is probably represented by a specimen in the collection of Agriculture Canada in Ottawa dated 1961 from Rondeau Provincial Park on Lake Erie (Aiken *et al.* 1979). By the late 1970s its Canadian distribution included the full length of the St. Lawrence River, much of southern Ontario, southern Quebec and Okanagan Lake in British Columbia. *Myriophyllum spicatum* was almost certainly absent from the Rideau Canal in the mid-1960s. Plants of *M. spicatum* die back in the fall leaving propagating root crowns, often with unexpanded shoots attached (Grace and Wetzel 1978). Throughout the year the abscission of buds from crowns and the fragmentation of stems allows the plant to extend its range vegetatively with minimal reliance on sexual reproduction (Patten 1956). The plants survive and grow overwinter under the ice (Stanley 1976). Dense beds severely limit water-based recreation and are of little value as a food for waterfowl (Elser 1969). *Myriophyllum spicatum* also competes successfully with desirable waterfowl foodplants. Obviously the beds provide shelter and spawning areas for game fish and a suitable habitat for freshwater crustaceans. Furthermore the dense beds may compete effectively with algae for nutrients thus contributing to clear water by limiting unsightly algal blooms (Davis *et al.* 1973). Major infestations of *M. spicatum* in Wisconsin, Maryland and Ontario have been followed by gradual

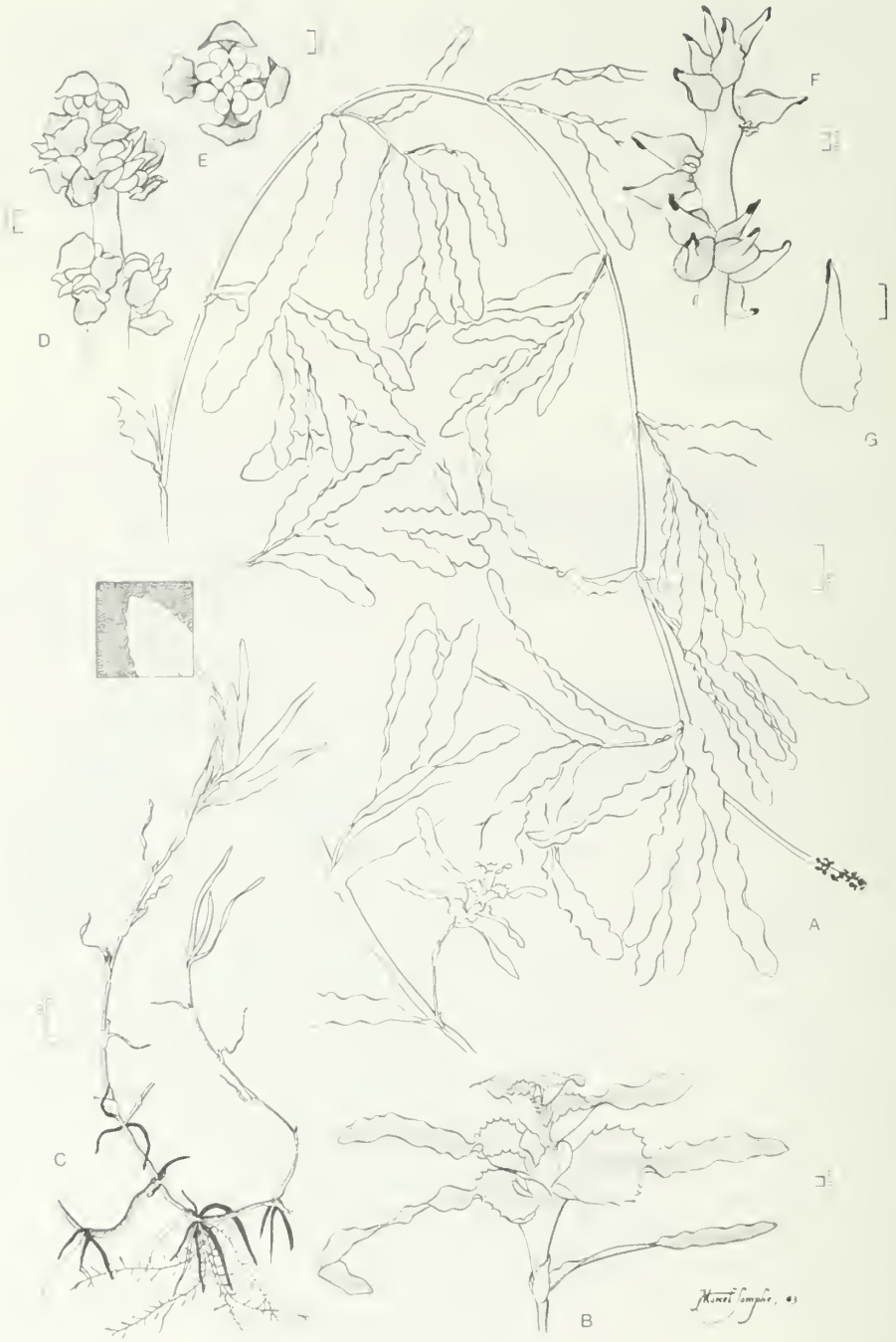

Figure 5. *Potamogeton crispus*. A, branch with crisped and undulate sessile leaves, winter bud and spike; B, winter bud showing the stem, short internode, and bud scales with dentate broadened bases; C, young plant from the winter bud with roots and a detail of the serrate margin of the leaf; D, few-flowered spike; E, flower from above; F, fruiting spike; G, achene showing the beak and the denticulate dorsal keel.

declines (Carpenter 1980, Bayley *et al.* 1968). In an Ontario study, decline after major infestation was associated with insect grazing (Painter and McCabe 1987).

