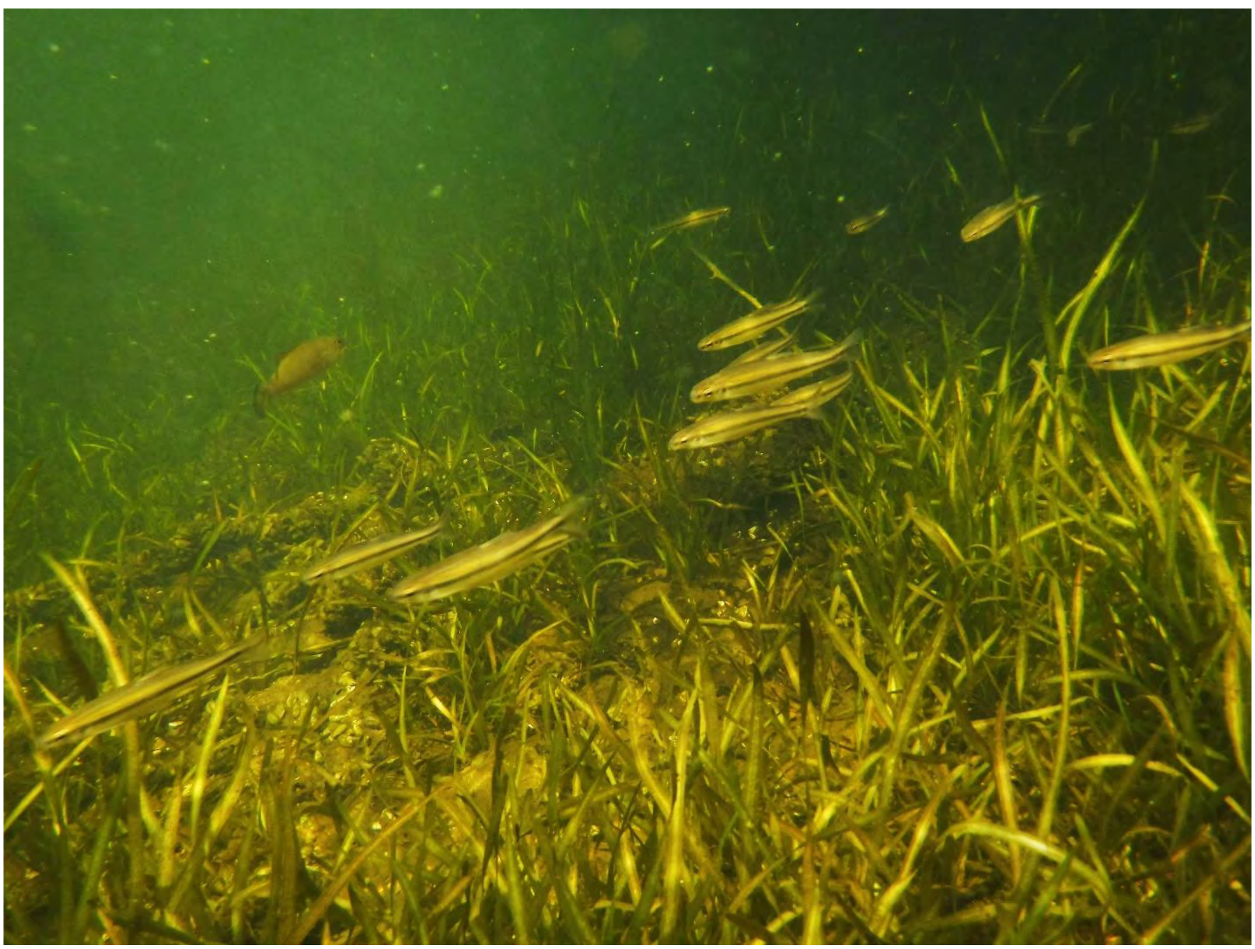
WHITE LAKE Property Owners Association Preservation Project

REPORT
AQUATIC PLANT SURVEY OF WHITE LAKE 2020

David Overholt, BA and D. Conrad Grégoire, PhD



"I *do not believe that botanists are aware how charged the mud is with seeds……*

I took in February three table-spoonfuls of mud from three different points, beneath water, on the edge of a little pond; this mud when dry weighed only 6 ¾ ounces; I kept it covered up in my study for six months, pulling up and counting each plant as it grew; the plants were of many kinds, and were altogether 537 in number; and yet the viscid mud was all contained in a breakfast cup!

Considering these facts, I think it would be an inexplicable circumstance if water-birds did not transport seeds of fresh-water plants to vast distances, and if consequently the range of these plants was not very great."

Charles Darwin 1859

The Origin of Species by Means of Natural Selection
reprint edition; Penguin Books, Baltimore 1968, page 377

2020
AQUATIC PLANT SURVEY OF WHITE LAKE

CONTENTS

1. SUMMARY OF CHANGES IN THE WHITE LAKE AQUATIC PLANT COMMUNITY SINCE 1976

The ability to study change over time in the assemblage of aquatic plants on White Lake was made possible by the efforts of L. J. Bond[1] when he published his findings on the observed occurrence and abundance of aquatic plants in the summer of 1976. A survey in the summer of 2020 was conducted to determine what changes occurred in the White Lake aquatic plant community over the previous 44 years. A total of 174 vegetated aquatic sites were visited. These sites were based upon 98 stations that Bond had established. The table below is a summary statement for some of the changes found in 2020. The table is based on the difference in relative frequency of occurrence of aquatic plants. It is evident but not too surprising to see that in 44 years some varieties have disappeared or are in decline while other types have increased their occurrence in the lake. A difference that was less than 5% was regarded as not significant. We were able to add 12 additional aquatic plants to the original Bond list.

COMMON NAME	SPECIES NAME	STATUS and CHANGES SINCE 1976
Richardson's Pondweed	*Potamogeton richardsonii*	The most dominant plant in 2020, major increase
Flat Stem Pondweed	*P. zosteriformnous*	new listing, 2nd dominant type, not seen in 1976
Large Leaf Pondweed	*P. amplifolius*	new listing, low occurrence
Robbin's Pondweed	*P. robinsii*	new listing, low occurrence
Floating Pondweed	*P. natans*	no significant change
White Stem Pondweed	*P. praelongus*	new listing, low occurrence
Variable Pondweed	*P. gramineus*	new listing, low occurrence
Sago pondweed	*Stuckenia pectinata*	severe decline, now rare
Horned pondweed	*Zannichellia palustris*	severe decline, now absent was 2nd dominant 1976
Slender Water Nymph	*Najas flexilis*	no significant change
Northen milfoil	*Myriophyllum sibricum*	decreased occurrence, was most dominant in 1976
Whorled Leaf	*M. verticallatum*	new listing, infrequent occurrence
Eurasian Water Milfoil	*M. spicatum*	new listing, invasive, widely distributed
Wild Celery, Tape Grass	*Vallisneria america*	no significant change
Water Star Grass	*Zosteralla dubia*	no significant change
Canada Waterweed	*Elodea canadensis*	no significant change
Coontail	*Ceratophyllum demersum*	no significant change
Common Bladderwort	*Utricularia vulgaris*	no significant change
Nitella	*Nitella*	new listing
aquatic moss	*Fontinalis*	new listing, in deep water
chara	*chara*	no significant change
White Water Lily	*Nymphaea ordorata*	increased occurrence
Yellow Water Lily	*Nuphar variegata*	no significant change
Star duckweed	*Lemna triscula*	no significant change
Water Marigold	*Megalodonta beckii*	new listing, common occurrence
frogbit	*Limnobium laevigatum*	new listing, rare occurrence
Arrowhead	*Sagittaria spp.*	No significant change
Pickerel Weed	*Pontederia cordata*	new listing
Common Bulrush	*Scirpus validus*	no significant change
Wild Rice	*Zizania aquatica*	increased occurrence

>5% increase occurrence	invasive	>5% decrease occurrence

[1]L.J. Bond, *Ecological Study of White Lake, Renfrew and Lanark Counties 1976*, Lanark District, Ministry of Natural Resources, March, 1977.

Part 1
Aquatic Plant Surveys of White Lake

2. THE 1976 BOND STUDY OF WHITE LAKE

A survey of aquatic plants completed in 1976 remains the only known systematic examination of aquatic macrophytes in White Lake. The authors decided that it was time to repeat and extend the study to document changes in aquatic plant population which have taken place since 1976.

L J. Bond, on behalf the Ministery of Natural Resources conducted an ecological survey of White Lake designed to elucidate the detriorated condition of the White Lake pickerel fisheries. By 1976 the sport pickerel population was reduced to 3% of it's previous stocked levels.[1] Bond examined several factors including lake chemistry, zooplankton, algae, spawning bed sedimentation as well as aquatic macrophytes (aquatic plants). Bond's research concluded that algal growth on shoals deprived pickerel eggs of the necessary oxygen required for their survival. Both this and sedimentation on spawning beds was attributed to a water regulation that maintained high water levels during the summer months. Such high water levels reduced the exposure of shoals to wave scouring that otherwise would suppress the effects of algae and sedimentation. L. J. Bond's conclusions lead to a modification of the water level regime that was controlled by the White Lake Dam. These changes saw a dramatic return in the numbers of age classes for many fish species.The modified drawdown is essentialy what is employed today.

The aquatic plant survey that Bond completed in 1976 drew no immediate conclusion on aquatic weed conditions. Bond stated that as it was the first study of its kind it, could establish a base line for comparisons with future surveys. Bond suggested a longitudinal study with possible surveys undertaken every 5 years. Such an ambitious project would help in understanding the dynamics of aquatic plant communities.

---

[1] H von Rosen White Lake Fisheries Assessment 1989 Fishery Assessment; Ministry of Natural Resources, Carleton Place District.

3. BOND 1976 AQUATIC PLANT SURVEY DESIGN

Bond selected 98 sampling stations spaced roughly ½ mile apart in shallows less than 2 meters deep and off shores that supported marsh environments. The lake was divided into four arbitrary sectors so comparisons could be drawn between different areas within the lake. A breakdown by sector of the 1976 survey year is provided below:

TABLE 1: THE 1976 SURVEY SCHEDULE

Sector #	Sector locations	number of stations (observations)	Observation days	1976 schedule
SECTOR 1	Village basin and part of main basin	23	3	August 9-11
SECTOR 2	Hayes and Banes bays, canal and approaches	24	2	August 17-18
SECTOR 3	Main basin and Pickerel Bay	28	6	August 18-23
SECTOR 4	Main Basin, 3 Mile Bay and Sunset Bay	23	1	August 25

Constraints on time (12 field days, August 9th to August 25th) and the number of sample sites (98) limited the 1976 search effort to a single-site observation at each sampling station. These observations were conducted at the surface by boat. Two graduate students worked a 5 metre radius, presumably the length of the boat employed. Underwater work was not performed. 25 species were identified, including 15 submerged and floating leaf aquatics, and 10 wetland types. The fact 98 stations were examined in such limited time is a tribute to the field effort that Bond made .

3.1 The Lake Couchiching Survey of 1972

Bond used a modified version of a Lake Couchiching Survey completed by M. Jones and D. Veal for the Ontario Ministry of the Environment in 1972.[1] That survey employed teams of divers to examine 86 sampling stations placed approximately 1 mile apart along 28 miles of shoreline. Stations were added in order to find differences in assemblage that could be accounted for by depth. The survey focused only on submerged aquatic types. Twenty different species of submerged aquatic plants were identified, but no attempt was made to record the presence and abundance of wetland plants.

4. 2020 AQUATIC PLANT SURVEY DESIGN

4.1 Aquatic Plants (macrophytes)

Aquatic macrophytes provide many ecological services to a lake. As a refuge for forage fish, a screen for foragers, a nutrient resource for algae, a damper on shoreline erosion, a filter for particulates held in suspension, and importantly a source for storage and release of essential nutrients and the oxygenation of water. They form a major food resource for many species of fish, waterfowl and crustaceans, and have a consequence on recreational hunting and fishing. They form a habitat for invertebrates like snails and larval insects. Since the arrival of zebra mussels in 2016, White Lake aquatic plants also provide an important substrate for the larval pediveliger of the zebra mussel. Aquatic plants like Water Nymph (*Najas flexilis*) provide a firm surface supporting juveniles above soft anoxic sediments. This likely provides the multi-year cohorts that have become a principle source for the shoreward recruitment of zebra mussels that we now see every year.

4.2 Constraints on Aquatic Plants

The primary limit to aquatic plant growth is the depth of water at which an aquatic plant can maintain a balance between photosynthetic carbon gain and respiratory carbon loss. Component wavelengths of light are attenuated by the presence of organic and inorganic matter suspended in the water column. This restricts the ability of a plant to photosynthesize. Light extinction of particular wavelengths that normally support photosynthesis will limit the tolerance of a particular plant by depth. Plants have been described growing at deep depths. Such a situation in a Manitoba lake found freshwater plant communities surviving at a depth of 14 metres (Pip and Simmons 1986[2]). Many of the plant types described at that depth are common to White Lake. However, attenuation effects have restricted their growth to about a third of the depth reported in this Manitoba example. This suggests a potential for White Lake aquatic communities to exploit changes in available radiance of White Lake waters. When we talk of aquatic plants we are usually referring to vascular flowering species. These have evolved from terrestrial ancestors to live in fresh water. There are also non-vascular types such as stonewarts, a form of macro-algae, and aquatic moss. These can be found in conditions that do not support vascular plants and can be expected at greater depths.

[1]M. Jones, D. Veal: Aquatic Plant Growths in Lake Couchiching 1972 Ontario Ministry of the Environment.
[2]Eva Pip, Kent Simmons: Aquatic Angiosperms at Unusual depths in Shoal Lake, Manitoba-Ontario 1985 Can. Field Naturalist.

Many known ecological influencers have arison in Ontario during the last 45 years:

- The effects of a warming climate with increased ice free days.
- Reduction of phosphate and nitrate enrichment through provincial regulation.
- Reduction of acid rain by international agreements.
- Increased shoreline site development.
- Intensified shoreline activity.
- Increased recreational boating activity.
- Increased sport fishing activity.
- Establishment of a water regime for White Lake since 1976.
- Introduction of game fish to the White Lake fishery.
- Introduction of notorious environmental engineers - zebra mussels, Eurasian milfoil and Phragmites.

Internal factors influencing aquatic plants are:

- The dynamics of resource limitation and community competition amongst plants that influence both aquatic plant distribution and abundance in White Lake.
- Competition and Interaction of aquatic plants with the algal community
- Lake morphology has been cited in the literature to have a primary influence on aquatic plant growth.
- Herbivory activity can either limit or spread aquatic plant types.
- Finally, water chemistry will ultimately determine the relative success of a plant community. The alkaline conditions of White Lake present both opportunity and challenge to aquatic plants.

Any or all of these factors have the potential to influence the frequency and abundance of aquatic plants over time with some consequence to the health of White Lake.

4.3 The 2020 Survey Methodology

The Bond study was limited to observations in shallow waters. Researchers have measured the relative success of different survey methods, and have shown a loss of information in surveys based on surface observations alone. Observations of abundace and site richness are significantly improved by in-water examination.[1] All of our observations were made in-water.

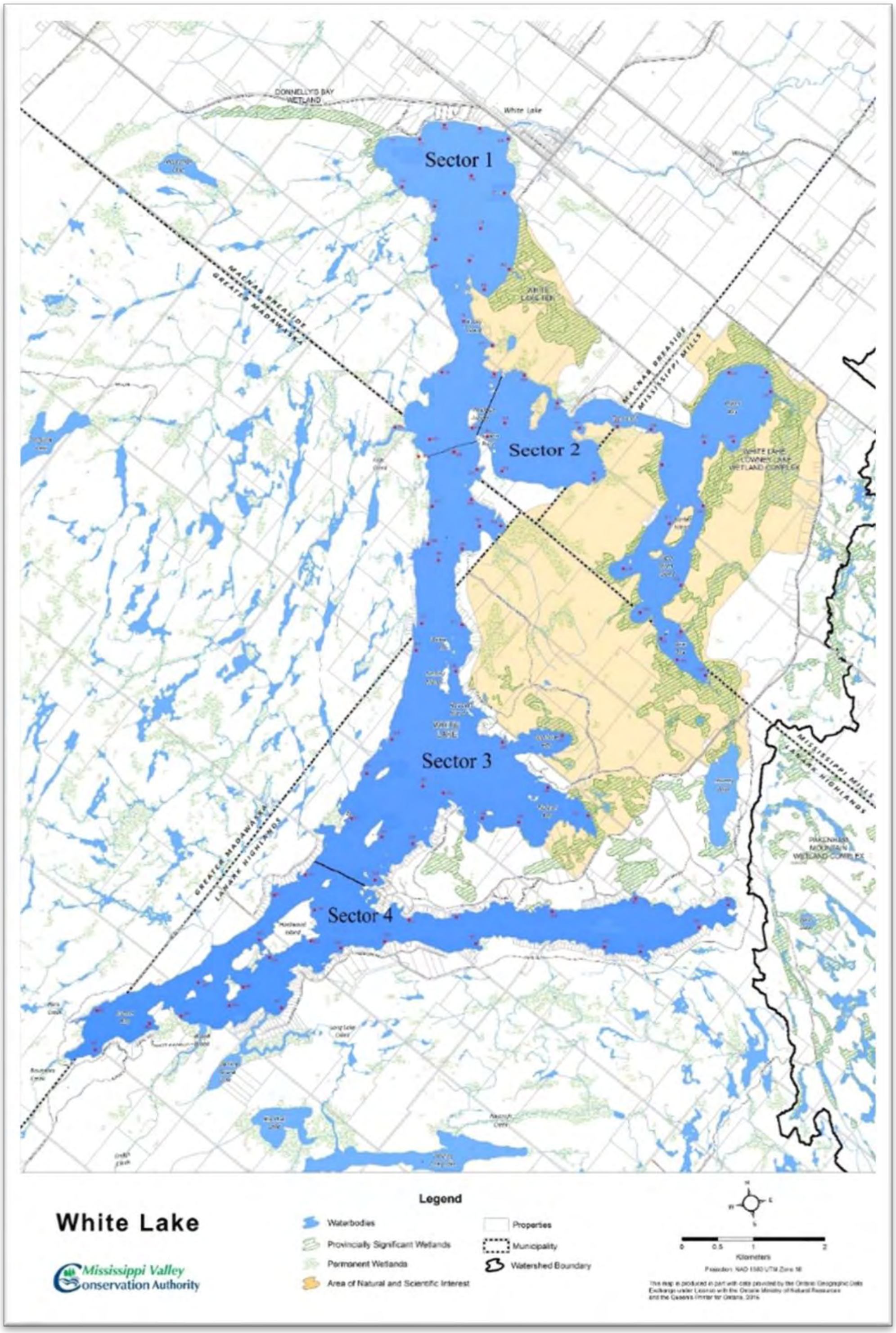
4.3.1 Station Selection

The locations of Bond's 98 stations were determined from a map published in the Bond report. Bond stations were matched from coordinates derived from Google Earthviews and then converted to White Lake GPS coordinates. Earthview images for these locations were provided for sampling stations. The map below is an overall view of the Bond sectors. Enlagements of this map for each sector showing the individual sampling stations can be found in the appendix.

---

[1] Rober S Capers: A Comparison of Two Sampling Techniques in the Study of Submerged Macrophyte Richness and Abundance Aquatic Botany 68 (2000) 87-92.

Map 1: Arbitrary Sectors Used by Bond and for the 2020 Surveys



4.3.2 Standardized Depth Sampling

We distinguish 'sampling station' as a location designated by Bond. However each sampling station was examined at selected depths whenever this was possible. Sampling stations could include the inshore (<2metre), 2 metre , 4 metre, 4.5 metre, and an occassional depth at >4.5 metres, so each station can be described by 4 sites. Sites were determined by a diver deploying an adjustable fixed line float. Coordinates for each site were recorded on the field sheet of that station.

Adjustable fixed line floats were used in order to standardize water depth to correspond to the drawdown of the lake during the sampling period. Tracking changes in water level at the White Lake dam allowed us to compensate for changes in depth. Our earliest record, July 7 (day 188) and last record, September 21st (day 264), cover a period when lake levels fell by 18 cm. This covers the 20 cm compensation range we used in the field.

Standardizing depth measurements to the late summer drawdown correspond to optimum conditions for light penetration and water temperatures that support maximum growth conditions during the late summer. Most plant studies seek the maximum frequency of occurrence and abundance of aquatic plants and focus their work on this late summer period. For longitudinal studies it is important to be able to carry forward standardized depths for making equivalent observatons in future sampling programs.

The individual search areas at each site had a radius of 5 metres around each depolyed buoy. Multiple schnorkel dives were necessary to complete the coverage of a single area.

4.3.3 Field Recording

Recording the presence and abundance of plants was carried out in-situ by using a soft lead pencil and a linoleum tile as a writing slate. Photo records using an inexpensive underwater camera (Fuji XP120) recorded ancillary information. All observations were compiled on wateprooof field sheets.
Each field sheet comprised a single sampling station.The record of occurrence and abundance associated with each plant type was recorded according to it's sample site at each station. Each field sheet represented several sites determined by depth, as an "inshore" or <2 metres, a 2 metre, 4 metre, 4.5 metre and sometimes a >4.5 metre site when necessary.

4.3.4 Recording Aquatic Plant Abundance

Our subjective abundance values are estimations for each plant type we encountered using a criteria proscribed by both the Bond and the Jones and Veal studies. The table below lists the evaluations that were applied in our study.

TABLE 2: FIELD EVALUATION FOR OBSERVED AQUATIC PLANTS

#1 HEAVY GROWTH (dense) Plants form continuous coverage over the sample area, little space between individuals.
#2 MODERATE GROWTH plants occur in dense patches or clumps with spaces between the clumps
#3 SCATTERED GROWTH Plants have varying distances between individuals. Infrequent dense clump. More than 15 plants
#4 OCCASIONAL GROWTH (sparse) Plants are not common, usually less than 15 individuals are present

M. Jones D. Veal 1972 AQUATIC PLANTS IN LAKE COUCHICHING p.5

We recorded some additional information that was not part of the original Bond study:

- A shore assessement as the percentage of undisturbed or disturbed plant cover. We found nearly all stations selected by Bond were associated with marshy environments. These shorelines are regarded as undisturbed cases.
- Benthic filamentous algae was recorded by appearance: as a "mat" covering bottom vegetation, as "clouds" of filamentous algae rising above the bottom, or as "draped" over macrophyte canopies.

4.3.5 Determining Sites that are within the Littoral Zone

A total of 207 observations were made in 2020. Twenty-eight littoral non-vegetated stations were included in our study as their shallow depths excluded solar radiation to be a limiting factor in explaining a lack of vegetation cover. Five stations were located in deeper waters and as such were un-vegetated. These stations were removed from further analysis as it is the change in plant cover within the littoral zone that interested us. The remaining 174 sites were vegetated, each bearing at least one plant type. This number (174) is used to form estimates on the percentage of occurrence and abundance for each plant type in White Lake. The percent occurrence for individual plants are included in the section covering White Lake plant types in section B.

Table 3 breaks down our 2020 observations according to the presence of plant cover. Ten dives were made in waters deeper than 4 metres in order to determine the depth of the vegetated zone.

TABLE 3: 2020 Survey Breakdown of Vegetated and Unvegetated Sites

SECTORS	2020 survey	vegetated	unvegetated	all
sector 1	depth <2m	21	1	22
	2m	4	0	4
	4m	4	0	4
	4.5m	0	0	0
sector 2	depth <2m	23	2	25
	2m	2	0	2
	4m	0	0	0
	4.5m	0	0	0
sector 3	depth <2m	22	2	24
	2m	19	4	23
	4m	16	7	23
	4.5m	0	3	3
	>4.5M	1	6	7
sector 4	depth <2m	23	1	24
	2m	22	1	23
	4m	17	6	23
	4.5m	0	0	0
ALL SECTORS	depth <2m	89	6	95
	2m	47	5	52
	4m	37	13	50
	4.5m	0	3	3
	>4.5m	1	6	7
	total sites	174	33	207

4.3.6 Reconciliation of Non-vegetated Stations Between the Survey Years

For both surveys not all stations proved to be under a vegetation cover. The following table compares the occurrence of non-vegetated stations as reported in the two surveys.

TABLE 4: Stations Reporting No Vegetation Cover

1976	2020	Likely cause	Depth,m
	#104	anomaly	1.4
#203		anomaly	2
	#210	anomaly	1.7
#301	#301	depth	5.6
#302		anomaly	0.5
	#303	anomaly	precipice
#309	#309	depth	6.3
#310		anomaly	2
#311		anomaly	3.6
#320		anomaly	6m
#321	#321	depth	8m
	#322	depth	7m
#403		misidentified	3m

Four stations had no aquatic plants as a consequence of their location in deep waters. Three of the 2020 stations are in agreement with Bond's observation of a lack of cover. Station #322 reported in 1976 the presence of Richardson's Pondweed. This is retained for the purpose of percentage estimates for 1976 although the indicated map location would place it in deep waters. No cover was found at that location in 2020. It is suspected this station was located nearer to the shore than indicated on Bond's map.

Station #320 had no plant cover in 1976. However we found plant cover at 2 and 4 metre depths. This difference might also be explained as an error in site location or to inferior visibility.

Station #403 in the above table is in less than 4 metres of water and well within the littoral zone. It proved to be a very productive site in our 2020 survey. However, it was characterized as completely unvegetated in 1976. This must represent observer error. Our 2020 observations are retained for our percentage calculations but not included in calculating 1976 percentages to reduce underestimating the 1976 data.

For the remaining 13 unvegetated stations, 7 are in shallow waters. These may represent localized and on-going fluctuations within the vegetaton cover between study years.

5. LAKE MORPHOLOGY

A shallow basin morphology can subject aquatic plants to vigorous energetic wave action and the scouring effects of lake ice. The fetch of a lake orientated to prevailing wind conditions will expose aquatic plants to energetic action unless structures are present such as islands and shoals that can absorb their impacts. Added to this is the energetic wake created by recreational watercraft.

5.1 Sectors 1 and 2: 9.77 km²

These sectors represent 29% of the open surface area of White Lake waters. They encompass the greatest contiguous areas of shallow waters for the entire lake.

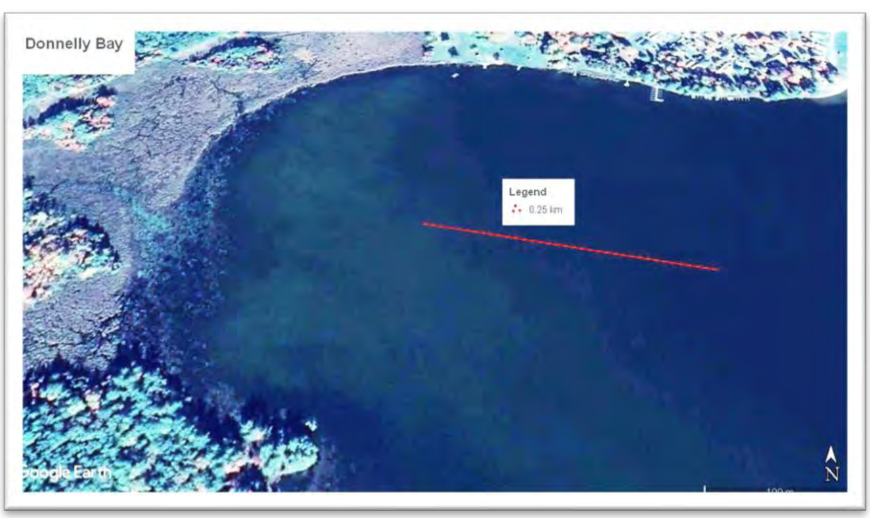
Sector 1 had only 4 stations associated with depths to 2 metres, and another 4 stations with depths of 4 metres. These deeper sites are situated outside the Village Basin proper. As such they are part of the contiguous main body of the lake. Sector 2 has 2 deep stations not associated with the Hayes Bay-Bane Bay basins. 55 observations were made in sectors 1 and 2. 44 lay within the Village Basin, Hayes Bay and Bane Bay complex, all at depths less than 2 metres. Although these areas are very much a part of integral White Lake, to a degree they operate as separate bodies of water having a reduced interaction with the main body of the lake.They are influenced by groundwater inputs supporting a rich calcareous environment . These properties have an influence on the submerged vegetation to be found there.

5.2 Morphology of the Village Basin: 3.13 km²

The Village Basin has been known to have formed marl deposits over the centuries by the precipitation of calcium carbonate from groundwater sources. These features can be distinctive benches that are indicative of marl formations. The Village Basin with its fens along with Hayes and Bane Bays are under the influence of groundwater varying in its concentration of calcium carbonate carried in solution.

The Village Basin near White Lake Village once held logs retained in bag booms. Remnants of the forest harvest can still be seen in numerous large logs on the bottom. Undecomposed wood detritus, mainly tree bark, has created a hardened substrate that does not support aquatic vegetation.

Donnellys Bay forms a large area of exremely shallow water that once was the entrance to an ancient spillway. The photo below shows lightened areas where water is less than 0.5 metres (scale 0.25 km) in depth.



5.3 Morphology of Hayes and Bane Bays: 2.85 km²

Hayes and Bane Bays comprise 14% of the open surface area of White Lake. Well established within the littoral zone these basins are markedly lacking in any extensive submerged aquatic plant cover. Hayes and Banes were defined by 15 aquatic types. Only four of these types offered a high density rating and this at only 4 locations. These are Richardson's Pondweed, Northern Milfoil, Bladderwort and Chara.

5.4 Possible influencers on aquatic macrophytes in the shallow basins of Hayes and Banes Bay

Shallow basins like Hayes and Banes are subject to ice and boat scouring. This can disrupt the cover normally associated with inshore plant growth. The images below illustrate the shallow nature of Hayes and Bane Basins. Scour lines from boating activity are clearly evident in the soft sediment.

Hayes Bay, north end: October 2019

Bane Bay, south end: October 2019

The sediment of the substrate when particulate size is too fine can prevent roots of certain plants from taking a firm hold. Research has indicated sediment texture can have a greater inflence than sediment chemistry in determining plant growth[1]. In Hayes and Bane Bays the presence of Richardson's Pondweed is a frequent submerged type. This suggests that particle size is not particularly restrictive to plants.

Aquatic plants have unique systems to support carbon utlization. Chief amongst these is utilizing alternative carbon sources. Aquatic plants utilize free aqueous CO_2 as a souce for carbon but they must overcome lower rates of diffusion and boundary layer effects which generates resistence to the transport of dissolved gases. This has been described as a bottleneck limiting the ability of aquatic plants to fix carbon.[2] By accessing carbolic acid (HCO_3^-) aquatic plants adapt the diffusion boundary layer to augment CO_2 aquisiton. Certain plants utilize a mechanism of "protonation" or the hydrolysis of water, whereby hydrogen ions are made available to transport carbon molecules to translocation sites on leaf surfaces.[3] This ability makes use of the alkalinity of lakes like White Lake where calcium carbonate is found in abundance. Various autotrophs from bacteria, algae and aquatic plants such as chara and Richardsons pondweed can live on this process. The degree of carbonate use varies between species and not every aquatic type will benefit from it.

---

[1] Z Qui et al. Effects of Substrate Grain Size on the Growth and Morphology of the Submerged Macropphyte Vallisneria natans Limnologica 2011.

[2] Ole Pedersen, T D Colmer, K Sand-Jensen; Underwater Photosynthesis of Submerged Plants- Recent Advances and Methods Frontiers in Plant Science 21 May 2013.

[3] Ted McConnaughey; Acid Secretion, Calcificaton, and Photosynthetis Carbon Concentrating Mechanisms Canadian Journal of Botany 1998 76:1119-1126.

Fen environments themselves are not considered nutrient deficient. However calcium readily bonds to many essential nutrients. Thus phosphorus, iron, sodium, magnesium can be made less available to wetland plants. This co-precipitation of essential elements can limit the type of plant growing within a fen. Referred to as "poor fens" these become habitats that favour a proportionately higher number of rare plant species[1]. The "poor fen" classification has been applied by Vivian R Brownell to some White lake fen habitats adjacent to the Village Basin .[2] This co-precipitation of nutrients will have some influence on submerged aquatic plants as well.

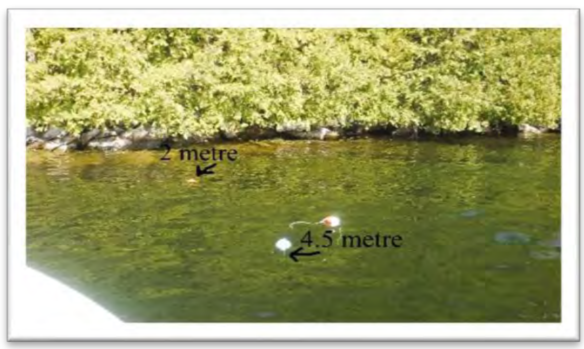
5.5 Morphology of Sector 3: 4.13 km^2

Research on other lakes has indicated that the morphology of relatively shallow temperate lakes has an influence on the production of aquatic plant biomass. Littoral slope influences sediment deposition with increasing slope adversely affecting plant biomass.[3]

Our 2020 study shows sections of shoreline in Sector 3 and in particular Pickerel Bay exhibiting examples of loss in plant cover where slope becomes excessive. These photos show the displacements of the 2 metre and 4 metre buoys over a 5-metre distance approximating a 40% slope. The underwater vegetation at these sites was virtually nil as no sediment can accumulate to support aquatic plant life. The slope continued beyond the photic zone for plant growth.

SECTOR 3 STATION 324

SECTOR 3 STATION 304

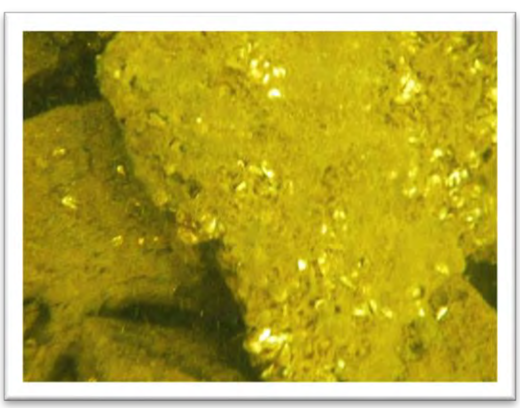


[1] Paul Keddy WETLAND ECOLOG:Y Principles and Conservation 2014, pg 105.
[2] Vivian R Bownell 2001 A Biological Inventory and Evaluation of the White Lake Study Area, Eastern Ontario MNRF kemptville District Office.
[3] C M Duarte and J Kalff Influence of Lake Morphology on the Response of Submerged Macrophytes to Sediment Fertiization Canadian Journal ofFish and aquatic Science Vol45 1988.

STATION 304 4 METRES

Pickerel Bay has many rocky shoals at varying depths and reduced slopes that were barren of aquatic plants. The examples below show the entrance to Eggshape Bay taken at several depths.

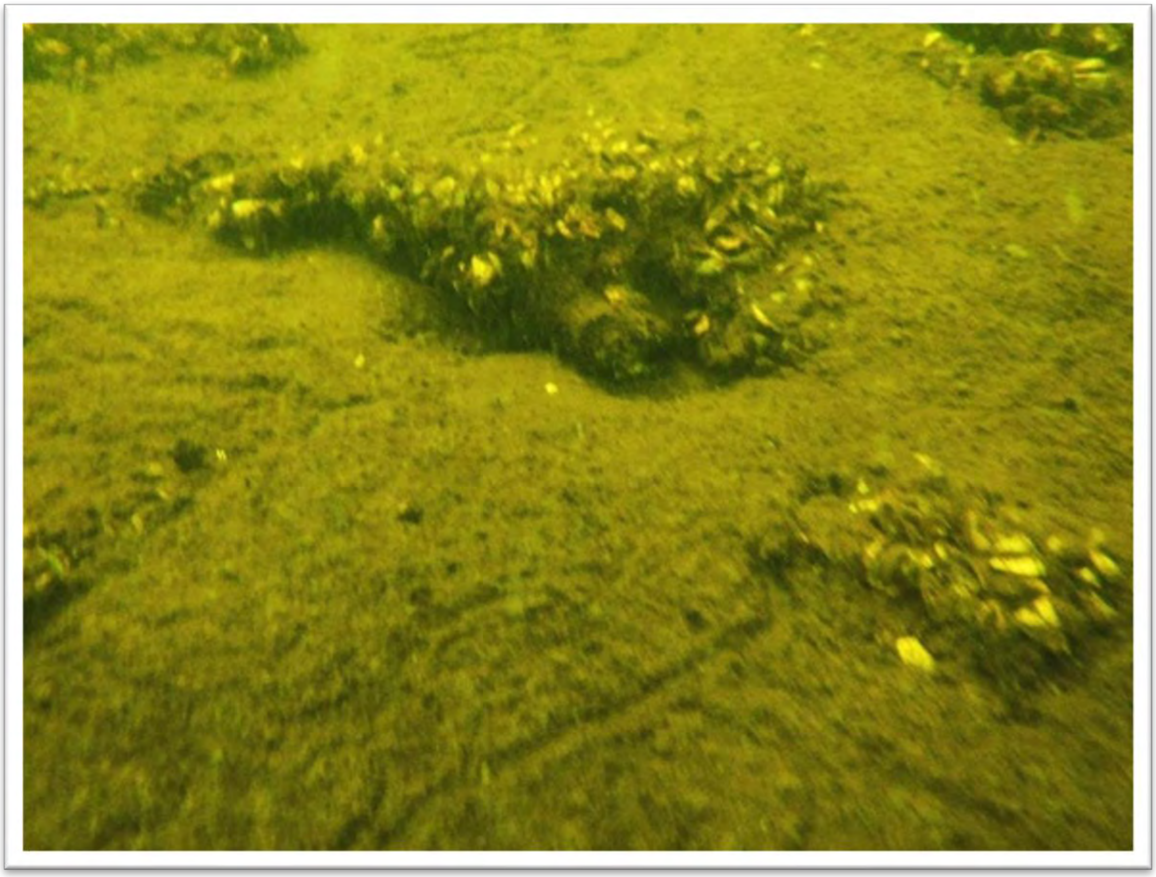
SITE 328 2 metres



SITE 328 4 metres

SITE 328   4.5 metre

Accumulated sediments at depth with no aquatic vegetation. Tracks of the Banded Mystery Snail can be seen in the sediment.



Sectors 3 and 4 encompass the main body of the lake representing 49 kms of shoreline. Large sections of associated littoral form steep slopes that run to deeper non vegetated waters. Aquatic plants form ribbons of growth that cross this gradient. However these same sectors also include many pocket marshes of various sizes and these do support rich aquatic plant growth. Examples of high site richness can be found there.

