

FACTORS ASSOCIATED WITH THE DISTRIBUTION OF
MYRIOPHYLLUM IN BRITISH COLUMBIA

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The geographic distribution of the nine species of Myriophyllum L. known from British Columbia is shown on maps. Tables and figures show the distribution as a function of altitude, ecological zone, pH of the water, lake sediment chemistry and lake water chemistry. Some mechanisms of Myriophyllum spread within British Columbia are discussed.

The exceptionally wide diversity of habitats in British Columbia, created, in part, by variations in altitude, latitude, geology and proximity to the Pacific Ocean, offers a valuable opportunity to investigate the effects of such variables on the distribution of aquatic plants. The effects of these geographic factors on the distribution of terrestrial vegetation is fairly well known (2) but similar knowledge for aquatic plants is not available.

Nine species of Myriophyllum are known from British Columbia and listed in Table I. These are all readily distinguished by 2-dimensional thin layer chromatography of their flavenoid pigments (1). This technique may be needed to confirm species identifications of herbarium, fragmentary or non-flowering material but is rarely needed to identify living material in the field.

Table I. Myriophyllum species found in British Columbia

1. M. aquaticum (Vell.) Verd.
M. brasiliense Camb.
2. M. exalbescens Fern.
3. M. farwellii Morong.
4. M. heterophyllum Michx.
5. M. hippuroides Nutt.
6. M. quitense H.B.K.
M. elatinoides Gaud.
7. M. spicatum L.
8. M. ussuriense (Regel) Maxim.
9. M. verticillatum L.

IN: Proceedings of the First International Symposium on Watermilfoil (Myriophyllum spicatum) and related Haloragaceae species. July 23 and 24, 1985. Vancouver, B.C., Canada. The Aquatic Plant Management Society, Inc. 1986.

Materials and Methods

For several years the author has been building a computerized dataset on the aquatic plants of British Columbia. For each lake or pond in which aquatic plants have been found, or in which they have been sought, the following information is stored, when available: aquatic plant presence or absence, water chemistry, sediment chemistry and lake morphometry parameters, growing season water temperature, drainage basin information, geographical information and the Biogeoclimatic zone (2) in which the lake is found. Similar, but less comprehensive, files exist for rivers and streams, wetlands, sloughs and ditches and park and garden pools. Data from these latter files were included to compile the distribution maps, Figures 1 and 2 and Tables 2 and 3. Figures 3 to 9 were compiled only from the lakes and pond data set since the others lack sediment and water chemistry data.

M. exalbescens Fern. has been found in 318, and M. verticillatum L. in 100 bodies of water. These are widespread and common species in British Columbia and sufficient water and sediment chemistry data exist to justify statistical analyses for these two species. There are not sufficient data available for the other species of Myriophyllum. M. spicatum L. has been found in 60 bodies of water in British Columbia but few of these have had water and sediment samples taken. However, due to the importance of this species as a weed, the existing data have been analyzed and tentative associations are presented.

Results and Discussion

Geographical Distribution

Figures 1 and 2 are distribution maps showing the locations in British Columbia where each species has been recorded. These maps were prepared by putting one dot in the centre of each 1:50 000 topographic map sheet where at least one distribution record exists. Some data in map sheets with many small lakes may represent several distribution records. If a species grows in a large lake, which extends over several mapsheets, then each map sheet received a dot.

M. aquaticum (Vell.) Verde., (M. brasilliense Camb.), is recorded from one artificial pond in a display garden in North Vancouver. Pistillate plants have been growing there for at least eight years and flower annually. The plants overwinter in an active vegetative condition and have been observed sheathed in ice in the winter where they were sprawling up the sides of a small waterfall.

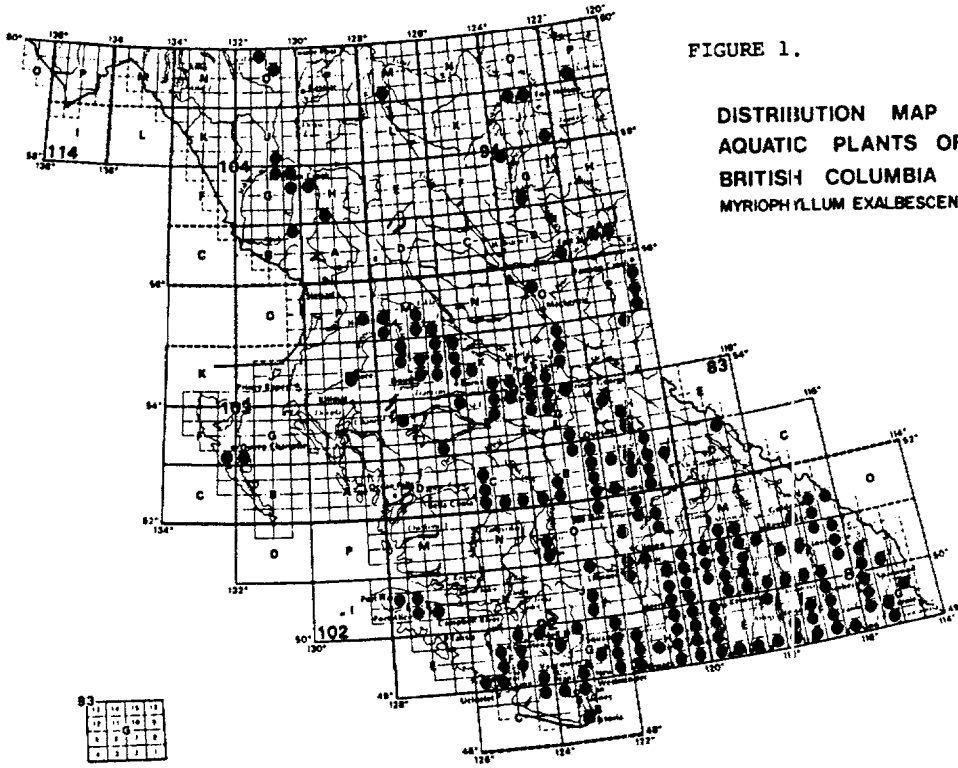
M. heterophyllum Michx. is known from four ponds in Queen Elizabeth Park in Vancouver. In one pond, where M. spicatum L. also occurs, the M. heterophyllum bed has not been replaced by the invasive M. spicatum, which has completely dominated the remainder of the pond over the last eight years.

M. quitense H.B.K., (M. elatinoides Gaud.), has been found only on Vancouver Island; primarily in habitats with high wave action or in flowing waters. These include five lakes, one slough and two streams.