Myriophyllum spicatum may be confused with *M. sibiricum* and *M. verticillatum* but differs from both in lacking turions and having abundant branching in water deeper than 1 m. (Aiken et al.1979). *Myriophyllum sibiricum* doesn't form the canopy characteristic of *M. spicatum* (Aiken and Picard 1980). Useful features in the identification of *Myriophyllum spicatum* are its long branching stems with internodes 20 - 70 mm. long, and leaves with 10 - 20 pectinate divisions. Its smaller buds are quite unlike the prominent winter bud turions of *Myriophyllum sibiricum* and *M. verticillatum* (Weber 1972, Weber and Nooden 1974). The biology of this species has been reviewed by Aiken *et al.* (1979).

The earliest verifiable collection of *Potamogeton crispus* in North America was made in 1841-2 in Philadelphia, Pennsylvania (Bennett 1901). Stuckey (1979) has shown the distribution in North America to 1978 covering much of the continental United States and southeastern Canada, and Catling and Dobson (1985) extended the known range in Canada from southern Ontario (outside the Canadian Shield region) and southwestern Quebec to southern British Columbia and Alberta, with isolated localities in south-central Saskatchewan.

Potamogeton crispus is a perennial that produces summer-dormant apices (Wehrmeister 1978). Stuckey et al. (1978) found that it survived in a vegetative stage throughout an Ohio winter in water temperatures of 1-4^{o}C, under 50 cm of ice and 12.5 cm of snow. Light intensity in this situation would be reduced to approximately 10% incident light or 1291 lx. Extensive beds may deplete water nutrients and later, upon decaying, would lead to depletion of dissolved oxygen, thus becoming deleterious to fish (Cypert 1967; Gupta 1973). It presents a major problem to water-based recreation, fish hatcheries and the important tourist industry (Simes 1961; Falter et al. 1974; Harmen 1974; Stuckey 1979; Hellquist and Crow 1980).

Seeds and vegetative parts are a valuable food eaten by both dabbling and diving ducks and coots (McAtee 1939; and Cypert 1967). Krecker (1939) discovered that a large assortment of aquatic invertebrates are harbored in *Potamogeton crispus*, implying possible value in the culture of game fish. High nitrogen levels may suggest value as a compost material (Riemer and Toth 1969) and abundant nutrients indicate potential as a supplement in animal feed (Boyd 1968).

Potamogeton crispus is quite distinctive among North American Pondweeds in having strap-like leaves with serrulate margins (Catling and Dobson 1985, and
Riley 1979). The biology of this species has been reviewed by Catling and Dobson (1985).

Potamogeton pusillus var. *tenuissimus* is a native North American species distributed across North America from Newfoundland to Alaska, south to northern Florida, Louisiana and California, and is most abundant in the northeast part of its range (Haynes 1974; and Hellquist and Crow 1980).

It is common in lakes, ponds and slow-moving streams and rivers 1/2 to 2 m deep (Oosting 1932; Voss 1972), often in acidic and alkaline waters and occasionally in brackish water along the coast (McAtee 1939; Martin and Uhler

Figure 6. *Potamogeton pusillus* var. *tenuissimus*. A, habit showing the filiform stem, the linear leaves, stipules and spikes; B, winter bud; C, stipule and translucent gland at base of the leaves; D, flower from above; E, achene from the side and from above showing the prominant beak and rounded back.

1939; Riley 1979). McAtee's view that it is tolerant of shade is supported by our observations, especially at Seeleys Bay in the Rideau Canal system. Fruiting occurs from early June through late September (Haynes 1974). The plants are apparently annual and begin to develop in April and May. Seeds, foliage and winter buds are consumed by a variety of waterfowl (McAtee 1939; Martin and Uhler 1939).

A distinctive feature of *Potamogeton pusillus* var. *tenuissimus* (Fig. 3) which separates it from the closely related *P. pusillus* var. *pusillus* is evident in the mature fruit; the former being mostly widest at or below the middle with round sides, and the latter being widest above the middle with concave sides (Haynes 1974). It also differs from closely related species in having conspicuous nodal glands at the leaf base and free, delicate, whitish stipules. There is no comprehensive review of the biology of this species.

6. ANNOTATED LIST OF SPECIES

The frequency and cover values listed below are for sites in which the species occurred rather than overall cover values which are in Table 2.

Acorus calamus L. - appeared sparingly only at sites 2 and 3.

Ceratophyllum demersum L. - frequent at all sites with a high mean frequency of 64% but low mean cover values from 3.5 - 4.2%.

Elodea canadensis Michx. - in 11 sites with a mean frequency of 63% and mean cover values from 5 - 9%. Sometimes a serious weed, but generally not so at present in the Rideau System. The biology of this species has been reviewed by Spicer and Catling (1988).

Elodea nuttallii (Planch.) St. John - only at site 2 with a mean frequency of 56% and mean cover of slightly more than 1%.

Hydrocharis morsus-ranae L. - in sites 1 to 5 at the lower end of the canal system with a relatively high mean frequency of 52% and low mean cover except in site 5 where cover was 57% in navigation channels and 66% in adjacent areas. The biology of this species has been reviewed by Catling and Spicer (1988).

Lemna minor L - only at sites 9 and 10 where mean frequency was 12% and mean cover 0.08 - 0.12%.

Lemna trisulca L. - in all sites, its submerged habit preventing it from drifting like its relative *L. minor*. Mean frequency was 67 - 70% and mean cover 3 - 7%.

Myriophyllum heterophyllum Michx. - a rare species found only at site 12 where it was quite scarce.

Myriophyllum sibiricum Komarov (previously *M. exalbescens* but see Ceska and Ceska 1986) - in 10 sites with a mean frequency of 37.8% in navigation channels and 60.4% in adjacent areas. Mean cover in channels was less than 1% and over 5% in adjacent areas.

Myriophyllum spicatum L. - a dominant species throughout the Rideau canal system, presenting major problems to boating activities, approaching 100% frequencies in some sites (mean 85.3 - 87.7%) and absent only at site 5.