5.6 Morphology of Sector 4 and Three Mile Bay: 6.52 km^2

Sector 4 excluding its islands comprises 6 square kilometers of open water of which Three Mile Bay represents a third of the area. Three Mile Bay In many ways is different from Pickerel Bay. Along the southern shore towards the western entrance to the lake, the littoral zone drops quickly to 5 metres. It has a restricted littoral area to support plant growth. But for much of the bay littoral depth is unrestricted. The north shore has many shallow coves with depths of 2 to 3 metres. All of these support a complete coverage by aquatic plants. The main axis of the Bay running from east to west has a length of 4.8 kms. The associated gradient over this distance is barely distinguishable. Water depths standardized to the late summer draw-down range from 0.5 metres at the eastern extremity to just 5.5 metres at the western end. About half of the bay supports a vegetation cover over the entire width of the basin. This must represent the area with the highest productivity for the entire lake.

5.7 Relationship of Shoreline Length to Lake Area

A point of interest to lake ecologists is the nature of the food web that exists between a lake's littoral and pelagic zones. Lakes can be assessed by using an index. A Shore Line Development Index is derived by the measured shore length compared to the length required to encircle an equivalent surface area.

A lake nearing perfect circularity approaches the minimum index value of 1. Shorelines as they become complex have increasing index values. The table below breaks down White Lake into component areas. Published estimates have given the surface area of White Lake to be 2249.5 ha or 22.5 km^2 with a shore length of 97.9km. (Mathers and Kerr 1989[1]). This is a close fit to measurements made with Google photo imagery: 22.29 km^2 (if island areas are not removed) and a shoreline length of 99.61 km when island shore lengths are included.

TABLE 5: THE WHITE LAKE BASIN OPEN WATER AREAS and SHORELINE LENGTH

SECTOR and MAIN BASIN	AREA km^2	SHORE Km		ISLANDS	AREA km^2	SHORE km
1a: VILLAGE BASIN	3.13	7.48		Hardwood	0.41	4.59
1b: sub-sector	1.6	5.73		Isle #1	0.01	0.38
SECTOR 1: all	**4.73**	**13.21**		isle #2	0.01	0.48
2a: CANAL and APPROACHES	2.19	8.34		Isle #3	0.03	1.05
2b: HAYES and BANE	2.85	11.31		Bog	0.01	0.42
SECTOR 2: all	**5.04**	**19.65**		Ross	<0.01	0.22
3a: Pickerel Bay	1.87	7.48		Avalon	<0.01	0.21
Sector 3b: main basin	4.13	16.48		Isle #4	<0.01	0.17
SECTOR 3: all	**6**	**23.96**		Isle #5	<0.01	0.1
4a: Three Mile Bay	2.42	12.39		Birch	0.04	1.06
Sector 4b: main basin	4.1	13.8		Barry	0.02	0.77
SECTOR 4: all	**6.52**	**26.19**		Curley	0.01	0.6
White Lake Basin: 1b,3b,4b	12.7	47.30		Howard	0.03	0.31
				Stanley	1.03	0.91
White Lake: All Sectors	**22.29**	**83.01**		Waba	0.01	0.44
				Deadman	<0.01	0.09
				Andrew	0.03	0.62
				Jacob	<.01	0.15
				Myrtle	<.01	0.3
				Russell	0.08	1.43
Island areas and perimeters	1.86	16.6		Barber	0.12	1.58
				Little Birch	0.02	0.59
OPEN WATER AREA and PERIMETER:				Kitty	<0.01	0.13
(- Isle areas, + Isle perimeters)	**20.43**	**99.61**		**total isles**	**1.86**	**16.6**

From the above table an Index of Development can be calculated for White Lake[2]:

Index of Development[1]: $DI = L_{lake} / 2 \sqrt{(\Pi \cdot A_{lake\ area})}$

DI White Lake = 6.2

[1] A Mathers and S J Kerr 1989; The Fishery of White Lake; Technical Report TR-107, Southcentral Sciences Section, Ontario Ministry of Natural Resources, Kemptville, ON 31p. 1998.

[2] Wetzel, R.G.; LIMNOLOGY; W.B. Sunders Co., pub, Toronto, 1975 pg. 31.

The Index of Development for White Lake would be 4.96 if islands were ignored. It becomes 6.22 when they are included. That is, the total shoreline length when treated as a a perfect circumference would need to contain an area that is 6.2 times greater than the present water surface area.

Lake morphology possessing an increased index value is thought to exhibit an influence on predator-prey interactions in exchanges between littoral and pelagic regions within a lake. The index has been used to predict changes in predation patterns of game fish challenged by the increased complexity of littoral shoreline morphology. In turn this has an affect on the trophic relationship between ecological zones[1]. The above has been a feature attributed to oligotrophic systems however the index might be considered as a proxy for some of the influence aquatic plants have on lakes of similar areas but posessing very different indices. The productivity of the shallow areas of the littoral zone extending from the shore to 2 metres in depth may potentially have a greater significance in lakes with large D.I. values.
We might ask whether we can expect relatively more trophic interactions to be occuring in such lakes relative to their areas as their morphological gradients will be related to the D.I. index.

5.8 Bond Survey Analysis

Two types of estimates are employed in the Bond and Couchiching analysis. These are "Frequency of Occurrence" and "Frequency of Abundance". It is theoretically possible for a plant to appear with a low or 'sparce' abundance, and be observed at every site that one visits.This would give an evaluation of a sparse abundance rating 100% of the time with a frequency of occurrence rating of 100%, as the plant was found in all 174 sites. The opposite extreme would be a plant whose frequency of occurrence is less than 1% for all sites but it occurrs with a maximum abundance rating of 1 or 'dense'. We might conjecture such a situation to be a newly introduced plant in an early stage of invasion or perhaps the opposite: a plant that is struggling to survive under some limiting condition. This may be the case for Sago Pondweed in White Lake.

6. AQUATIC PLANT FIELD LIST

The list[2] of aquatic plant species was built upon the one employed by Bond in 1976. Several additions were made as new species were observed in the field.

Table 6 lists species identified in the field in 1976 and 2020. For both surveys, marsh plants under represent the marsh lands. Our study concentrates on submerged emergent and floating leaf types and avoids observations which could skew frequency and abundance comparisons for aquatic plants. This appears to have been a concern of the Bond report as well. We use the term TYPE and do not presume a taxonomic expertise. The use of TYPE allows some ecological observations to be made while acknowledging the morphological plasticity or 'heterophylly' of aquatic plants; a "taxonomic chaos" that faces every observer![3] For example Sagittaria is identified as two species by Bond; *S. graminea* or "Arrowhead" and *S. latifolia* or "swamp potato", but accounts for only 4 cases in 1976. We combined our 2020 data under the genus "Sagittaria" and refer to it as the type "arrowhead" on the understanding the speciation present in Sagittaria is likely greater than these two particular forms.

[1] Schindler D.E. 2002 Habitat Coupling in Lake Ecosystems; OIKOS 98:177-189.
[2] With the assistance of J.-P. Thonney; personal communication.
[3] Robert G. Wetzel 1975: Limnology: p364: see "heterophylly".

TABLE 6: FIELD LIST OF AQUATIC PLANTS IDENTIFIED IN FIELD

x: plant type present in the survey year

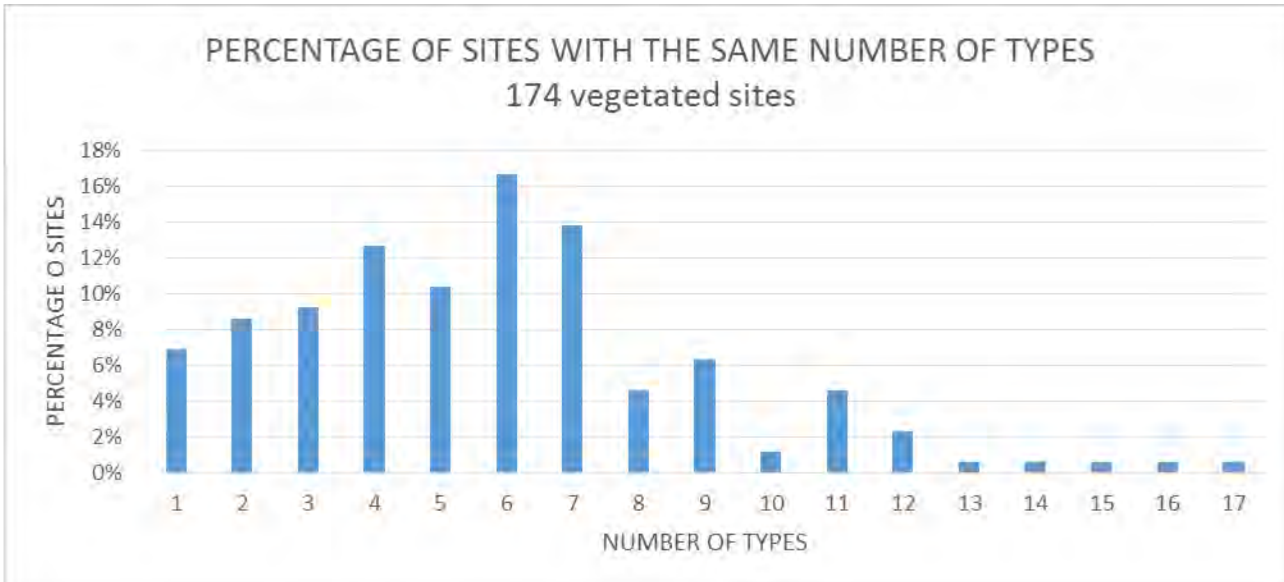
TYPE	SPECIES	2020	1976
SUBMERGED and FLOATING LEAF			
chara	chara	x	
Nitella	Nitella	X	
aquatic moss	Fontinalis	X	
Richardsons Pondweed	Potamogeton richardsonii	x	x
Large Leaf Pondweed	P. amplifolius	x	
Robbins Pondweed	P.Probinsii	x	
Floating Pondweed	P. natans	x	x
Flat Stemmed Pondweed	P. zosteriformnous	x	
Sago pondweed	Stuckenia pectinata	x	x
Variable Pondweed	P. gramineus	X	
White stem Pondweed	P. praelongus	X	
Horned pondweed			X
Slender Water Nymph	Najas flexilis	x	x
Northen milfoiil (“milfoil”-Bond)	M. sibricum	x	x
Eurasian rmilfoil	M. s picatum	X	
Whorled Leaf rmilfoil(	M. verticallatum	x	X
Common Bladderwort	Utricularia vulgaris	x	x
Tape Grass	Vallisneria america	x	x
Canada Waterweed	Elodea canadensis	x	x
Coontail	Ceratophyllum demersum	x	x
Water Star Grass	Zosteralla dubia	x	x
White Water Lily	Nymphaea ordorata	x	x
Yellow Water Lily	Nuphar variegata	x	x
Star duckweed	Lemna triscula	x	x
Water Marigold	Megalodonta beckii	X	
frogbit	Limnobium laevigatum	X	
EMERGENT			
Arrowhead	Graminea latifolia	x	x
Pickerel Weed	Pontederia cordata	x	
Common Bullrush	Scirpus validus	x	x
Wild Rice	Zizania aquatica	x	x

TYPE	SPECIES	2020	1976
WETLAND TYPES			
Bur Reed	Sparganium	x	x
American Reed	Phragmites a. americanus	x	x
Eurasian Common reed*	Phragmites a. australis	X	
cattail	Typha latifolia	x	x
Sweet Gale	Myrica gale	x	x
Bushy Cinquefoil	Potentilla palustris	X	
Soft rush	Juncus effusus		X
Water Arum	Calla palustris	?	?
water smartweed	Acorus calamus	x	
marsh fern	Thelypteris palustris	X	
swamp milkweed	Asclepias incarnata	X	

7. 2020: SITE RICHNESS

Site richness is simply the number of different aquatic plant types found at a given site. The following graph illustrates that few sites contain a large type count, the maximum being 17 at site 412. Sites with 10 or more types represent 11% of all vegetated sites surveyed in the lake. The remaining 89% of sites had 9 or fewer co-occurring types.

FIGURE 1

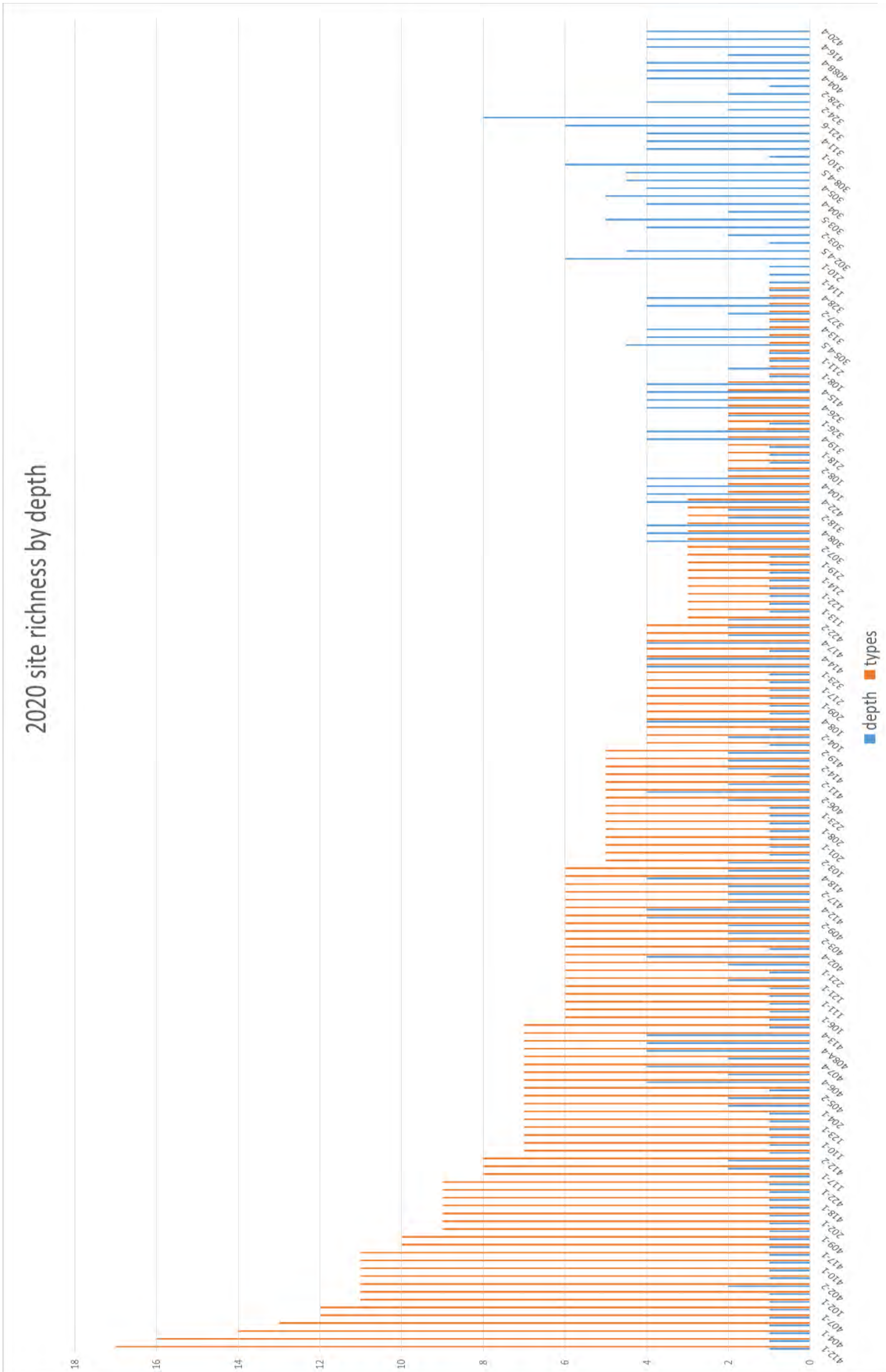


The following graph shows site richness for the entire lake as the number of types which occur at each site (orange bars) and the depth at which they were found (blue bars). This gives the magnitude of site richness and the influence of water depth.

Fifteen sites reported more than 10 types. All but one of these were in waters less than 2 metres deep. Of these fifteen sites, eleven are from Sector 4. This indicates that Sector 4 of White Lake contains the greatest variety of submerged aquatic plant assemblages. It must be noted that Hardwood Island contributed four of these species-rich sites.

Islands with low occupancy, lower land use and with features offering morphological buffers serve to preserve and protect site richness of aquatic plants.

FIGURE 2-1: 2020 SITE RICHNESS WITH DEPTH, ALL SECTORS



Site richness in an undisturbed context represents some influence of morphological features that support and maintain richness. However, pertinent to this study are results from a Conneticut survey of 99 lakes. It was found that species richness in these lakes was positively influenced by human interaction attributed to recreational use and land occupancy. In other words, increased richness might be an expression of the impact from human agency operating beyond natural processes. It was noted that both native and invasive species responded similarily to disturbance as both groups of plants were being spread by similar processes. The implication for White Lake is that positive change in site richness over long periods may in part be the influence of human activity.[1] The current spread of the invasive European Watermilfoil adds to site richness but will over time establish high density cells, and these can reduce the diversity of our native species with follow-on consequences for faunal species richness.

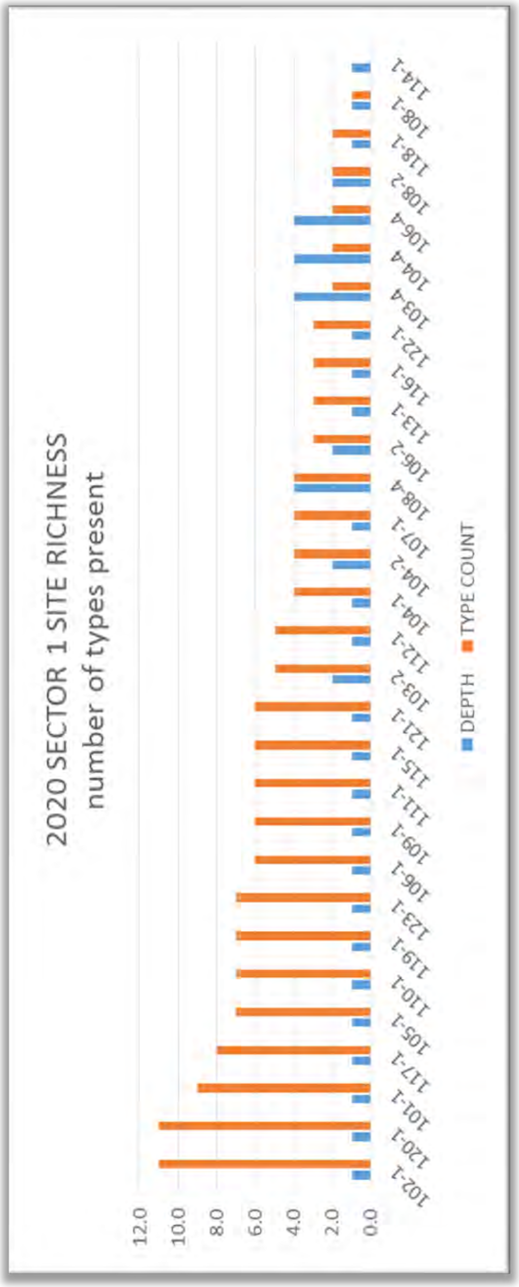
---

[1] R.S. Capers, R Selsky, J Bugbee, J White: Species Richness of Both Native and Invasive Aquatic Plants Influenced by Environmental Conditions and Human Activity Botany: 87: 306-314 (2009).

7.1 Site Richness by Sector

The following four charts represent site richness for each sector. They show that regardless the number of plant types present, site richness follows a similar pattern, with a few sites yielding a high number of aquatic types but the majority of sites with half their number a best.

FIGURE 2-2: 2020 SITE RICHNESS WITH DEPTH SECTORS 1 and 2



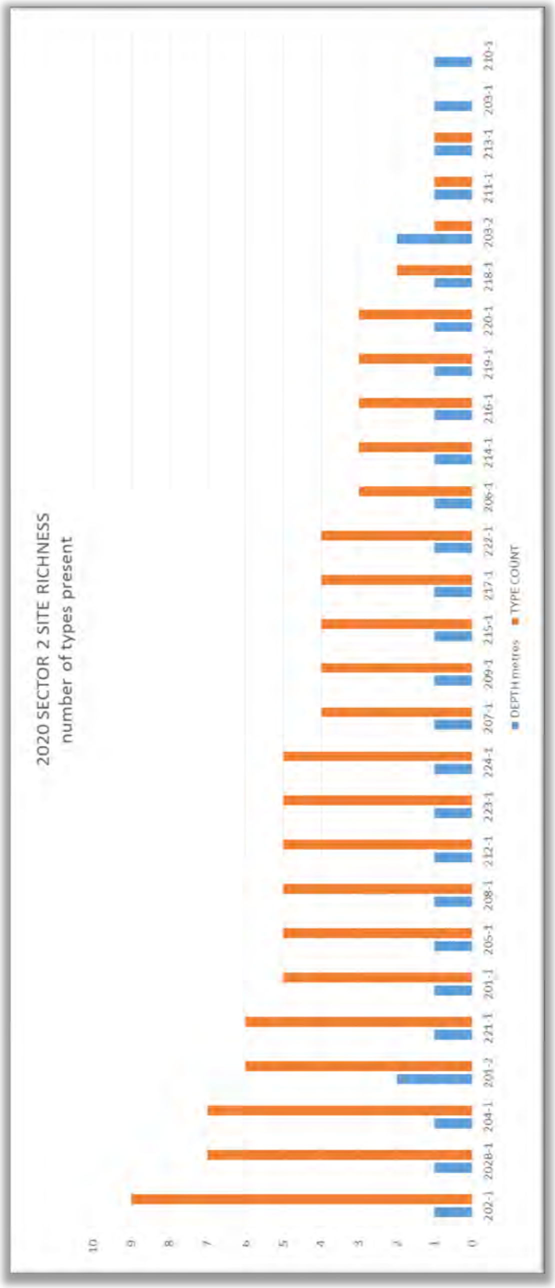
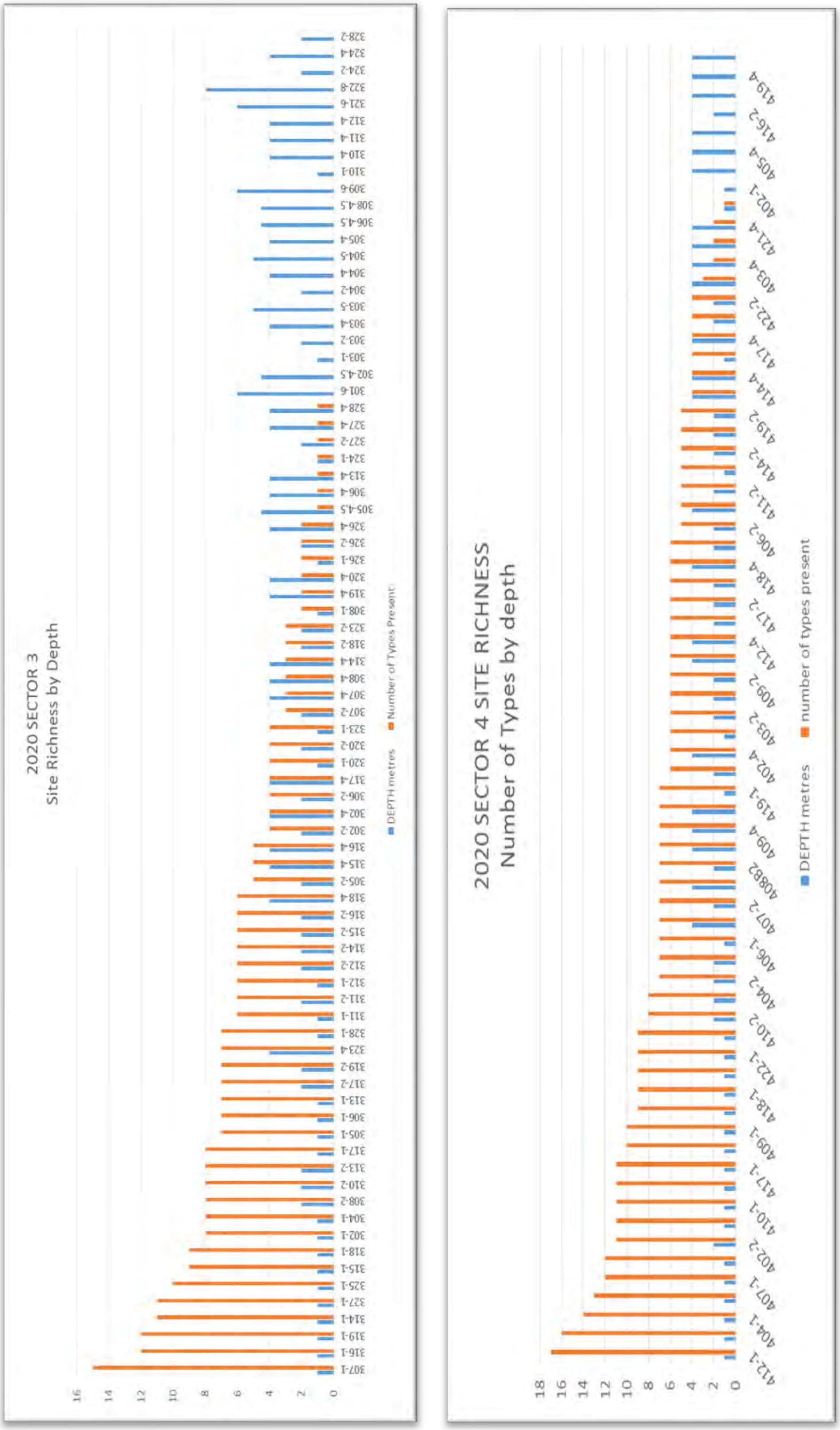


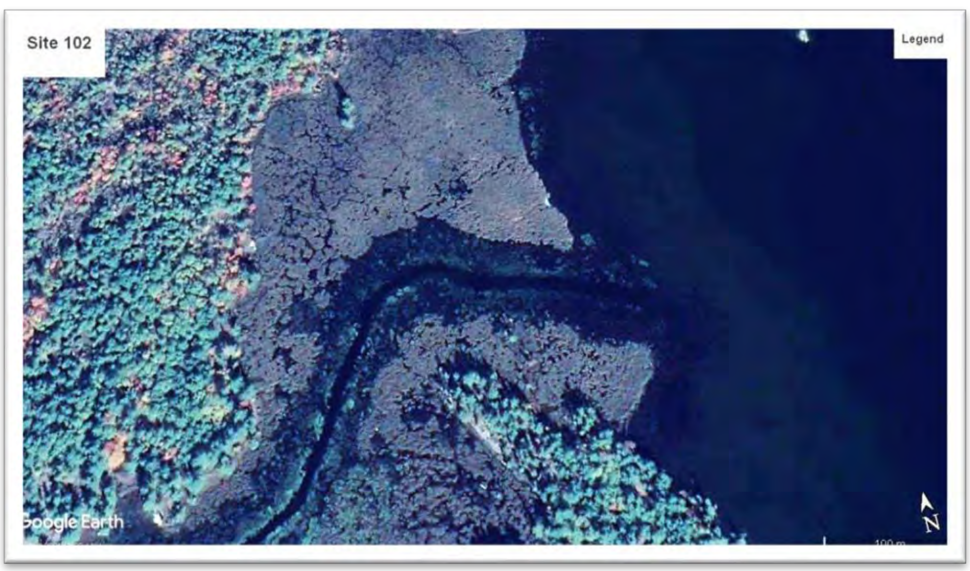
FIGURE 2-3: 2020 SITE RICHNESS WITH DEPTH SECTORS 3 and 4



7.2 Examples of Sites with Maximum Richness in each Sector

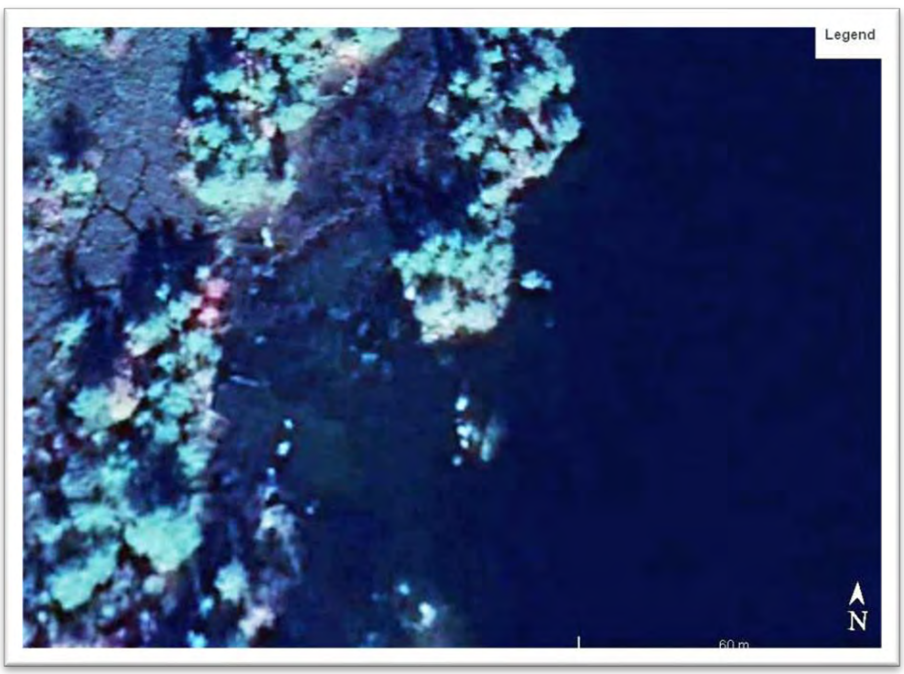
These photos illustrate the morphological benefits that provide protection of site richness. Site 102 receives protection at the confluence with a stream. Site 202 is protected by an island. Site 307 has an underwater barrier of bedrock while site 412, our richest site, is an inconspicuous pocket marsh on the leeward side of an island.

SECTOR 1, SITE 102
Approaches to Fish Creek, 11 aquatic types

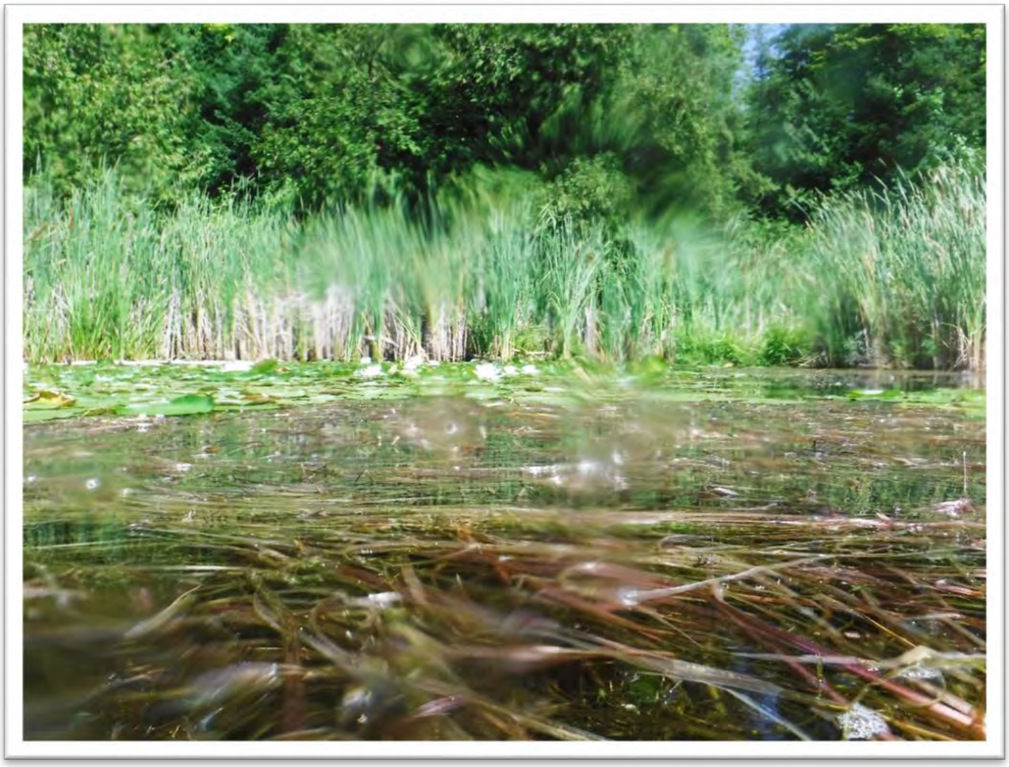


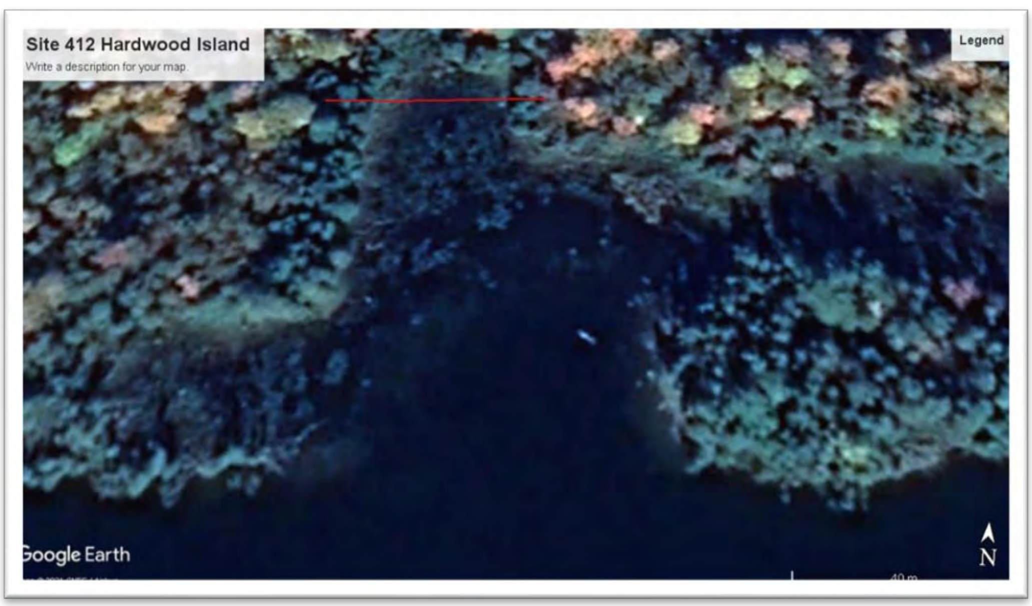
SECTOR 2, SITE 202
Isle Protection, 9 aquatic types

SECTOR 3, SITE 307
barrier protection, 15 aquatic types



SECTOR 4, SITE 412
Hardwood Island pocket marsh, 17 aquatic types





8. 2020: ABUNDANCE OF AQUATIC PLANTS

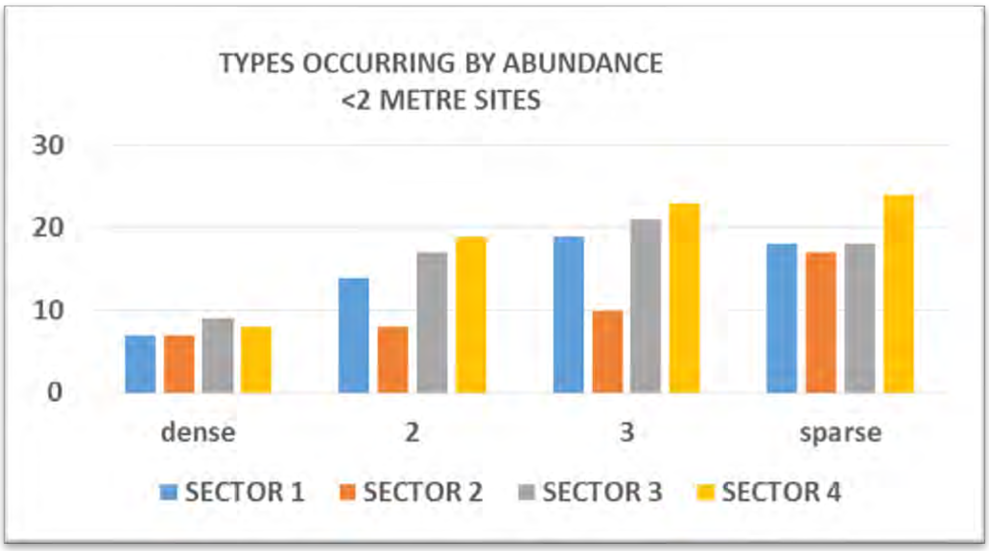
Potamgeton ampliflolius **Fish Creek August 23 2020 C. Grégoire**

8.1 2020: Variation in Occurrence of Plant Types – by Sector

Excluding Fontinalis, there were 29 different types of aquatic plants identified in White Lake. These vary in occurrence by depth, abundance and location. The following graphs and table show these variations.

Sector 2, which includes the approaches to the Channel, the Canal, Hayes and Bane Bays, has the least variety of aquatic types present (orange bars). At 2 metres we see that Sectors 3 and 4 are matched by the number of different types present(grey and yellow bars). As anticipated from the above site richness graphs, there are fewer varietes that occur as dense in all sectors. At 4 metres very few types contribute to a high density valuation.