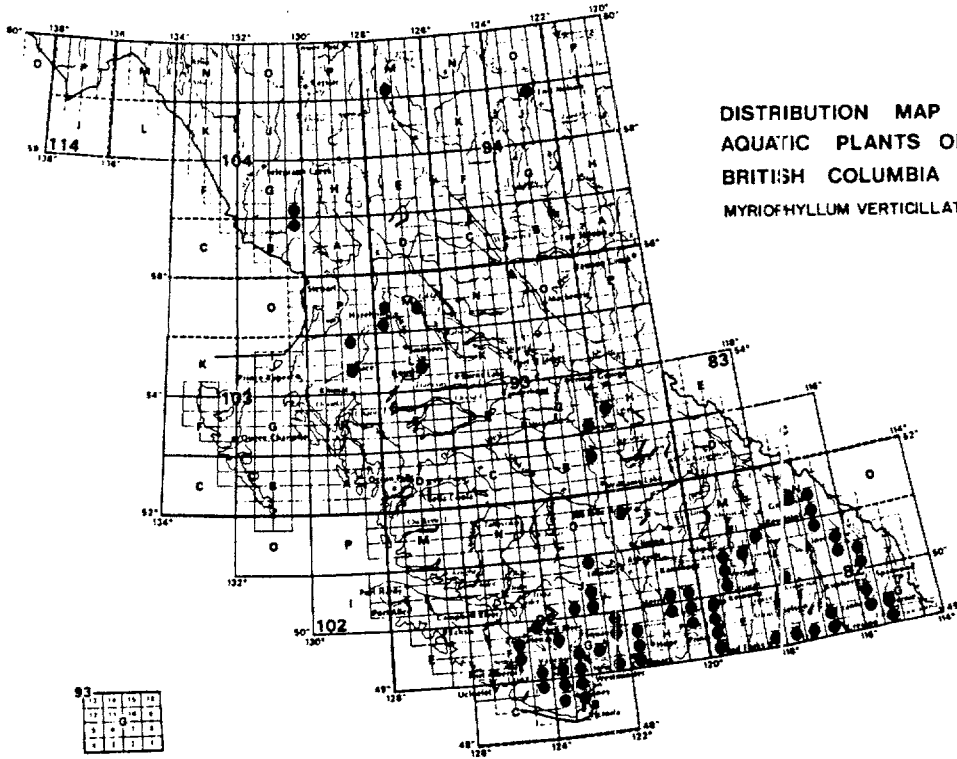
M. hippuroides Nutt. is found throughout the lower Fraser Valley in most wetlands, roadside and drainage ditches, shallow ponds and sheltered, shallow or 'weedy' water bodies. It is uncommon in large, open lake situations.

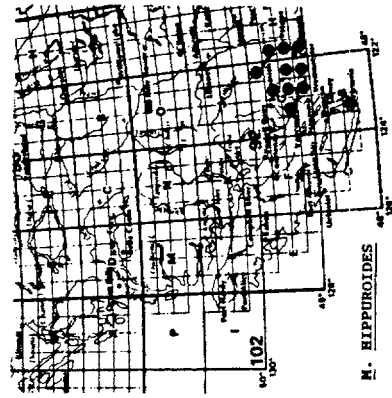
FIGURE 1.

DISTRIBUTION MAP
AQUATIC PLANTS OF
BRITISH COLUMBIA
MYRIOPHYLLUM EXALBESCENS

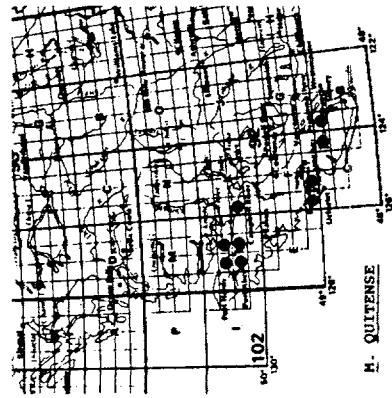


DISTRIBUTION MAP
AQUATIC PLANTS OF
BRITISH COLUMBIA
MYRIOPHYLLUM VERTICILLATUM

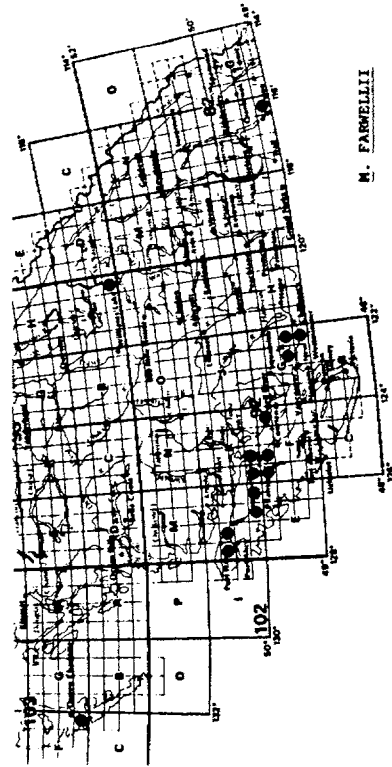




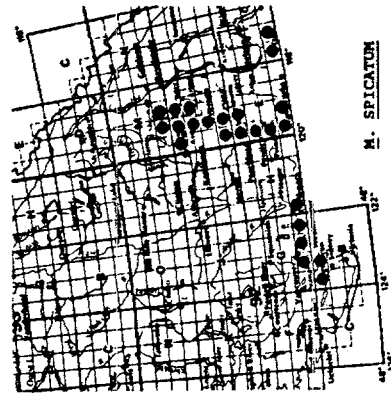
M. HIPPUROIDES



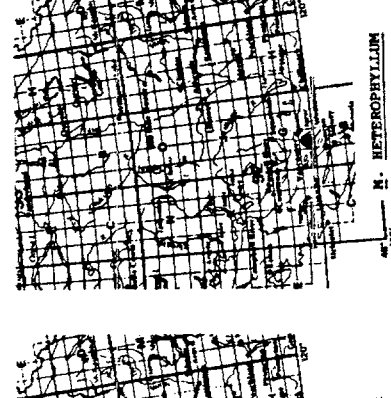
M. QUITENSE



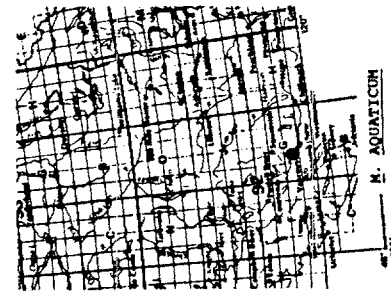
M. FARWELLI



M. SPICATUM



M. HETEROPHYLLUM



M. AQUATICUM



M. USSURIENSE

FIGURE 2. Distribution Maps of *M. aquaticum*, *M. farwellii*, *M. heterophyllum*, *M. hippuroides*, *M. quitense*, *M. spicatum*, and *M. ussuriense* in British Columbia.

M. ussuriense (Regel) Maxim. is most commonly found in the same habitats as M. hippuroides in the lower Fraser Valley but also in suitable, seasonally exposed habitats in the Shuswap, Kootenay and Kennedy Lake valleys. This species flowers when growing as a short, erect, terrestrial on exposed mud banks after water levels drop in late summer.

M. farwellii Morong. is found primarily on northern Vancouver Island but there are a few other isolated locations in British Columbia, including the Queen Charlotte Islands, and the lower Fraser Valley. M. farwellii habitats are often characterized by extensive amounts of wood debris, usually associated with logging.

M. spicatum is largely confined to the Okanagan and lower Fraser valleys. Other locations include Champion Lake, the Pend Oreille River, Shuswap Lake, Magic Lake on South Pender Island and a slough in Duncan on Vancouver Island. It is believed this species was first introduced to British Columbia around 1970 and has not yet had sufficient time to spread to all suitable habitats in British Columbia.

M. exalbescens and M. verticillatum are found in a wide variety of habitats throughout British Columbia. M. exalbescens is more common in alkaline conditions, with higher sodium, potassium and sulphate levels, than M. verticillatum.