Mean cover ranged between 42.7% in navigation channels to 21.9% in adjacent areas. The biology of this species has been reviewed by Aiken *et al.* (1979).

Najas flexilis (Willd.) Rostk. and Schmidt. - too scarce for cover values and found only at site 5 with a 20% frequency in the navigation channel and 16% in adjacent areas. At site 12 it was even less conspicuous outside the channel.

Nuphar variegata Engelm. - present in 5 sites but not a problem to navigation.

Nymphaea odorata Ait. - in 6 sites with a high mean frequency of 60% in site 13 but low mean cover values everywhere.

Potamogeton crispus L. - the third most abundant species in all but site 4 with a mean frequency of 49 - 60.7% and mean cover of 5.4 - 11.1%.

Potamogeton epihydrus Raf. var. *epihydrus* - few plants in the channel at site 9 but observed at no other locations.

Potamogeton gramineus L. - only at site 8 in the navigation channel where a few plants were found among more common pondweed species.

Potamogeton illinoensis Morong - at 7 sites with a mean frequency of 26 - 35.3%, reaching 80% in the navigation channel at site 9. Mean cover ranged from 7.8% in 3 navigation channels to less than 1% in adjacent areas.

Potamogeton natans L. - a few plants were found outside the navigation channel at site 9 but none elsewhere.

Potamogeton pectinatus L. - in 7 sites with a high mean frequency of 52% outside the navigation channel at site 3 and a high mean cover of 20.8% at the same location.

Potamogeton praelongus Wulf. - few plants were present in the navigation channel at site 13.

Potamogeton pusillus L. var. *tenuissimus* Mert. and Koch. - in most sites with a mean frequency of 53.5 - 65.5%, reaching 100% within and outside channels at site 10. Mean cover was 18.3 - 29.5%.

Potamogeton richardsonii (Benn.) Rydb. - in 12 sites with a mean frequency of 40.8 - 47.3% and mean cover of 3.1 - 4.6%. At site 9 a high 92% mean frequency was noted in the navigation channel.

Potamogeton robbinsii Oakes - few plants were observed in navigation channels at 5 sites, frequencies not exceeding 4%.

Potamogeton strictifolius Benn. - at site 9 a few plants were recorded in the navigation channel and nowhere else in the canal system.

Potamogeton vaseyi Robbins. - in 3 sites only, insignificantly in sites 3 and 11 but reaching 100% mean frequency throughout site 5 where a mean cover of 74% was recorded in the navigation channel and 77.5% in adjacent areas.

Potamogeton zosteriformis Fern. - a common species in all but site 10 with a mean frequency of 56.6 - 67.3% and mean cover approaching 8%.

Ranunculus longirostris Godron - mean frequency of 12 - 20.7% in 9 sites but low mean cover of less than 2%.

Spirodela polyrhiza (L.) Schleiden - in the navigation channels only at sites 1 and 13 but in adjacent areas at 7 sites where excessive surface

aquatic growth prevented drifting of this tiny plant. Of course cover values are insignificant.

Vallisneria americana Michx. - 36.4% mean frequency in navigation channels at 10 sites but more common at 55.3% frequency outside the channel. Mean cover was minimal at 2.8 - 7.4% but very significant growth in late summer was evident after harvesting of competing species.

Wolffia borealis (Engelm.) Landolt - at 3 sites (same three as the following) with a high mean frequency of 60% at site 7 in the navigation channel.

Wolffia columbiana Karst. - at 3 sites (same three as the former) with a high mean frequency of 60% at site 7 in the navigation channel.

Other macrophytes

Amblystegium riparium (Hedw.)B.S.G. - prominent at site 5 but absent from other locations.

Chara globularis Thuill. and *C. vulgaris* L. - present only at site 8 and generally insignificant.

Nitella flexilis (L.)Agardh. - a mean frequency of only 16% outside of main channels at site 8 and minimal cover.

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REFERENCES

Aiken, S.G. and J.M. Gillett. 1974. The distribution of aquatic plants in selected lakes of Gatineau Park, Quebec. Canad. Field - Naturalist 88: 437-448.

Aiken, S.G., P.R. Newroth and I. Wile. 1979. The biology of Canadian weeds. 34. *Myriophyllum spicatum* L. Can. J. Pl. Sci. 59: 201-215.

Aiken, S.G. and R.R. Picard. 1980. The influence of substrate on the growth and morphology of *Myriophyllum exalbescens* and *Myriophyllum spicatum* Can. J. Bot. 58: 1111-1118.

Bayley, S., H. Rabin and C.H. Southwick. 1968. Recent decline in the distribution and abundance of Eurasian milfoil in Chesapeake Bay. Chesapeake Science 9: 173-181.

Bennett, A. 1901. Notes on *Potamogeton*. J. Bot. 39: 198-201.

Boyd, C.E. 1968. Fresh-water plants: a potential source of protein. Econ. Bot. 22: 359-368.

Bristow, J.M., A.A. Crowder, M.R. King and S. Vanderkloet. 1977. The growth of aquatic macrophytes in the Bay of Quinte prior to phosphate removal by tertiary sewage treatment (1975 - 1976). Naturaliste Can. 104: 465-473.

Carpenter, S.R. 1980. The decline of *Myriophyllum spicatum* in a eutrophic Wisconsin Lake. Can. J. Bot. 58: 527-535.

Catling, P.M. and I. Dobson. 1985. The biology of Canadian weeds. 69. *Potamogeton crispus* L. Canad. J. Pl. Sci. 65: 655-668.

Catling, P.M., B. Freedman, C. Stewart, J.J. Kerekes and L.P. Lefkovitch. 1986. Aquatic plants of acid lakes in Kejimkujik Nationaal Park, Nova Scotia; floristic composition and relation to water chemistry. Can. J. Bot. 64(4): 724-729.

Catling, P.M. and K. Spicer. 1988. The Biology of Canadian Weeds. *Hydrocharis morsus-ranae*. Canad. J. Plant Sci. in press.