FIGURES 3-1, 3-2



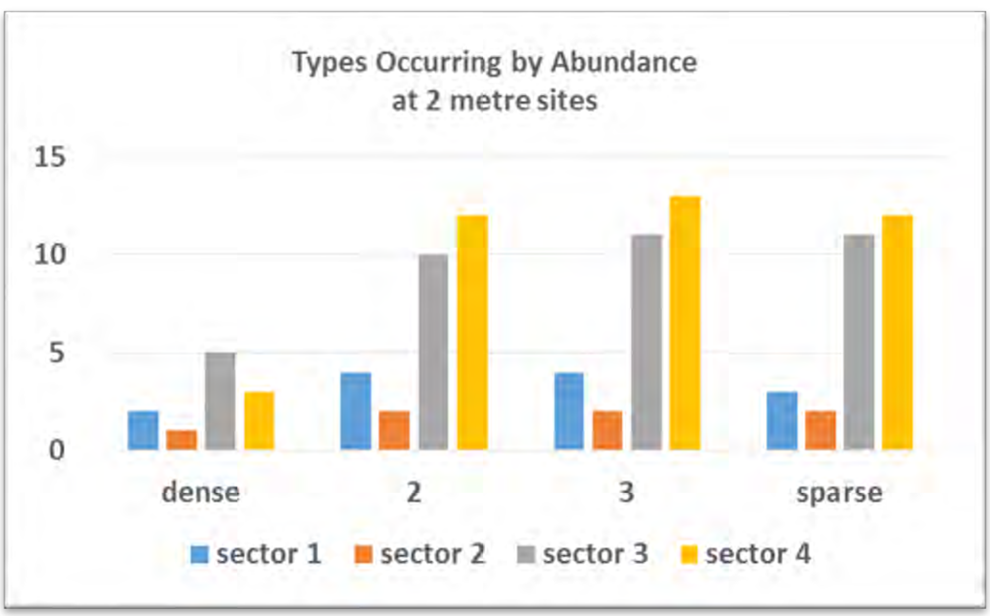


FIGURE 3-3

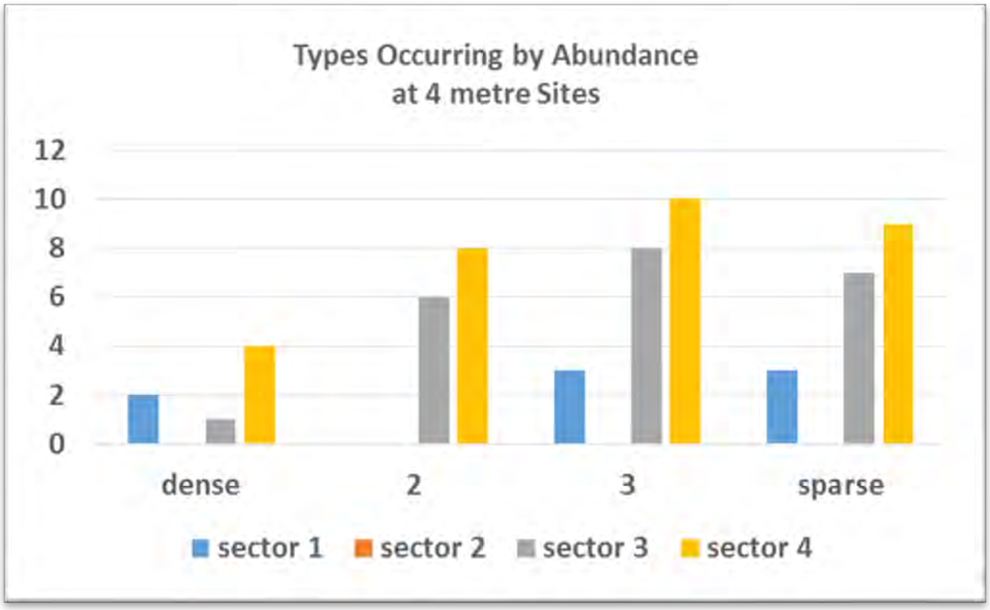


TABLE 7 Aquatic Types that Share the same abundance by depth

cumulative values of sectors

depth	1 dense	2	3	4 sparse	total
<2 m	31	58	73	77	239
2m	9	27	30	28	94
4m	7	15	21	19	62
total	47	100	124	124	395

x^2 = 4.02: not significant

Chi square returned no statistical significance in similarity by 'type' suggesting that all submerged aquatic plants occur at all depths and abundances. As the abundance graphs confirm, nearly every submerged plant is present to some extent at all depths and abundances. Type itself does not distinguish a significant difference by abundance or depth. This supports the null hypothesis for the above table.

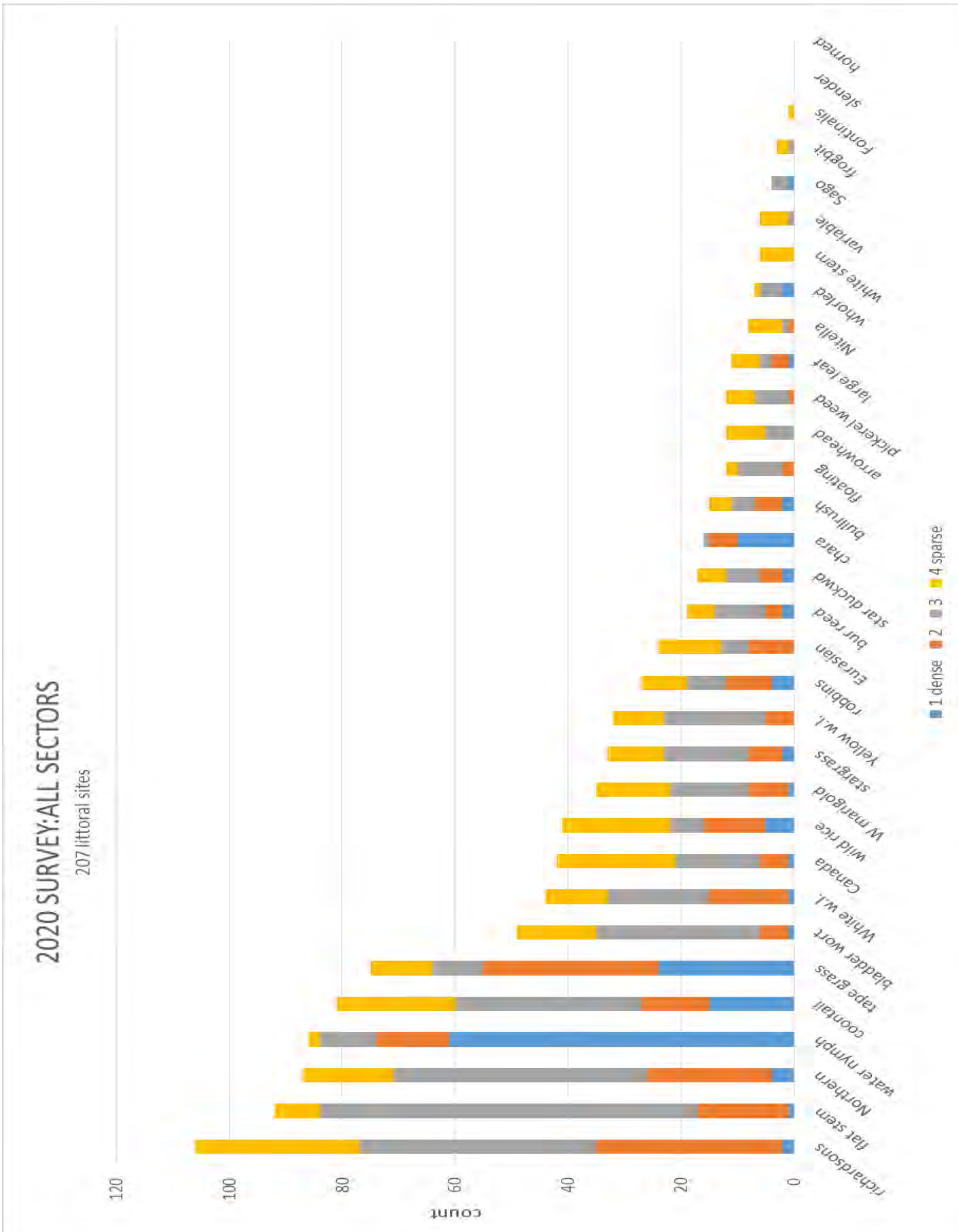
8.2 2020: Abundance of Aquatic Plants – All Sectors

Richardsons Pondweed was the most frequently seen aquatic type but it was not the most abundant. Slender Water Nymph, Tape Grass, Coontail and Chara surpass it in the number of high density cases.

The most abundant aquatic plant in White Lake by far is *Najas flexilis* or Slender Water Nymph. This was also the most abundant plant found within every sector. Only in Sector 2 was it's abundance matched by chara.

Figure 4-1 shows abundance values for each type of plant ranked according to its frequency of occurrence. There are 6 major contributors in both frequency and abundance: Richardsons Pondweed, Flat Stem Pondweed, Northern Water Milfoil, Coontail and Tape Grass. Figures 4-2 to 4-9 illustrates local variation from the overall abundance pattern of the lake. Sectors 3 and 4, including Three Mile Bay, preserve a general pattern of occurrence and abundance, whereas Pickerel Bay shows Eurasian Water Milfoil as more commonly occurring than Northern Water Milfoil. There is also a reduction in occurrence of Richardsons Pondweed and Flat Stem pondweed. Both the Village Basin and Hayes/Banes Bays have their greatest abundance associated with emergents and floating leaf varieties over submerged types even though Richardson's and Robbin's Pondweed are supported in these shallow waters.

Figure 4-1 ABUNDANCE RATING ALL SECTORS



8.3 2020: Abundance of Aquatic Plants by Sector

Sector 1

Figure 4-2

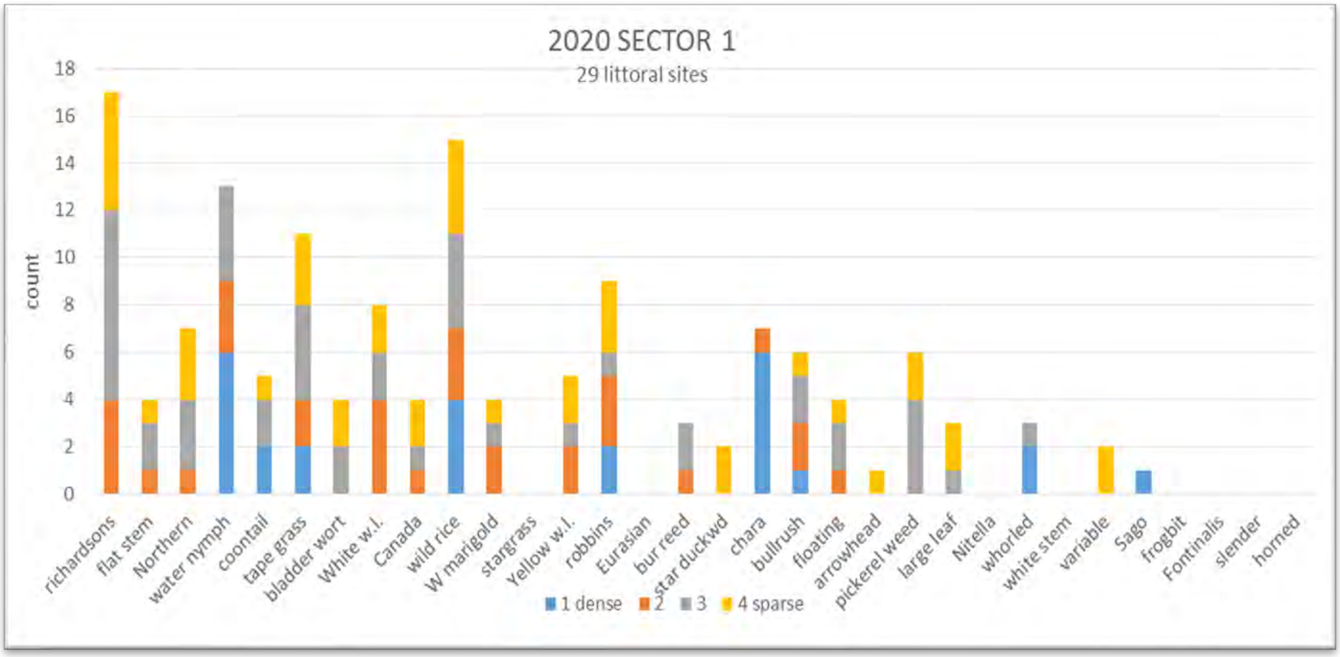
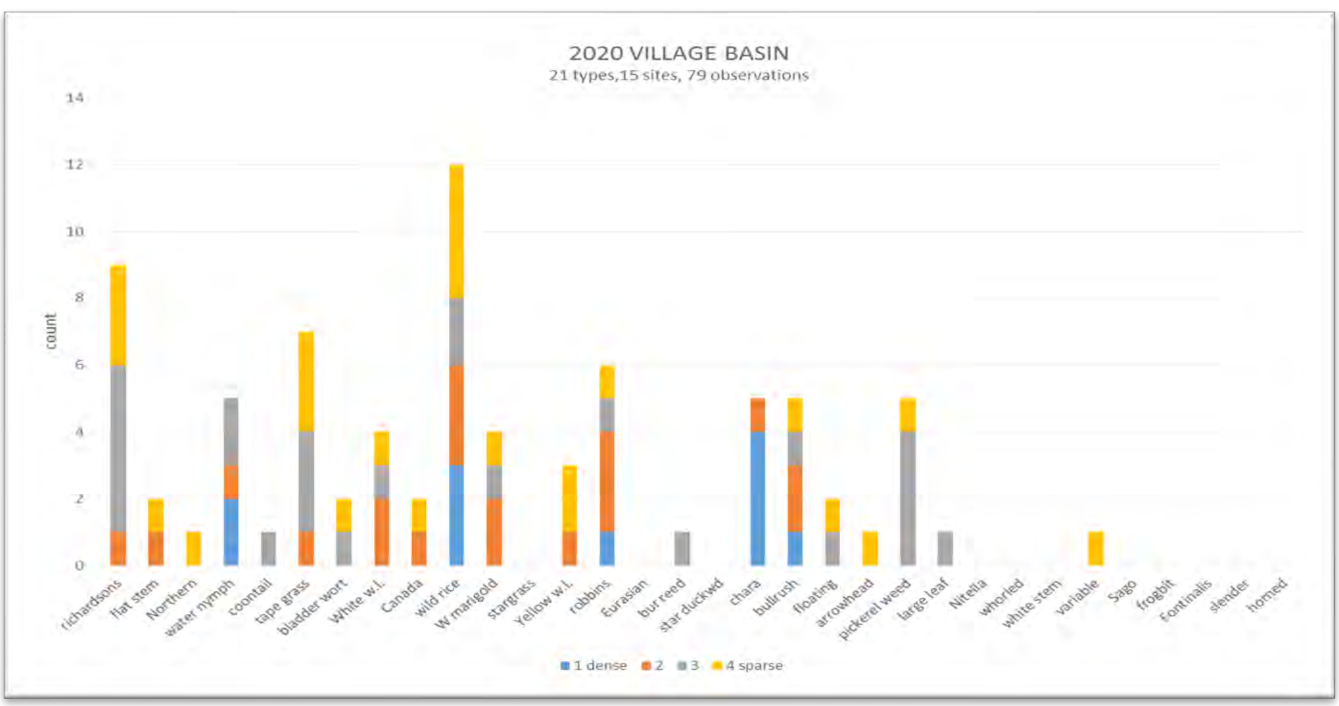


Figure 4-3 **VILLAGE BASIN**



Sector 2

Figure 4-4

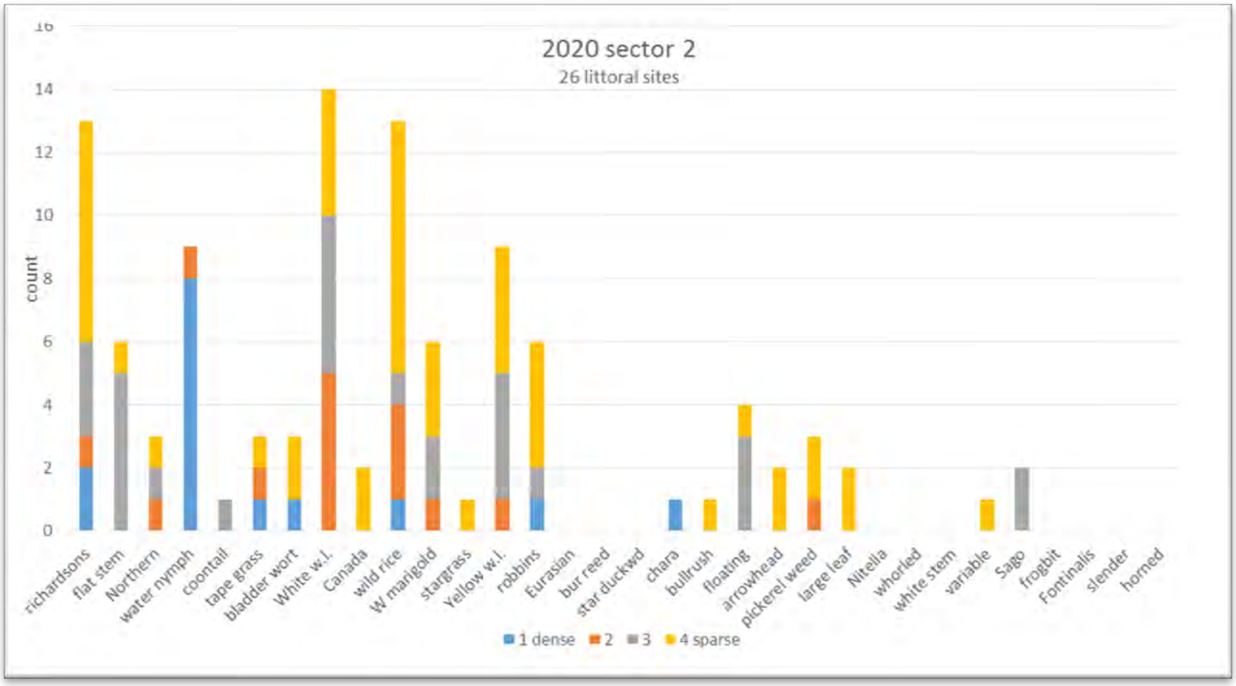
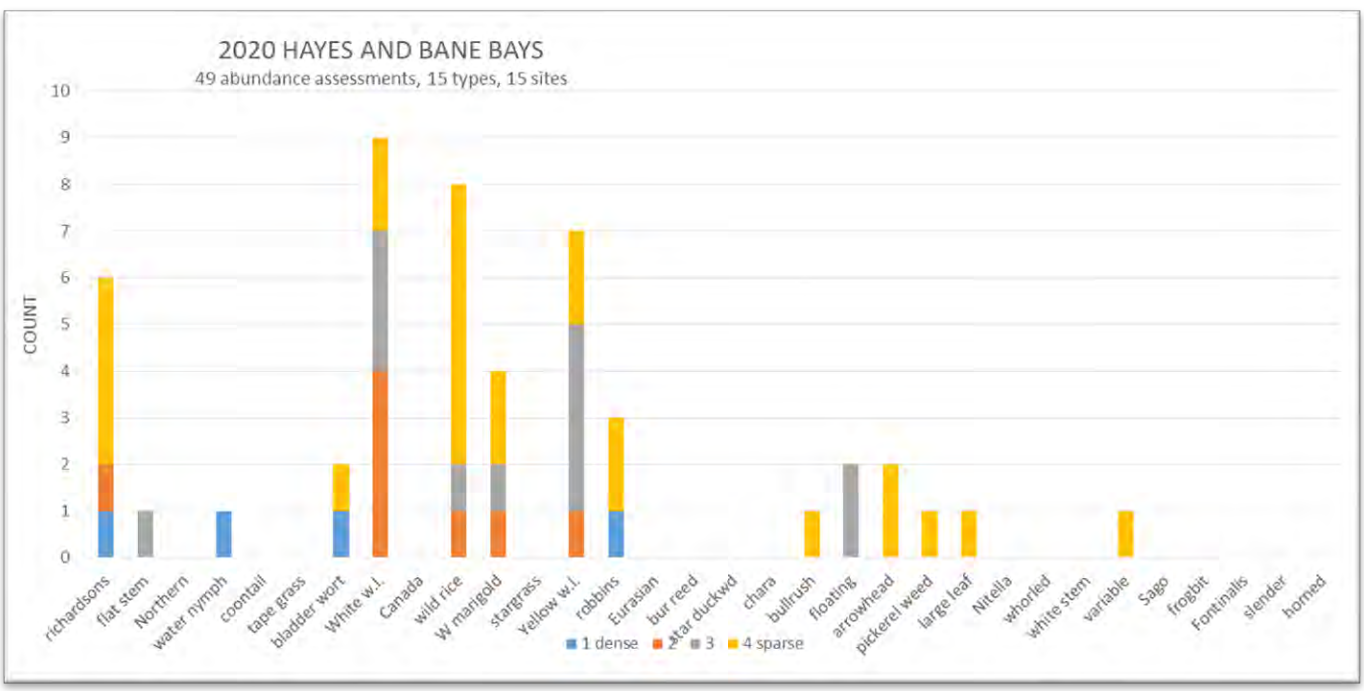


Figure 4-5 HAYES and BANE BAY BASINS



Sector 3

Figure 4-6

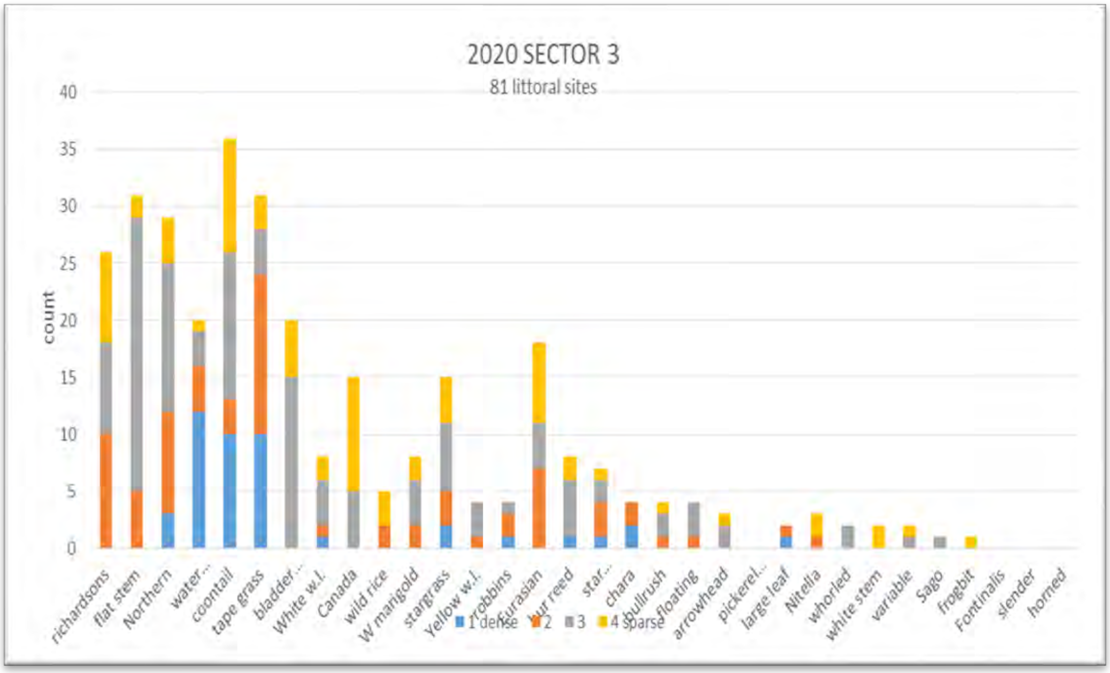
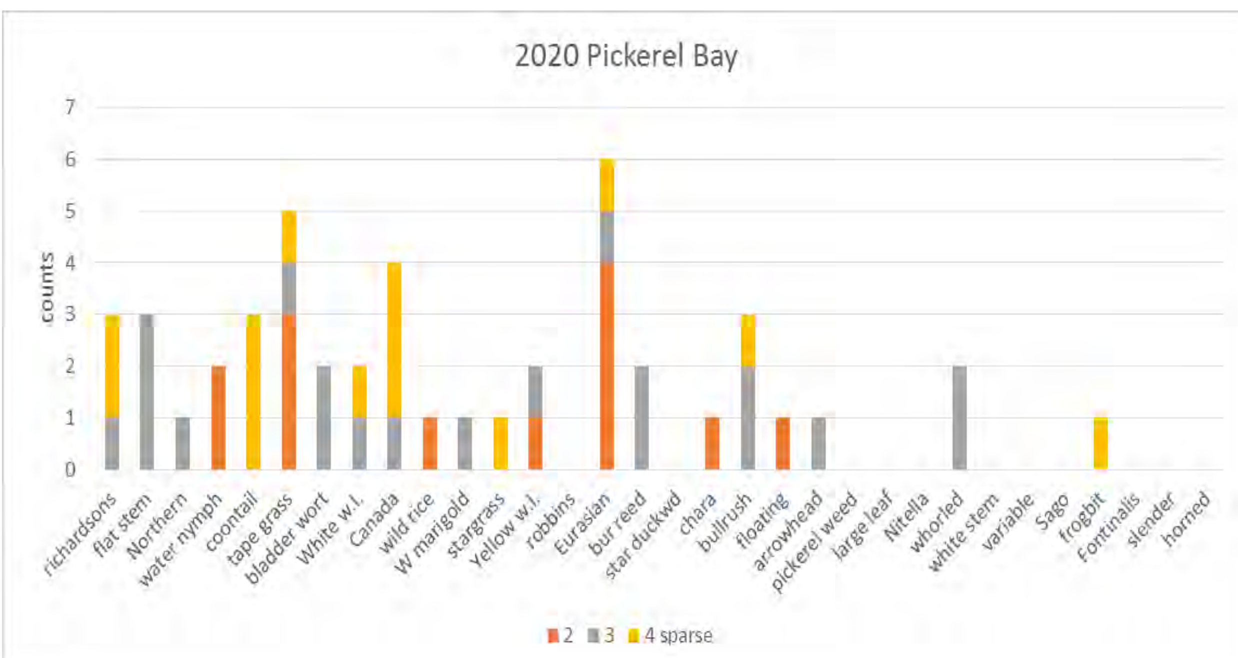


Figure 4-7 PICKEREL BA



Sector 4

Figure 4-8

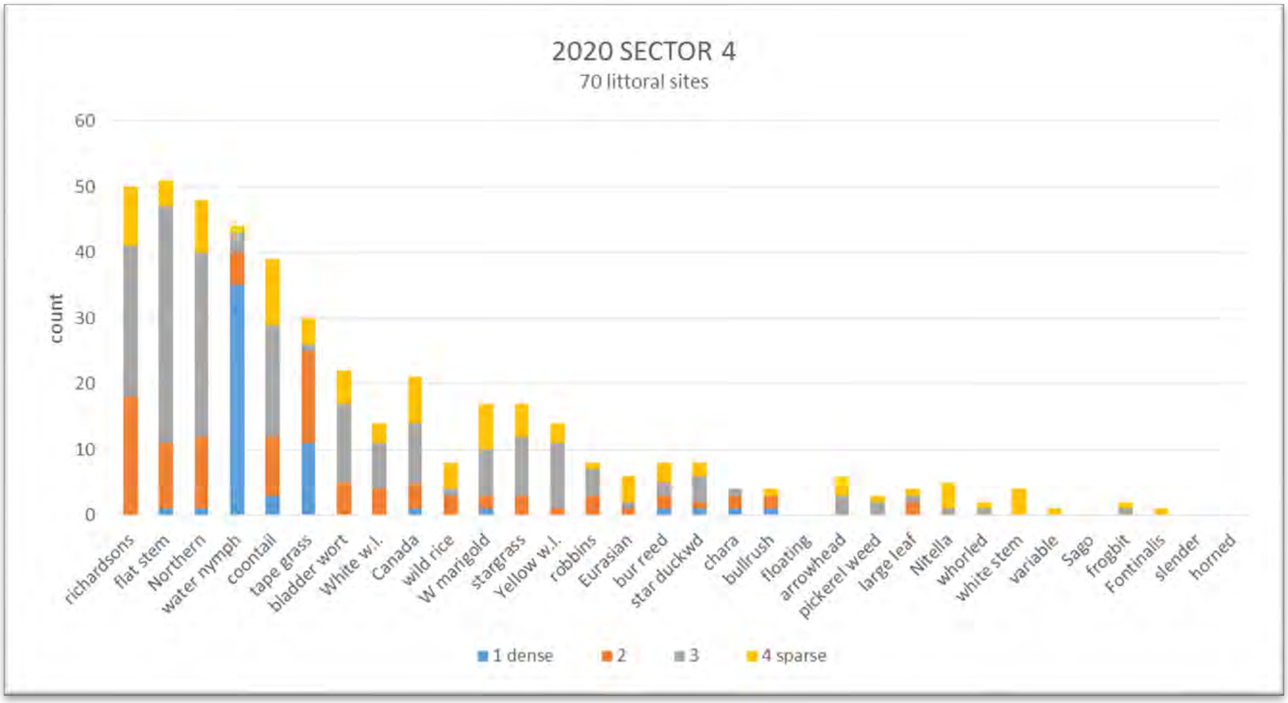
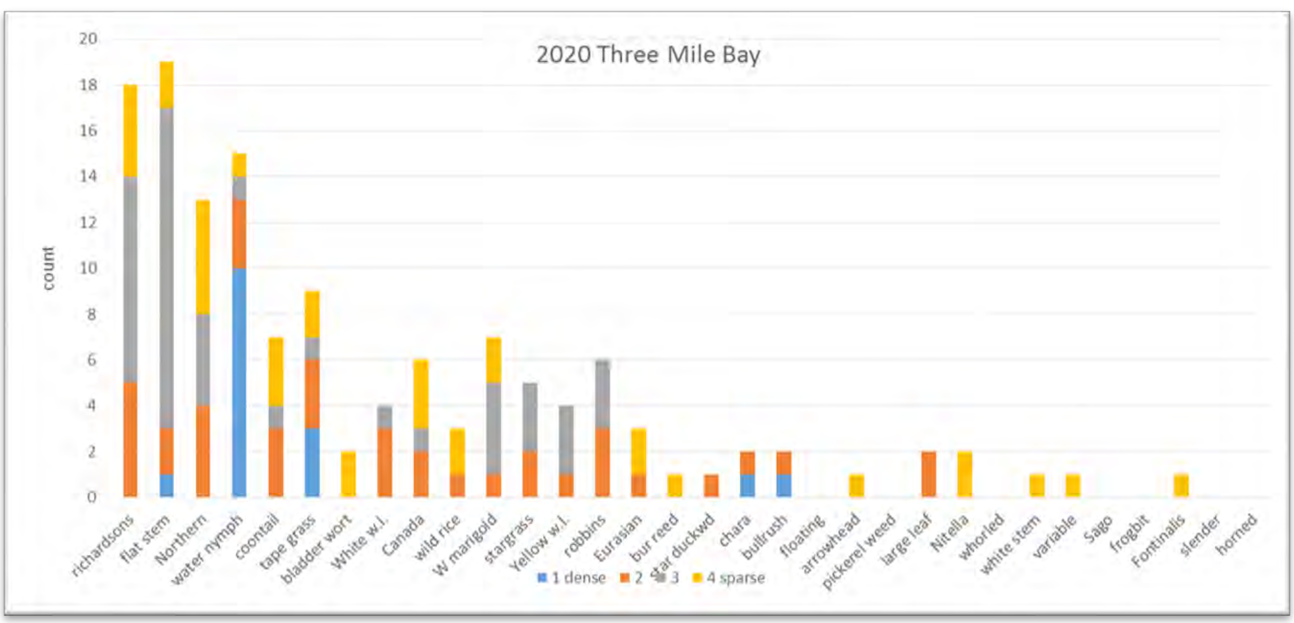


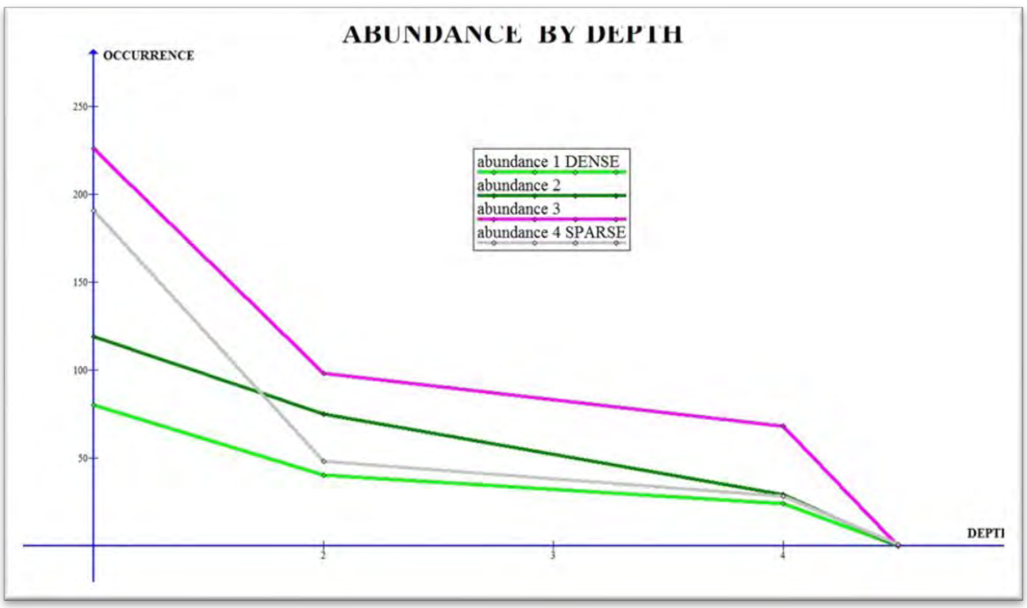
Figure 4-9 **THREE MILE BAY**



9. 2020: AQUATIC PLANT ABUNDANCE AND DEPTH

The graph and table below show the frequency of abundance versus depth for all vegetation observed during the 2020 survey. Plants rated as moderate in abundance (purple) were the most frequently observed category, especially in shallow waters where there were over 200 occurrences. Plants with the highest abundance rating or dense (light green), were the least frequently observed category. Plants exhibiting a less dense or clumping occurrence, with a value of 2 (dark green line), had an intermediary occurrence. The second highest occurrences were plants occuring as sparse. Three of the abundance ratings converge at 4 metre depths while plants that occur at rating 3 or scattered growth (purple), exhibit a higher occurrence. This pattern in abundance at 4 metres is interpreted as the result of an increase in exposure of the underlying substrate.

Figure 5



Unlike the previous results shown in table 7, abundance values irrespective of aquatic plant type, have a strong statistical significance with depth even when excluding the single case record found at 4.5 metres.

Table 8 2020: abundance by depth

depth	1 dense	2	3	4 sparse	total
<2	80	119	226	191	616
2	40	75	98	48	261
4	24	29	68	28	149
4.5	0	0	0	1	1
total	144	223	392	268	1027

X^2 26.41 df 6 p= 0.01

We conclude that depth is a significant factor affecting the frequency of occurrence by abundance.

9.1 2020: Aquatic Plant abundance Values and Depth

We examine the abundance rating of each plant type by the rating of abundance associated with each depth in all 4 sectors. The stacked colours of each bar represent depths. For example, blue represents depths under 2 metres. The contribution of each plant by each abundance value can be traced across the whole lake according to its occurrence at depth.