Krajina's Biogeoclimatic Zones

Krajina's Biogeoclimatic zones (2) are defined by climate, geology and vegetation factors. Implicit in these zones are altitudinal ranges which are affected by aspect, exposure, latitude and proximity to the Pacific Ocean. Table II shows the distribution of Myriophyllum in British Columbia

Table II. The Distribution of Myriophyllum Species in British Columbia by Krajina's Biogeoclimatic Zones

Species	Zones											
	C D F	C W H	I W H	I D F	P P B	C A L	B W B	E S S	S B S	S W S	A T B	M H
<u>M. exalbescens</u>	12	31	30	111	34	58	21	18	9	2	2	
<u>M. verticillatum</u>	24	28	11	33	3	3	1	8	1	2		
<u>M. spicatum</u>	40		1	2	20							
<u>M. ussuriense</u>	9	6	1	3								
<u>M. farwellii</u>	8	15	1									
<u>M. hippuroides</u>	37	14										
<u>M. quitense</u>	3	5										
<u>M. heterophyllum</u>	4											
<u>M. aquaticum</u>	1											

Note: The numbers in the body of the Table are the number of lakes in which the given species occurs for each Krajina zone.

by biogeoclimatic zone. This Table includes lakes, rivers, garden pools, sloughs and wetlands. Species like M. exalbescens and M. verticillatum which have the widest geographical distribution are also found in the greatest variety of ecological zones. The zone with the lowest elevation, and smallest annual temperature, ranges the CDF zone, hosts the greatest variety of species; all nine species of Myriophyllum are found here.

The percentage of the total number of lakes and ponds in which each of the common Myriophyllum species grows, found in each biogeoclimatic zone is given in Figure 3. M. exalbescens is found in all biogeoclimatic zones except the coastal mountain hemlock zone. In this zone the ground freezes in the winter before an insulating blanket of snow has fallen. M. verticillatum is absent only in the same coastal mountain hemlock zone and also the alpine tundra zone. Both M. exalbescens and M. verticillatum are most prevalent, 35% and 31% respectively, in the interior douglas fir zone, a valley bottom habitat. However, only 11% of the M. exalbescens is found in the two coastal zones, CDF and CWH, while 41% of the M. verticillatum is found in these two coastal zones. M. spicatum is confined almost exclusively to the two zones in which the Okanagan and lower Fraser valleys are found. This probably reflects the initial spreading phase of this recently introduced aquatic plant rather than any indication of habitat limitations. The productivity of M. spicatum is highest in the PPBG zone of the Okanagan Valley but whether this is due to limnological or ecological differences of the locations or genotypic differences in the plants is not known.

Altitude

The distribution of all the Myriophyllum species in British Columbia, in 100 m increments of altitude above sea level, is given in Table III. This Table includes lakes, rivers, garden pools, sloughs and wetlands. M. exalbescens is found 45% of the time between 700 and 1 000 m and only 10% of the time below 200 m. In contrast M. verticillatum occurs only 21% of the time between 700 and 1 000 m about 35% of the time below 200 m. This altitudinal differentiation is, in part, a reflection of the altitudinal ranges of the biogeoclimatic zones in which the two species are most prevalent.

The percentage occurrence of the common Myriophyllum species growing in British Columbia lakes and ponds, in 100 m increments of altitude above sea level, is given in Figure 4. M. verticillatum is not found above 1 300 m while M. exalbescens grows up to 1 800 m. Comparison of Table 3 and Figure 4 shows that about one half of the M. verticillatum waterbodies in the under 200 m range are not lakes; they are sloughs, ditches, backwaters and slow streams in the lower Fraser Valley. M. exalbescens does not have a similar large group of 'non-lake' habitats at low elevations.

These percentage occurrence figures are subject to bias from several sources. Some parts of British Columbia are characterized by a few large lakes (southern interior valleys) and others by many small lakes (lower Fraser Valley, Cariboo plateau). The extent and density of sampling is by no means uniform throughout the province. In one area many small lakes with virtually identical floras may be sampled, while in others only one representative lake has been sampled. Sampling density in northern British

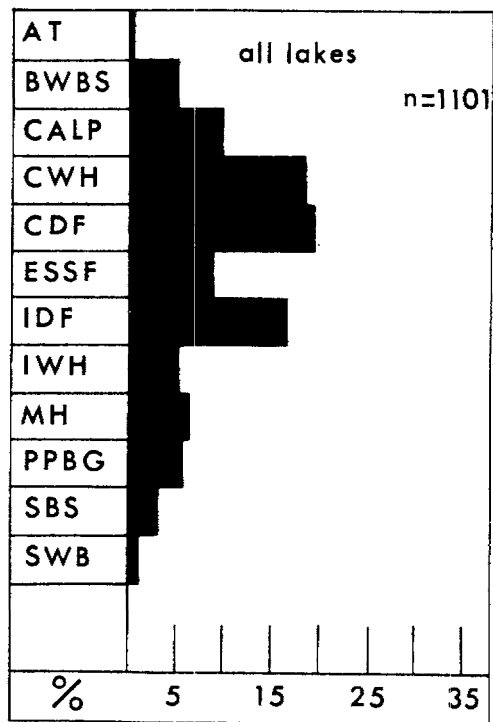
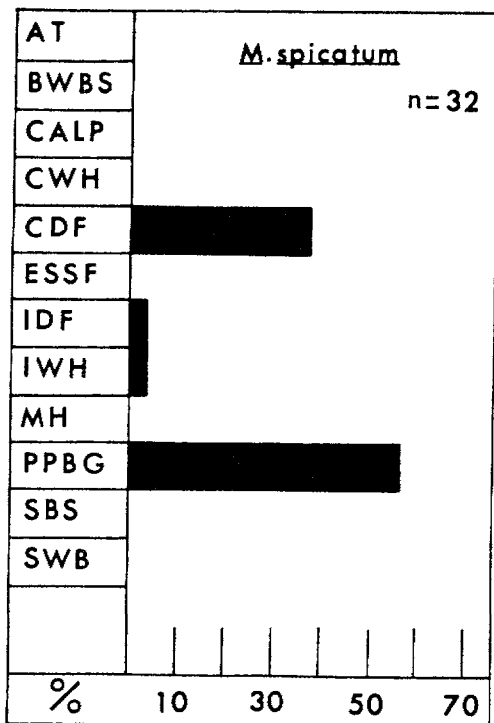
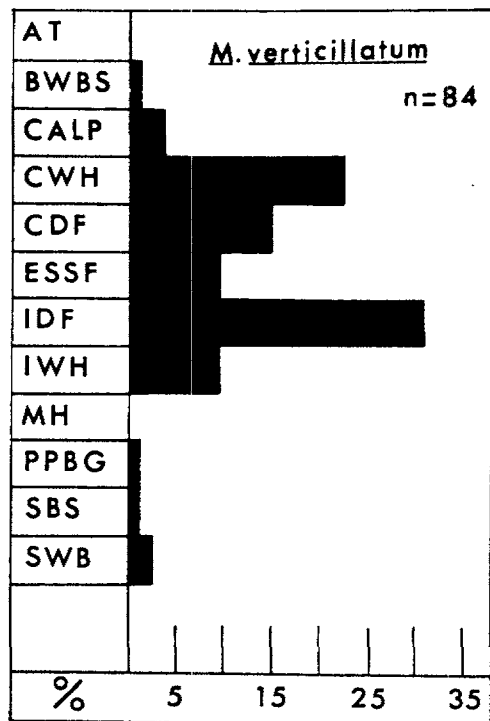
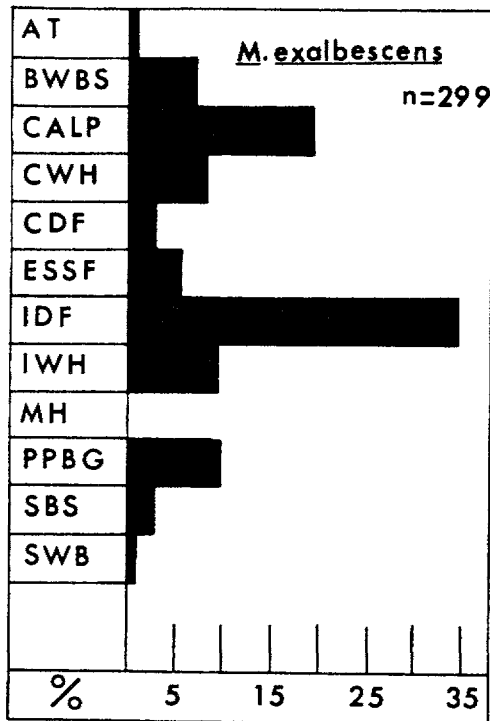