Cecile, C.P. 1981. Oshawa Second Marsh baseline study - interim report - integration and interpretation of ecological data. 141 pp.

Ceska, A. and O. Ceska. 1986. Notes on *Myriophyllum* (Haloragaceae) in the far east: the identity of *Myriophyllum sibiricum* Komarov. Taxon 35: 95-100.

Coffey, B.T. and C.D. McNabb. 1974. Eurasian watermilfoil in Michigan. Mich. Bot. 13: 159-165.

Cooke, G.D. E.B. Welch, S.A. Peterson and P.R.Newroth. 1986. Lake and reservoir restoration. Butterworths, Boston.

Crowder, A.A., J.M. Bristow, M.R. King and S. Vanderkloet. 1977. Distribution, seasonality, and biomass of aquatic macrophytes in Lake Opinicon (Eastern Ontario). Naturaliste Can. 104: 441-456.

Crowder, A.A., J.M. Bristow, M.R. King and S. Vanderkloet. 1977. The aquatic macrophytes of some lakes in southeastern Ontario. Naturaliste Can. 104: 457-464.

Cypert, E. 1967. The curley-leaved pondweed problem at Reelfoot Lake. J. Tenn. Acad. Sci. 42: 10-11.

Davis, G.J., M.N. Jones and D. Davis. 1973. Seed germination in *Myriophyllum spicatum* L. J. Elisha Mitchell Sci. Soc. 89: 246-247.

Dale, H.M. 1986. Comparison of the 1984 aquatic macrophyte flora in Lake Temagami, Northern Ontario, with the Flora published in 1930. Canad. Field - Nat. 100: 571-573.

Elser, H.J. 1969. Observations on the decline of watermilfoil and other aquatic plants, Maryland, 1962-1967. Hyacinth Control J. 8: 52-60.

Falter, C.M., J. Leonard, R. Naskali, F. Rabe and H. Bobisud. 1974. Aquatic and wetland plants of southwestern United States. Water Pollution Control Research Series. U.S. Govt. Printing Office, Wash. D.C. 1777 pp.

Fraser, D. and J.K. Morton. 1983. Aquatic plants in Lake Superior Provincial Park in relation to water chemistry. Canad. Field - Nat. 97(2): 181-186.

Gow, D., P. Kelly and K. McLean. 1982. Biological Research Projects - St. Clair National Wildlife Area. 85 pp.

Grace, J.B. and R.G. Wetzel. 1978. The production biology of Eurasian watermilfoil (*Myriophyllum spicatum* L.): a review. J. Aquat. Pl. Manage. 16: 1-11.

Gupta, O.P. 1973. Aquatic weed control. World Crops 25: 182-190.

Hammer, U.T. and J.M. Heseltine. 1988. Aquatic macrophytes in saline lakes of the Canadian prairies. Hydrobiologia 158: 101-116.

Harmen, W.N. 1974. Phenology and physiognomy of the hydrophyte community in Ostego Lake, N.Y. Rhodora 76: 497-508.

Haynes, R.R. 1974. A revision of north american *Potamogeton* subsection *Pusilli* (Potamogetonaceae). Rhodora 76: 564-649.

Hellquist, C.B. and G.E. Crow. 1980. Aquatic vascular plants of New England: Part 1. Zosteraceae, Potamogetonaceae, Zannichelliaceae, Najadaceae. N.H. Agric. Exp. Sta., Univ. of N.H. Sta. Bull. 515.

Hunter, M.L., Jr., J.J. Jones and J.W. Witham. 1986. Biomass and species richness of aquatic macrophytes in four Maine (U.S.A.) lakes of different acidity. Aquatic Bot. 24: 91-95.

Krecker, F.H. 1939. A comparative study of the animal population of certain submerged aquatic plants. Ecology 20: 553-562.

Martin, A.C. and F.M. Uhler. 1939. Food of game ducks in the United States and Canada. U.S.D.A. Tech. Bull. No. 634: 157 pp.

Maycock, P.F., A.A. Reznicek and D. Gregory. 1978. Flora of Pt. Pelee National Park, Essex Co., Ontario, Erindale College, University of Toronto. Unpub. ms. 149 pp.

McAtee, W.L. 1939. Wildfowl Food Plants. U.S. Biol. Surv. Coll. Press. 1-141 pp.

Miller, G.E. and H.M. Dale. 1979. Apparent differences in aquatic macrophyte floras of eight lakes in Muskoka District, Ontario from 1953 to 1977. Canad. Field - Nat. 93(4): 386-390.

Nichols, S.A. and S. Mori. 1971. The littoral macrophyte vegetation of Lake Wingra. Trans. Wis. Acad. Sci. Arts Lett. 59: 107-119.

Oosting, H.J. 1932. Distribution of the genus *Potamogeton* in Michigan. In Papers of the Mich. Acad. of Sci. Arts and Lett. 15: 141-171.

Painter, D.S. and K.J. McCabe. 1987. Investigations in the disappearance of Eurasian watermilfoil in the Kawartha Lakes. Environment Canada.

Patten, B.C. 1956. Notes on the biology of *Myriophyllum spicatum* L. in a New Jersey Lake. Bull. Torrey Bot. Club 83: 5-18.

Pip, E. 1987. Distribution and species richness of aquatic macrophytes in a group of Manitoba ponds. Naturaliste Can. (Rev. Écol. Syst.) 114: 167-175.

Pringle, J.S. 1969. Checklist of the spontaneous vascular flora of the Royal Botanical Gardens, Hamilton, Ontario. Royal Botanical Gardens, Tech. Bull. 4: 46 pp.

Reed, C.F. 1970. Selected weeds of the United States. Agric. Res. Serv., U.S. Dept. Agric., Agric. Handb. 366. 463 pp.

Reed, C.F. 1977. History and distribution of Eurasian watermilfoil in United States and Canada. Phytologia 36: 417-436.