Figure 6-1 2020 AQUATIC PLANTS ALL SECTORS BY DEPTH: ABUNDANCE VALUE 1

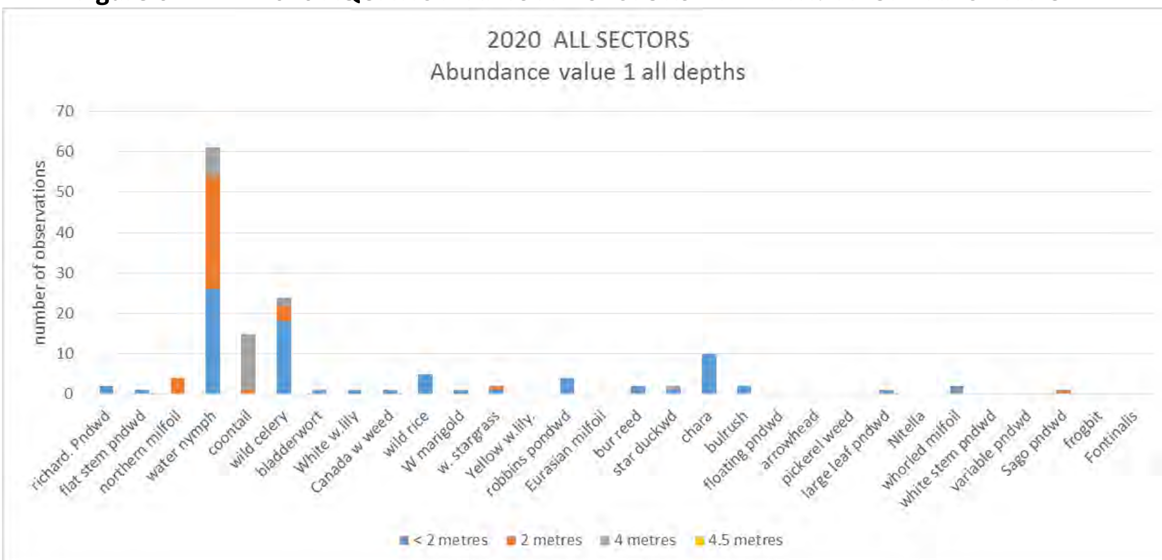


Figure 6-2 2020 AQUATIC PLANTS ALL SECTORS BY DEPTH: ABUNDANCE VALUE 2

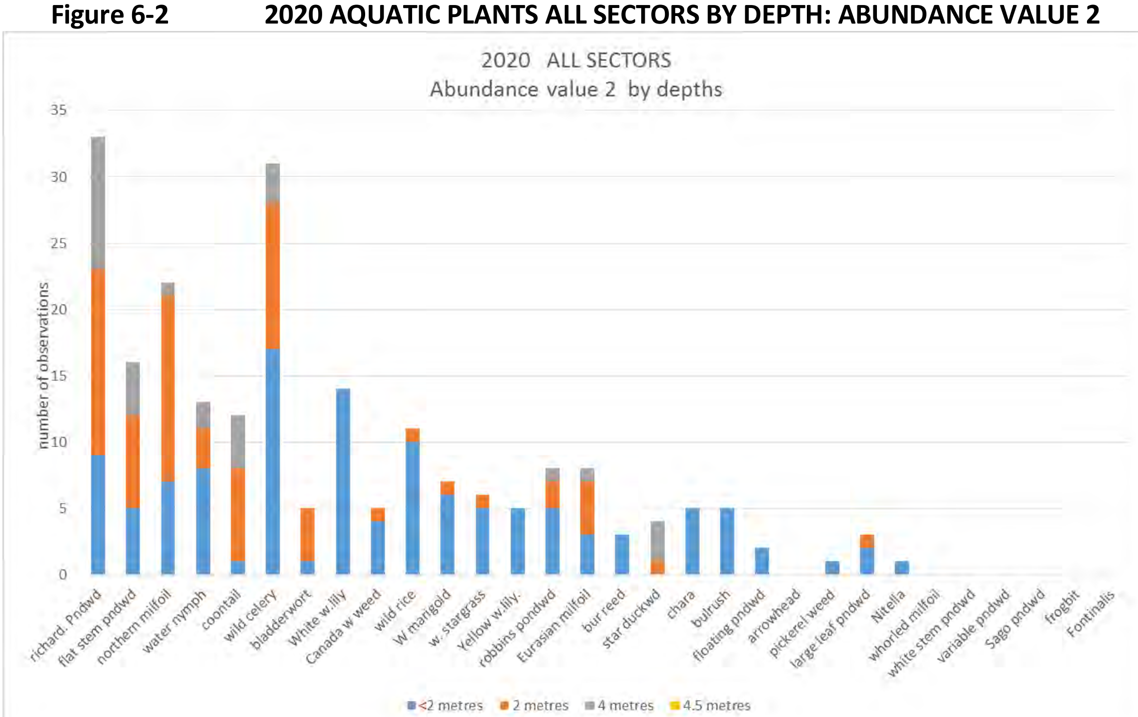


Figure 6-3 2020 AQUATIC PLANTS ALL SECTORS BY DEPTH: ABUNDANCE VALUE 3 ALL DEPTHS

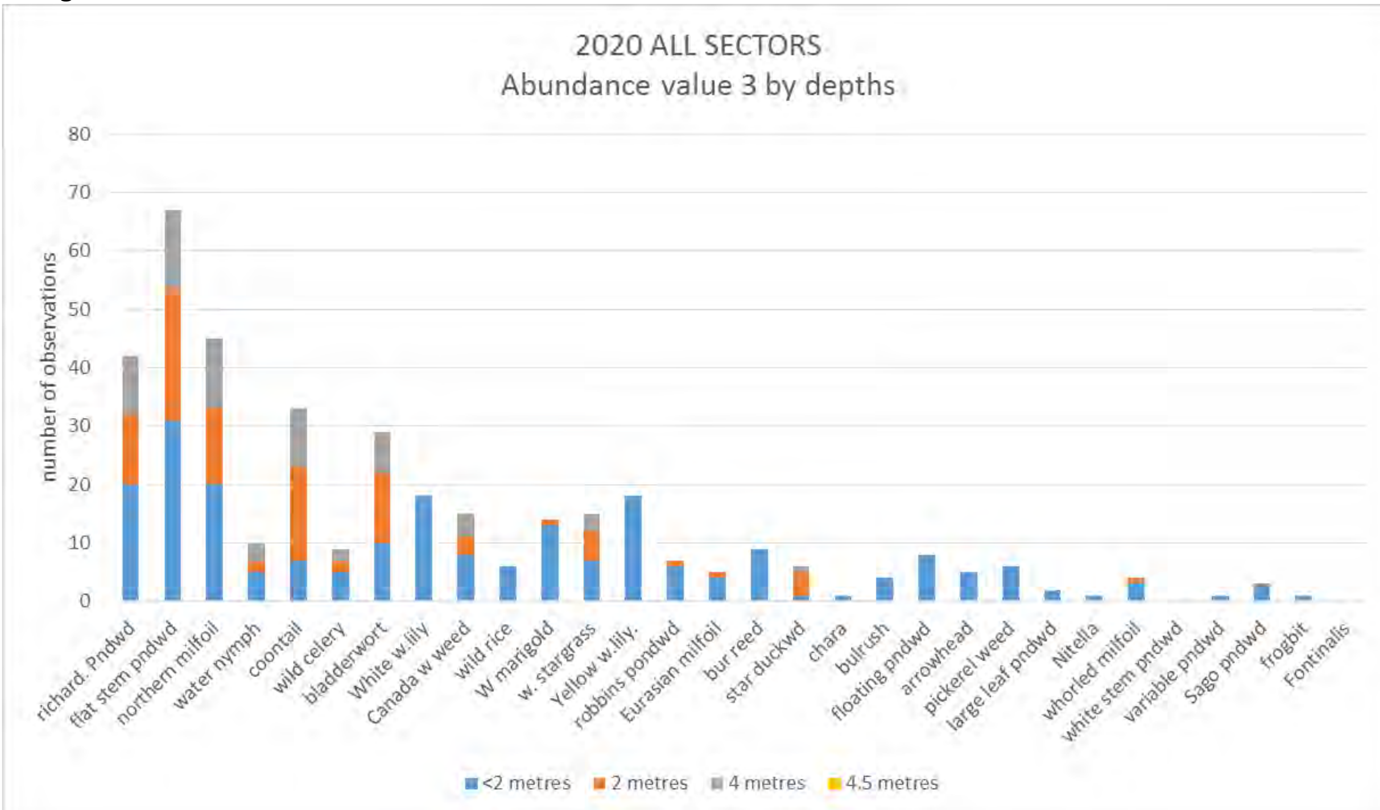
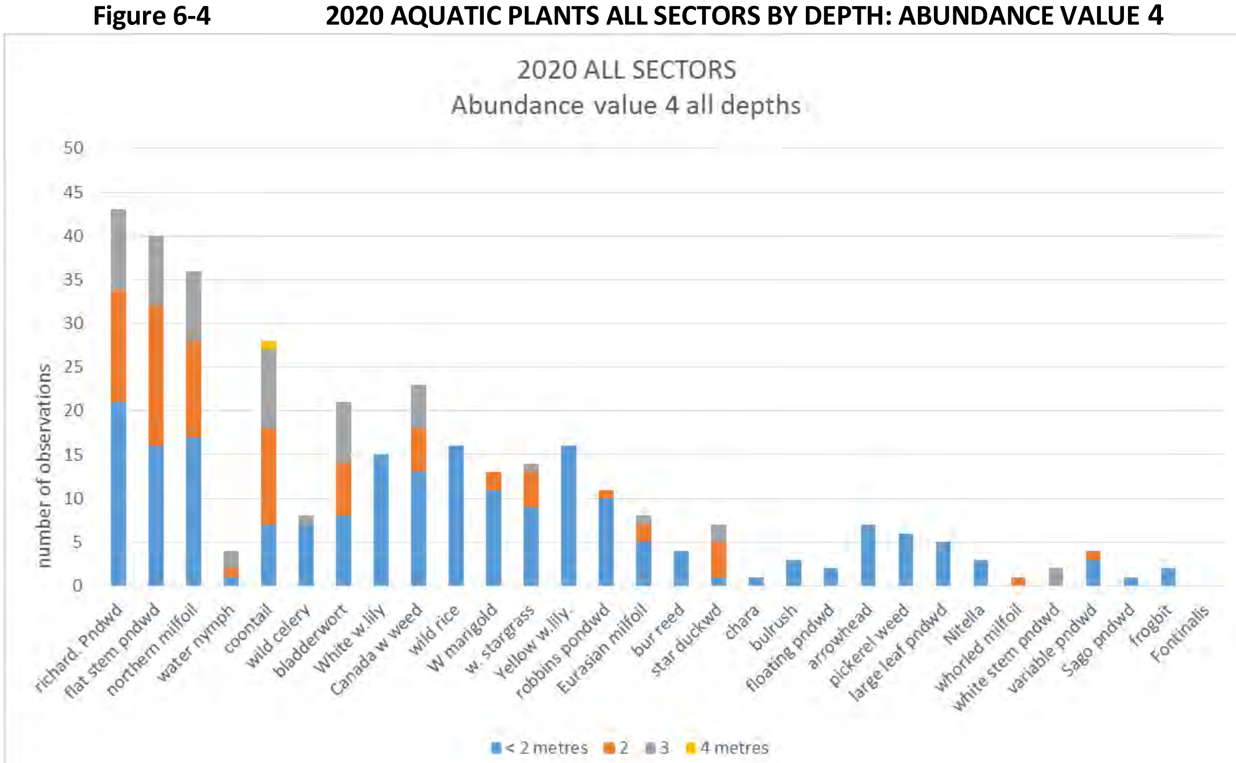
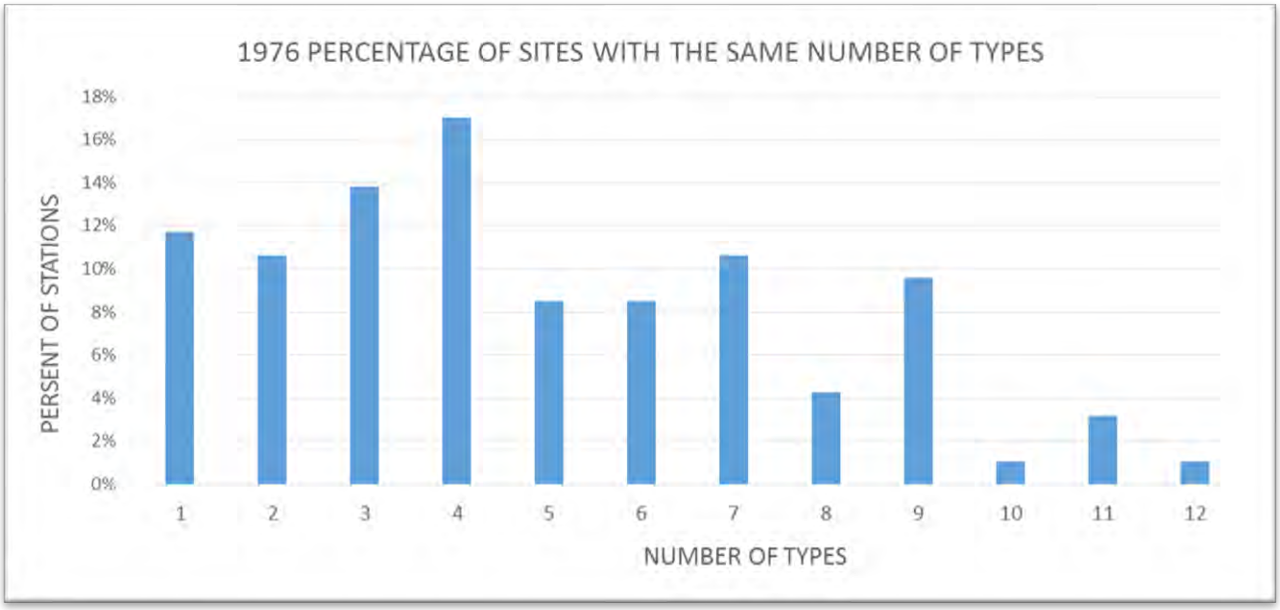


Figure 6-4 2020 AQUATIC PLANTS ALL SECTORS BY DEPTH: ABUNDANCE VALUE 4



10. 1976: AQUATIC PLANT SITE RICHNESS

Figure 7 **1976: PERCENTAGE SITE RICHNESS FOR ALL STATIONS**



As with the 2020 graphs, a similar distribution of richness is shown with the 94 vegetated stations of 1976. Only station #307 contained the highest number of types present (12 types). 14 sites (15%) had 9 or more types.

10.1 1976 Station Richness

The following figures (8-1 to 8-5) represent station richness for each sector and for all 98 stations as reported in L J Bond's 1976 report.

Figure 8-1 **1976: STATION RICHNESS –ALL STATIONS**

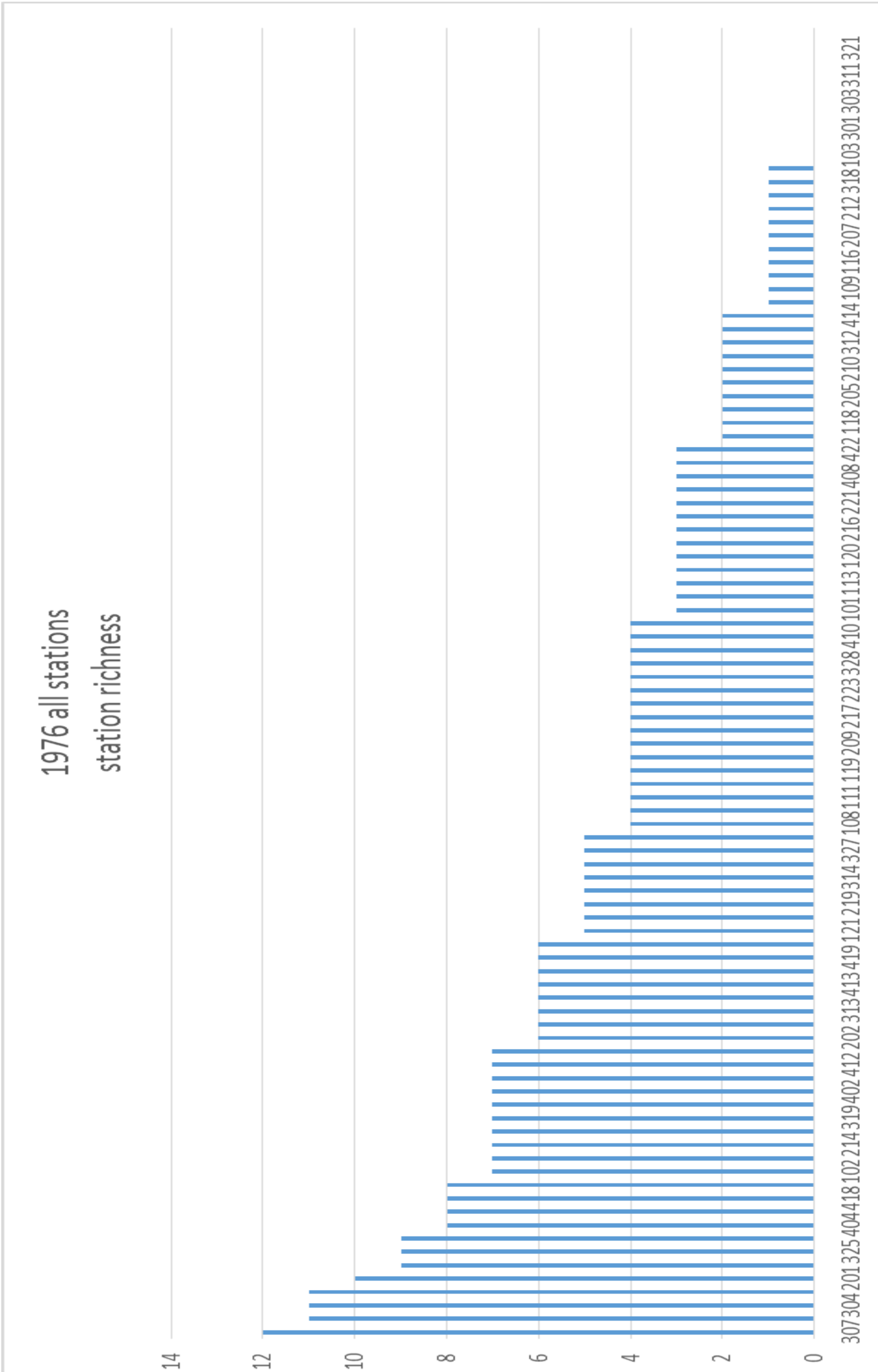


Figure 8-2 1976: STATION RICHNESS –SECTOR 1

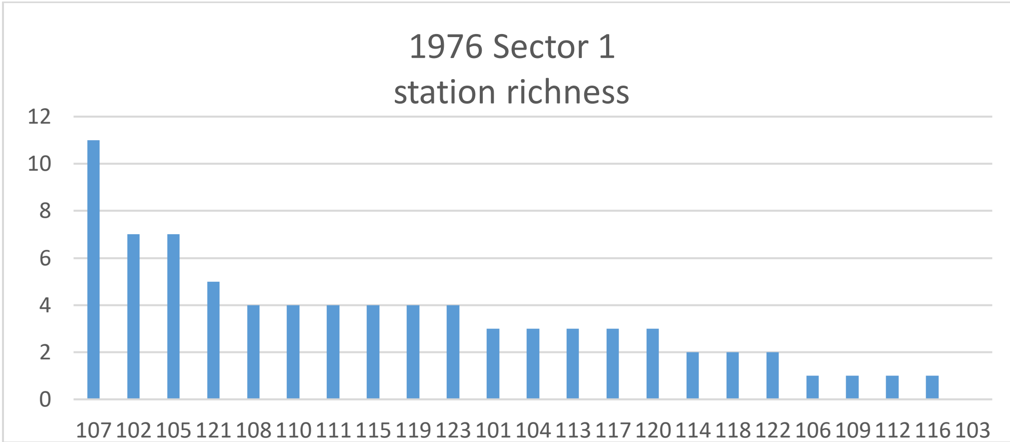


Figure 8-3 1976: STATION RICHNESS SECTOR 2

Figure 8-4 1976: STATION RICHNESS SECTOR 3

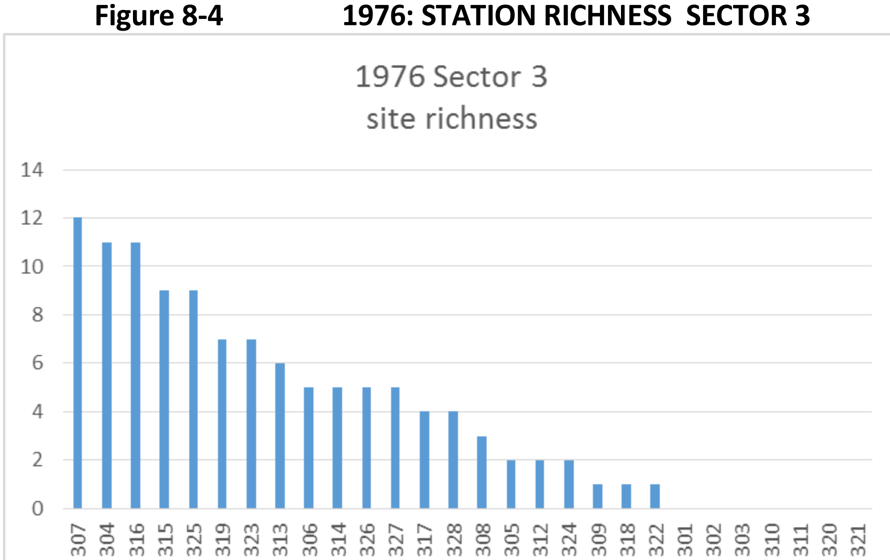
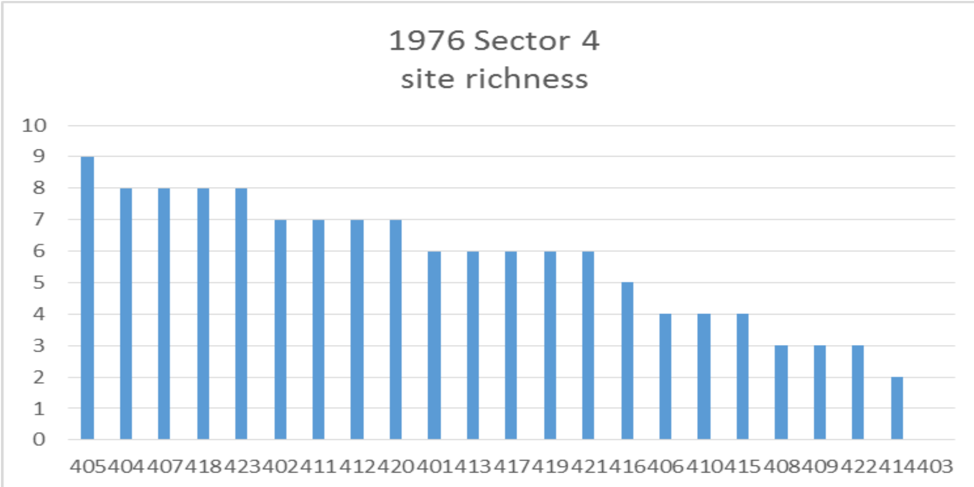


Figure 8-5 **1976: STATION RICHNESS SECTOR 4**



11. 1976: ABUNDANCE OF AQUATIC PLANTS

11.1 1976 Abundance Values by Type

The following figures (9-1 to 9-9) illustrate the abundance values reported for individual types in L. J. Bond's 1976 report:

Figure 9-1 1976: ABUNDANCE BY TYPE ALL SECTORS

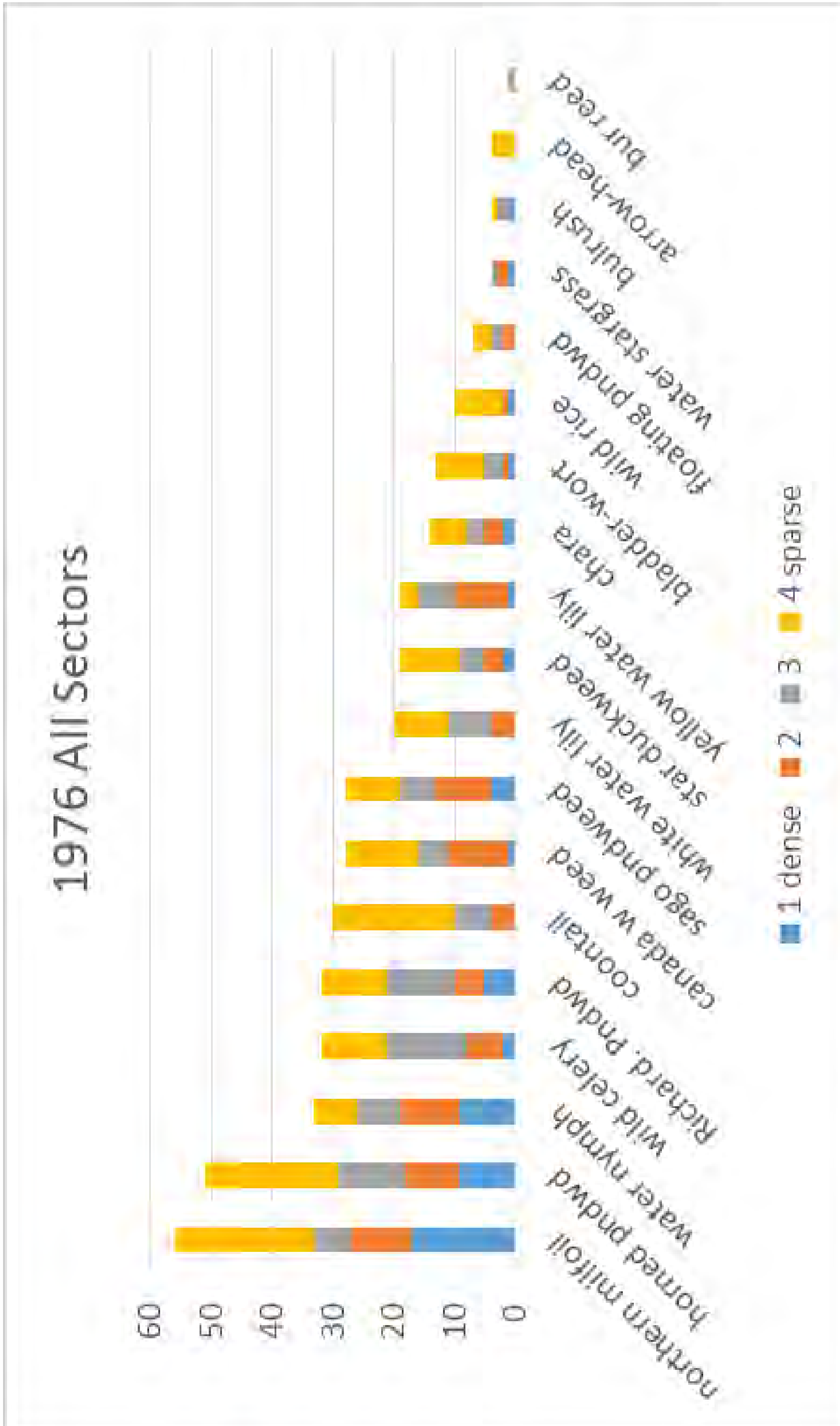


Figure 9-2 1976: ABUNDANCE BY TYPE SECTOR 1

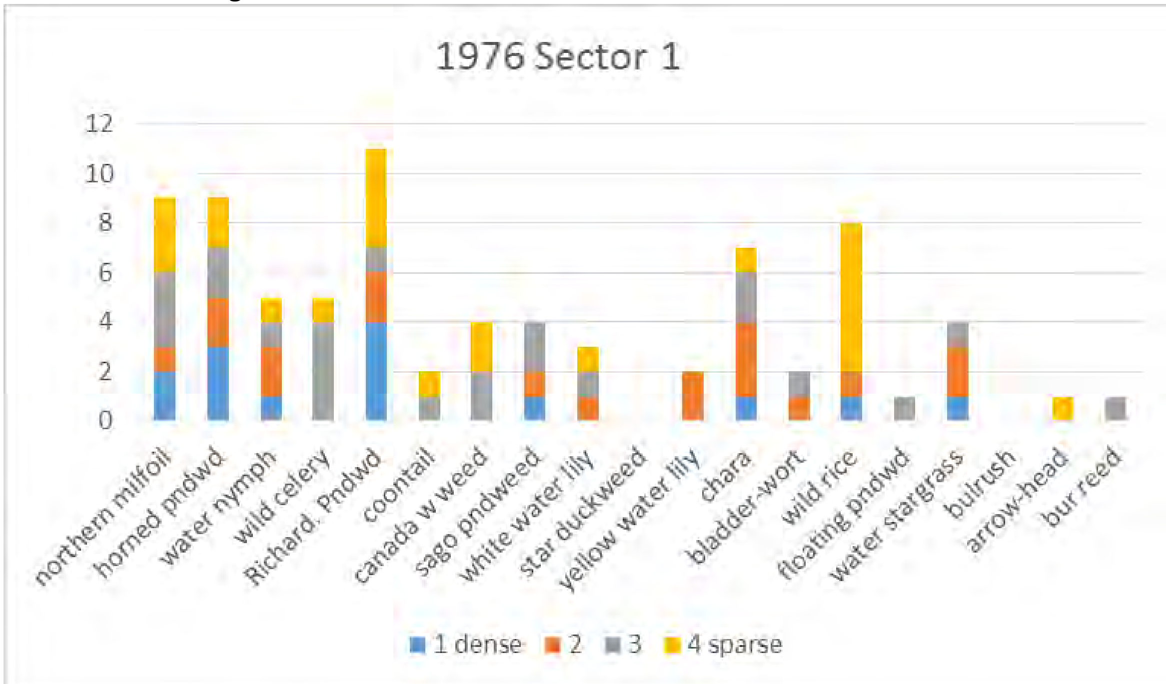


Figure 9-3 1976: ABUNDANCE BY TYPE VILLAGE BASIN

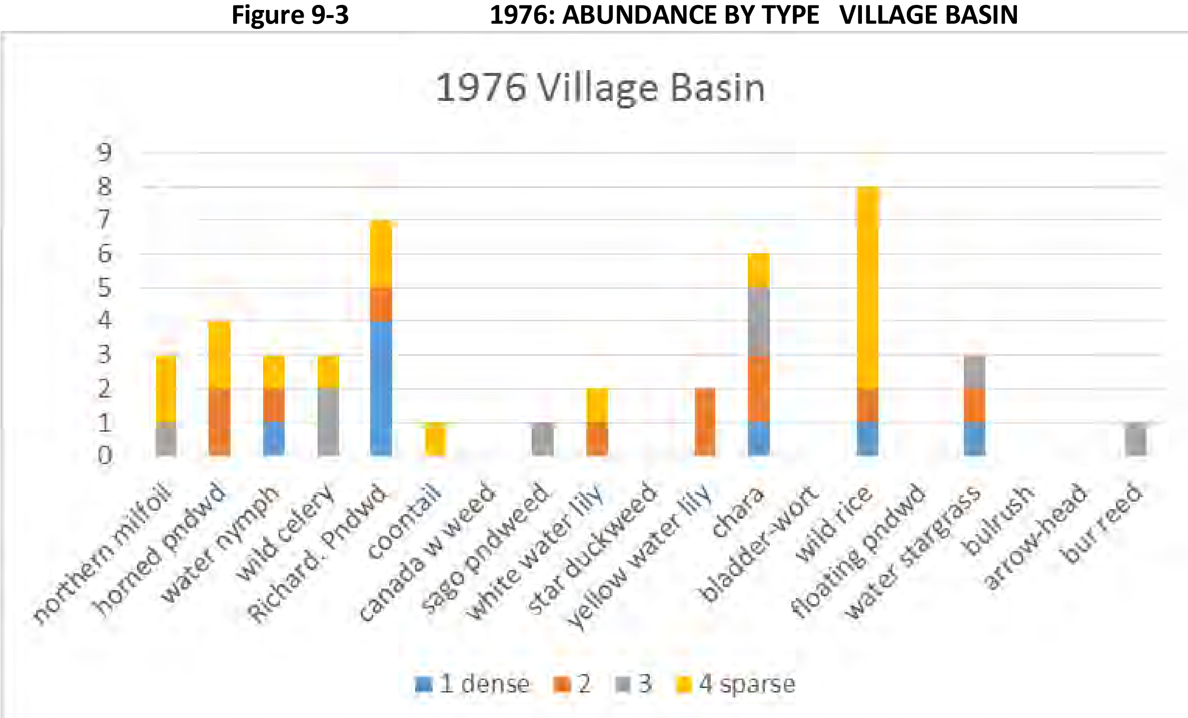


Figure 9-4 1976: ABUNDANCE BY TYPE SECTOR 2

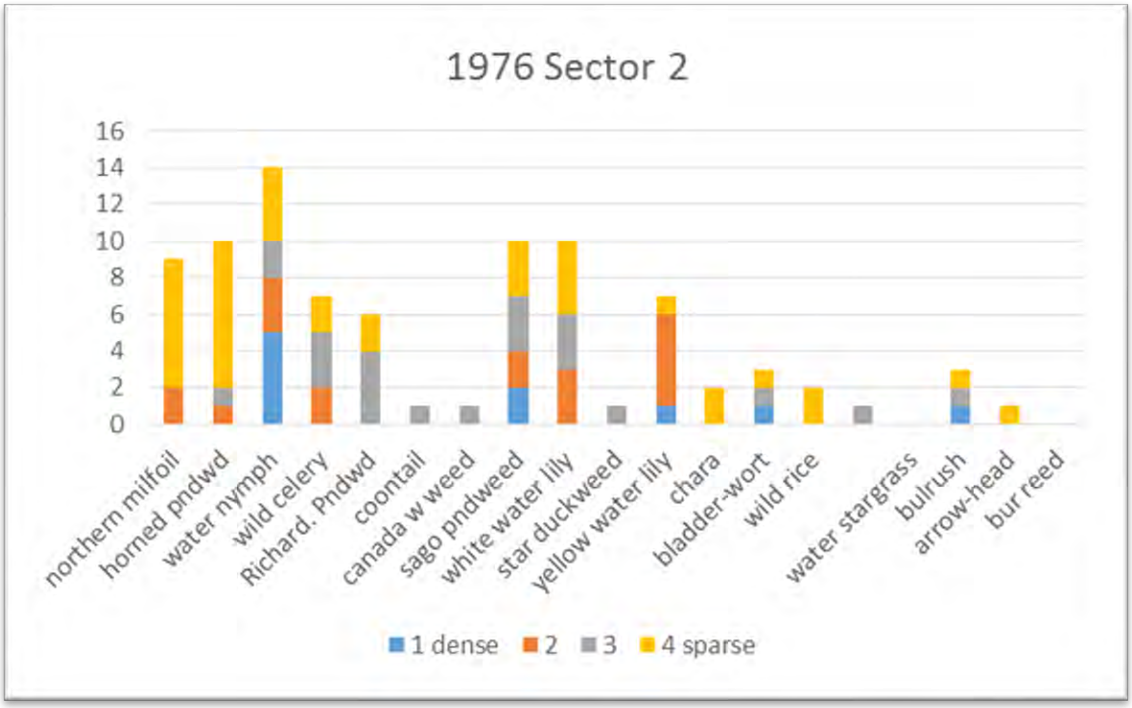


Figure 9-5 1976 ABUNDANCE BY TYPE HAYES and BANE BAYS

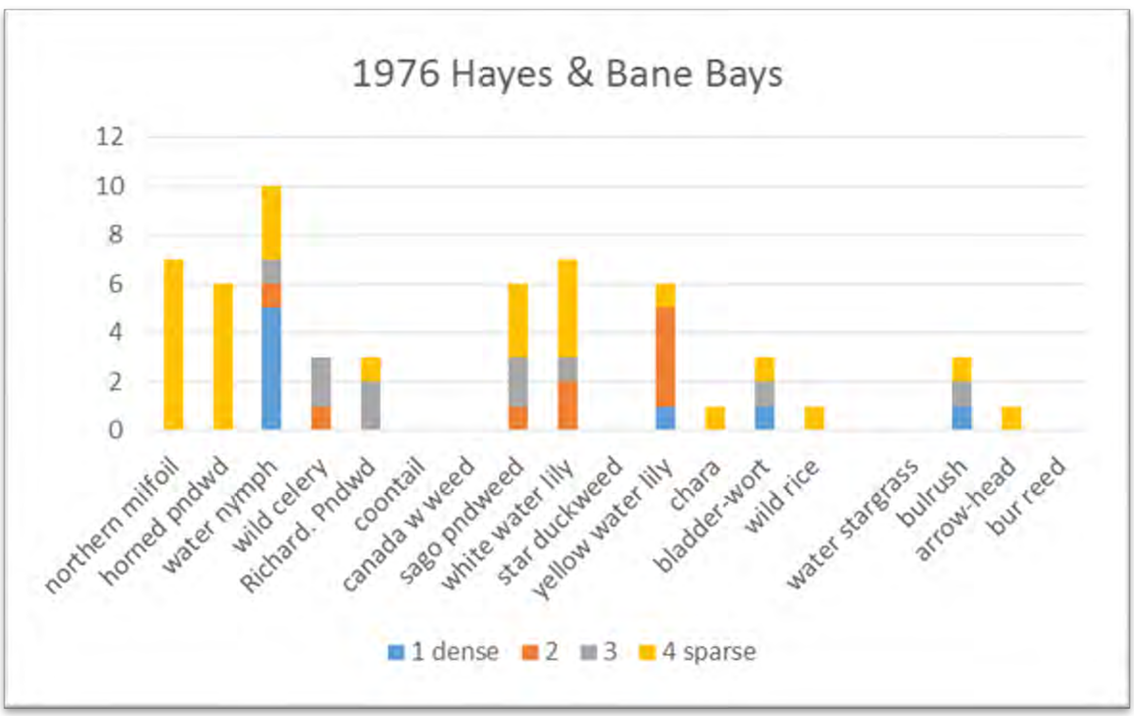


Figure 9-6 1976 ABUNDANCE BY TYPE SECTOR 3

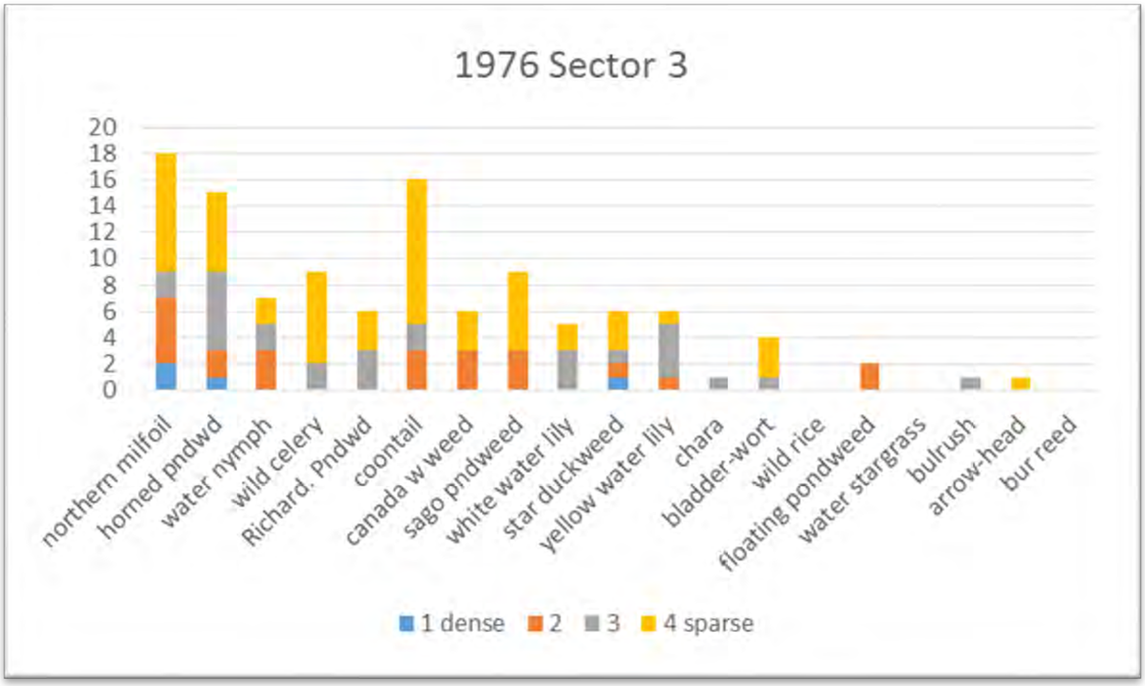


Figure 9-7 ABUNDANCE BY TYPE PICKEREL BAY

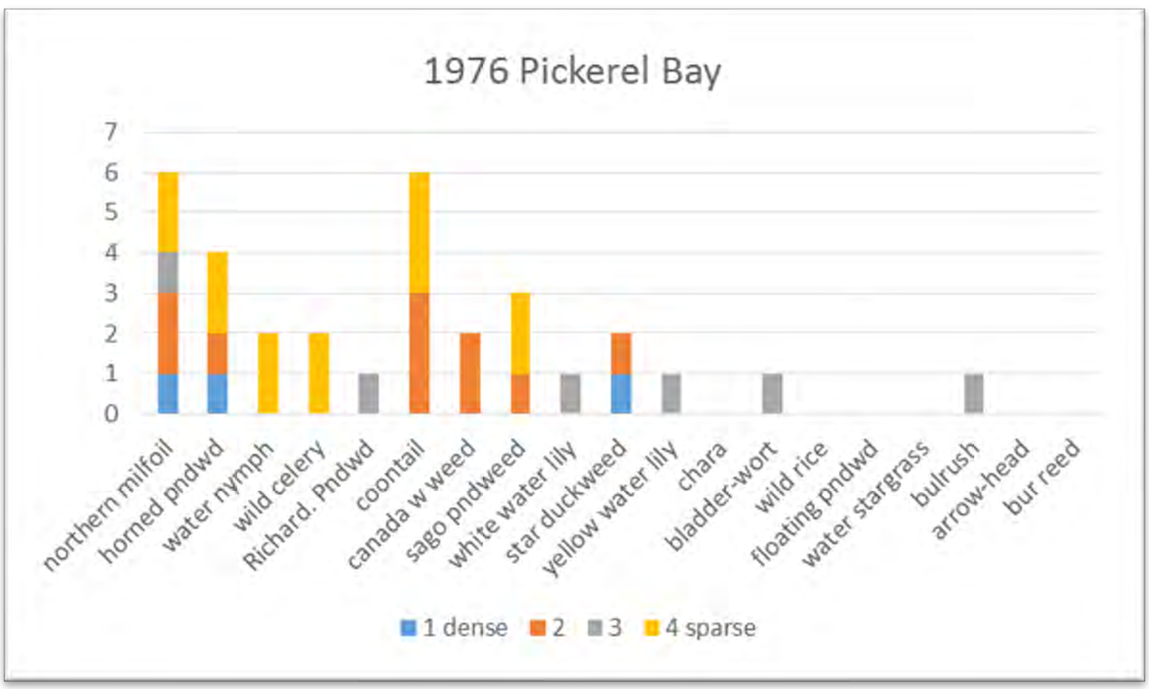


Figure 9-8 **1976 ABUNDANCE BY TYPE SECTOR 4**

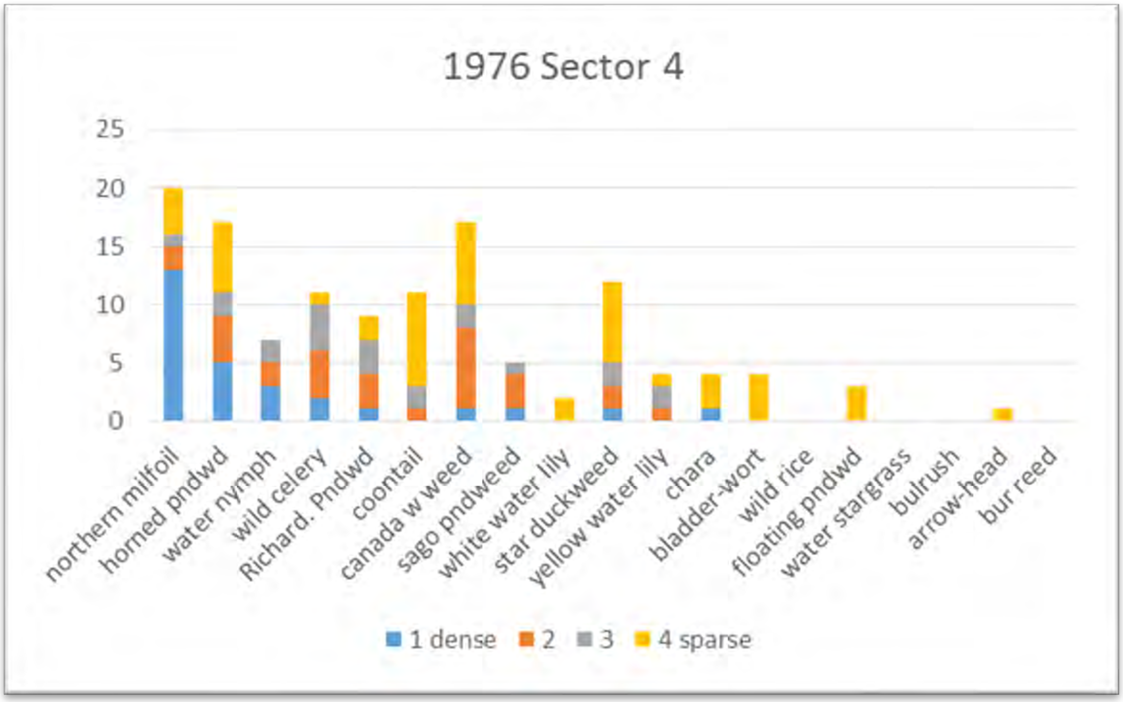
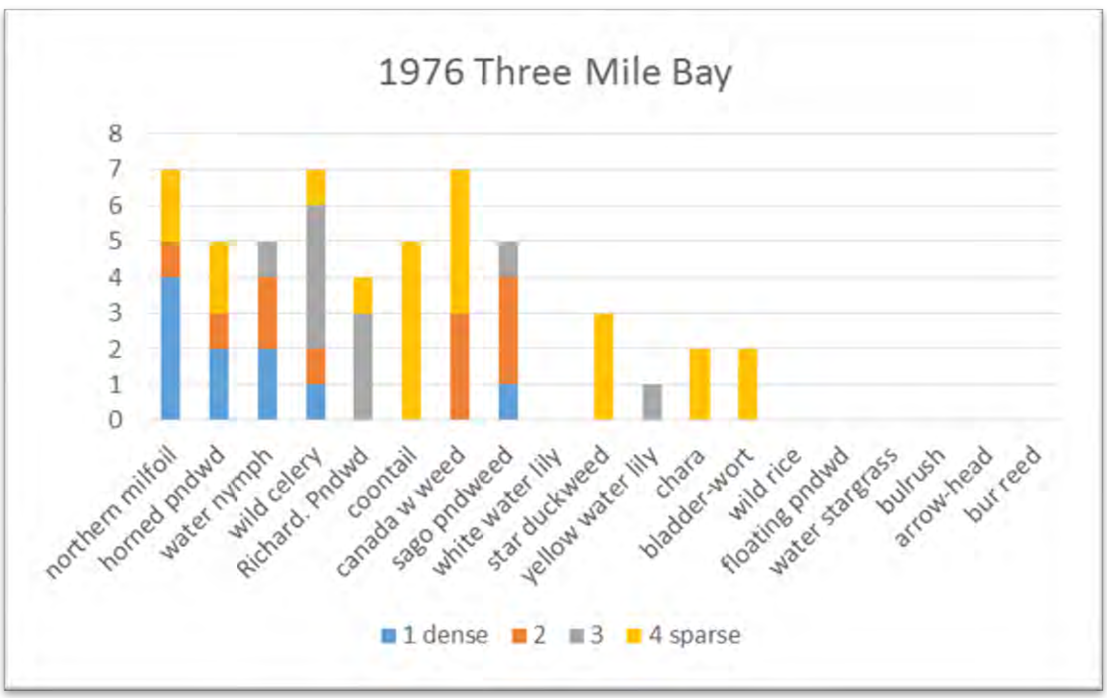
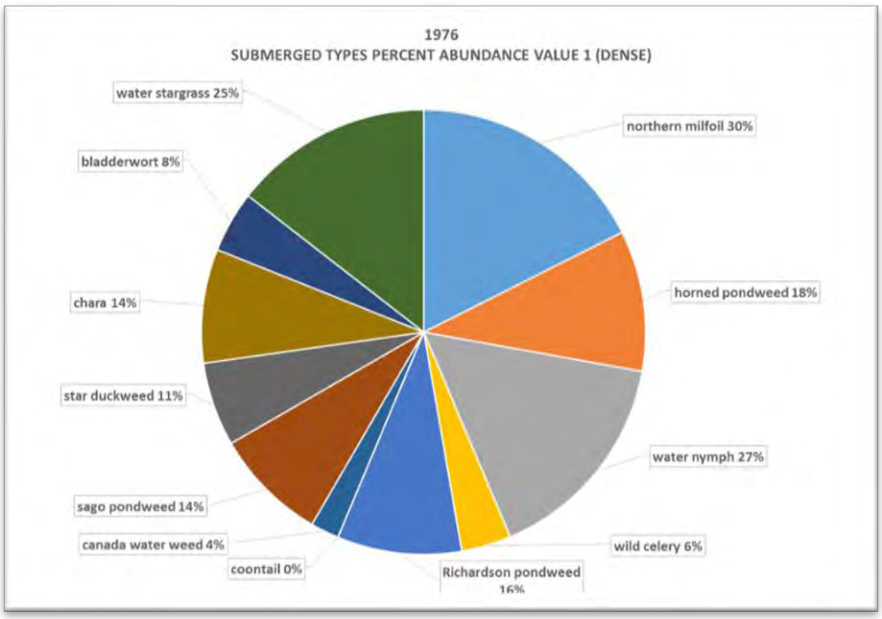


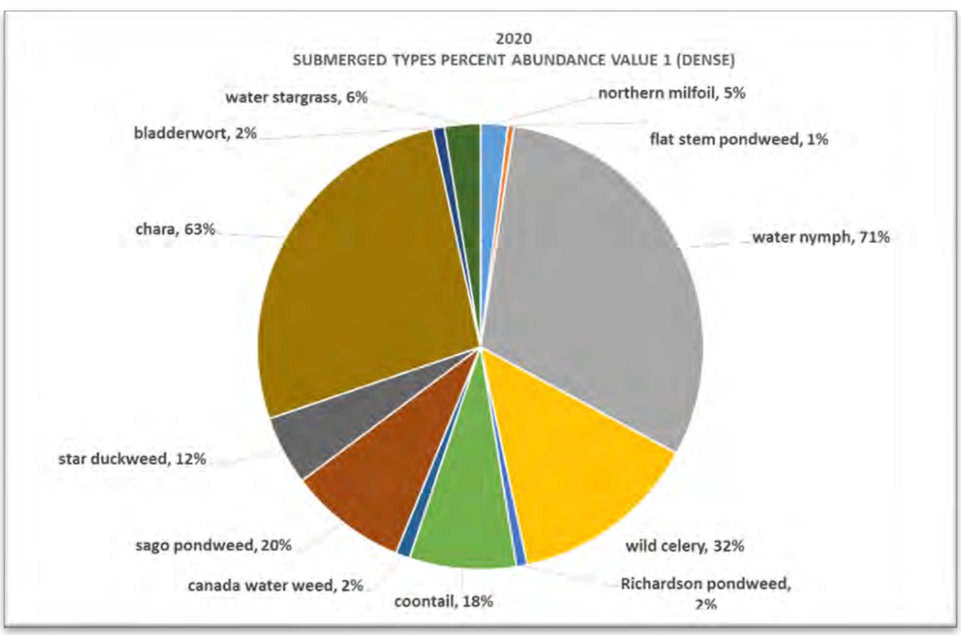
Figure 9-9 **ABUNDANCE BY TYPE THREE MILE BAY**



11.2 A Comparison of "Dense" Abundance of Submerged Types: 1976 – 2020

The following charts show the change in proportion of "high density" occurring for each type between years. Although northern watermilfoil occurred frequently in both years, the high density of northern watermilfoil was proportionately less in 2020 (5%) compared to 1976 (30%). Dense stands of slender water nymph proportionatley increased as did chara and Richardsons pondweed. Sago managed to maintain a proportionate high density even though its frequency of occurrence is in sharp decline. Horned pondweed, once common and often rated as dense in 1976, is now not present. It is replaced by thin stem pondweed with a similar frequency of occurrence. Thin Stem pondweed has yet to form a similar proportion of high density. The segments in the pie chart indicate the importance the density value has for the plant relative to others. Density "1" between years is relatively more signifanct for Chara when compared with other plants even though the frequency of occurrence of chara itself is stable. The segments do not represent absolute values.





12. CHANGES IN THE WHITE LAKE AQUATIC PLANT COMMUNITY 1976-2002

Table 9 shows which aquatic types were new to the 2020 survey and which ones were absent. Apart from present or absent types, the majority of plants were common to both surveys. Eighteen types were present for both years. Nine were unique to 2020 and only one type (horned pondweed) was unique to 1976.

Table 9 Unique and Shared Aquatic Types: 1976-2020

1976 only	common to both years	2020 only
horned pondweed	northern watermilfoil	thin stemmed pondweed
	water nymph	Eurasian Watermilfoil
	wild celery	Large Leaf pondweed
	Richardson's Pondweed	Variable pondweed
	coontail	White stem pondweed
	Canada waterweed	water marigold
	Sago pondweed	Whorled/variable water milfoil
	White water lily	Nitella
	star duckweed	Fontinalis
	Yellow water llily.	
	Chara	
	bladderwort	
	wild rice	
	floating pondweed	
	water stargrass	
	bulrush	
	arrowhead	
	bur reed	

12.1 Similarity Between Survey Years

In order to understand the changes among these commonly shared types we employed a Similarity Index to assess change between the two sampling years. We looked at 2 factors:

- The similarity of an aquatic plant type that occurs at stations in both survey years
- The similarity of stations in their shared species richness between survey years.

To make comparisons to 1976 we normalized to the 1976 stations. The 2020 sites were used to rate the presence or absence of individual types at each 2020 station. This process also increases the likelihood of an agreement when a given type was present in 1976.

12.2 Similarity Index

The index is the difference in the number of stations sharing in a given type divided by the sum of stations that shared and did not share in a given type:

Index of similarity:	SET A ∩ SET B	the set of intersected observations
	SET A ∪ SET B	The union of observations

Tufts University "Jaccard Similarity Index"

12.3 Similarity of Individual Plant Types Occurring at Stations: 1976-2020

Results from applying this index are displayed in the following tables. It is the percentage of sampling stations sharing in the presence of a given aquatic type These compare the occurrence of submerged aquatic plant types that are shared by stations for the years 1976 and 2020 for individual sectors and for the lake as a whole. For instance, northern milfoil scored the highest in similarity followed by Canada water weed and coontail when comparing all stations (tables 10-1 to 10-5). Of the four types reporting the least or having no correspondence, three of these are inshore emergent types, perhaps reflecting the less ameliorated conditions of aerial exposure. The higher the percentage suggests the least amount of change being experienced by a particulart plant type between survey years.

Tables 10-1 to 10-4

SECTOR 1	
chara	56%
Richardson’s Pondweed	53%
white water lily	38%
wild rice	35%
northern milfoil	27%
sago pondweed	20%
floating pondweed	20%
yellow water lily	17%
wild celery	14%
bulrush	1%
water nymph	0%
coontail	0%
Canada water weed	0%
star duckweed	0%
bladder-wort	0%
water stargrass	0%
arrow-head	0%
bur reed	0%

SECTOR 2	
coontail	100%
Canada w weed	100%
yellow water lily	33%
white water lily	29%
northern milfoil	22%
Richardson’s pondweed	20%
wild celery	13%
sago pondweed	9%
wild rice	7%
water nymph	0%
star duckweed	0%
chara	0%
bladder-wort	0%
floating pondweed	0%
water stargrass	0%
bulrush	0%
arrow-head	0%
bur reed	0%

SECTOR3	
coontail	50%
white water lily	44%
northern milfoil	43%
yellow water lily	43%
Canada water weed	31%
wild celery	30%
Richardson’s pondweed	29%
floating pondweed	25%
water nymph	20%
bladder-wort	14%
sago pondweed	11%
star duckweed	9%
bulrush	6%
chara	0%
wild rice	0%
water stargrass	0%
arrow-head	0%
bur reed	0%

SECTOR 4	
northern milfoil	91%
Canada water weed	57%
star duckweed	50%
Richardson’s pondweed	41%
wild celery	39%
coontail	36%
yellow water lily	29%
bladder-wort	14%
water nymph	8%
white water lily	7%
sago pondweed	0%
chara	0%
wild rice	0%
floating pondweed	0%
water stargrass	0%
bulrush	0%
arrow-head	0%
bur reed	0%

Table 10-5

ALL STATIONS	
northern milfoil	54%
Canada water weed	40%
coontail	39%
Richardson's pondweed	37%
yellow water lily	31%
wild celery	28%
white water lily	27%
star duckweed	27%
chara	20%
wild rice	16%
floating pondweed	13%
sago pondweed	10%
bladder-wort	10%
water nymph	9%
bulrush	1%
water stargrass	0%
arrow-head	0%
bur reed	0%

12.4 Similarity of Stations of Aquatic Plant Types: 1976-2020

Figure 10 below measures the similarity in type occurrence that is common to both years as the percentage of similarity at each station. To the right are 30 stations with no plant occurrences in common. Four of these are in deep water sites with no vegetation. The remaining 26 are sites where plants are present but are not common to both years.

Of the 94 vegetated stations there were 58 that shared some degree of similarity. Nineteen of these stations (35%) shared in common 50% of their aquatic plant types. Three stations have over 60% shared in common with the highest percentage (75%) being Site 415 in Three Mile Bay.

Table 11 lists the 19 stations having a similarity of 50% or greater. Sector 1 exhibited the most number of stations with high agreement. These are from the Village Basin. This may indicate that the Village Basin exhibits more resistence to change over time than other parts of the lake.

TABLE 11 Stations With 50% or More Aquatic Types in Common Between 1976-2020

SECTOR 4	%	SECTOR 3	%	SECTOR 2	%		SECTOR 1	%
415	75	307	53	219	60		111	60
402	67	306	50	201	50		121	60
419	63	315	50	215	50		116	50
417	60						117	50
422	50						118	50
							119	50
							120	50
							122	50

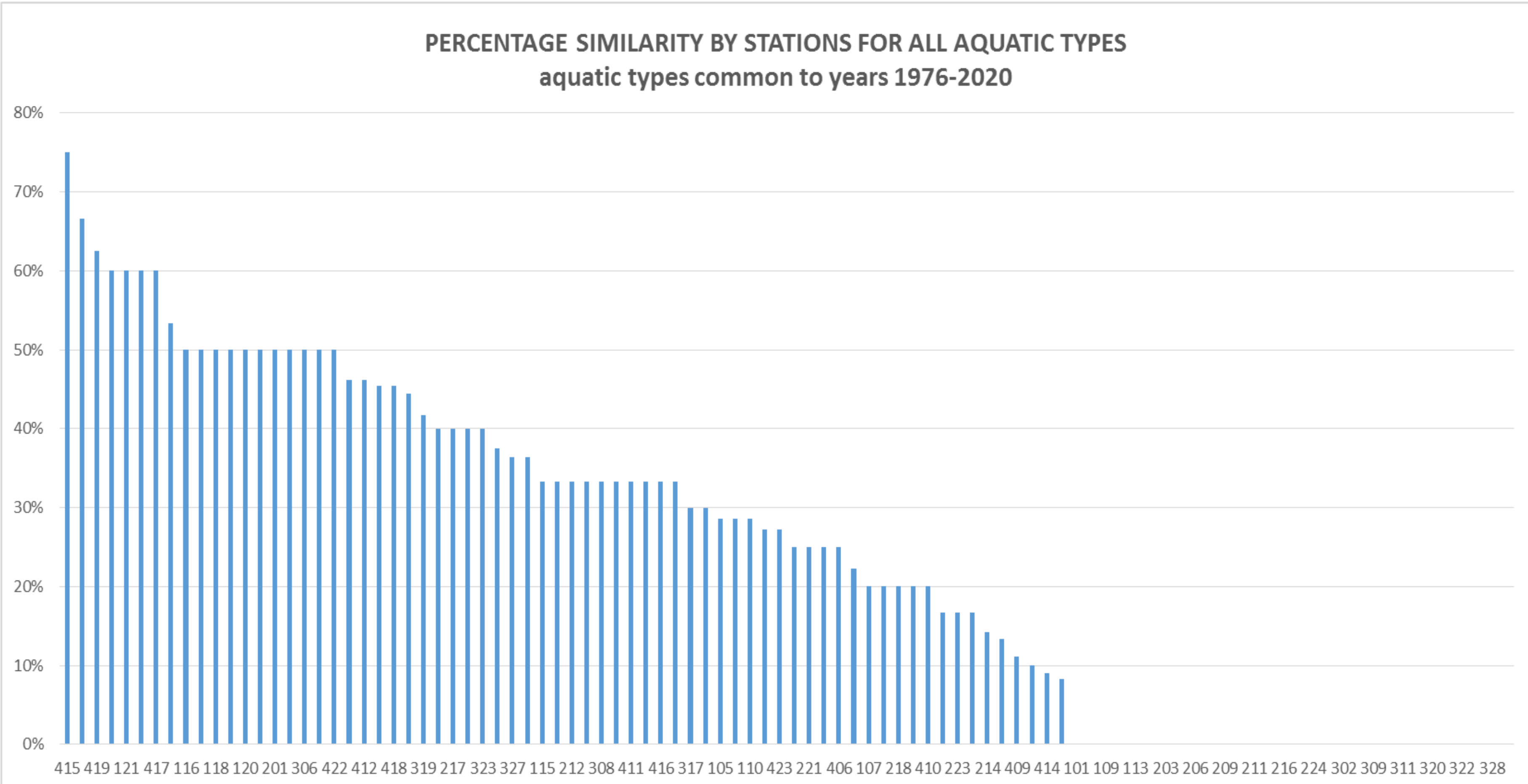


Figure 10: PERCENT SIMILARITY IN COMPOSITION OF PLANTS AT STATIONS 1976-2020

13. COMPARISON OF RESULTS FOR 2020 AND 1976

The changes which have occurred since 1976 among dominant aquatic plants include a complete loss of horned pondweed, a relative decline in Northern Milfoil, the rise of Richardsons pondweed, and the near collapse of Sago Pondweed.

Several species not observed in 1976 now are common in the lake today. Chief among these are thin stem pondweed, water marigold, Robbin's pondweed, and large leaf pondweed. These are established in most sectors. The most infuential change is Flat Stemmed pondweed representing over 9% of all vegetated cases and closely matched to Richardson's pondweed in frequency of occurrence. Flat stemmed pondweed appears to have replaced Hormed pondweed completely.

Among emergent plant types there appears to be a significant increase in wild rice and bulrush. Wild rice beds in White Lake have been augmented by hunting clubs in previous decades in order to encourage foraging by migratory waterfowl.

Only one plant (Horned Pondweed) was missing from the 2020 data. Another twelve plants have been added during the 2020 survey.

European watermilfoil is an invader that is present in sectors 3 and 4. Although its occurrence is low relative to our native species, we should be concerned at it has the ability to dominate aquatic environments and to become a recreational nuisance and an ecological hazard.

13.1 Relative Changes in the White Lake Aquatic Plant Community

The following table is a summary of change in the aquatic community expressed as the difference in relative frequencies of plants between years. It follows the practice used in Wisconsin lake surveys[1].

The relative frequency for each year was calculated as the number of observations for a given type divided by the number of observations for all types expressed as a percentage. The percentage is calculated on the habit of the plant as not all species can grow at all depths. For submerged types, the divisor is the total number of vegetation cases as these plants have the opportunity to be present at all depths, (n=1027). Those restricted to inshore waters like floating leaf and emergents, the divisor is the number of inshore vegetated cases (n=616). For the 1976 data all vegetated cases are used (n=406), as that survey was limited to only shallow water observations although actual depths were not provided.

The amount of change is the difference between these values. Most submerged types show small differences between years. Nine of the eleven submerged aquatic types differ by less than 5%. Changes of 5% or more are highlighted in colour.

---

[1] L L Amery: Aquatic Macrophyte Survey: Bone Lake, Polk Co. Wisc. July 2017.

13.2 Relative Frequency of Submerged, Floating Leaf and Emergent Aquatic Plants: 1976 - 2020

occurrence of a type relative to all occurring types

species	common name	1976	2020	change
	SUBMERGED TYPES	**n/406**	**n/1027**	
Potamogeton richardsonii	Richardson's Pondweed	8%	10.6%	3%
Utricularia vulgaris	common bladderwort	3%	4.9%	1.7%
Zosteralla dubia	water star-grass	1%	3.2%	2.2%
Ceratophyllum demersum	coontail	7%	8.1%	1.1%
Vallisneria americana	wild celery	8%	7.3%	0%
Najas flexilis	water nymph	8%	8.5%	0%
Potamogeton pectinata	Sago pondweed	7%	0.5%	-6.4%
Myriophyllum sibricum	northern milfoil	14%	8.5%	-5.3%
Lemna triscula	star duckweed	5%	1.7%	-3.0%
Elodea canadensis	Canada water weed	7%	4.1%	-2.8%
Chara spp	chara	3%	1.6%	-1.9%
	FLOATING LEAF and EMERGENTS	**n/406**	**n/616**	
Zizania aquatica	wild rice	2%	10.1%	8%
Typha latifolia	cattail	5%	10.6%	6%
Nymphaea odorata	White waterlily	5%	10.3%	5%
Sparganium spp.	bur reed	0.5%	4.7%	4%
Nuphar variegata	Yellow water lily	5%	7.9%	3%
Scirpus validus	common bulrush	1.8%	4.4%	3%
Potamogeton natans	floating pondweed	1.4%	3.4%	2%
Sagittaria spp.	arrowhead	1.7%	4.2%	3%
	MISSING TYPE			**na**
Potamogeton palustris	Horned pondweed	13%	0.0%	-
	NEW TYPES	**na**	**n/1027**	**-**
Potamogeton zosteriformis	flat stem pondweed	0%	9.3%	-
Megalodonta beckii	W marigold	0%	3.4%	-
Myriophyllum spicatum	Eurasian water milfoil	0%	2.6%	-
Potamogeton robbinsii	Robbins pondweed	0%	2.6%	
Pontederia cordata	pickerel weed	0%	1.2%	-
Potamogeton amplifolius	large leaf pondweed	0%	1.1%	-
Nitella spp	Nitella	0%	0.8%	-
Myriophyllum heterophyllum.	whorled water milfoil	0%	0.7%	-
Potamogeton praelongus	white stem pondweed	0%	0.7%	-
Potamogeton gramineus	variable pondweed	0%	0.6%	-
Limnobium spp	frogbit	0%	0.3%	-
Fontinalis spp.	Fontinalis	0%	0.1%	-

>5% increased occurrence	invasive	>5% decreased occurrence

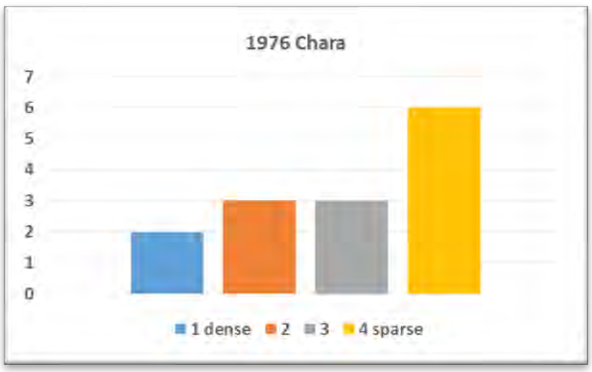
PART 2

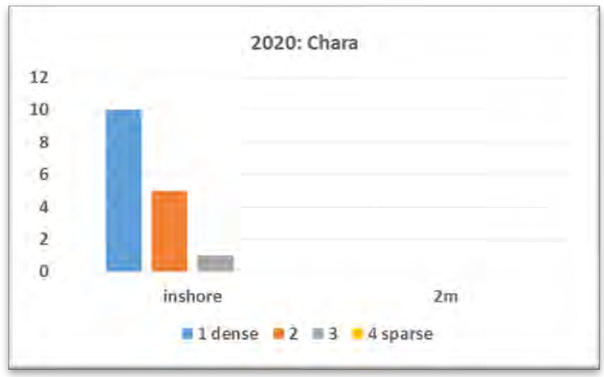
THE AQUATIC PLANTS OF WHITE LAKE

A. NON-VASCULAR PLANTS

CHARA
***Chara spp**.**

Chara was observed at 16 sites in 2020. It is the 18th most frequently seen plant type, appearing in 9% of the vegetated sites we examined. All of these are located in shallow waters less than 2 metres deep. Most reports were confined to the Village Basin and Hayes/Banes Bays. Of the 16 sites, 10 sites (60%) had formed dense mats covering the substrate.





In 1976 chara was recorded at 14 of 94 stations (15%). The table below compares these time periods. There is a close match in the number of cases where chara has occurred as well as the sectors where it was found. There is enough similarity to suggest that chara has not changed in frequency of occurrence, however the frequency of abundance for dense stands has become noticeable.

Occurrence and Percent Contribution by Sector for Chara

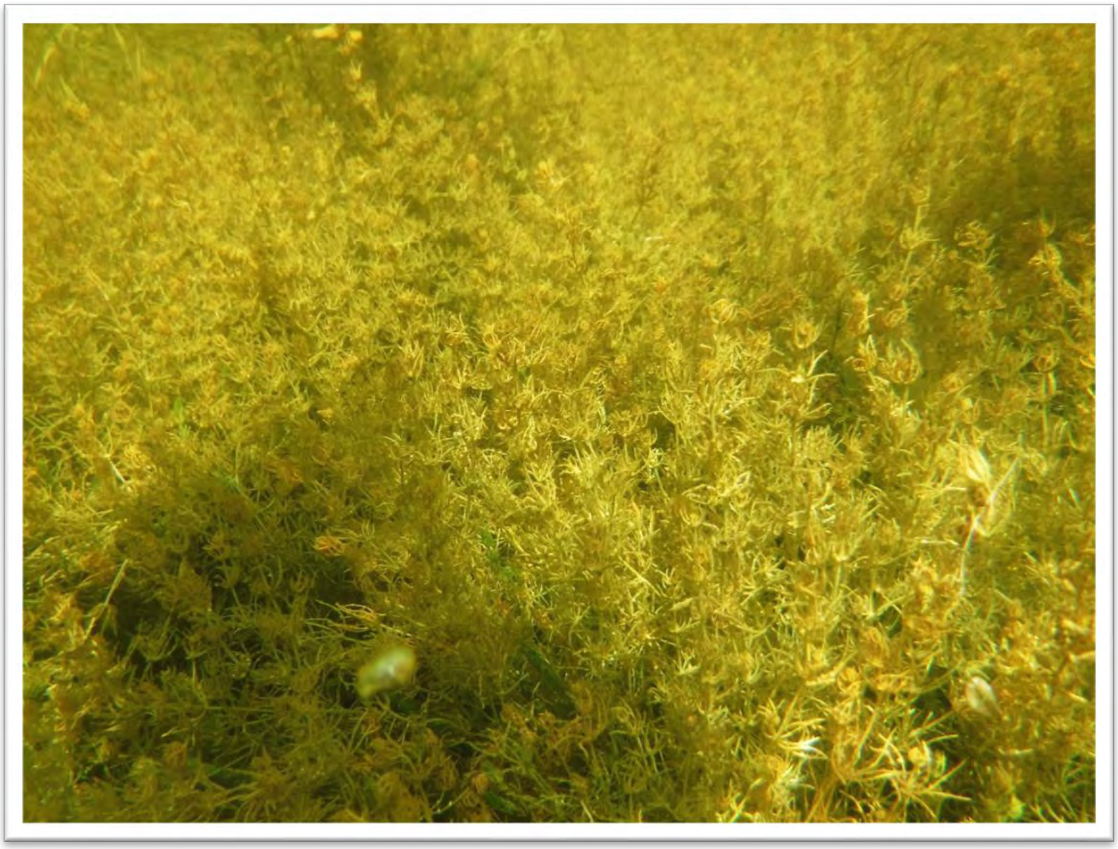
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	7	50%	sector 1	7	44%
sector 1	2	14%	sector 2	1	6%
sector 3	1	7%	sector 3	4	25%
sector 4	4	29%	sector 4	4	25%
Village Basin	6	40%	Village Basin	5	31%
Hayes/Bane Bays	1	7%	Hayes/Bane	1	6%
Pickerel Bay	0	0%	Pickerel Bay	2	13%
Three Mile bay	2	14%	Three Mile	2	13%
ALL (94)	14	15%	ALL (174)	16	9%

Chara is not a true vascular plant but a macro-alga, a member of the stonewort family. It is known to be a quick colonizer of reservoirs where it can form a thick continuous carpet. Where it has to compete with vascular plants, it often is reduced to ‘point communities’, a situation that likely describes White Lake chara. Like Sago Pondweed, chara is known to be a good food resource for waterfowl. Chara develops calcium carbonate encrustation on stems and leaves. Lakes with heavy concentrations of Chara report $CaCO_3$ as a major contributor of their sediments (Wang et al 2017). Encrustation is thought to reduce epiphytic algae. Chara beds are noted for their associated clear waters because of the limits chara puts on phytoplankton growth by shading, encrustations, or by allelopathy (chemical interaction)[1].

[1] E van Donk, W J van de Bund: Impact of Submerged Macrophytes Including Chara on Phyto- and zooplankton communities: allelopathy Versus other Mechanisms Aquatic Botany 72 (2002) 261-274).

* spp = many species

SITE 418 chara bed in Three Mile Bay



FONTINALIS spp.

The genus Fontanalis refers to a group of plants called submerged aquatic moss. Fontinalis was seen only once in the 2020 survey of the Bond stations, at Site 421 at the drawdown depth of 4.5 metres. It was not recorded in the 1976 survey as they did not target deep waters. Fontanalis is often associated with fast flowing waters of streams and rivers. It has a preference for less alkaline waters. A pH around 8.4 is thought to be a limiting condition. Fontinalis depends on CO_2 utilization for photosynthesis and it does not utilize carbonate sources for carbon acquisition. It has been observed that the success of this plant to survive episodes of CO_2 unavailability is by adapting to an extended seasonal growing period. It is a plant that spreads by spore dispersal but more commonly through fragmentation.[1]

Occurrence and Percent Contribution by Sector for

2020 sites	2020 Cases	2020 %
sector 4	1	-
Three Mile	1	-
ALL (174)	1	-

SITE416

---
[1] S C Maberly Photosynthesis by *Fontinalis antipyretica;* New Phytologist 1985 100, 141-155

SITE416 Fontanella 15x

NITELLA spp.

The genus Nitella are a cosmopolitan group of macro-algae which can cover a wide range of water depths for which some species are selective. This selectivity has resulted in morphological differences between them. The eight cases recorded for 2020 are associated with waters that are less than 2 metres deep. [see abundance and depth tables page 36]. All appear to be of the same type, exhibiting a stick-like and branching structure.

The Bond Survey of 1976 did not report the presence of this plant.

Occurrence and Percent Contribution by Sector for Nitella spp.

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1			sector 1	1	
sector 2			sector 2	-	
sector 3			sector 3	2	
sector 4			sector 4	5	
Village Basin			Village Basin	-	
Hayes/Bane Bays			Hayes/Bane	-	
Pickerel Bay			Pickerel Bay	-	
Three Mile bay			Three Mile	2	
ALL (94)	not	observed	ALL (174)	8	5%

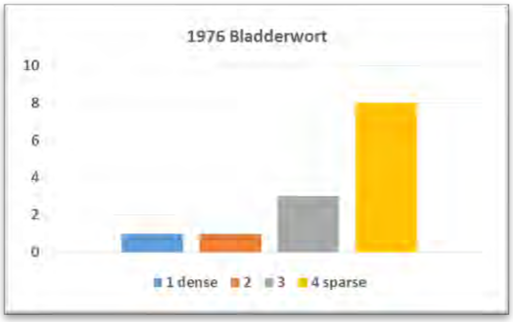
SITE 401

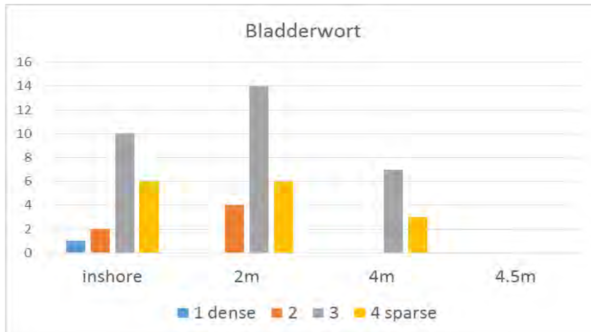
B. SUBMERGED AQUATIC VASCULAR PLANTS

Potamogeton amplifolius

BLADDERWORT
Utricularia vulgaris

Bladderwort occurred as the 7th most frequently seen plant. Eighty percent of observations were in Sectors 3 and 4. It can colonize all littoral depths of water in White Lake but was frequently seen at 2 metres. Only one case of high abundance was found.





Occurrence and Percent Contribution by Sector for Bladderwort

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	2	15%	sector 1	4	8%
sector 2	3	23%	sector 2	3	6%
sector 3	4	31%	sector 3	20	38%
sector 4	4	31%	sector 4	25	48%
Village Basin	0	0%	Village Basin	2	4%
Hayes/Bane Bays	3	23%	Hayes/Bane	2	4%
Pickerel Bay	1	8%	Pickerel Bay	2	4%
Three Mile bay	2	15%	Three Mile	4	8%
ALL (94)	13	14%	ALL (174)	52	30%

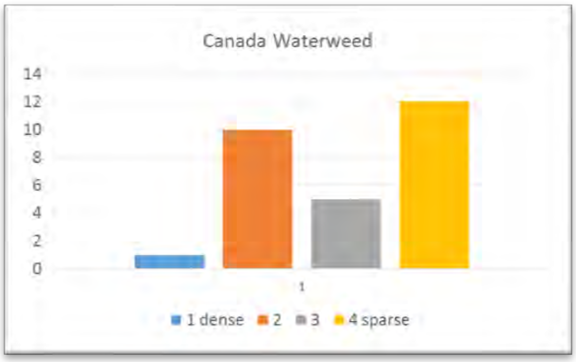
Bladderwort is unusual in that it derives some nutrients by carnivory as well as photosynthesis.
The Bladderworts make up one third of the flowering plants that are dependent to some degree on carnivory. Small vessels called utricles function as faunal traps. Each utricle is under lower water pressure as the utricle is pumped out by internal glands. Hairs at the entrance to the utricle trigger an uptake of water and this draws organisms and detritus into the chamber. A door seals off the chamber and any small organisms like micro-crustaceans become trapped and eventually reduced by digestive enzymes produced by glands on the internal walls of the chamber. This feeding behaviour has been described as a closed system, whereby periphyton (algae that grows on the plant itself) derive a benefit from leaked nutrients. The periphyton in turn are grazed upon by microorganisms and some of these become trapped inside the utricles (Serova 2012)[1].

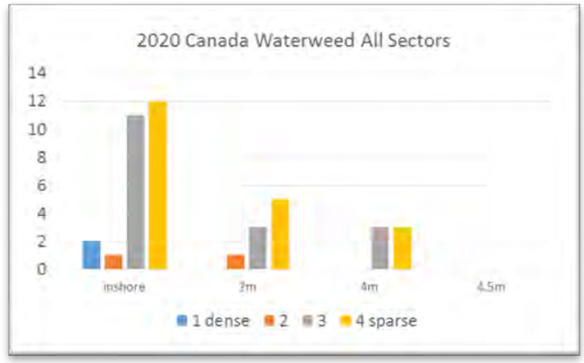
Bladderwort does not form roots. It is often seen in White Lake as a long strand draped over supporting vegetation. Because of its carnivorous nature it has been used as an indicator for nutrient poor conditions in some lakes.

1: D. Sirova 2012 Hunters or Gardeners? Plant-microbe Interactions in Rootless Carnivorous <u>*Utricularia*</u> thesis: University of South Bohemia in Ceske Budejovice, Faculty of Science

CANADA WATERWEED
Elodea Canadensis

Canada Waterweed occurred at 24% of the sites visited in 2020. This places it as the 9th most frequently seen aquatic plant. It achieved an abundance of '1' on 2 occasions: sites #224 and #405.





Both survey years show similar patterns with Sector 4, and Three Mile Bay providing approximately half of the occurrences, while the shallows of Hayes/Bane and Village basins hardly contribute at all. Based on these figures it appears that Elodea has not changed in occurrence in White Lake.

Occurrence and Percent Contribution by Sector for Canada Waterweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	4	14%	sector 1	5	12%
sector 1	1	4%	sector 2	2	5%
sector 3	6	6	sector 3	14	34%
sector 4	17	21%	sector 4	20	49%
Village Basin	0	0%	Village Basin	2	5%
Hayes/Bane Bays	0	0%	Hayes/Bane	0	0%
Pickerel Bay	2	7%	Pickerel Bay	4	10%
Three Mile bay	7	25%	Three Mile	6	15%
ALL (94)	28	30%	ALL (174)	41	24%

Elodea is common to hard water lakes in North America and has become an invasive species through Europe. It can be found at depths up to 8 metres but requires relatively clear waters. Although it can produce seed, this is a rarity as often the plant is represented by only one sex within the community.[1] It survives primarily by producing large numbers of overwintering buds from leaf tips that survive the winter in a dormant state.