FIGURE 3. Percentage occurrence of *Myriophyllum* by Krajinina's Bigeoclimatic Zones of British Columbia.

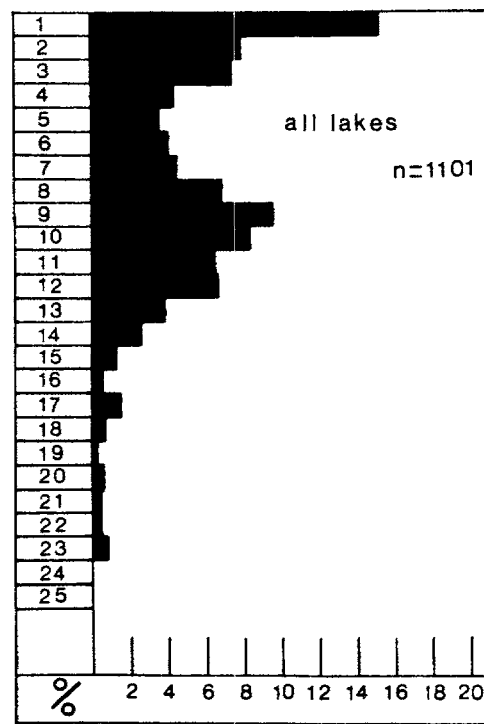
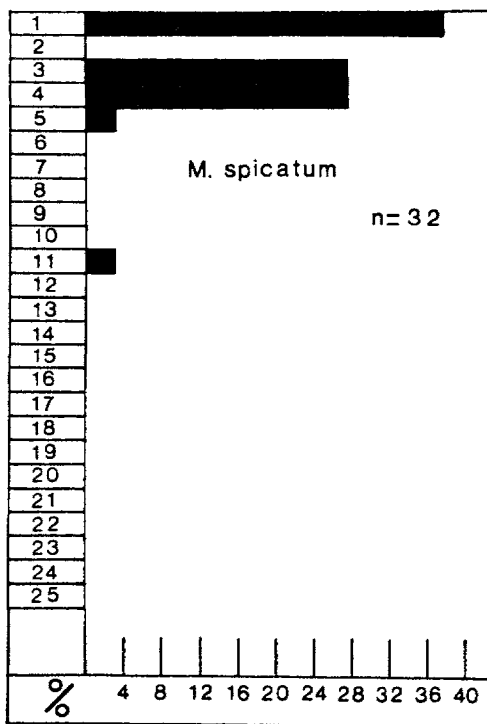
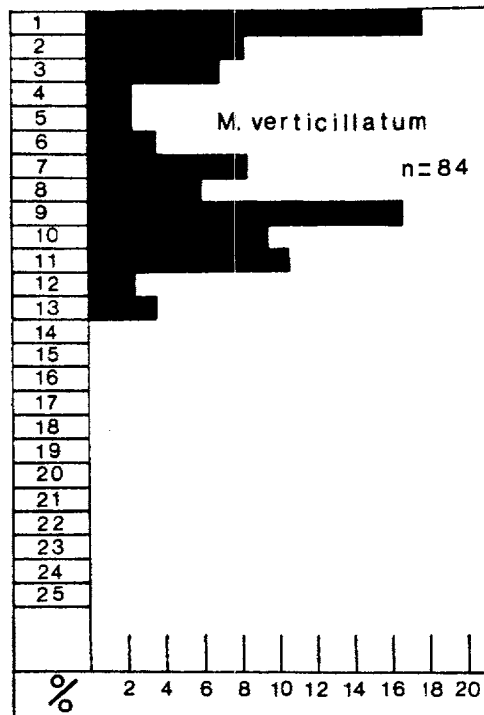
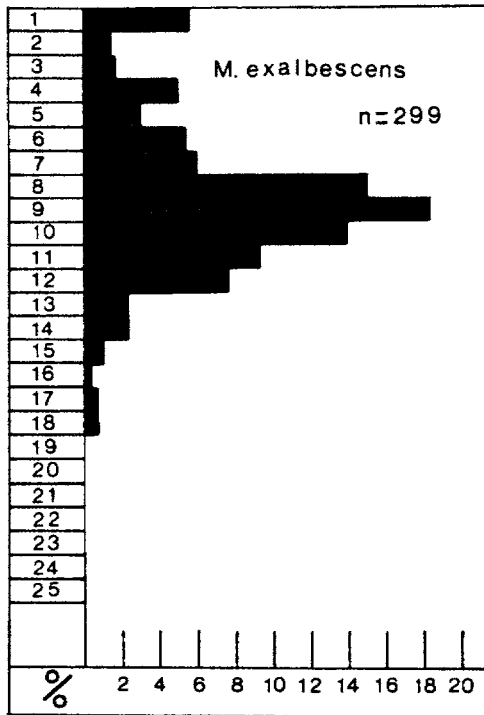


FIGURE 4. Percentage occurrence of Myriophyllum by altitude in British Columbia.