Rideau Valley Conservation Authority. 1971. The ecological impact of aquatic herbicides on the Rideau River System. Internal Report. 40 pp.

Rideau Valley Conservation Authority. 1974. A review of the chemical control of submerged aquatic plants. Internal Report. 6 pp.

Rideau Valley Conservation Authority. 1979*a*. Report on the aquatic weed harvesting project on Kemptville Creek - 1978. Internal Report. 2 pp.

Rideau Valley Conservation Authority. 1979*b*. Technical report on the aquatic weed harvesting program on Kemptville Creek. Internal Report. 4 pp.

Rideau Valley Conservation Authority. 1979*c*. Report on aquatic weed harvesting program - 1979. Internal Report. 3 pp.

Rideau Valley Conservation Authority. 1979*d*. Report to the Minister, Minister of Natural Resources from the Rideau Valley Conservation Authority on the control of aquatic weeds in the Rideau watershed. Internal Report. 14 pp.

Rideau Valley Conservation Authority. 1980. Aquatic weed harvesting report - 1980. Internal Report. 4 pp.

Riemer, D.N. and S.J. Toth. 1969. A survey of the chemical composition of *Potamogeton* and *Myriophyllum* in New Jersey. Weed Sci. 17: 219-223.

Riley, J.L. 1978. Guide to the vascular plants and wildlife of the Rouge River valley, Ont. Field Biologist, special pub. no. 1: 53 pp.

Riley, J.L. 1979. Ontario's Pondweeds (Genus *Potamogeton*). Ont. Field Biologist Vol. 33, No. 2, Dec. 1979: 1-25.

Riley, J.L., S. Varga and M.J. Oldham. 1981. Additions and changes to the checklist of vascular plants of the Rouge River valley in metropolitan Toronto and Durham region, Ont. Field Biologist 35(1): 25-35.

Schloesser, D.W. and B.A. Manny. 1986. Distribution of submersed macrophytes in the St. Clair - Detroit River system, 1978. J. of Freshw. Ecol. 3(4): 537-544.

Singer, R. 1983. The macrophyte community of an acidic lake in Adirondack (New York, U.S.A.): a new depth record for aquatic angiosperms. Aquatic Bot. 16: 49-57.

Simes, J.C. 1961. Control of pondweed, *Potamogeton crispus* in both flowering and static situations with Endothal. Proc. N.E. Weed Contr. Conf. 15: 558-559.

Spicer, K. and P. M. Catling. 1988. The biology of Canadian weeds. *Elodea canadensis*. Canad. J. Plant Sci. 68: 1035-1051.

Springer, P.F. and R.E. Stewart. 1959. Condition of waterfowl feeding grounds on the Susquehanna Flats during the fall of 1959 with notes on the invasion of a serious pest plant. Bur. Sport Fish. and Wildl., Admin. Rep. Mimeo. 7 pp.

Stanley, R.A. 1976. Response of Eurasian watermilfoil to subfreezing temperature. J. Aquat. Pl. Manag. 14: 36-39.

Stuckey, R.L. 1979. Distributional history of *Potamogeton crispus* (Curly pondweed) in North America. Bartonia 46: 22-42.

Stuckey, R.L., J.R. Wehrmeister and R.J. Bartolotta. 1978. Submersed aquatic vascular plants in ice-covered ponds of central Ohio. Rhodora 80: 575-579.

Voss, E.G. 1972. Michigan Flora Part 1, gymnosperms and monocots. Bull. 55, Cranbrook Inst. of Sci. and Univ. of Mich. Herb. p. 92.

Weber, J.A. 1972. The importance of turions in the propagation of *Myriophyllum exalbescens* (*Haloragaceae*) in Douglas Lake, Michigan. Mich. Bot. 11: 115-121.

Weber, J.A. and L.D. Nooden. 1974. Turion formation and germination in *Myriophyllum verticillatum*; phenology and its interpretation. Mich. Bot. 13: 151-158.

Wehrmeister, J.R. 1978. An ecological life history of the pondweed *Potamogeton crispus* L. in North America. M.S. thesis, Ohio State Univ., Columbus, Ohio. 157 pp. (Reprinted, the Ohio State Univ., Center for Lake Erie Area Research, Columbus, CLEAR Tech. Rep. No. 99).

Wile, I. and G. Hitchin. 1977. An assessment of the practical and environmental implications of mechanical harvesting in southern Chemung Lake. Ministry of the Environment. Internal Report. 180 pp.

APPENDICES

Table 1. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Burritts Rapids (site 1).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	48	8	2.04	.32
Elodea canadensis	8	4	.04	.04
Hydrocharis morsus-ranae	40	44	.12	.04
Lemna trisulca	76	76	-	1.48
Myriophyllum sibiricum	20	84	.04	5.16
Myriophyllum spicatum	96	56	66.12	8.80
Nuphar variegata	-	8	-	.28
Nymphaea odorata	4	52	-	1.32
Potamogeton crispus	56	12	1.68	.20
Potamogeton pectinatus	-	44	-	11.12
Potamogeton pusillus var. *tenuissimus*	28	76	3.48	51.76
Potamogeton richardsonii	28	56	.84	1.68
Potamogeton zosteriformis	52	28	2.76	.20
Ranunculus longirostris	-	8	-	.08
Spirodela polyrhiza	48	40	-	-
Vallisneria americana	4	44	.04	1.40

Table 2. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at east end of Smiths Falls (site 2).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Acorus calamus	4	8	-	-
Ceratophyllum demersum	48	56	1.24	4.48
Elodea nuttallii	-	56	-	1.08
Hydrocharis morsus-ranae	32	16	-	-
Lemna trisulca	64	60	.36	.36
Myriophyllum sibiricum	36	32	1.00	.20
Myriophyllum spicatum	96	92	48.48	47.64
Potamogeton crispus	16	12	.20	-
Potamogeton pectinatus	4	-	-	-
Potamogeton pusillus var. *tenuissimus*	80	44	19.96	.48
Potamogeton richardsonii	52	20	1.72	.68
Potamogeton zosteriformis	72	56	5.12	1.68
Ranunculus longirostris	8	12	-	.12
Vallisneria americana	36	36	-	-