Under non-adverse conditions, aquatic plants satisfy their carbon requirements from dissolved aquatic CO_2 derived from the atmosphere. Carbonate availability from groundwater sources as found in alkaline lakes like White Lake can offer another carbon source for some aquatic plants when dissolved CO2 is reduced. Elodea is known to be adapted to the higher energy demands required for carbon acquisition from such carbonate sources.

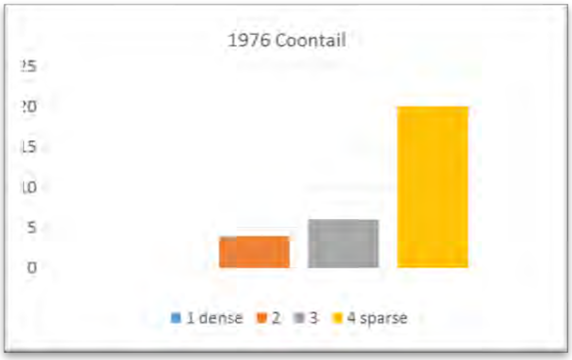
Elodea has been shown to be intolerant to iron limitation. It is thought that observed rise and decline in the density of Elodea beds seen over time reflects this limitation as the plant can quickly deplete iron from the immediate sediment. In White Lake iron would be a limiting resource for Elodea since concentrations for this element range from 50 to 100 ppb.

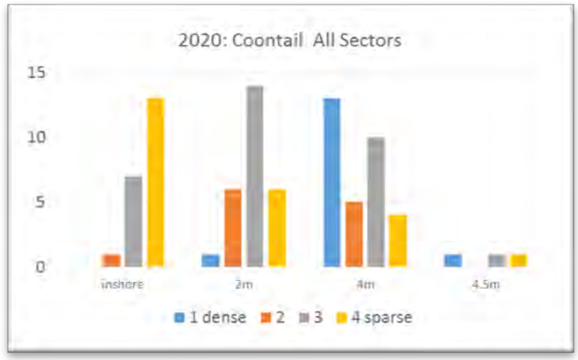
[1] K.W. Spicer, P. M. Catling The Biology of Canadian Weeds 88: *Elodea Canadensis* Michx
1988: Can. J. of Plant Science 68: 1035-1051

[2] B. Olsen, T V Madsen Growth and physiological acclimation to temperature and inorganic carbon availability by two submerged aquatic macrophyte species, *Callitriche cophocarpa* and *Elodea Canadensis* Functional Ecology; 2000 14,252-260

SITE 409 inshore

COONTAIL
Ceratophyllum demersum





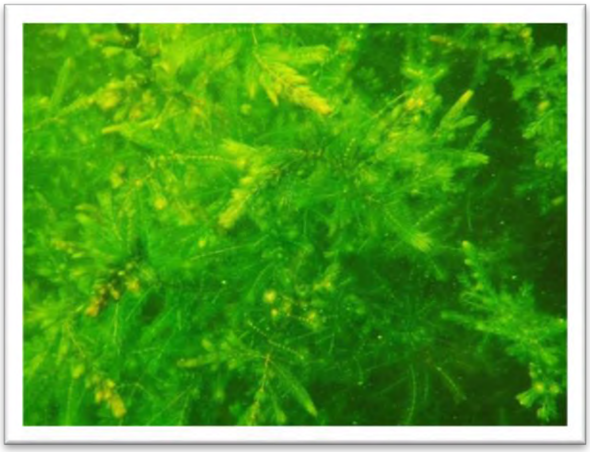
Occurrence and Percent Contribution by Sector for Coontail

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	2	7%	sector 1	5	6%
sector 2	1	3%	sector 2	0	-
sector 3	16	53%	sector 3	40	49%
sector 4	11	37%	sector 4	37	45%
Village Basin	1	3%	Village Basin	1	1%
Hayes/Bane Bays	0	0%	Hayes/Bane	0	-
Pickerel Bay	6	20%	Pickerel Bay	4	5%
Three Mile bay	5	17%	Three Mile	7	9%
ALL (94)	30	32%	ALL (174)	82	47%

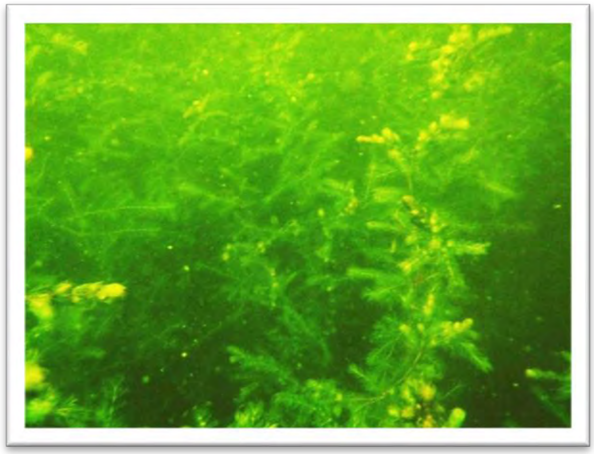
C. demersum has the appearance of a rooted plant as it forms multiple stems growing vertically from a horizontal stolon. The image below shows a 1 metre section arranged in the way that it is normally found on the bottom. When retrieved It forms a single continuous plant.

SITE 414

Coontail with density value "1"

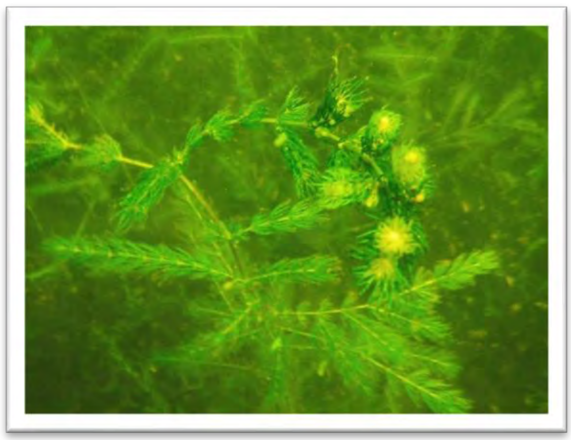


SITE 318 4 metres



SITE 410 4 metres

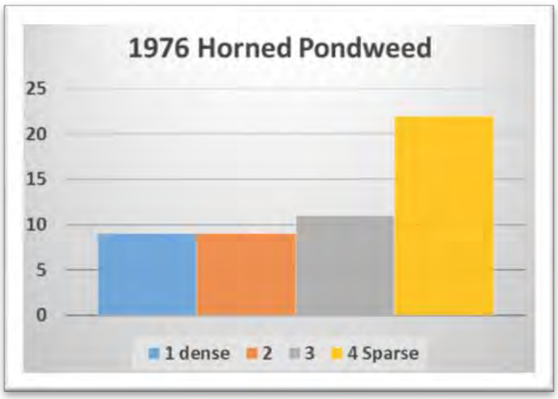
SITE 414

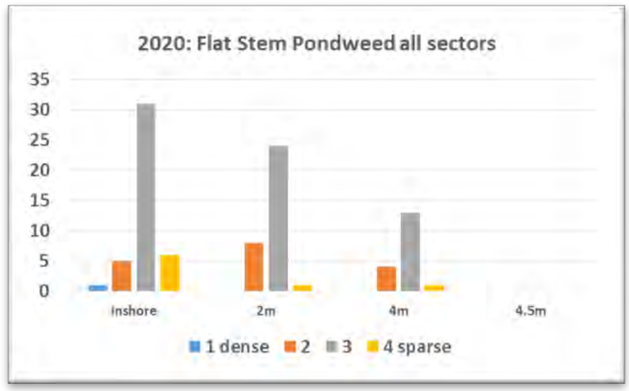


The highly dissected leaves are a distinctive of Coontail. They exhibit whorls with a wide variation in size on the same stem.

FLAT STEMMED PONDWEED
Potamogeton zosteriformnous

Flat stemmed pondweed is the 2nd most commonly seen aquatic plant in White Lake in 2020.
It was found at all vegetated depths but only at one inshore site did it support an abundance value of 1 (Site 420). Most observations found the plant scattered among other species throughout the weed beds, often with a low-density value of "3" (grey bars). It shows a progressive decrease in occurrence by depth.





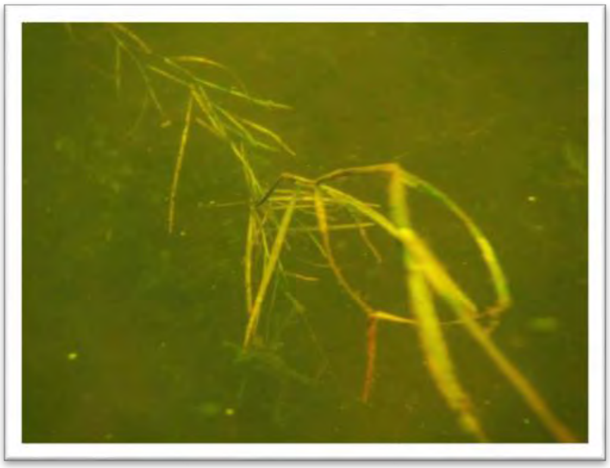
The 1976 Bond survey never encountered Flat Stemmed Pondweed. Instead, the 2nd most prevalent aquatic plant in that year was Horned Pondweed, a plant with some distinctive features such as crescent shaped seeds. We can only speculate on this shift that replaced a once dominant occurrence of Horned Pondweed with Flat Stem Pondweed. The table below constructs a comparison of the occurrence and percent contribution of these two distinct types. No horned pondweed was encountered in White Lake during the 2020 survey.

There is the possibility these two plant types have been mis-identified when considering their overall relative occurrence (51% vs. 55%) is so similar.

Percent Occurrence of Flat Stemmed Pondweed (2020) Compared with Horned Pondweed (1976)

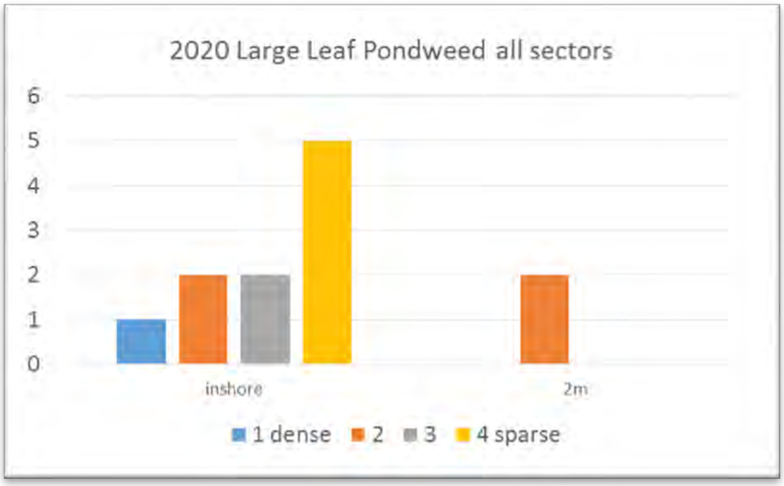
1976 HORNED PONDWEED			2020 FLAT STEMMED PONDWEED		
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	9	18%	sector 1	6	6%
sector 2	10	20%	sector 2	6	6%
sector 3	15	29%	sector 3	31	33%
sector 4	17	33%	sector 4	52	55%
Village Basin	4	8%	Village Basin	2	2%
Hayes/Bane Bays	6	12%	Hayes/Bane	1	1%
Pickerel Bay	4	8%	Pickerel Bay	3	3%
Three Mile bay	5	10%	Three Mile	20	21%
ALL (94)	51	54%	ALL (174)	95	55%

SITE 417: Flat Stem Pondweed 4 metre depth



LARGE LEAF PONDWEED
Potamogeton amplifolius

Large leaf Pondweed is an impressive plant. It looks like lettuce leaves when first emerging from the sediments. This plant was found at sites in shallow waters. Nine of the 11 cases were in less than 2 metres of water. Only a single site reported a maximum density of ‘1’.

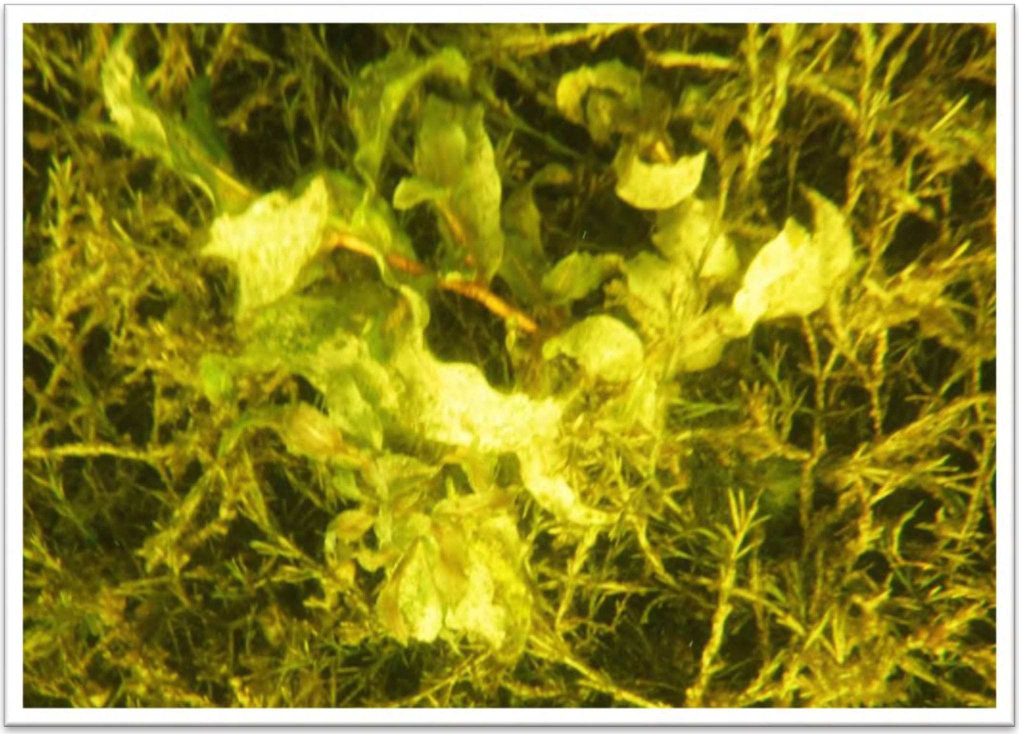


The 1976 Bond study did not report on this species. An obvious plant like *amplifolius,* can be frequently seen in shallow waters. This suggests it may have arrived in the lake since the Bond study.

Occurrence and Percent Contribution by Sector for Large Leaf Pondweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	-	-	sector 1	3	25%
sector 2	-	-	sector 2	2	17%
sector 3	-	-	sector 3	3	25%
sector 4	-	-	sector 4	4	33%
Village Basin	-	-	Village Basin	1	8%
Hayes/Bane Bays	-	-	Hayes/Bane	1	8%
Pickerel Bay	-	-	Pickerel Bay	-	-
Three Mile bay	-	-	Three Mile	2	16%
ALL (94)	-	-	ALL (174)	12	7%

SITE 408

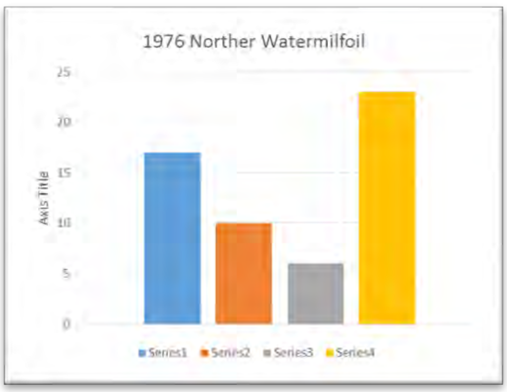


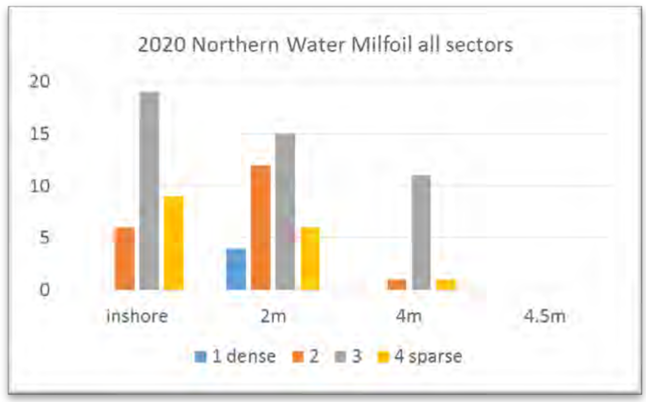
SITE 411

NORTHERN WATER MILFOIL

Myriophyllum sibiricum

Northern Milfoil was the 3rd most frequently seen water plant in the White Lake Survey. It was observed on 84 occasions representing 50% of the vegetated sites visited in 2020. However, it's occurrence in the shallows of the Village basin and Hayes/Bane Bays was less than 1% of all the cases for Northern Milfoil. Pickerel Bay had only one site reporting Northern Milfoil. The Greatest concentrations were found within the main body of the lake including Sectors 3 and 4. Combined they represent over 88% of all the reported occurrences of Northern Milfoil.





The 1976 Bond study in contrast found a more even distribution of Milfoil. Sectors 3 and Sectors 1 and 2 combined, each contributed 32% of the cases and Sector 4 slightly more. The percent contribution of Milfoil in Three Mile Bay appears to be about the same as it was in 1976. The greatest change appears to be a decline in its occurrence in the White Lake shallows particularly the Village and Basin and Hayes Bay sites.

Occurrence and Percent Contribution by Sector for Northern Water Milfoil

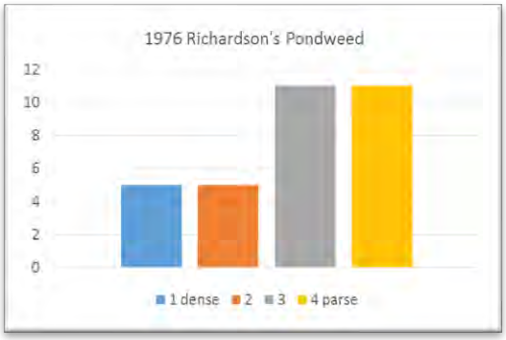
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	9	16%	sector 1	7	8%
sector 2	9	16%	sector 2	2	2%
sector 3	18	32%	sector 3	30	36%
sector 4	20	36%	sector 4	45	54%
Village Basin	3	5%	Village Basin	1	1%
Hayes/Bane Bays	7	13%	Hayes/Bane	0	-
Pickerel Bay	6	11%	Pickerel Bay	4	10%
Three Mile bay	7	13%	Three Mile	12	14%
ALL (94)	56	60%	ALL (174)	84	48%

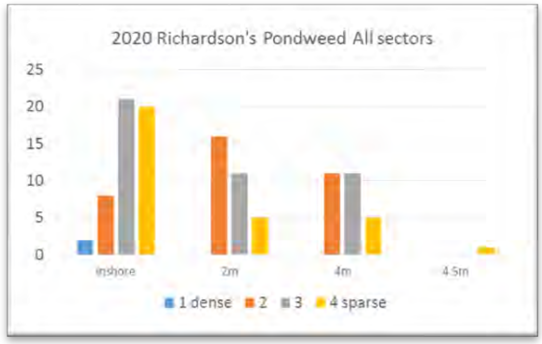
SITE 416

RICHARDSON'S PONDWEED

Potamogeton richardsonii

Richardson's Pondweed is the most commonly seen aquatic plant in White Lake. Our 2020 survey found Richarson's Pondweed at 106 of 174 vegetated sites (61%).





Richardson's Pondweed was frequently seen at all depths in 2020. The greatest number of occurrences were in sector 4 where it represented 47% of the 106 cases for Richardson's. Neither Hayes nor Village basin proper contributed nearly as much to the presence of this plant (~5%). Except for a single shallow water site, Richardson's was not seen to attain a maximum abundance rating of "1". As a significant canopy former, self shading is an issue that influences the degree to which it can concentrate.

Occurrence and Percent Contribution by Sector for Richardson's Pondweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	11	34%	sector 1	19	17%
sector 1	6	19%	sector 2	12	11%
sector 3	6	19%	sector 3	28	25%
sector 4	9	28%	sector 4	51	46%
Village Basin	7	22%	Village Basin	10	9%
Hayes/Bane Bays	3	9%	Hayes/Bane	6	5%
Pickerel Bay	1	3%	Pickerel Bay	4	4%
Three Mile bay	4	13%	Three Mile	19	17%
ALL (94)	32	34%	ALL (174)	110	63%

The 1976 survey reported Richardson's on 32 occasions or 34 % of all stations visited. At that time, it was the 5th most common aquatic species to be seen. This suggests that Richardson's has increased its occurrence, and displaced Northern Milfoil as the most frequently occurring plant in White Lake.

In 1976 Richardson's was reported at a third of all stations, Sector 1 contributed 34% of cases, Sector 4 28% and Village basin with Hayes/Bane Bays contributing 22% and 9% respectively. The lower number of cases for the Village Basin and Hayes/Bane Bays may reflect special conditions that this plant requires for survival.

Richardson's Pondweed is one of several submerged aquatic plants that thrives in a marl habitat. It is known as a calcifier along with chara, algae and certain cyanobacteria. Richardson's develop encrusted surfaces of calcium carbonate on its upper leaf surfaces. These become obvious as the summer progresses and water temperature rises. This precipitate can exceed the total biomass of the plant itself.

Aquatic plants face particular challenges. They can have reduced thicknesses of cell walls and an increased proportion of chloroplasts found nearer to cell surfaces to promote photosynthesis and gas exchange in an environment where light is limiting and where CO_2 diffusion rates through water are slow and stagnant. Surface boundary layers between the surface of a leaf and the water are resistant to gas exchange. Under these conditions aqueous CO_2 acquisition rates can at times be limiting. Potamogeton has the ability to extract carbon from calcium carbonate as an alternative source. This is accessed by using the difference in potential between external leaf surfaces. Enzyme supported reactions produce internal concentrations of CO_2 often greater than the external ambient supply. Excess CO_2 leaked from cells recombines as calcium carbonate on upper leaf surfaces. During the fall a pulse of this precipitated $CaCO_3$ occurs with senescence. This calcification product is thought to contribute to a large degree to the accumulation of calcium carbonate of marl sediments.[1]

---

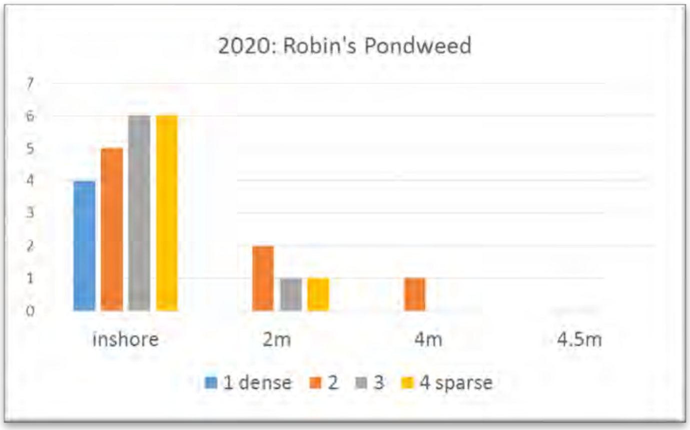
[1] Ted McConnaughey; Acid Secretion, Calcification, and Photosynthetic Carbon Concentrating mechanisms Canadian Journal of Botany, 76, 119-1126 (1998).

SITE 411 4 metres

SITE 422 Three Mile   4 metres

ROBBINS PONDWEED
Potamogeton robinsii

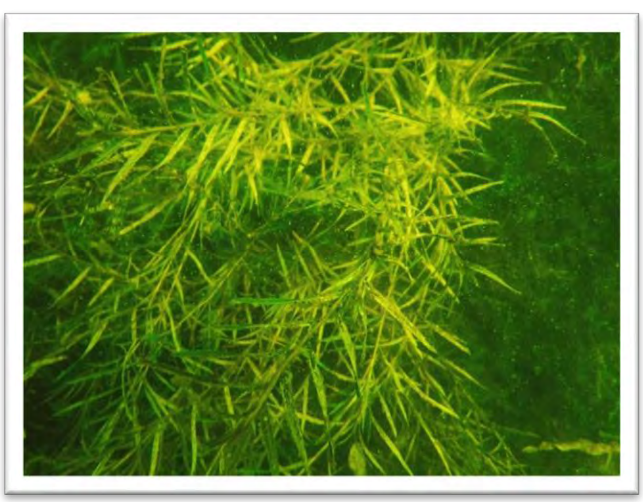
Robbins Pondweed was the 14th plant by occurrence, with all cases occurring within the Village Basin proper for Sector One, and Hayes/Bane Bays for sector 2.



Occurrence and Percent Contribution by Sector for Robbin's Pondweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	-	-	sector 1	9	35%
sector 2	-	-	sector 2	5	19%
sector 3	-	-	sector 3	4	15%
sector 4	-	-	sector 4	8	31%
Village Basin	-	-	Village Basin	6	23%
Hayes/Bane Bays	-	-	Hayes/Bane	3	12%
Pickerel Bay	-	-	Pickerel Bay	0	-
Three Mile bay	-	-	Three Mile	6	22%
ALL (94)	-	-	ALL (174)	26	15%

SITE 418 Inshore



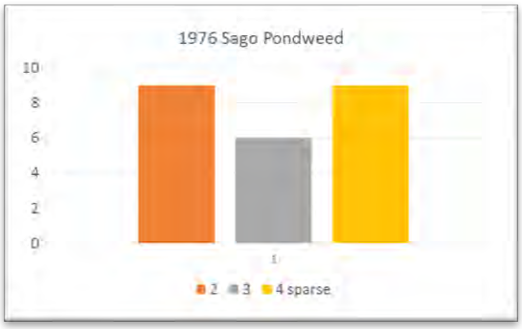
SITE 123 Village Basin

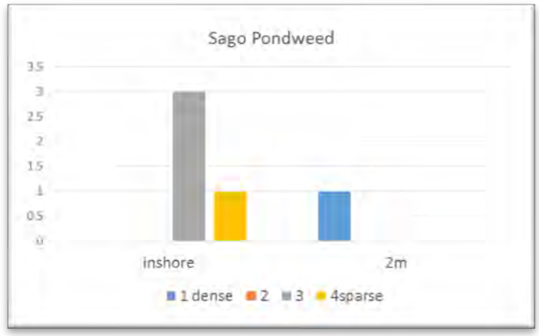
leaf section with central vein

SAGO PONDWEED

Stuckenia pectinata/Potamogeton pectinatus

This aquatic plant illustrates a severe reduction in both frequency and abundance between years. Our 2020 survey found this plant on 5 occasions representing 3 percent of all of the sites we examined. All 5 sites were associated within the main body of the lake. No examples were found at sites in sub basins. This plant occupies the 28th position by occurrence. Only at a single site did it rate a high density.





The 1976 survey ranked Sago as their 8th most frequently observed water plant. It was present in all sectors and sub-basins in the lake. Bond observed this plant at 28 of the 94 vegetated stations that he visited, representing 30 % of his observations on aquatic plants. Of the sites reporting the presence of Sago, 4 ranked at the highest density. Bond found the highest numbers associated with Sector 2. This suggests an affinity for calcareous conditions.

Sago was a common aquatic plant in White Lake 44 years ago. It can be concluded that Sago has undergone a severe reduction since 1976.

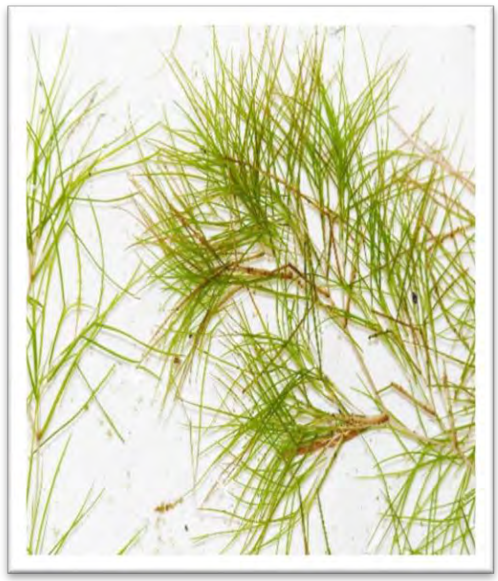
Occurrence and Percent Contribution by Sector for Sago Pondweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	4	14%	sector 1	2	40%
sector 2	10	36%	sector 2	2	40%
sector 3	9	32%	sector 3	1	20%
sector 4	5	18%	sector 4	0	0%
Village Basin	1	4%	Village Basin	0	0%
Hayes/Bane Bays	6	21%	Hayes/Bane	0	0%
Pickerel Bay	3	11%	Pickerel Bay	0	0%
Three Mile bay	5	18%	Three Mile	0	0%
ALL (94)	28	30%	ALL (174)	5	3%

Sago has been recognized as a cosmopolitan species, one of the more important food resources for North American waterfowl and invertebrates. It favours hard water conditions and under high alkalinity (150 ppm), can be the only aquatic plant present in the water. It has been known to be a nuisance plant growing to a high density and suppressing other native plants. Like other members of the pondweed family, it utilizes a complex of rhizomes and tubers to aid its spread. It generates enough seed to produce a seed bank that can be viable for some time. It also spreads by using its rhizomes and tubers. Sago is unrestricted by depth. It is salt tolerant and can grow in reduced O_2 conditions.

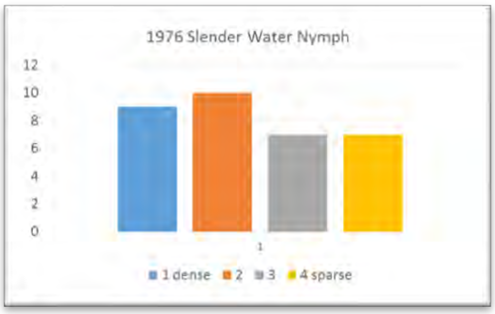
Waterfowl derive a benefit from Sago but in return Sago seed germination is stimulated when it passes through the digestive tract of waterfowl. Experiments have shown Sago seed germination to be 6X greater than Sago not exposed to a waterfowl's digestive gut.[1]

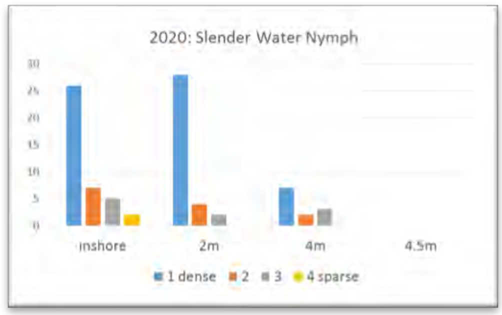
These photos are examples of Sago from White Lake in 2020. Sago has fine thread-like leaves that give it a grassy appearance. In fact, each leaf is composed of 2 leaves fused together.



SLENDER WATER NYMPH
Najas flexilis

The 2020 survey found Slender Water Nymph to be the 4th most frequently occurring plant. It was also the plant that achieved the greatest abundance in the lake. Najas occurred at 86 locations representing 49% of all vegetated sites. Of these 86 occurrences, 70% had an abundance rating of ‘1’ meaning dense. Over 50% of these high-density cases were in sector 4 and of these a third came from Three Mile Bay.





The 1976 Bond study found Najas at 33 stations representing 35% of observations where Najas was present. Najas represented their 3rd most frequently observed plant. The overall occurrence of Najas in White Lake has not been greatly altered. However, Najas occurrence in Hayes and Bane Bays appears reduced since 1976. The 2020 report found Najas at only one site in Hayes Bay whereas in 1976 it was found at almost all of the locations there. Three Mile Bay shows an apparent increase in Najas as it is a plant that is found at all vegetated depths. Its density may be increasing in Three Mile Bay. Comparing only the shallow water results from 2020, Najas was present at the maximum density at 10 sites at depths less than 2 metres whereas Bond found only 3 such cases for similar water depths.

Occurrence and Percent Contribution by Sector for Slender Water Nymph

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	5	15%	sector 1	13	15%
sector 2	14	42%	sector 2	9	10%
sector 3	7	21%	sector 3	20	23%
sector 4	7	21%	sector 4	44	51%
Village Basin	3	9%	Village Basin	5	6%
Hayes/Bane Bays	10	30%	Hayes/Bane	1	1%
Pickerel Bay	2	6%	Pickerel Bay	3	3%
Three Mile bay	5	15%	Three Mile	15	17%
ALL (94)	33	35%	ALL (174)	86	49%

The 1976 study found Najas with an abundance rating of ‘1’ on 27% of occurrences.

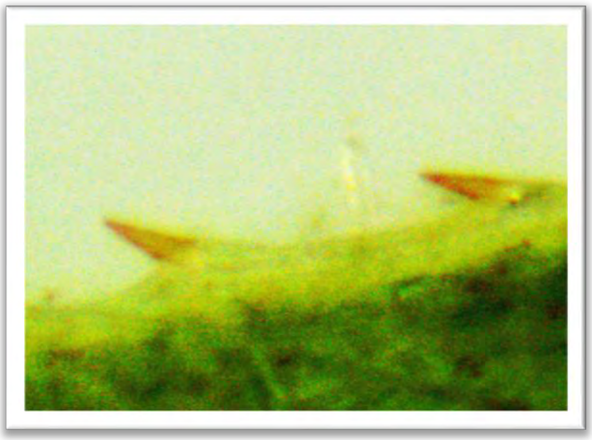
The impression is that Slender Water Nymph is established in most sectors and sites and at multiple depths, and that the frequency of abundance has increased dramatically since 1976. Since the 1976 survey *Najas flexilis* has been taxonomically placed in its own genus (Naiad).
Slender Water Nymph has a global range but only in North America is the population stable and undiminished. Unlike other flowering aquatic vascular plants, it is not known to spread vegetatively. It produces seed but this does not build into a perennial seedbank. The plant is an annual so renewed growth depends on annual seed germination.[1]

The leaves feel smooth but they carry miniscule marginal spikes along their edges. Perhaps these spikes help to mesh the plants together forming a carpet over the lake sediment.

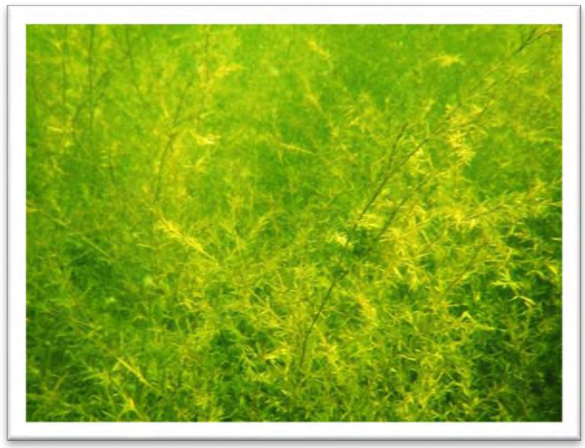
---

[1]R Wingfield et.al. :2006 Assessing and predicting the success of Najas Flexilis; Hydrobilogy 570:79-86.

SITE 417 Three Mile Bay *N. flexilis* leaf 45x



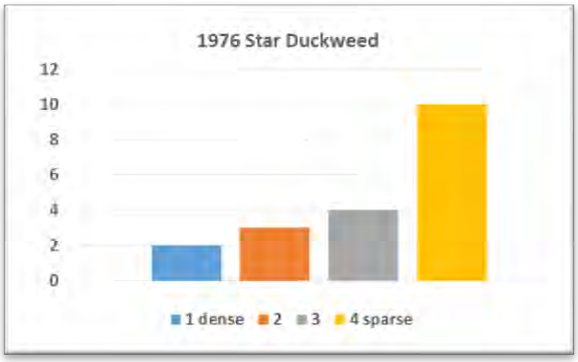
SITE 422 Three Mile Bay

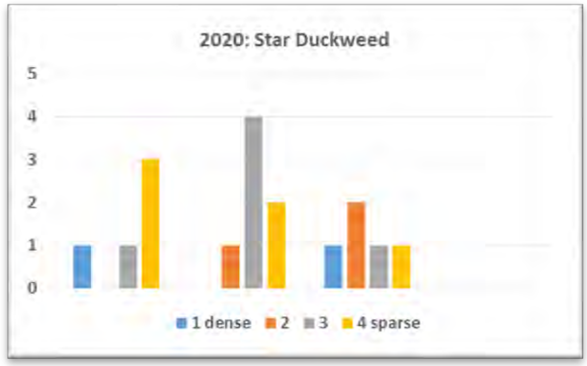


STAR DUCKWEED

Lemna triscula

Star duckweed was seen less frequently in 2020 than in 1976. In both survey years, sector 4 had the largest contribution. It is scarce to absent in the shallows of sector 2 and neither study noted duckweed present in the Village Basin nor Hayes and Bane Bays. The impression is a preference for deeper waters. Of the 17 reports for 2020 only 4 were in waters less than 2 metres deep.





Occurrence and Percent Contribution by Sector for Star Duckweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	-	-	sector 1	2	12%
sector 2	1	5%	sector 2	-	-
sector 3	6	32%	sector 3	7	41%
sector 4	12	63%	sector 4	8	47%
Village Basin	-	-	Village Basin	-	-
Hayes/Bane Bays	-	-	Hayes/Bane	-	-
Pickerel Bay	2	11%	Pickerel Bay	-	-
Three Mile bay	3	16%	Three Mile	1	6%
ALL (94)	19	20%	ALL (174)	17	10%

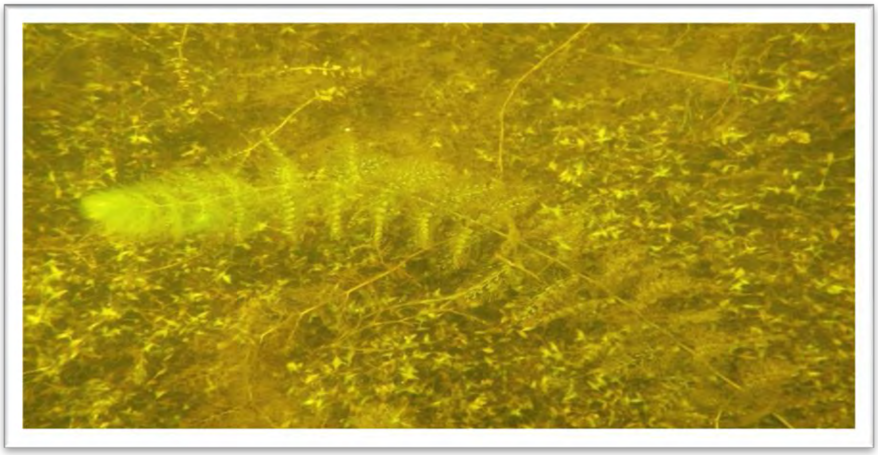
Star duckweed is composed of a parent frond with budding daughter fronds (laminae) attached to it. It is capable of flowering but this is not often witnessed. As a submerged type it has adapted to low light conditions. This allows it to survive even when shaded by a close relative; *Lemna minor* (Floating duckweed). These two types have served as models to test theories about plant colonization and competition under the influence of radiation. Keddy demonstrated that surface mats of *L. minor* have a reproduction potential that is 6 times faster than *L. triscula* in protected ponds[2]. Interestingly, free floating *L. minor* was never encountered in the protected pocket marshes of White Lake in either survey year. Several authors have suggested the Lemna genus becomes vulnerable to poor growth with pH > 8.