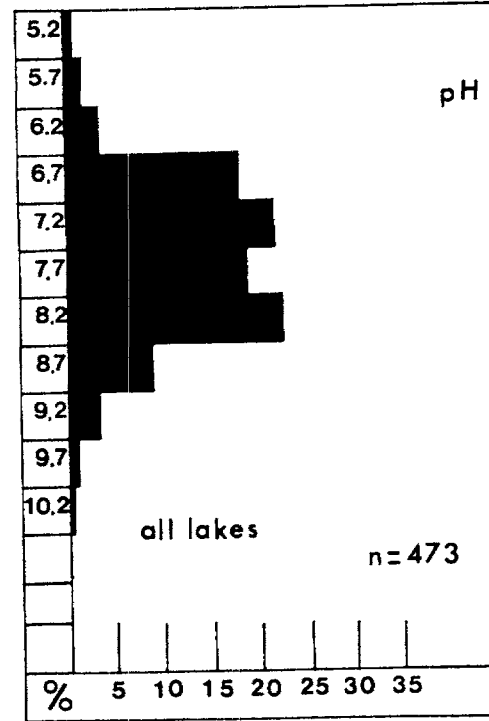
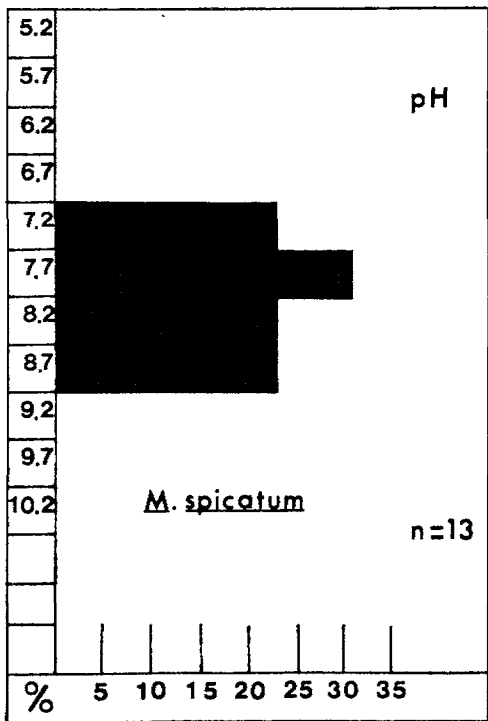
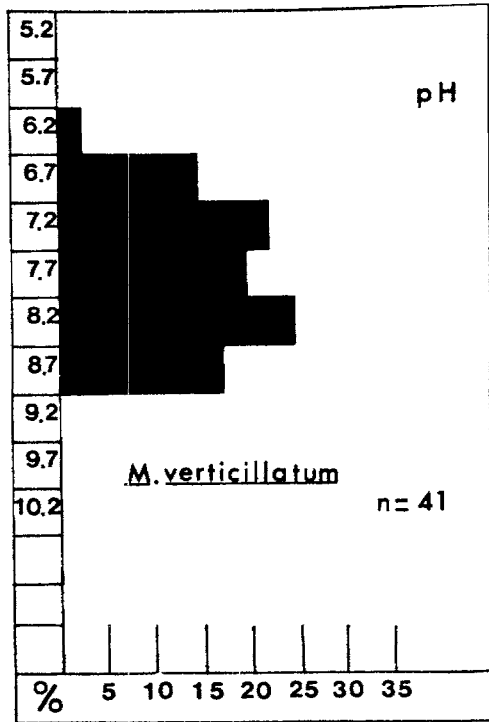
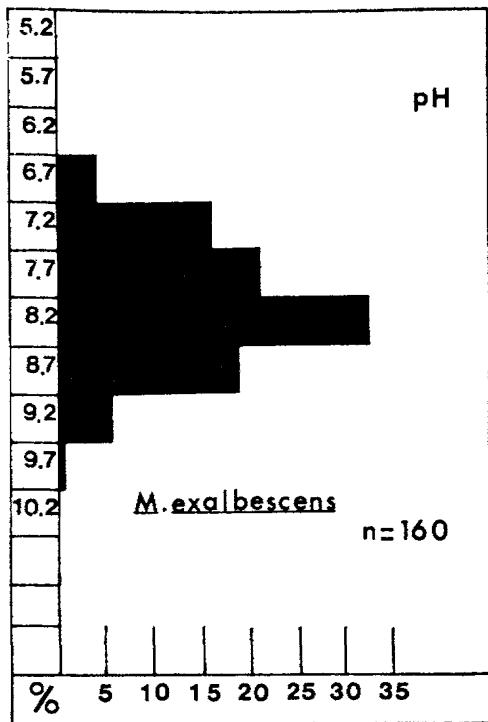


FIGURE 5. Percentage occurrence of Myriophyllum by pH in British Columbia.

Table III. The Distribution of Myriophyllum Species in British Columbia

By Altitude in 100 m Increments

Species	Altitude																	
	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	
	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8
	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
<u>M. exalbescens</u>	28	4	5	21	11	19	20	48	56	44	29	23	8	7	3	1	2	2
<u>M. verticillatum</u>	33	7	6	3	3	5	6	9	15	9	11	2	2	3				
<u>M. spicatum</u>	38	2	9	11	2							1						
<u>M. ussuriense</u>	14		1	3		1												
<u>M. farwellii</u>	3	10	10							1								
<u>M. hippuroides</u>	49		2															
<u>M. quitense</u>	7	1																
<u>M. heterophyllum</u>			4															
<u>M. aquaticum</u>	1																	

Note: The numbers in the body of the Table are the number of lakes in which the given species occurs for each 100 m altitude block. The first block is lakes below 100 m, i.e. from 0 to 99 m in altitude.

Columbia is very low and uncommon species and habitats have likely been missed.

pH

The pH ranges of the common Myriophyllum species found in British Columbia lakes are given in Figure 5. The increments are 0.5 pH units centred on the pH values listed on the axes of the Figures. The pattern of distribution of M. verticillatum by pH is much like that of the entire set of lakes but has a more restricted range. M. exalbescens grows in lakes with higher pH values. This disparity is even more pronounced if maximum pH values are plotted rather than the mean pH values in Figure 5.

Morphometry

There is a tremendous range of values for the morphometric characteristics of lakes in British Columbia. Characteristics recorded include total area and volume, littoral (shallower than 6 m water depth) area and volume, littoral area and volume as a percent of the total area and volume, mean and maximum depth, length of shoreline, and shoreline development index. No correlations were found with any of these characteristics and any species of aquatic plant. Apparently specific habitats within lakes are more significant than gross lake morphology. Personal experience indicates that markedly dissimilar lakes may still contain very similar habitats, in localized areas, which support similar plant communities.

Water Chemistry

Figures 6 and 7 show the 75th, 90th and 95th percentile limits of some

standard water chemistry characteristics for the common Myriophyllum species. The characteristics displayed are hardness, alkalinity, ammonia, organic and total nitrogen, pH, conductivity, total dissolved phosphorus, dissolved chloride, sulphate, potassium and sodium and total calcium and magnesium. These star diagrams facilitate comparisons of patterns and quantities among species. M. spicatum grows in softer water than the other species and tolerates higher ammonia levels. M. exalbescens tolerates harder, more alkaline, high sulphate lakes while M. verticillatum is generally confined to carbonate lakes with lower sodium, potassium and sulphate and higher ammonia.

A correlation matrix indicates that water hardness in M. verticillatum lakes correlates at 0.94 with calcium and magnesium but much lower with potassium, 0.74, and sodium, 0.45. However, in M. exalbescens lakes the correlations with hardness are 0.53 for calcium and 0.82, 0.84, and 0.87 for potassium, sodium and magnesium respectively. In M. exalbescens lakes the correlations with sulphate are 0.63 and 0.60 for potassium and calcium respectively but very low for sodium and magnesium. All correlations with sulphate are very low in M. verticillatum lakes.