Table 3. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at west end of Smiths Falls (site 3).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Acorus calamus	12	-	-	-
Ceratophyllum demersum	84	52	2.76	1.92
Elodea canadensis	72	68	2.88	3.56
Hydrocharis morsus-ranae	32	44	.04	.28
Lemna trisulca	88	92	2.84	1.40
Myriophyllum sibiricum	24	52	.72	2.96
Myriophyllum spicatum	100	88	68.40	13.12
Nuphar variegata	12	32	-	1.36
Nymphaea odorata	-	28	-	1.04
Potamogeton crispus	44	36	1.12	1.20
Potamogeton illinoensis	4	-	-	-
Potamogeton pectinatus	-	52	-	20.76
Potamogeton richardsonii	52	88	2.72	17.88
Potamogeton robbinsii	4	-	-	-
Potamogeton vaseyi	4	-	-	-
Potamogeton zosteriformis	92	92	5.16	27.76
Ranunculus longirostris	28	-	.48	-
Vallisneria americana	68	52	2.92	2.32

Table 4. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Perth (site 4).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	72	68	2.72	5.88
Elodea canadensis	88	68	8.68	3.88
Hydrocharis morsus-ranae	52	56	3.28	1.64
Lemna trisulca	32	32	-	.04
Myriophyllum spicatum	96	92	42.60	45.68
Nymphaea odorata	28	32	.04	.20
Potamogeton pusillus var. *tenuissimus*	80	68	34.36	37.56
Potamogeton zosteriformis	12	48	-	-
Vallisneria americana	76	28	4.68	.64

Table 5. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Portland (site 5).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	80	76	5.96	3.08
Elodea canadensis	72	64	.76	.44
Hydrocharis morsus-ranae	100	100	57.00	65.96
Lemna trisulca	100	96	9.12	6.16
Myriophyllum sibiricum	64	56	1.48	.16
Najas flexilis	20	16	-	-
Potamogeton crispus	64	64	2.80	2.12
Potamogeton pusillus var. *tenuissimus*	4	-	-	-
Potamogeton richardsonii	40	32	.52	.20
Potamogeton robbinsii	4	-	-	-
Potamogeton vaseyi	100	100	74.00	77.48
Potamogeton zosteriformis	48	15	.16	.40
Ranunculus longirostris	4	-	-	-
Vallisneria americana	92	84	4.00	3.40
Other macrophytes:				
Amblystegium riparium	100	100	57.00	65.96

Table 6. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Westport (site 6).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	80	76	3.80	11.52
Elodea canadensis	100	84	19.48	18.80
Lemna trisulca	80	92	1.12	20.00
Myriophyllum sibiricum	12	76	-	3.72
Myriophyllum spicatum	100	84	59.84	11.76
Nymphaea odorata	-	16	-	-
Potamogeton crispus	84	60	7.28	2.12
Potamogeton illinoensis	12	40	-	.32
Potamogeton pectinatus	12	-	-	-
Potamogeton pusillus var. *tenuissimus*	44	-	.96	-
Potamogeton richardsonii	-	16	-	-
Potamogeton zosteriformis	100	56	4.92	.24
Ranunculus longirostris	28	20	-	-
Vallisneria americana	8	100	-	14.40

Table 7. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Newboro (site 7).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	28	64	.36	.44
Elodea canadensis	60	72	1.56	5.64
Lemna trisulca	68	64	-	1.44
Myriophyllum sibiricum	64	72	1.40	10.08
Myriophyllum spicatum	76	72	2.68	4.48
Potamogeton crispus	100	96	43.76	19.80
Potamogeton illinoensis	4	-	-	-
Potamogeton pectinatus	-	8	-	-
Potamogeton pusillus var. *tenuissimus*	88	100	28.20	42.20
Potamogeton richardsonii	36	40	-	.04
Potamogeton robbinsii	4	-	-	-
Potamogeton zosteriformis	80	80	13.36	6.36
Ranunculus longirostris	-	12	-	-
Spirodela polyrhiza	-	28	-	1.00
Vallisneria americana	28	60	.04	.12
Wolffia borealis	60	-	.52	-
Wolffia columbiana	60	-	.52	-

Table 8. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Chaffeys Lock (site 8).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	40	24	5.00	1.96
Elodea canadensis	72	84	2.60	29.92
Lemna trisulca	48	20	-	-
Myriophyllum sibiricum	60	68	1.08	14.28
Myriophyllum spicatum	72	96	18.04	14.44
Nuphar variegata	8	-	4.60	-
Potamogeton crispus	40	8	4.72	3.00
Potamogeton gramineus	4	-	-	-
Potamogeton illinoensis	60	24	15.08	.36
Potamogeton pectinatus	4	-	-	-
Potamogeton pusillus var. *tenuissimus*	52	40	5.28	.96
Potamogeton richardsonii	76	88	17.36	4.08
Potamogeton robbinsii	4	-	-	-
Potamogeton zosteriformis	92	68	20.56	3.16
Ranunculus longirostris	12	8	-	-
Spirodela polyrhiza	-	4	-	-
Vallisneria americana	36	68	4.00	24.04
Wolffia borealis	-	4	-	-
Wolffia columbiana	-	4	-	-
Other macrophytes:				
Chara globularis var. *globularis*	-	4	-	-
Chara vulgaris var. cf. *vulgaris*	-	4	-	-
Nitella flexilis	-	16	-	.50