---

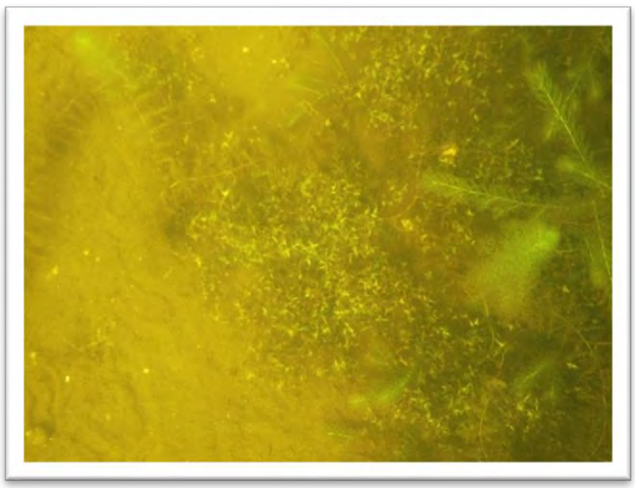
[1] Paul A. Keddy Lakes as Islands: The Distributional ecology of Two Aquatic Plants, Lemna minor L. and L. triscula L. Ecology (1976) 57: pp. 353-359.

[2] C L McLay The Distribution of Duckweed Leman perpusilla in a Small Southern Lake: An experimental Approach; Ecology (1974) 55: pp. 262-276.

SITE 402 4 METRES
coontail above duckweed bed, Hardwood Island



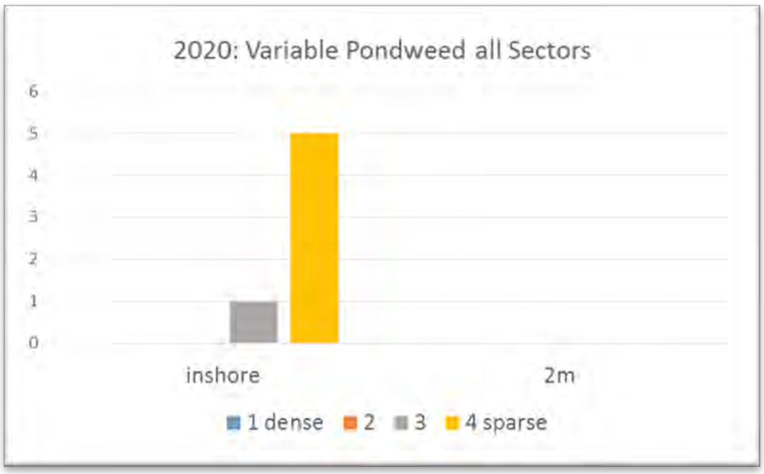
SITE 402 4 metres
Duckweed carpet with exposed sediment (lower left)



SITE 402 Star Duckweed

VARIABLE PONDWEED
Potamogeton gramineus

Variable Pondweed was found in shallow waters on only six occasions. However, it was widely distributed in all areas except the Village Basin and Pickerel Bay. It is a relatively short branching plant with narrow leaves.



Variable pondweed is an attractive plant that has been used in horticultural water gardens. It is a source of food for waterfowl which can significantly reduce the occurrence of the plant. As the name suggests, it exhibits morphological plasticity as do many other Potamogeton. It is known to have hybridized with at least 17 other potamogeton species. It is considered sensitive to contamination and nutrient degradation.

Occurrence and Percent Contribution by Sector for Variable Pondweed

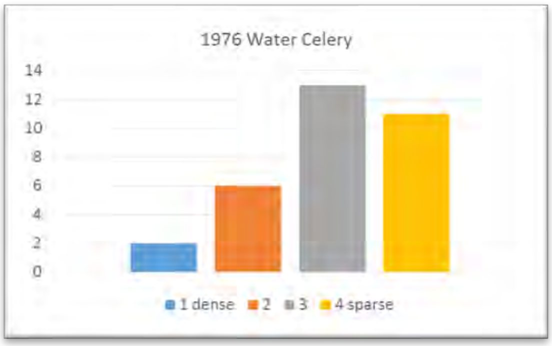
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	-	-	sector 1	2	33%
sector 2	-	-	sector 2	1	17%
sector 3	-	-	sector 3	2	33%
sector 4	-	-	sector 4	1	17%
Village Basin	-	-	Village Basin	0	-
Hayes/Bane Bays	-	-	Hayes/Bane	1	17%
Pickerel Bay	-	-	Pickerel Bay	0	-
Three Mile bay	-	-	Three Mile	1	17%
ALL (94)	-	-	ALL (94)	6	3%

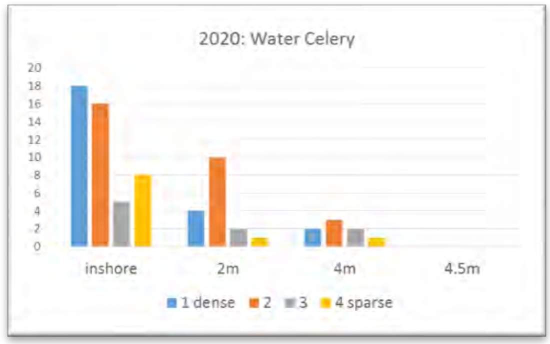
SITE 216 Hayes Bay

SITE 318

WATER CELERY or TAPE GRASS
Vallisneria Americana

Water Celery or tape grass was our 6th most frequently observed plant in the 2020 survey. It appeared on 72 occasions, 41% of our sites. It attained the second greatest abundance frequency of "1" (dense), exceeded only by *Najas flexilis* (Water Nymph). One third of these ratings were from Three Mile Bay. Sector 4 had one station near Hardwood Island (#412) with the high abundance rating "1" occurring at all of the vegetated depths. (see photos below). Sector2 had the fewest sightings of wild celery with only 3 cases. No Vallisneria occurred in Hayes or Bane Bays.



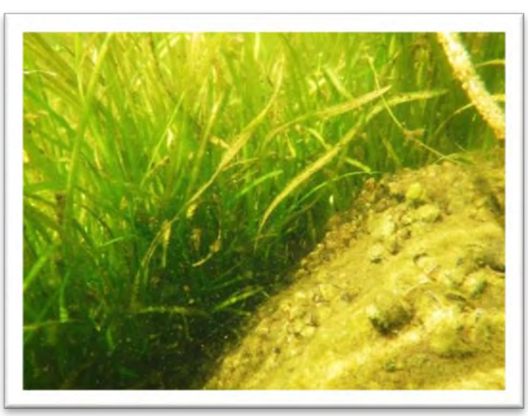


The 1976 Bond observations saw wild celery in 32 of 94 vegetated stations (34%) of their observations. It also occurred as their 4th most frequent plant in White Lake. It appeared more frequently in Sector 2 (7 occasions) compared to 2020, including 3 cases reported in Hayes/Bane Bays.

Wild Celery (*Vallisneria americana*) COMPARISON OF COUNT and PERCENT CONTRIBUTION

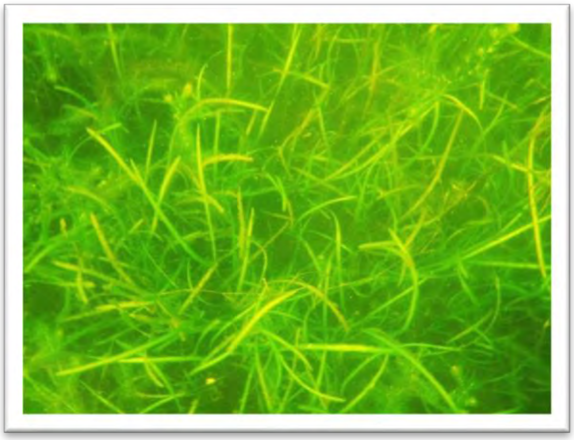
1976 STATIONS	1976 cases	2020 %	2020 SITES	2020 cases	2020 %
sector 1	5	16%	sector 1	11	15%
sector 2	7	22%	sector 2	2	3%
sector 3	9	28%	sector 3	30	42%
sector 4	11	34%	sector 4	29	40%
village basin	3	9%	village basin	7	10%
Hayes/Bane Bays	3	9%	Hayes/Bane Bays	0	-
Pickerel Bay	2	6%	Pickerel Bay	6	8%
Three Mile Bay	7	21%	Three Mile Bay	9	13%
ALL (94)	32	34%	ALL (174)	72	41%

Abundance "dense": < 2 metres



Abundance dense: 2 metres

Abundance dense: 4 metres



A flowering angiosperm like Vallisneria is dioecious (male and female flowers on different plants) need to access the water surface to accomplish pollination. Female flowers form hydrophobic depressions on the water's surface that causes the male flower to tip into them. Quite often the community has only a single sex present, then the plant spreads primarily by vegetated means.[1]

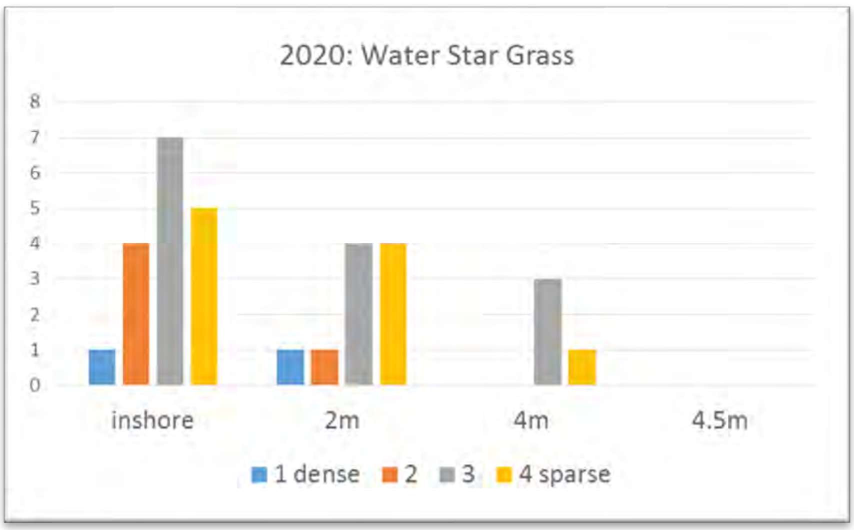
SITE 315: August 16: Vallisneria stalks with flowering heads reach for the surface

WATER STAR-GRASS
Zosteralla dubia

Water Star-grass ranked 12th in frequency of occurrence in 2020. It can be found at all depths but all abundances assessed as 'dense' were inshore sites where the water was less than 2 metres deep. Sector 1 did not appear to support Water Star-grass. Perhaps alkalinity and depth are determining factors.

The Bond study in contrast reported Water Star-grass only within Sector 1. All but 1 sighting was within the Village Basin. It represented 16th in occurrence at Bond stations.

As this plant can thrive at a variety of depths, the Bond assessment most likely underestimates the occurrence of this plant.



Occurrence and Percent Contribution by Sector for Water Star-grass

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	4	100%	sector 1	0	-
sector 2	0	-	sector 2	1	4%
sector 3	0	-	sector 3	15	48%
sector 4	0	-	sector 4	15	48%
Village Basin	3	75%	Village Basin	0	-
Hayes/Bane Bays	0	-	Hayes/Bane	0	-
Pickerel Bay	0	-	Pickerel Bay	1	4%
Three Mile bay	0	-	Three Mile	5	16%
ALL (94)	4	4%	ALL (174)	31	18%

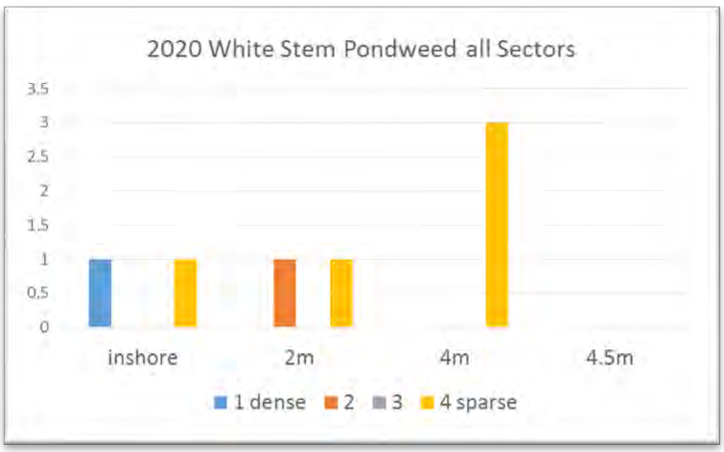
SITE 404

Zosteralla has indistinct veins in its leaves compared to other plants and this is used to distinguish it from similar forms.

WHITE STEM PONDWEED
Potamogeton praelongus

This attractive plant was not reported as observed in the Bond report. Perhaps it occurred in deeper waters and was not seen from the boat they were using. In 2020 the plant was observed at only 6 sites, four of these were in 4 metres of water. It is a plant similar in appearance to Richardson's pondweed and this may mean it is under-represented. As seen in the graph, the abundance ranking was "4" or "sparse" for most occurrences.

This plant is tall, but appears to have a thinner stem than Richardson's. As the name suggests, the stem is whitened when viewed under good illumination.

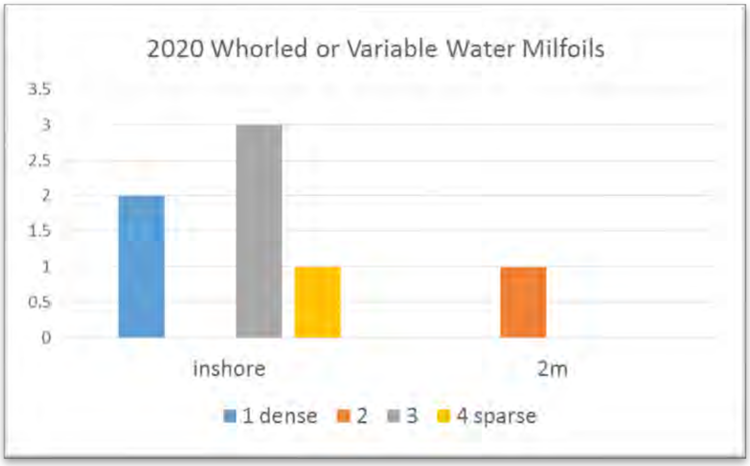


Occurrence and Percent Contribution by Sector for White Stemmed Pondweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1			sector 1	0	-
sector 1			sector 2	0	-
sector 3			sector 3	2	
sector 4			sector 4	5	
Village Basin			Village Basin	0	-
Hayes/Bane Bays			Hayes/Bane	0	-
Pickerel Bay			Pickerel Bay	0	-
Three Mile bay			Three Mile	1	
ALL (94)	not	observed	ALL (174)	7	4%

WHORLED LEAF AND/OR VARIABLE WATERMILFOILS
Potamogeton verticallatun/heterophyllum

Whorled of variable water Milfoils occur at low frequencies in shallow waters. Our survey found the presence of this large plant in shallows occurring in high density.



The Bond survey acknowledged the presence of these Whorled/ Variable species however it was not included as separate observations, but instead combined with Northern Watermilfoil. We can assume the plant was present in White Lake in 1976.

Occurrence and Percent Contribution by Sector for Whorled Type Watermilfoils

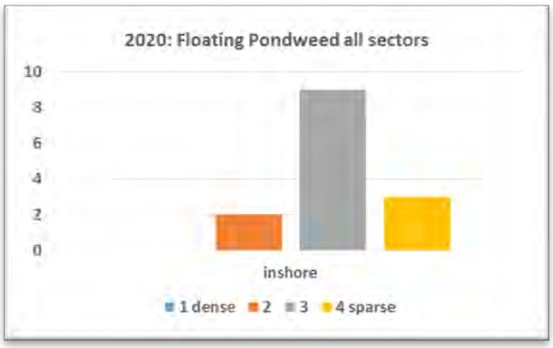
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	-	-	sector 1	3	-
sector 2	-	-	sector 2	-	-
sector 3	-	-	sector 3	3	-
sector 4	-	-	sector 4	2	-
Village Basin	-	-	Village Basin	-	-
Hayes/Bane Bays	-	-	Hayes/Bane	-	-
Pickerel Bay	-	-	Pickerel Bay	2	-
Three Mile bay	-	-	Three Mile	-	-
ALL (94)	?	?	ALL (174)	7	4%

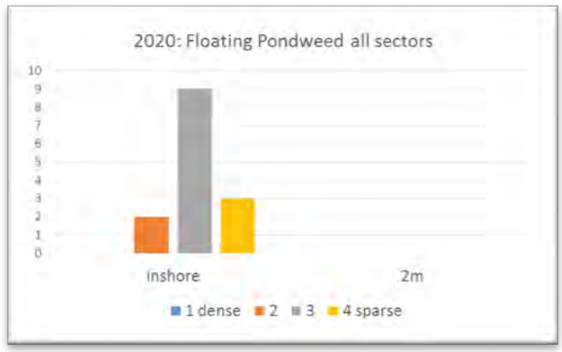
The Northeastern United States consider the spread of Variable watermilfoil to be invasive and a major nuisance in some lakes.

C. FLOATING LEAF AQUATIC VASCULAR PLANTS

FLOATING LEAF PONDWEED
Potamogeton natans

Floating Leaf pondweed is restricted to shallow waters.



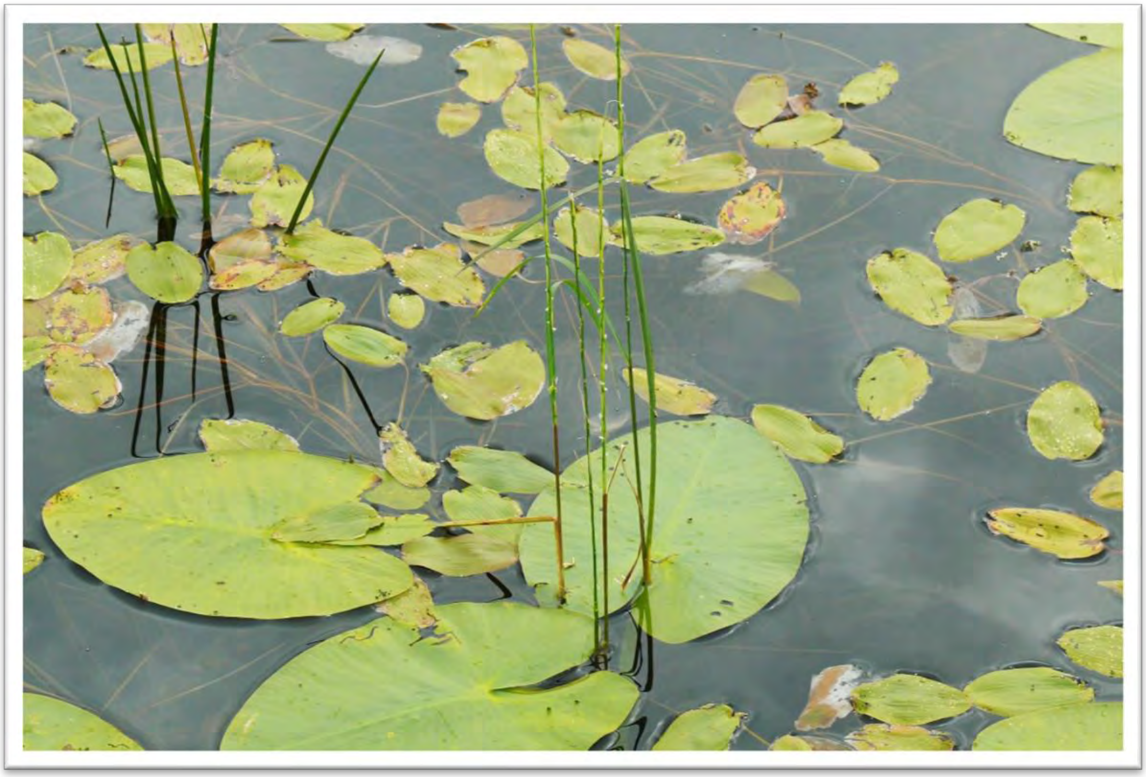


Compared to 1976 reports, the 2020 survey found double the amount of floating pondweed, with Sector2 providing the highest number of occurrences.

Occurrence and Percent Contribution by Sector for Floating Leaf Pondweed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	1	14%	sector 1	4	29%
sector 2	1	14%	sector 2	6	42%
sector 3	2	29%	sector 3	4	29%
sector 4	3	4%	sector 4	0	-
Village Basin	0	-	Village Basin	2	17%
Hayes/Bane Bays	0	-	Hayes/Bane	4	29%
Pickerel Bay	0	-	Pickerel Bay	1	7%
Three Mile bay	0	-	Three Mile	0	-
ALL (94)	7	7%	ALL (94)	14	15%

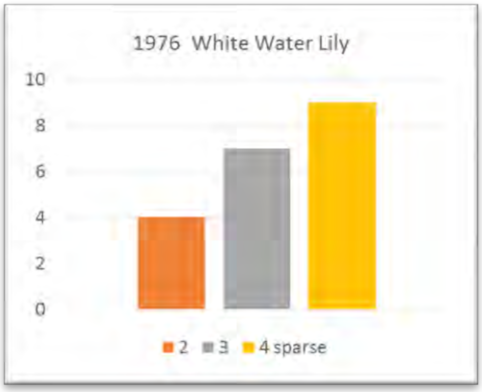
SITE 327 Egg Bay P. natans with larger Yellow water Lily

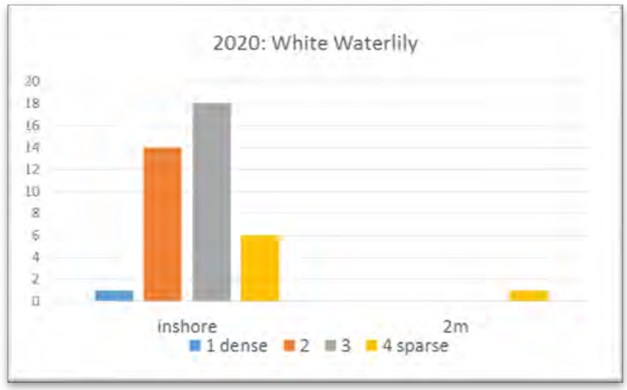


SITE 213 Hayes Bay

WHITE WATER LILY
Nymphaea odorata

White Water Lily was seen in 18% of the sites we visited in 2020. It is the 8th most frequently seen plant. The largest contribution came from sector 3.

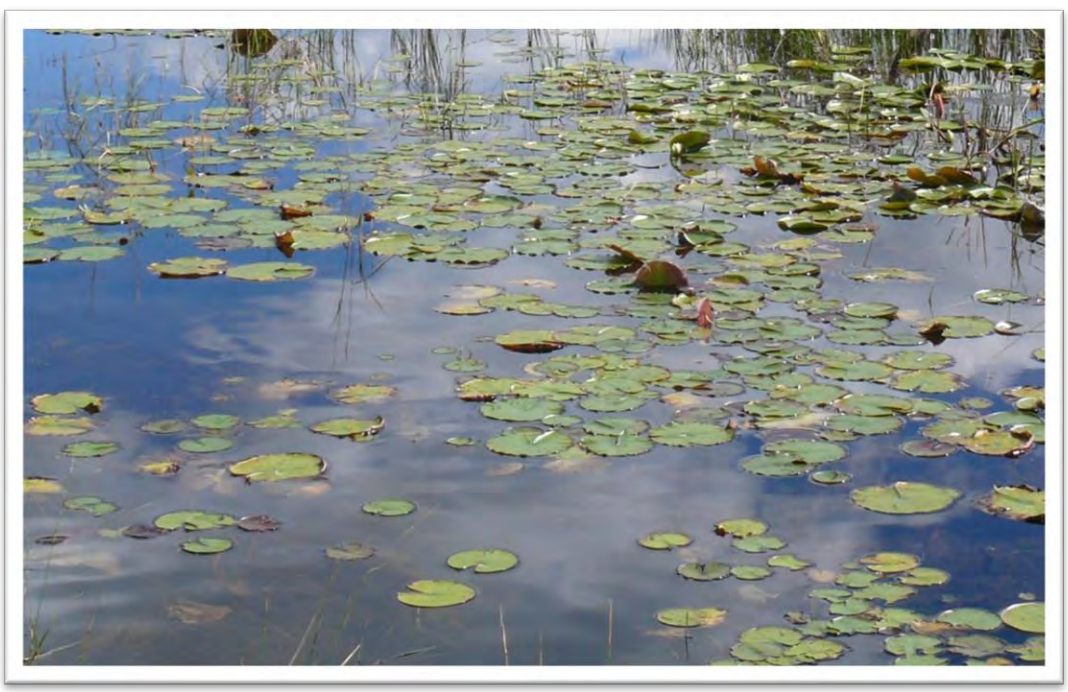




Occurrence and Percent Contribution by Sector for White Water Lily

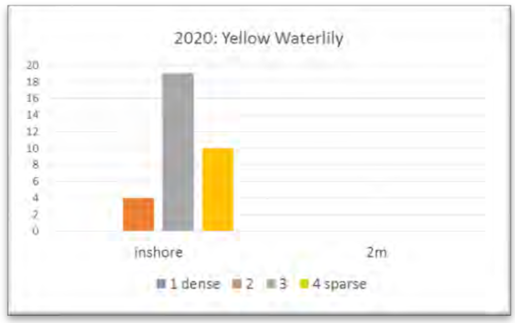
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	3	15%	sector 1	8	20%
sector 2	10	50%	sector 2	12	29%
sector 3	5	25%	sector 3	7	17%
sector 4	2	10%	sector 4	14	34%
Village Basin	2	10%	Village Basin	3	7%
Hayes/Bane Bays	7	35%	Hayes/Bane	7	17%
Pickerel Bay	2	5%	Pickerel Bay	2	5%
Three Mile bay	0	-	Three Mile	4	10%
ALL (94)	20	21%	ALL (94)	41	44%

SITE 208



YELLOW WATER LILY
Nuphar variegate

Yellow water lily occurred at 34% of the stations in 2020, a third more frequent than in 1976. The largest change appears to be a doubling in occurrence outside of Three Mile Bay but within the main body of sector 4.



Occurrence and Percent Contribution by Sector for

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	2	11%	sector 1	5	16%
sector 2	7	36%	sector 2	9	28%
sector 3	6	32%	sector 3	4	13%
sector 4	4	21%	sector 4	14	43%
Village Basin	2	11%	Village Basin	3	9%
Hayes/Bane Bays	6	32%	Hayes/Bane	7	22%
Pickerel Bay	1	5%	Pickerel Bay	2	6%
Three Mile bay	1	5%	Three Mile	4	13%
ALL (94)	19	20%	ALL (94)	32	34%

Nuphar serves as an important source of food as all parts of the plant are associated with herbivorous insects, snails, water beetles, turtles, birds or mammals. Humans too have found a use for the rhizomes and seed when it is well cooked.

The yellow flower that we see are the outer sepals that encase the actual floral petals. The yellow flowers receive a variety of pollinating insects that are attracted to a nectar bowl at the base of the flower. Nuphar flowering begins with a first day partial opening that exposes the female stigma. On the following day the flower head opens completely to expose the pollinating stamens. It is thought this is a way to control pollination exposure in order to limit self-fertilization.[1]

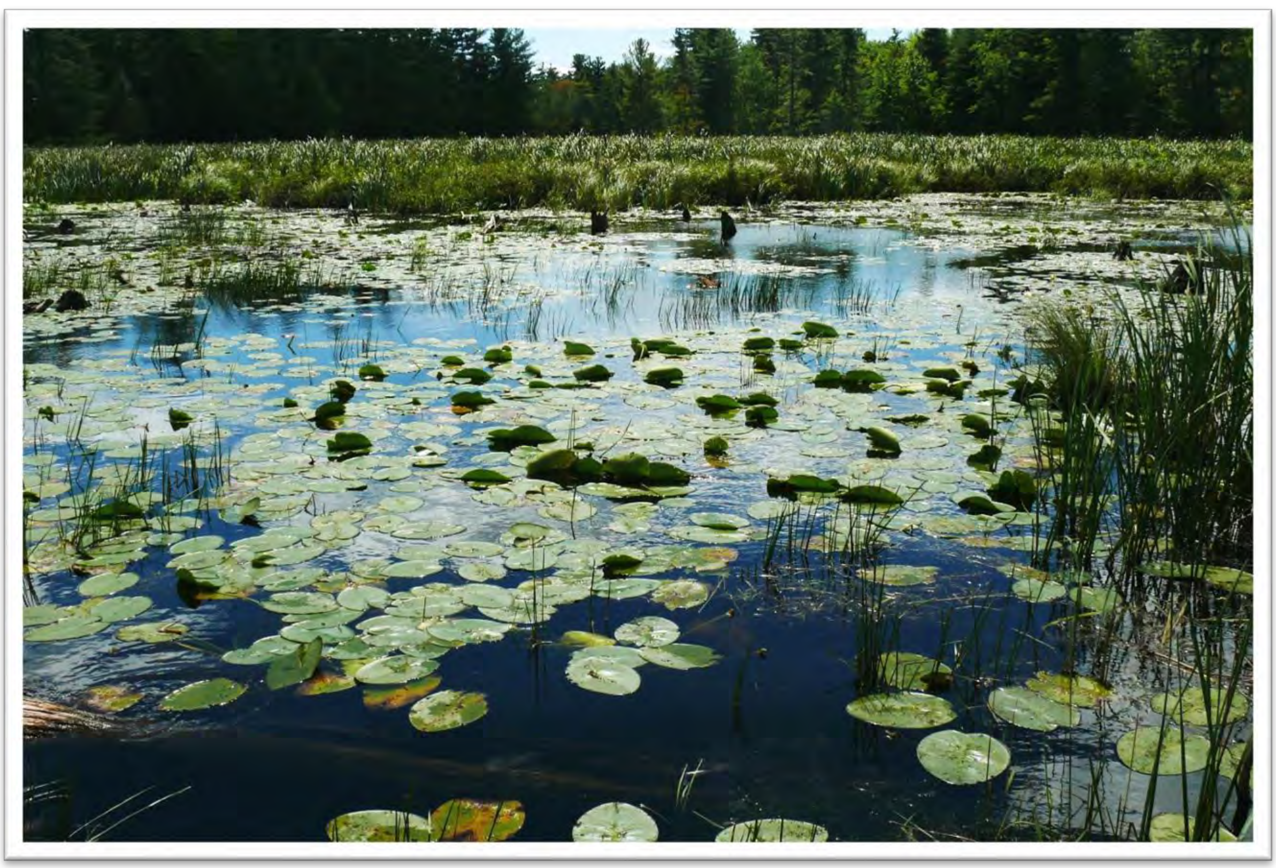
The genus Nuphar has several shared characteristics. It withstands a variety of pH conditions and periods of hypoxia in wetland soils. Air is circulated through younger leaves and through the rhizome before venting to the atmosphere by way of older leaves. Nuphar has been used as a bio-sensor for measuring cadmium contamination levels that could threaten other wetland species.[2]

---

[1] Donald J Padgett; A Biosystematic Monograph of the Genus Nuphar sm. (Nymphaeaceae); Dissertation, University of New Hampshire, Fall 1976.

[2] E S Thompson, F R Pick, L I Bendell-Young; The Accumulation of Cadmium by the Yellow Pond Lily, *Nuphar variegatum;* Archives of Environmental Contamination and Toxicity, 1966.

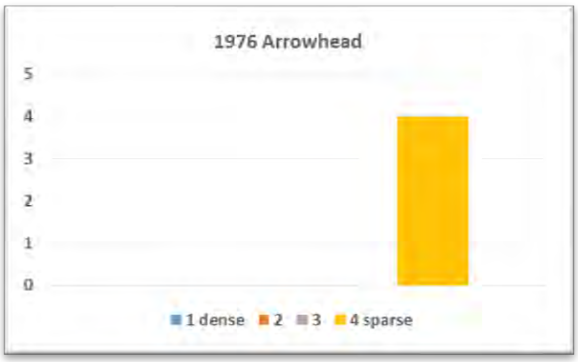
SITE 101

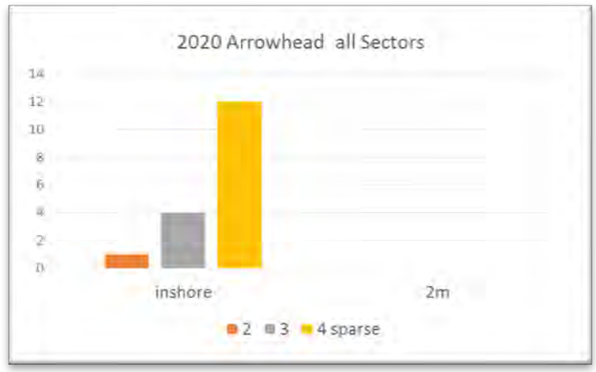


D. EMERGENT AQUATIC VASCULAR PLANTS

ARROWHEAD
Sagittaria spp.

In 2020 a total of 17 sightings were made of the genus Sagittaria, half of which were from Sector 4. In 1976 only 4 stations reported this type.





Occurrence and Percent Contribution by Sector for Arrowhead spp.

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	1	-	sector 1	2	12%
sector 2	1	-	sector 2	3	18%
sector 3	1	-	sector 3	3	18%
sector 4	1	-	sector 4	9	53%
Village Basin	0	-	Village Basin	2	12%
Hayes/Bane Bays	1	-	Hayes/Bane	3	18%
Pickerel Bay	0	-	Pickerel Bay	1	6%
Three Mile bay	0	-	Three Mile	2	12%
ALL (94)	4	4%	ALL (94)	17	18%

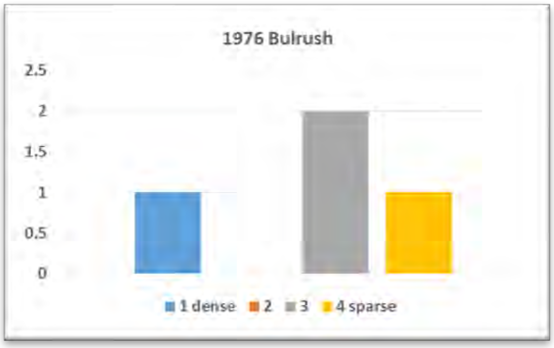
Sagittaria species are known for their morphological plasticity in the shape and dimension of leaves. This is thought to signify differences in nutrient availablity. Within this genus, populations can express either monoecious flowering (both sexes occurring on the same plant) or dioecious flowering (single sex flowers on same plant). This difference is thought to vary with pollinator success. Dioecious plants tend to be more successful in permanent wetlands. [1]

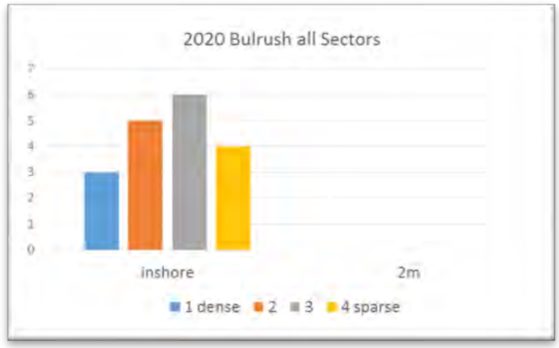
---

[1]FAW Research Collaboration Portal datasheet/1091.

SITE 222 **SITE 327**

BULRUSH
Scirpus validus





Bulrush appears to have increased significantly over the previous years especially so for the Village Basin and Sector 4.

Occurrence and Percent Contribution by Sector for Bulrush

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	0		sector 1	7	39%
sector 2	3		sector 2	1	6%
sector 3	1		sector 3	3	16%
sector 4	0		sector 4	7	39%
Village Basin	0		Village Basin	6	33%
Hayes/Bane Bays	3		Hayes/Bane	1	6%
Pickerel Bay	1		Pickerel Bay	2	11%
Three Mile bay	0		Three Mile	4	22%
ALL (94)	4	4%	ALL (94)	18	19%

Bulrush depends on overwintering rhizomes to store enough carbohydrates to carry it into the following summer growing period. It produces seed that can survive as a seed bank for multiple years but the seed germinates best where there is an intermittent water drawdown that can expose mud flats.

It is thought that damage to stems particularly during the early summer months can be enough to diminish bulrush stands over time.[1] White Lake bulrush stands in the Village Basin are subject to boat traffic and are at risk of injury.

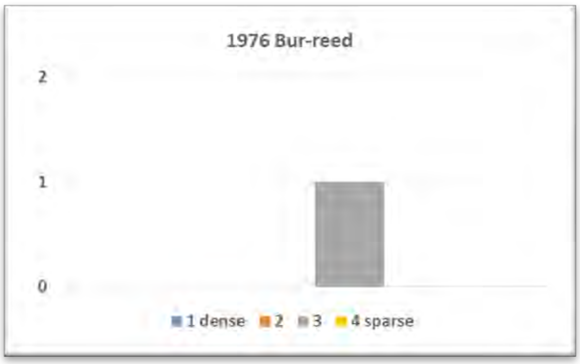
[1] J Barrick, D Hoverson, P McGinley, N Turyk; Water Quality and Bulrush Evaluation in Clark Lake, Door County, Wisconsin; May 2007.

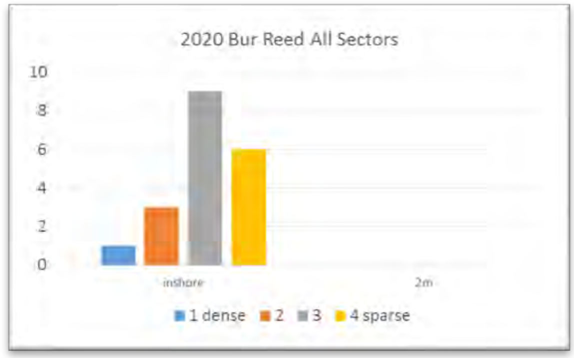
SITE 115 Village Basin

BUR REED

Sparganium spp.

Bur reed is an emergent that is restricted to shallow waters. It may have become more frequent in White Lake pocket marshes over the last 44 years. We encountered it at 19 of our stations (11%).