For most water chemistry parameters the full range of values may be from 2 to 8 times the 95th percentile value; the species have very wide tolerance ranges even though preferred ranges may be much more restricted. These very wide, overlapping, tolerance ranges for water chemistry characteristics mean that predicting water density from aquatic plants, or the converse, is not practical for most species and characteristics studied to date.

Sediment Chemistry

The star diagrams for some sediment characteristics are given in Figures 8 and 9. There was insufficient data to analyze M. spicatum. Both M. verticillatum and M. exalbescens have the same general pattern and grow in much higher organic carbon and kjeldahl nitrogen levels than the average sediment levels for all lakes. M. verticillatum grows in higher magnesium and total phosphorus levels at high percentiles, than M. exalbescens.

A correlation matrix shows high correlations among percent volatiles, kjeldahl nitrogen and total and organic carbon. The coefficients are generally highest in M. verticillatum lakes, next in M. exalbescens lakes but still over 0.9 in the entire lake data set. There is a 0.98 correlation of inorganic carbon with calcium in sediments of M. verticillatum lakes; this value is only 0.71 in M. exalbescens lakes.

For sediment chemistry characteristics measured, the full range of values is only up to twice the 95th percentile value.

Means of Transport

Myriophyllum distribution is also a function of the means of transport. Quarantine check stations have shown that viable fragments of Myriophyllum are moved on boat trailers and motors from one recreational lake to another (3). Boaters and water skiers also spread fragments within a lake. Ducks and geese may introduce Myriophyllum to ponds and sloughs where they regularly feed. Ducks which were suddenly flushed from a pond heavily overgrown with M. spicatum were observed to trail stem fragments from their feet as they flew away. Resident Canada goose populations have a regular circuit

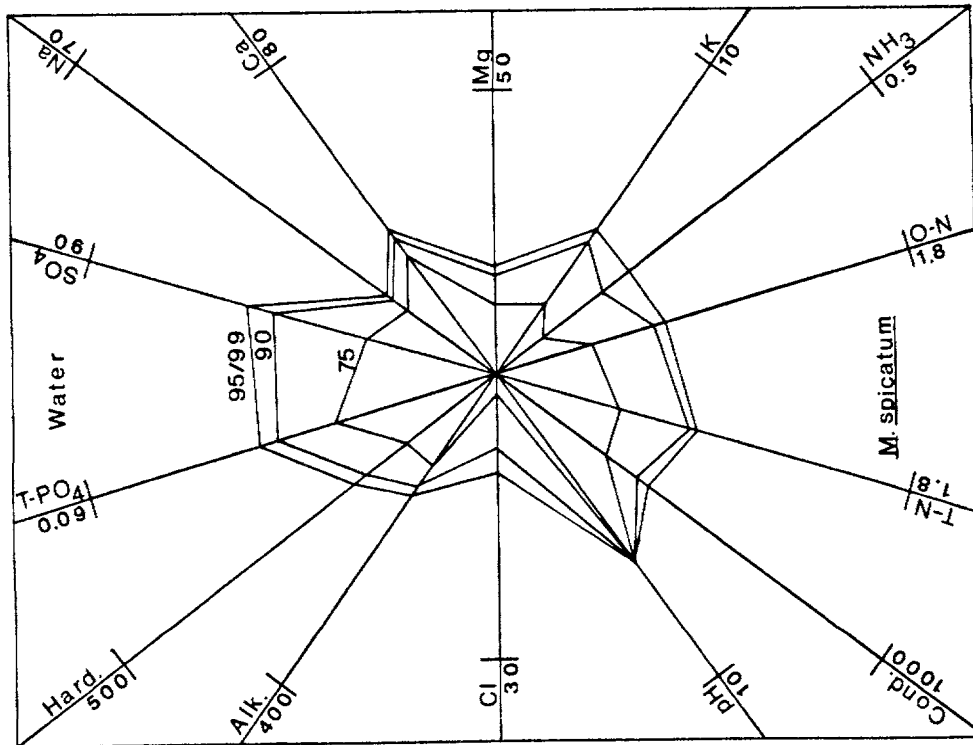
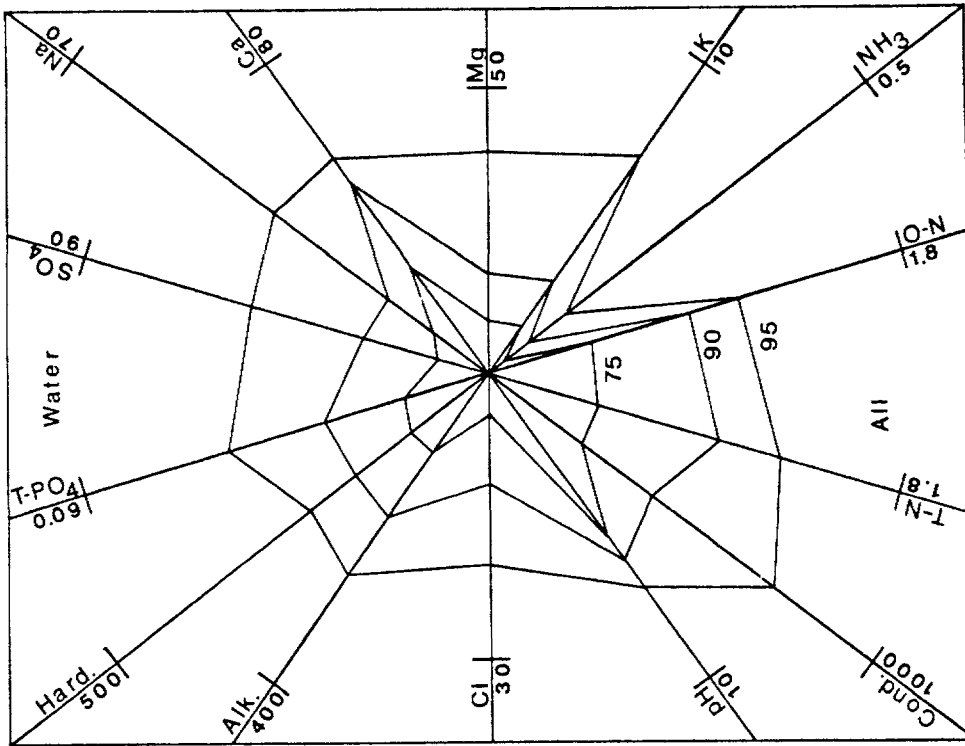


FIGURE 6. Star diagrams of water chemistry characteristics for M. spicatum and the entire lake data set.