Table 9. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Davis Lock (site 9).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	100	92	13.52	6.96
Elodea canadensis	100	92	11.56	5.92
Lemna minor	-	12	-	.12
Lemna trisulca	92	92	-	37.08
Myriophyllum sibiricum	-	4	-	-
Myriophyllum spicatum	96	92	18.96	9.08
Nuphar variegata	-	24	-	.44
Nymphaea odorata	-	48	-	2.20
Potamogeton crispus	48	60	.16	.60
Potamogeton epihydrus var. *epihydrus*	4	-	-	-
Potamogeton illinoensis	80	-	8.12	-
Potamogeton natans	-	4	-	-
Potamogeton pectinatus	16	-	4.40	-
Potamogeton pusillus var. *tenuissimus*	16	-	-	-
Potamogeton richardsonii	92	-	13.12	-
Potamogeton robbinsii	4	-	-	-
Potamogeton strictifolius	4	-	-	-
Potamogeton zosteriformis	96	24	19.44	.12
Spirodela polyrhiza	-	4	-	-
Vallisneria americana	-	100	-	15.84

Table 10. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Seeleys Bay (site 10).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	56	92	.68	1.44
Elodea canadensis	4	-	-	-
Lemna minor	12	12	-	.08
Lemna trisulca	40	44	-	-
Myriophyllum spicatum	100	100	37.96	49.68
Potamogeton crispus	100	100	7.12	5.40
Potamogeton pusillus var. *tenuissimus*	100	100	47.00	32.92
Potamogeton richardsonii	4	-	-	-
Ranunculus longirostris	4	-	-	-
Spirodela polyrhiza	-	12	-	.08
Vallisneria americana	4	-	-	-

Table 11. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Cranberry Lake (site 11).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	84	76	5.12	6.84
Elodea canadensis	56	12	.88	1.40
Lemna trisulca	84	96	3.24	4.80
Myriophyllum sibiricum	4	-	-	-
Myriophyllum spicatum	92	100	75.76	50.44
Nuphar variegata	-	8	-	1.00
Potamogeton crispus	68	32	9.56	6.08
Potamogeton illinoensis	52	36	.16	-
Potamogeton richardsonii	52	36	.68	.72
Potamogeton vaseyi	4	-	-	-
Potamogeton zosteriformis	72	84	2.24	16.72
Vallisneria americana	-	4	-	-

Table 12. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Brewers Mills (site 12).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	60	64	.72	1.08
Lemna trisulca	-	4	-	-
Myriophyllum heterophyllum	4	-	-	-
Myriophyllum spicatum	100	92	73.12	8.20
Najas flexilis	-	4	-	-
Potamogeton crispus	36	28	3.96	.36
Potamogeton illinoensis	-	4	-	-
Potamogeton pusillus var. *tenuissimus*	68	88	2.96	65.72
Potamogeton richardsonii	16	24	.60	2.36
Potamogeton zosteriformis	64	60	9.84	17.68
Vallisneria americana	12	64	4.04	4.36

Table 13. Mean frequencies and cover values for vascular aquatic plants in and near the navigation channel at Joyceville (site 13).

	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
Ceratophyllum demersum	64	92	2.44	8.56
Elodea canadensis	-	88	-	18.12
Lemna trisulca	72	100	-	.04
Myriophyllum sibiricum	56	100	1.16	5.60
Myriophyllum spicatum	28	60	.28	5.00
Nymphaea odorata	-	60	-	3.96
Potamogeton crispus	72	80	50.32	18.20
Potamogeton praelongus	4	-	-	-
Potamogeton pusillus var. *tenuissimus*	28	8	22.72	4.20
Potamogeton richardsonii	72	8	3.80	.40
Potamogeton zosteriformis	28	68	.68	9.52
Ranunculus longirostris	-	64	-	4.52
Spirodela polyrhiza	12	100	-	.28
Vallisneria americana	-	24	-	7.72
Wolffia borealis	-	36	-	-
Wolffia columbiana	-	36	-	-

Table 14. Locations where *Acorus calamus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
2	4	8	-	-
3	12	-	-	-

Table 15. Location where *Amblystegium riparium* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
5	100	100	57.00	65.96

Table 16. Locations where *Ceratophyllum demersum* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	48	8	2.04	.32
2	48	56	1.24	4.48
3	84	52	2.76	1.92
4	72	68	2.72	5.88
5	80	76	5.96	3.08
6	80	76	3.80	11.52
7	28	64	.36	.44
8	40	24	5.00	1.96
9	100	92	13.52	6.96
10	56	92	.68	1.44
11	84	76	5.12	6.84
12	60	64	.72	1.08
13	64	92	2.44	8.56

Table 17. Location where *Chara globularis* var.*globularis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
8	-	4	-	-

Table 18. Location where *Chara vulgaris* var. cf.*vulgaris* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
8	-	4	-	-

Table 19. Locations where *Elodea canadensis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	8	4	.04	.04
3	72	68	2.88	3.56
4	88	68	8.68	3.88
5	72	64	.76	.44
6	100	84	19.48	18.80
7	60	72	1.56	5.64
8	72	84	2.60	29.92
9	100	92	11.56	5.92
10	4	-	-	-
11	56	12	.88	1.40
13	-	88	-	18.12

Table 20. Location where *Elodea nuttallii* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
2	-	56	-	1.08

Table 21. Locations where *Hydrocharis morsus-ranae* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	40	44	.12	.04
2	32	16	-	-
3	32	44	.04	.28
4	52	56	3.28	1.64
5	100	100	57.00	65.96

Table 22. Locations where *Lemna minor* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
9	-	12	-	.12
10	12	12	-	.08

Table 23. Locations where *Lemna trisulca* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	76	76	-	1.48
2	64	60	.36	.36
3	88	92	2.84	1.40
4	32	32	-	.04
5	100	96	9.12	6.16
6	80	92	1.12	20.00
7	68	64	-	1.44
8	48	20	-	-
9	92	92	-	37.08
10	40	44	-	-
11	84	96	3.24	4.80
12	-	4	-	-
13	72	100	-	.04

Table 24. Location where *Myriophyllum heterophyllum* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
12	4	-	-	-

Table 25. Locations where *Myriophyllum sibiricum* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	20	84	.04	5.16
2	36	32	1.00	.20
3	24	52	.72	2.96
5	64	56	1.48	.16
6	12	76	-	3.72
7	64	72	1.40	10.08
8	60	68	1.08	14.28
9	-	4	-	-
11	4	-	-	-
13	56	100	1.16	5.60

Table 26. Locations where *Myriophyllum spicatum* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	96	56	66.12	8.80
2	96	92	48.48	47.64
3	100	88	68.40	13.12
4	96	92	42.60	45.68
6	100	84	59.84	11.76
7	76	72	2.68	4.48
8	72	96	18.04	14.44
9	96	92	18.96	9.08
10	100	100	37.96	49.68
11	92	100	75.76	50.44
12	100	92	73.12	8.20
13	28	60	.28	5.00

Table 27. Locations where *Najas flexilis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
5	20	16	-	-
12	-	4	-	-

Table 28. Location where *Nitella flexilis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
8	-	16	-	.50

Table 29. Locations where *Nuphar variegata* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	-	8	-	.28
3	12	32	-	1.36
8	8	-	4.60	-
9	-	24	-	.44
11	-	8	-	1.00

Table 30. Locations where *Nymphaea odorata* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	4	52	-	1.32
3	-	28	-	1.04
4	28	32	.04	.20
6	-	16	-	-
9	-	48	-	2.20
13	-	60	-	3.96

Table 31. Locations where *Potamogeton crispus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	56	12	1.68	.20
2	16	12	.20	-
3	44	36	1.12	1.20
5	64	64	2.80	2.12
6	84	60	7.28	2.12
7	100	96	43.76	19.80
8	40	8	4.72	3.00
9	48	60	.16	.60
10	100	100	7.12	5.40
11	68	32	9.56	6.08
12	36	28	3.96	.36
13	72	80	50.32	18.20

Table 32. Location where *Potamogeton epihydrus* var. *epihydrus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
9	4	-	-	-

Table 33. Location where *Potamogeton gramineus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
8	4	-	-	-

Table 34. Locations where *Potamogeton illinoensis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
3	4	-	-	-
6	12	40	-	.32
7	4	-	-	-
8	60	24	15.08	.36
9	80	-	8.12	-
11	52	36	.16	-
12	-	4	-	-

Table 35. Location where *Potamogeton natans* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
9	-	4	-	-

Table 36. Locations where *Potamogeton pectinatus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	-	44	-	11.12
2	4	-	-	-
3	-	52	-	20.76
6	12	-	-	-
7	-	8	-	-
8	4	-	-	-
9	16	-	4.40	-

Table 37. Location where *Potamogeton praelongus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
13	4	-	-	-

Table 38. Locations where *Potamogeton pusillus* var. *tenuissimus* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	28	76	3.48	51.76
2	80	44	19.96	.48
4	80	68	34.36	37.56
5	4	-	-	-
6	44	-	.96	-
7	88	100	28.20	42.20
8	52	40	5.28	.96
9	16	-	-	-
10	100	100	47.00	32.92
12	68	88	2.96	65.72
13	28	8	22.72	4.20

Table 39. Locations where *Potamogeton richardsonii* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	28	56	.84	1.68
2	52	20	1.72	.68
3	52	88	2.72	17.88
5	40	32	.52	.20
6	-	16	-	-
7	36	40	-	.04
8	76	88	17.36	4.08
9	92	-	13.12	-
10	4	-	-	-
11	52	36	.68	.72
12	16	24	.60	2.36
13	72	8	3.80	.40

Table 40. Locations where *Potamogeton robbinsii* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
3	4	-	-	-
5	4	-	-	-
7	4	-	-	-
8	4	-	-	-
9	4	-	-	-

Table 41. Location where *Potamogeton strictifolius* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
9	4	-	-	-

Table 42. Locations where *Potamogeton vaseyi* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
3	4	-	-	-
5	100	100	74.00	77.48
11	4	-	-	-

Table 43. Locations where *Potamogeton zosteriformis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	52	28	2.76	.20
2	72	56	5.12	1.68
3	92	92	5.16	27.76
4	12	48	-	-
5	48	15	.16	.40
6	100	56	4.92	.24
7	80	80	13.36	6.36
8	92	68	20.56	3.16
9	96	24	19.44	.12
11	72	84	2.24	16.72
12	64	60	9.84	17.68
13	28	68	.68	9.52

Table 44. Locations where *Ranunculus longirostris* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	-	8	-	.08
2	8	12	-	.12
3	28	-	.48	-
5	4	-	-	-
6	28	20	-	-
7	0	12	-	-
8	12	8	-	-
10	4	-	-	-
13	-	64	-	4.52

Table 45. Locations where *Spirodela polyrhiza* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	48	40	-	-
6	-	20	-	-
7	-	28	-	1.00
8	-	4	-	-
9	-	4	-	-
10	-	12	-	.08
13	12	100	-	.28

Table 46. Locations where *Vallisneria americana* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
1	4	44	.04	1.40
2	36	36	-	-
3	68	52	2.92	2.32
4	76	28	4.68	.64
5	92	84	4.00	3.40
6	8	100	-	14.40
7	28	60	.04	.12
8	36	68	4.00	24.04
9	-	100	-	15.84
10	4	-	-	-
11	-	4	-	-
12	12	64	4.04	4.36
13	-	24	-	7.72

Table 47. Locations where *Wolffia borealis* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
7	60	-	.52	-
8	-	4	-	-
13	-	36	-	-

Table 48. Locations where *Wolffia columbiana* was present, showing mean frequencies and cover values in and near the navigation channel. Site locations are given in Table 1.

Site No.	Mean Frequency		Mean Cover	
	Navigation Channel	Adjacent area	Navigation Channel	Adjacent area
7	60	-	.52	-
8	-	4	-	-
13	-	36	-	-