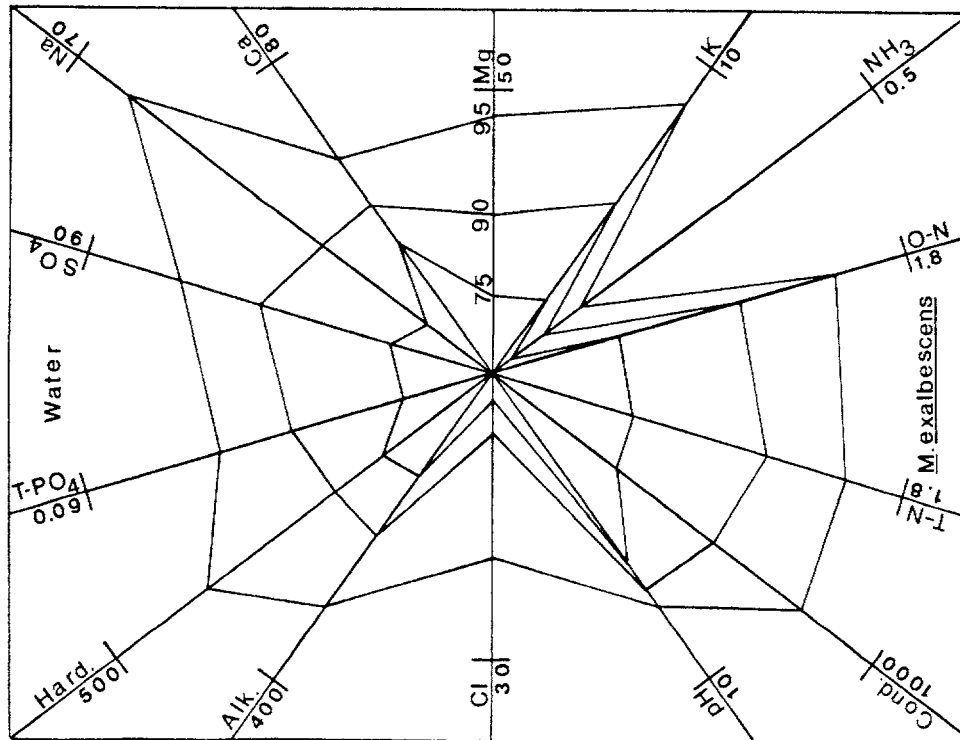
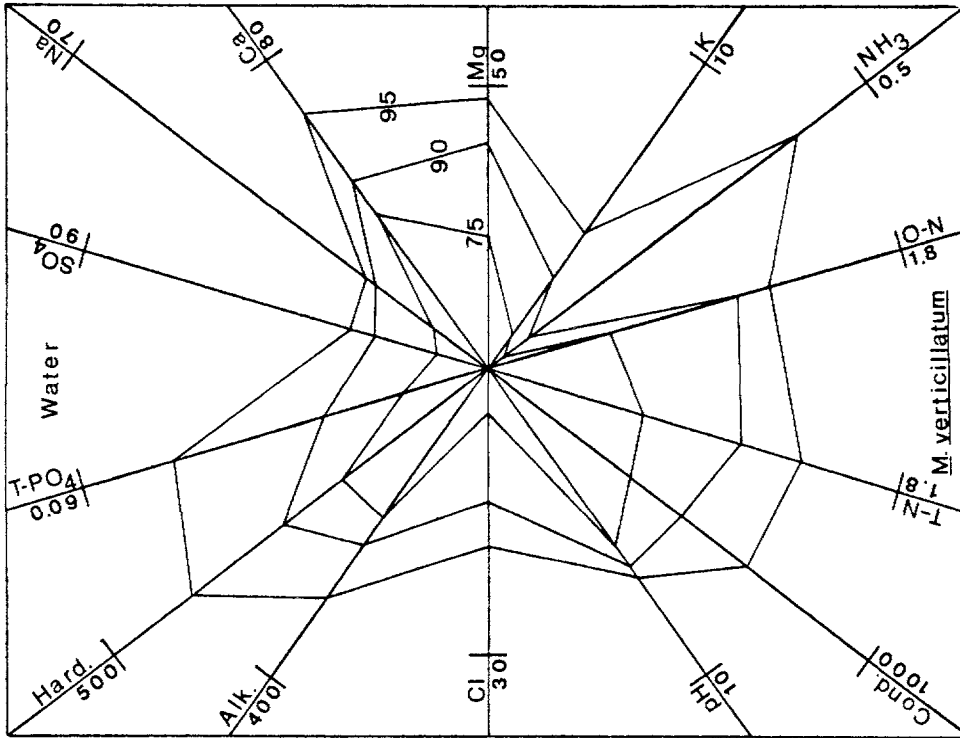


FIGURE 7. Star diagrams of water chemistry characteristics for *M. exalbescens* and *M. verticillatum*.

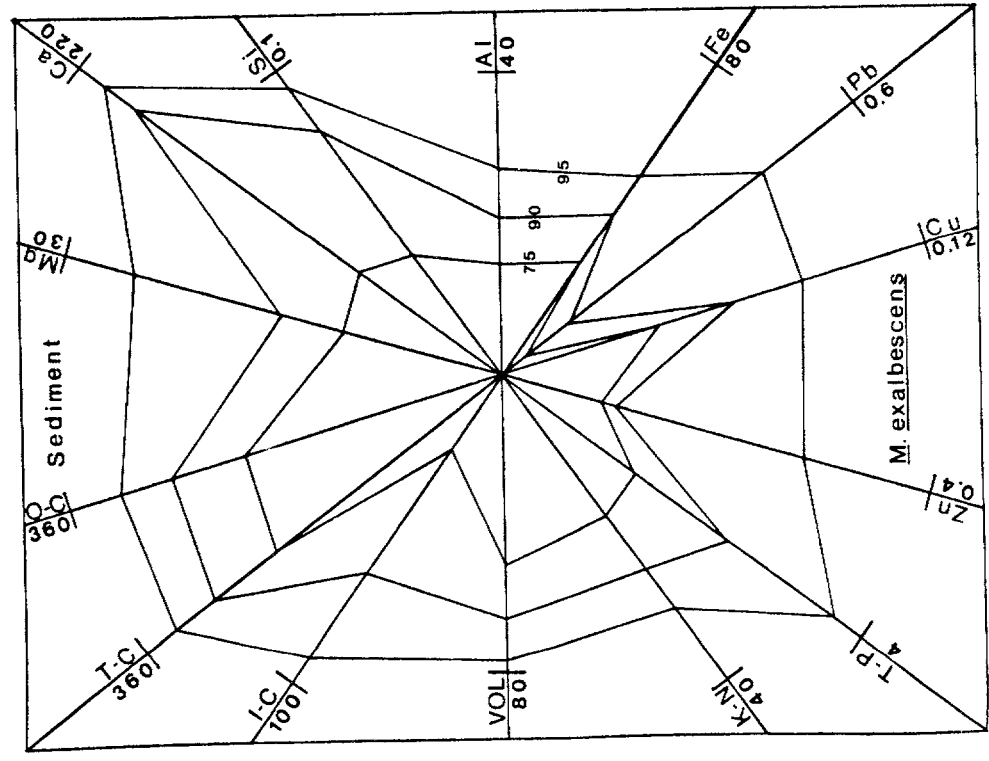
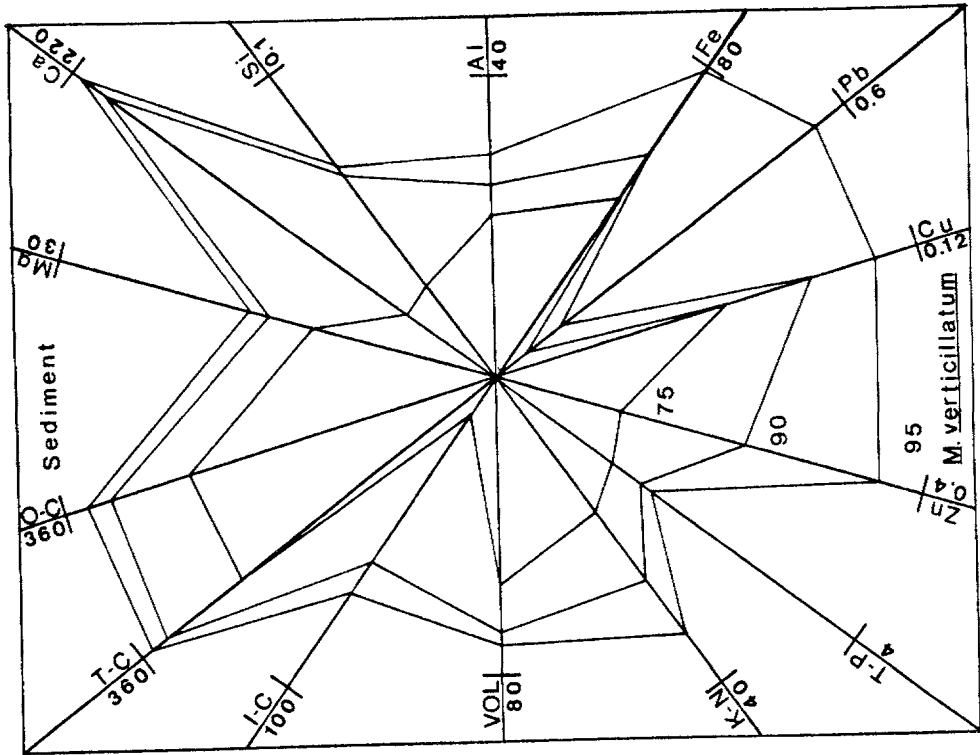


FIGURE 8. Star diagrams of sediment chemistry characteristics for M. exalbescens and M. verticillatum.

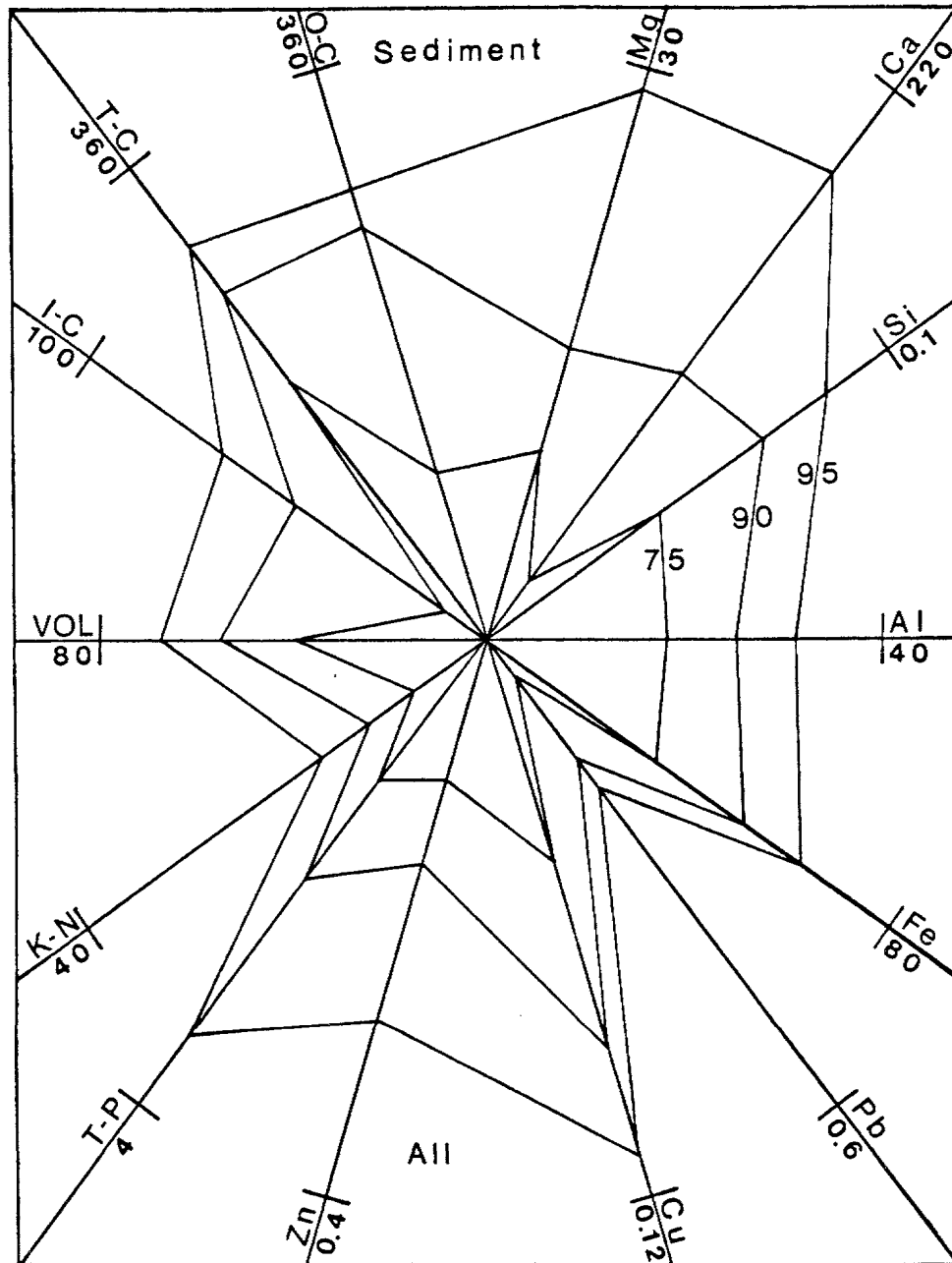


FIGURE 9. Star Diagram of Sediment Chemistry Characteristics for the entire lake data set.

of water bodies in which they forage. When one lake in the circuit becomes infected with M. spicatum the geese are believed to spread it around the whole circuit.

Heavy equipment used to clean out roadside ditches can also spread plants unless machinery is carefully cleaned after working in 'weedy' areas. Municipal equipment used for such jobs is often used to build ponds in parks or maintain beaches on lakeshores and in so doing may spread 'weeds'. When the spoils from ditch, pond and lakeshore cleaning are hauled and dumped, usually in wet or boggy areas as fill, further spread of the plants may occur.

Records show that within one or two years following construction of commercial parks and gardens, such common 'weedy' genera as Ceratophyllum, Elodea, Myriophyllum and filiform Potamogeton are present. They may be introduced by transplanting water-lilies and other aquatic plants growing in sediments from 'weedy' areas and by ducks and geese flying in from nearby sloughs and ditches.

Several instances are known of nurseries and garden shops selling aquatic plants, for ornamental ponds and pools, which are contaminated with viable fragments of M. spicatum. Several Myriophyllum species are prized aquarium plants and are actively shipped all over the world for this purpose. Some of these specimens find their way, accidentally or deliberately, into local waters. While most tropical species do not survive temperate zone winters; some do and become established. M. aquaticum and Elodea densa (Planch.) Casp., waterweed, have successfully overwintered in the lower Fraser Valley for many years. Salvinia, water fern, and Eichhornia crassipes (Mart.) Solms., water hyacinth, are occasionally introduced but do not overwinter.

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