Bur reed was present for both years, however Bond reported it only once in the Village Basin at station 107. This difference in reported cases has a reduced chance of observational bias as both sample sets are limited to the same inshore observations. Based on this we conclude the plant has indeed become more prevalent. The Bond report lists bur reed as sparse but a station in 2020 (#307) found bur reed to be "dense".

Occurrence and Percent Contribution by Sector for bur reed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	1	-	sector 1	2	11%
sector 2	-	-	sector 2	0	0%
sector 3	-	-	sector 3	8	42%
sector 4	-	-	sector 4	9	47%
Village Basin	1	-	Village Basin	1	5%
Hayes/Bane Bays	-	-	Hayes/Bane	0	0%
Pickerel Bay	-	-	Pickerel Bay	2	11%
Three Mile bay	-	-	Three Mile	2	11%
ALL (94)	1	1%	ALL (94)	**19**	20%

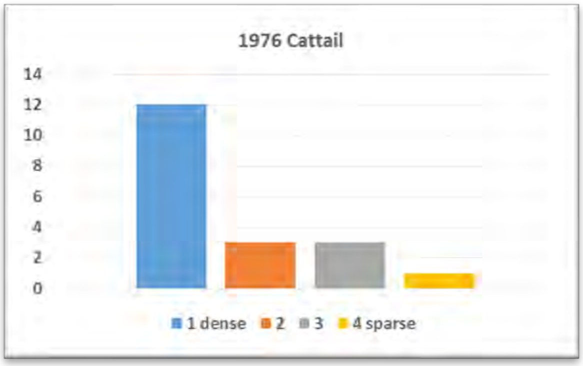
SITE 408

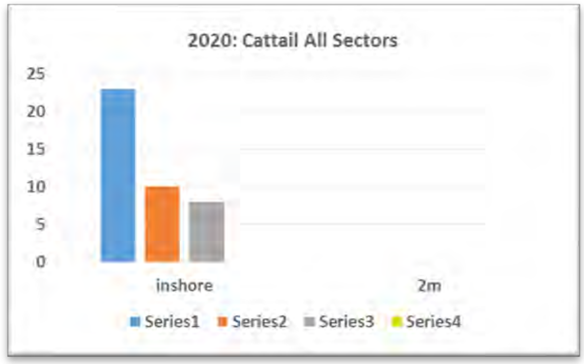
SITE 316

SITE 102

CATTAIL
Typha latifolia

Cattail often presents a wall of solid growth at the shores of wetlands. This would give it a high density of occurrence.





Observations between years suggest that cattail has increased in occurrence, with this change happening within all sectors. The greatest difference was in the Village Basin.

Occurrence and Percent Contribution by Sector for Common Cattail

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	3	16%	sector 1	10	24%
sector 2	11	57%	sector 2	15	36%
sector 3	2	11%	sector 3	8	20%
sector 4	3	16%	sector 4	8	20%
Village Basin	2	11%	Village Basin	6	15%
Hayes/Bane Bays	9	47%	Hayes/Bane	11	27%
Pickerel Bay	0	-	Pickerel Bay	5	13%
Three Mile bay	2	11%	Three Mile	3	7%
ALL (94)	19	20%	ALL (94)	41	44%

SITE 105: SECTOR 1

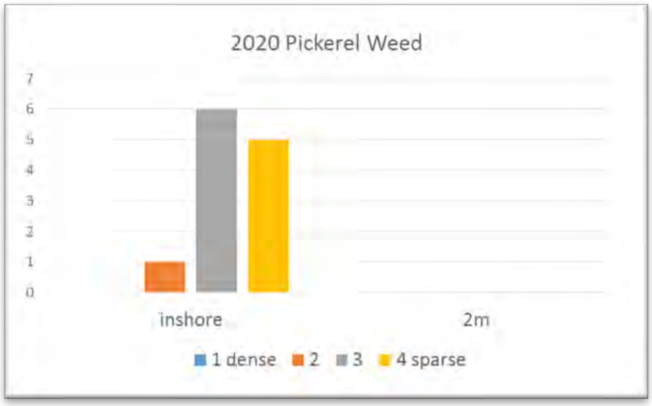
SITE 215: HAYES BAY

Site 323: PICKEREL BAY

SITE 423: THREE MILE BAY

PICKEREL WEED
Pontederia cordata

Pickerel weed is an inshore emergent that shows a distinctive blue inflorescence for much of the summer season. We found this plant favouring in the Village Basin in Sector 1. Nearly half of our reports come from there.



The 1976 Survey did not identify Pickerel Weed.

Occurrence and Percent Contribution by Sector for Pickerel Weed

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1			sector 1	6	50%
sector 2			sector 2	3	25%
sector 3			sector 3	0	-
sector 4			sector 4	3	25%
Village Basin			Village Basin	5	42%
Hayes/Bane Bays			Hayes/Bane	1	<1%
Pickerel Bay			Pickerel Bay	0	-
Three Mile bay			Three Mile	0	-
ALL (94)	-	-	ALL (94)	12	13%

Pickerel weed is self-incompatible for reproduction. It depends on attracting insects and birds to pollinate individual florets. These florets have styles of alternating length that encourages insect cross-pollination between florets which is a system called tristyly.

A two-year survey of a small Ontario lake found nine different species of pollinators visiting Pontederia stands, including flies, honey bees, bumblebees and hummingbirds.

An interesting suggestion is that pollinator numbers on Pickerel weed increase during drought years when flowering terrestrial plants are stressed.[1]

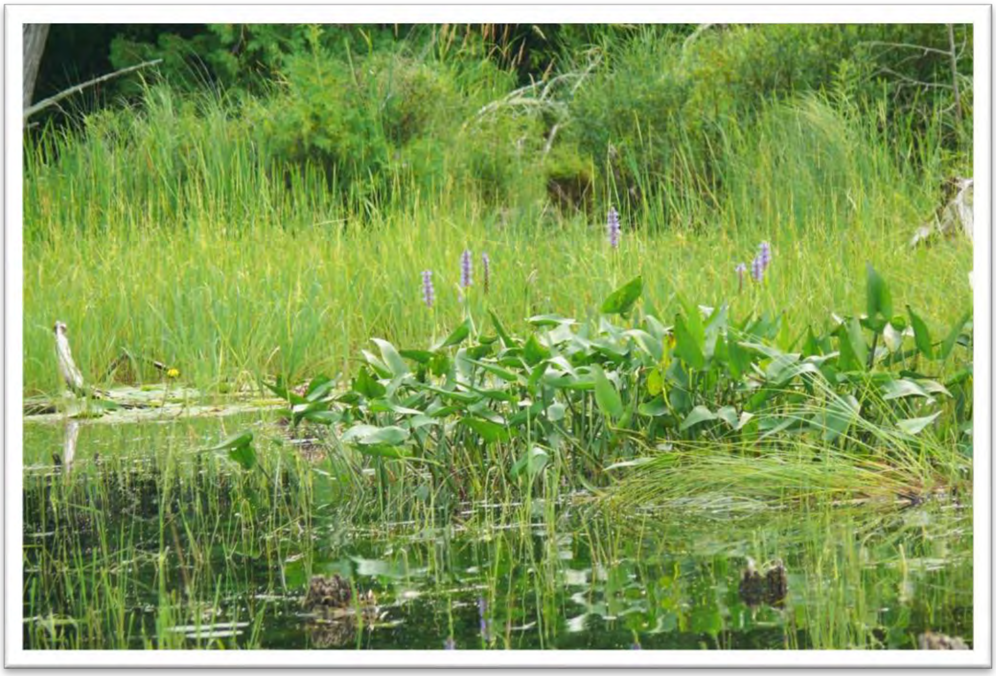
---

[1] Lorne M Wolfe, Spencer C H Barrett: Temporal Changes in the Pollinator Fauna of Trisylous *Pontederia cordata*, an aquatic plant; Canadian Journal of Zoology Vol. 66 1988.

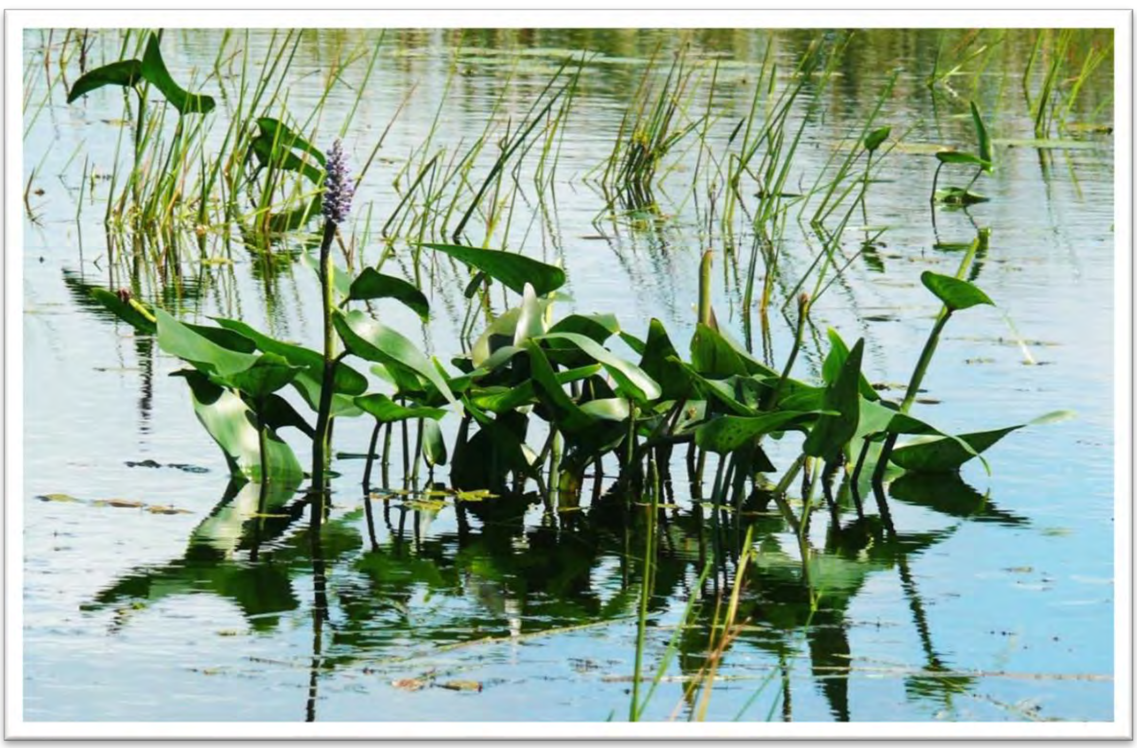
SITE 111

SITE 117

SITE 410



SITE 107



WATER MARIGOLD
Megalodona beckii

Water marigold appeared in 20% of our 2020 observations making it the 11th most commonly observed water plant. All cases were located in less than 4 metres of water, with 24 or 69% of the observations in waters less than 2 metres deep. Site #405 in sector 4 was rated highest in abundance. The 1976 Bond study did not report and occurrences of Water Marigold.

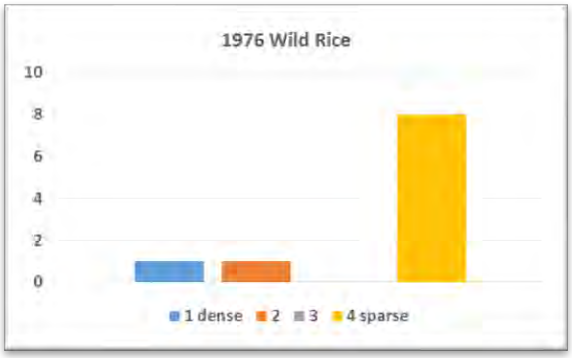
Occurrence and Percent Contribution by Sector for Water Marigold

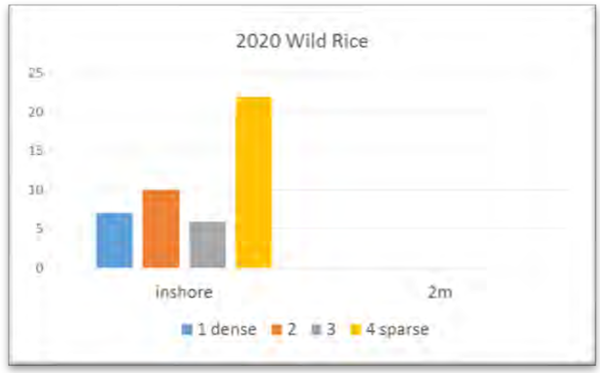
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1			sector 1	5	14%
sector 1			sector 2	6	16%
sector 3			sector 3	8	22%
sector 4			sector 4	18	49%
Village Basin			Village Basin	5	14%
Hayes/Bane Bays			Hayes/Bane	4	11%
Pickerel Bay			Pickerel Bay	1	3%
Three Mile bay			Three Mile	8	22%
ALL (94)	-	-	ALL (174)	37	21%

SITE 224

WILD RICE
Zizania aquatic

This shallow water species was found at 48% of all vegetated stations. It was restricted to waters less than 2 metres deep. 67% of the occurrences came from Sectors 1 and 2. Wild Rice is the 10th frequently occurring plant in 2020.





The 1976 survey found Wild Rice at 11% of stations. There were no reports for Sectors 3 and 4. The greatest occurrence was in the Village Basin. In 1976 it was the 14th most reported species.

The change in occurrence since 1976 are reports of Wild Rice in all sectors. 33% of the 2020 cases are from sectors 3 and 4. None were reported here in 1976. The abundance has also increased between the years.

Occurrence and Percent Contribution by Sector for Wild Rice

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	8	80%	sector 1	16	36%
sector 2	2	20%	sector 2	14	31%
sector 3	0	0%	sector 3	6	13%
sector 4	0	0%	sector 4	9	20%
Village Basin	8	80%	Village Basin	12	27%
Hayes/Bane Bays	1	10%	Hayes/Bane	9	20%
Pickerel Bay	0	0%	Pickerel Bay	1	2%
Three Mile bay	0	0%	Three Mile	3	7%
ALL (94)	10	11%	ALL (94)	45	48%

Wild rice serves as a major food source for wildfowl and indeed has been purposely cultivated to encourage migratory waterfowl during the hunting season. The planting of wild rice is advocated by Ducks Unlimited. In previous years the Arnprior Fish and Game Club have been involved in seeding rice beds (personal communication).

Wild Rice has ancient connections to First Nation peoples who harvested the rice beds by canoe. The White Lake Dugout, of indeterminate age, salvaged from Hayes Bay may have served just such a purpose.[1]

---

[1]Waba Museum, White Lake Village, Renfrew, Ontario

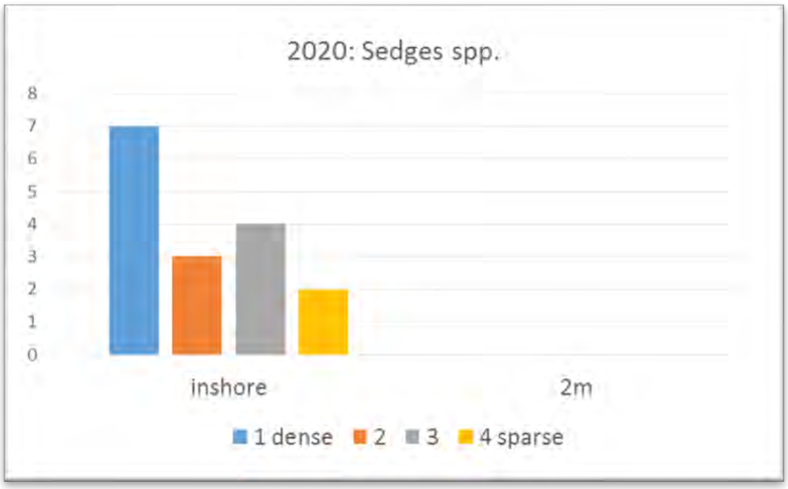
SITE 109 Village Basin

SITE 418

E. OTHER PLANTS

SEDGES spp.

We observed 16 stations having various unidentified sedge species growing in wetland environments.



The 1976 Bond report did not include any sedge species other than bulrush.

Occurrence and Percent Contribution by Sector for Sedges spp.

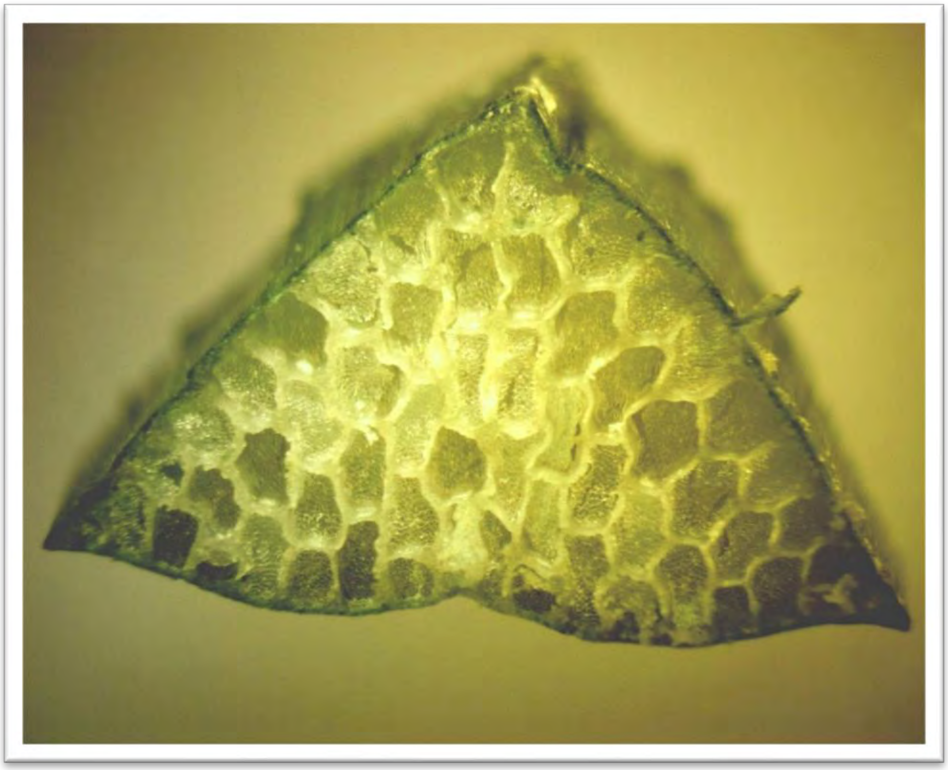
1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1			sector 1	2	13%
sector 2			sector 2	2	13%
sector 3			sector 3	7	43%
sector 4			sector 4	5	31%
Village Basin			Village Basin	2	13%
Hayes/Bane Bays			Hayes/Bane	-	-
Pickerel Bay			Pickerel Bay	2	13%
Three Mile bay			Three Mile	2	13%
ALL (94)	?	?	ALL (94)	16	17%

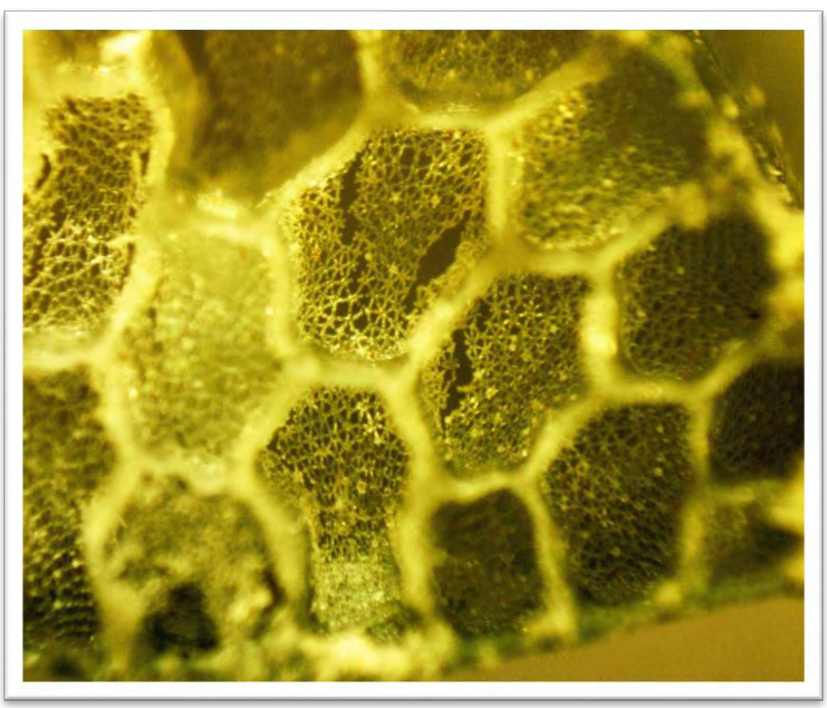
Brownell[1] lists 43 species of the sedge family as present in White Lake fens and marshes.
The White List includes 50 species of the genus Carex. Most are classed as rare, extremely rare, or sparse in occurrence in Lanark County[2].

---

[1]Vivian R. Brownell, A Biological Inventory and Evaluation of the White Lake Study Area, Eastern Ontario Ontario; Ministry of Natural Resources, Kemptville District Office, Kenptville, ON, 81p, 2001.
[2]David J White PLANTS OF LANARK COUNTY 2016 edition.

Distincitve Triangular cross section of stem 10x





15x

SWEET GALE

Myrica gale

Thirty percent of our shoreline observations found Sweet Gale present in marsh environments.

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	4	22%	sector 1	7	25%
sector 2	7	39%	sector 2	12	43%
sector 3	5	28%	sector 3	4	14%
sector 4	2	11%	sector 4	5	18%
Village Basin	4	22%	Village Basin	4	14%
Hayes/Bane Bays	7	39%	Hayes/Bane	9	32%
Pickerel Bay	1	6%	Pickerel Bay	2	7%
Three Mile bay	1	6%	Three Mile	1	3%
ALL (94)	18	19%	ALL (94)	28	30%

Occurrence and Percent Contribution by Sector for Sweet Gale

This plant is common to Ontario. It forms either male or female flowers in cone-like structures in the spring at about the time the leaves are formed. Leaves have a distinctive toothed tip. Leaves when crushed are aromatic and have been used to flavour beer. Attached spongy bracts allow the seed to disperse by floating on water.

SITE 102 Fish Creek

SITE 327 Egg Ba

SHRUBBY CINQUEFOIL
Potentilla fruticosa

Shrubby cinquefoil is a low bush that is capable of living in a wide range of habitats including landscaped gardens. Leaves are smoothly edged producing three terminal leaf clusters.[1] Stems have a reddish hue. The yellow flower is popular with pollinator bees.

[1] James H. Soper, Margaret L Heimburger SHRUBS OF ONTARIO 1985 ROM

SWAMP MILKWEED
Asclepias incarnata

Brownell[1] recorded swamp milkweed in 3 habitats on White Lake: 5a,5b, 6

SITE 423

[1]Vivian R. Brownell, A Biological Inventory and Evaluation of the White Lake Study Area, Eastern Ontario Ontario; Ministry of Natural Resources, Kemptville District Office, Kenptville, ON, 81p, 2001

SPOTTED JEWELWEED (Touch–Me-Not)
Impatiens capensis

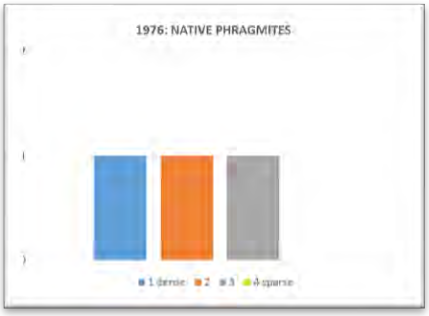
Brownell[1] identified Spotted Jewel Weed at two habitats, C12a, 16c

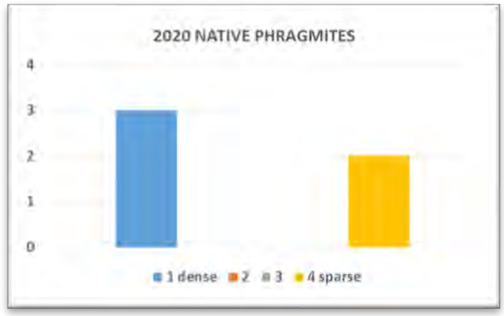
[1]Vivian R. Brownell, A Biological Inventory and Evaluation of the White Lake Study Area, Eastern Ontario Ontario; Ministry of Natural Resources, Kemptville District Office, Kenptville, ON, 81p, 2001

NATIVE PHRAGMITES

PHRAGMITES AUSTRALIS AMERICANUS

Native phragmites has a low occurrence for both survey years. However It does appear its density has increased. Phragmite depends on its rhizomes to expand the size of its cells and is less dependant on seed dispersal. Native [phragmites in its native habitat spreads slowly.





The Bond survey encounterd native cells on 3 occasions. One cell in Hays Bay (station 213) would appear to have spread to adjacent station 212. This particular cell appeared in Catlin's records in ..... It has formed a closed canopy at the edge of the wetland.

Occurrence and Percent Contribution by Sector for Native Phragmites

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	2		sector 1	0	
sector 2	1		sector 2	2	
sector 3	0		sector 3	2	
sector 4	0		sector 4	1	
Village Basin	2		Village Basin	0	
Hayes/Bane Bays	1		Hayes/Bane	2	
Pickerel Bay	0		Pickerel Bay	1	
Three Mile bay	0		Three Mile	1	
ALL (94)	3	3%	ALL (94)	5	5%

NATIVE PHRAGMITES SITES

1976 stations: #112, #123 #213	**2020 stations:** #212, #213, #216, #304, #325, #423

Station 216 has the densest occurrence of native phragmites.

Native phragmites can be distinguished from the invasive European form. At full maturity it's height is about 12 feet with a smaller inflourescence. Leaves tend to be more perpendicular to the stem as the plant tends not to crowd adjcent shoots. As a consequence, other species are not crowded out either and as a result native phragmites cells are found in association with other plant species. The leaf colour is a lighter green that trends towards yellow. It flowers earlier than the invasive and goes to seed earlier as well. It also begins to drop its sheath by August. The exposed stem will appear as a distinct continuous reddish hue that can exhibit a strong contrast to its background. This trait can be seen by mid August.

SITE 212
canopy forming native phragmites at the north end of Hayes Bay

SITE 212
Red culms of native phragmites in a variety of understorey plants

SITE 423

SITE 423: August 19 2020

native phragmites sheath parting to reveal the distinctive a red hue of the stem

SITE 325: August 20 2020
Culms (stems) support alternate leaves tending to the perpendicular with the stem

SITE 325: August 20 2020
Exposed stem of native phragmites showing distinctive colour of stem

SITE 216

Hayes Bay dense cell of native phragmites

F. INVASIVE AQUATIC PLANTS

EURASIAN COMMON REED
Phragmites australis australis

Phragmites australis australis is Canada's most invasive plant. Since 2017 seven small cells have been located immediate to the shores of Three mile Bay. These pose a risk to wetland habitats if they are allowed to become established. This invasive sub-species was not known to be in the area in 1976. There is anecdotal evidence to suggest the plant has been in the region for at least 20 years. Of the 7 cells on Three Mile Bay only one at present is under active management.

SITE 423 August 20 2020

SITE 423 20 August 2020

A useful service we should become familiar with is the application Early Detection and Distibution Mapping Ontario (EDDMAPS.on). This is a freely available service to Ontario Residents. It is supported by the Federation of Anglers and Hunters and the Ontario Government. All reports can be downloaded from the Eddmaps site. The example below is the most recent record for phragmites on White Lake located at site #423 at the extreme eastern end of Three Mile Bay.

EDDMAPS RECORD 8797493

EDDMapS
Early Detection & Distribution Mapping System

European common reed

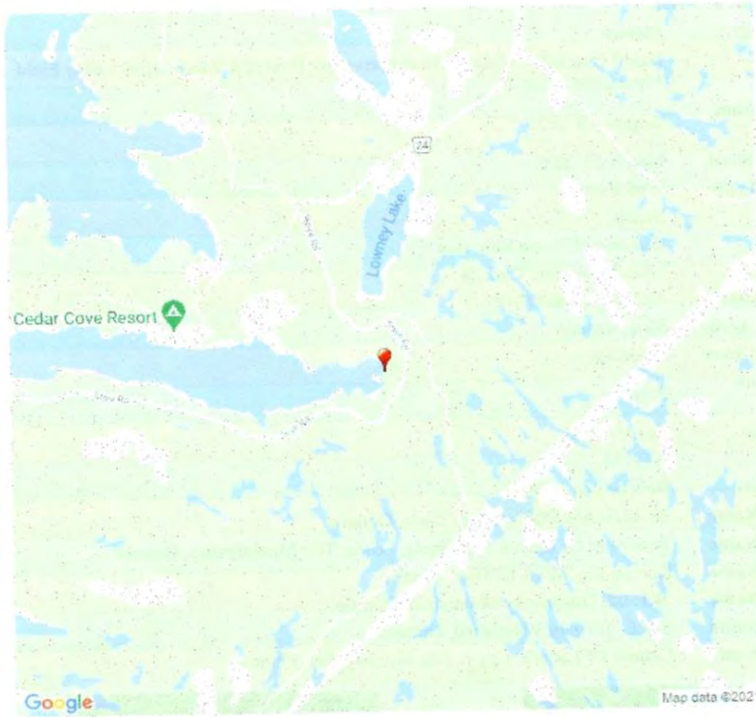
Phragmites australis ssp. australis **(Cavanilles) Trinius ex Steudel**

Record ID: 8797493

Phenology	Mature
Reporter	David Overholt , White Lake Preservation Project & Mississippi Valley Field Naturalists Team 1
Observation Date	August 19, 2020
Date Entered	March 27, 2021
Source Type	Web Report
Habitat	Beach
Locality	East end of Three Mile Bay
Location	Lanark, Ontario, Canada
Coordinates	45.25817, -76.47938
Infested Area	60 sq meters
Percent Cover	Moderate
Infestation Status	Positive
Reviewed	Not Verified
Datum	WGS84
Comments	New cell since 2018
Display Name	18, Fisheries Management Zone, Ontario
Display Name	Township Of Lanark Highlands, Lower Tier Municipality, Ontario
Display Name	Kemptville, MNR District, Ontario
Display Name	2KE-02, Quaternary Watershed, Ontario
Display Name	02KE, Tertiary Watershed, Ontario
Display Name	County Of Lanark, Upper Tier Municipality, Ontario

EDDMapS. 2021. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online

EDDMapS
Early Detection & Distribution Mapping System



EURASIAN WATER- MILFOIL
Myriophyllum spicatum

This plant considered the most invasive of submerged aquatic species was first noticed in the Kawartha Lakes where it became a nuisance in the mid 1970's. Now Eurasian Water Milfoil is an invader that has spread to White Lake waters.

The 2020 survey found Eurasian watermilfoil occurring at 27 sites. It is currently the 15th most frequently occurring plant. None of our locations reported Eurasian at a high density, and it is presently found only in Sectors 3 and 4. Sector 3 can claim the highest occurrence for this plant, with 74% of all the occurrences. Eurasian Water- Milfoil readily colonizes exposed substrates and Pickerel Bay appears to offer a great opportunity to spread without competition.

This species was not reported by Bond 44 years ago and most likely had yet to arrive in the lake.

Occurrence and Percent Contribution by Sector for Eurasian Water- Milfoil

1976 stations	1976 cases	1976 %	2020 sites	2020 Cases	2020 %
sector 1	-	-	sector 1	0	0%
sector 2	-	-	sector 2	0	0%
sector 3	-	-	sector 3	20	74%
sector 4	-	-	sector 4	7	26%
Village Basin	-	-	Village Basin	0	0%
Hayes/Bane Bays	-	-	Hayes/Bane	0	0%
Pickerel Bay	-	-	Pickerel Bay	9	33%
Three Mile bay	-	-	Three Mile	2	7%
ALL (94)	-	-	ALL (174)	27	16%

Eurasian water milfoil spreads by roots and rhizomes and also by "auto-fragmentation" in which the upper leaf portion with minimal agitation can become separated from the main stem[1]. These are free to establish in new locations. It is noted that under reduced nitrogen concentrations auto-fragmentation will increase as it is a mechanism of survival for the plant. It also reacts defensively to herbivorous activity by reducing the dietary quality of its leaves making them less appealing to herbivores.

Like other vascular aquatic angiosperms, it can sexually reproduce from a floral spike. Pollination is by water and air. The small seed that it produces can readily adhere to watercraft and water fowl.

As European Water-milfoil forms dense canopies other aquatic types are out competed. Although Eurasian water milfoil is a food resource for wildfowl, it will provide less nourishment than the native plants which it has displaced.

The plant is thought to require a lower amount of nutrients than other aquatic plants. When colonies are dense it is capable of extracting most of the dissolved reactive phosphorus that is available in sediment pore water. During the growth phase of this plant little nutrient leakage occurs from living tissue. Growth is in two distinct phases with stem production in early spring followed by root and rhizome production in late summer. At senescence in the late fall, the stored nutrients such as nitrogen and phosphorus are released into the water column. Experiments have shown that over 50% of the stored phosphorus can be released from the plant within 12 days.[2]

---

[1] Paul M Catling, Gisele Mitrow, 14a Eurasian Water Milfoil CBA/ABC Bulletin

[2] Craig S Smith, Michael S Adams 1986: Phosphorus Transfer from Sediments by *M. spicatum* American society of Limnology and Oceanography 1312-1321

SITE 422 inshore Eurasian Water Milfoil

SITE 318 shoals

SITE 319 Birch Island auto-fragmentation

Part 3

I. AQUATIC MACROPHYTES AND BENTHIC ALGAL BLOOMS

There is an inter-relationship between aquatic plants and the presence of various forms of algae. Algae find a structure to attach to and a source for soluble reactive nutrients that are returned to the water column by the photosynthetic functions of plants. The growth on plants is an algal community referred to as periphyton. This is a food resource for grazing snails and other invertebrates. Periphyton also compete with aquatic plants for limiting nutrients like phosphorus and for light. When a plant is under stress it can alter reproductive efforts in seed production or fragmentation.

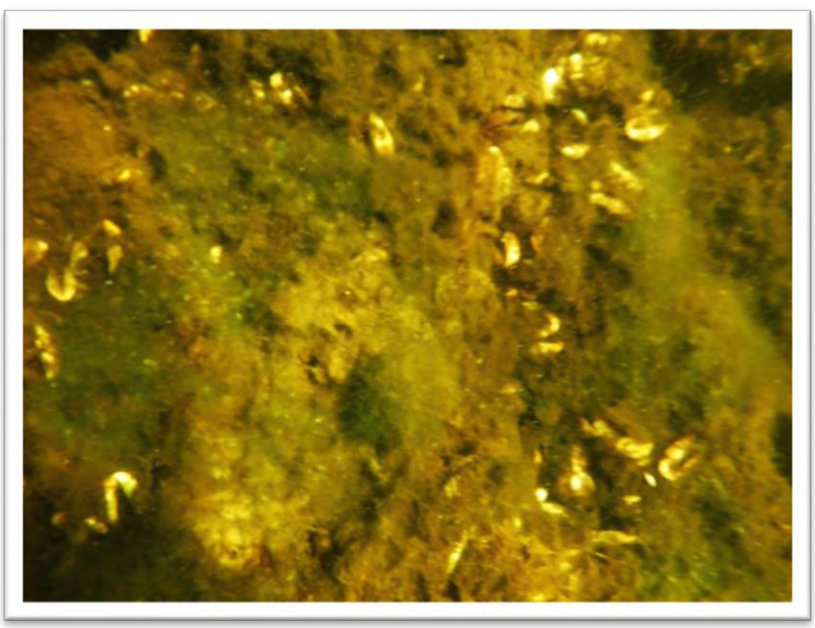
The table below shows the number of sites where there were obvious concentrations of benthic algae colonies. These 27 sites represent 17 of the 94 vegetated Bond sampling stations. Of these 17 stations 11 came from Sector 3. Six reports were from Sector 4 of which 2 were associated with Three Mile Bay. No reports came from either Hayes or Village Basins proper.

Occurrence and Appearance of Benthic Algal Colonies

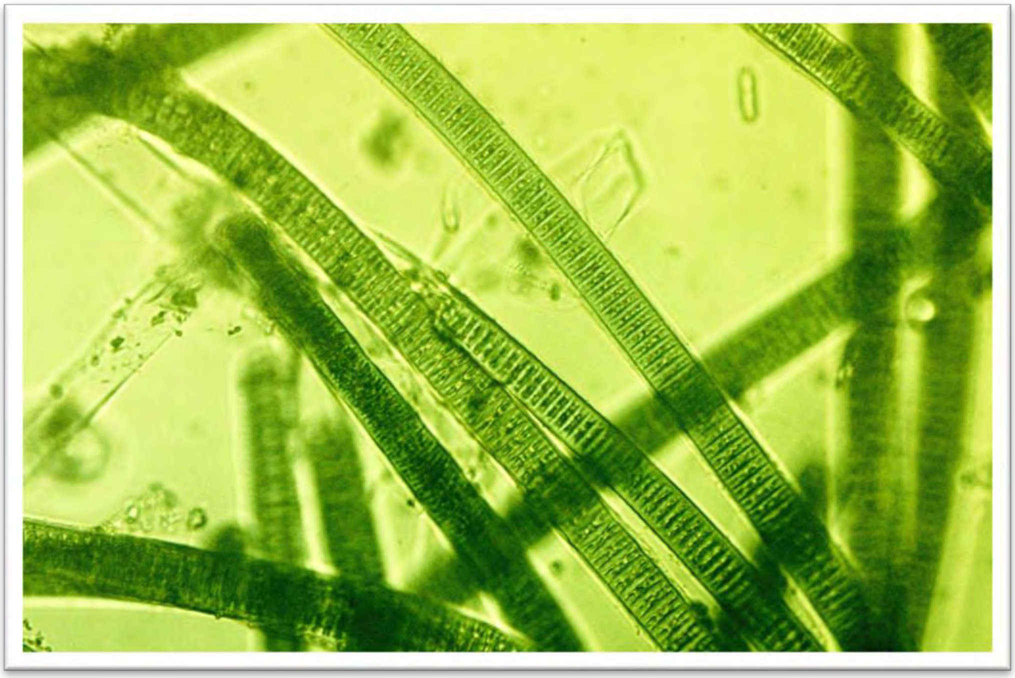
ALGAE FORMATIONS	mat M	cloud C	draped D	M+D	M+C+D	total
< 2 METRES	9	2	1	1	1	14
2 METRES	6	1	3	1	0	11
4 METRES	2	0	0	0	0	2
totals	17	3	4	2	1	27

Site #303 was one of several steep inclined sites with no vegetation. Algal matting over the substrate occurred at all depths. A noticeable die-off of zebra mussels was apparent. algae mats covered the substrate. The mat was composed of oscillatoria, a blue-green filamentous algae.

SITE 303 algal colony matted onto the substrate

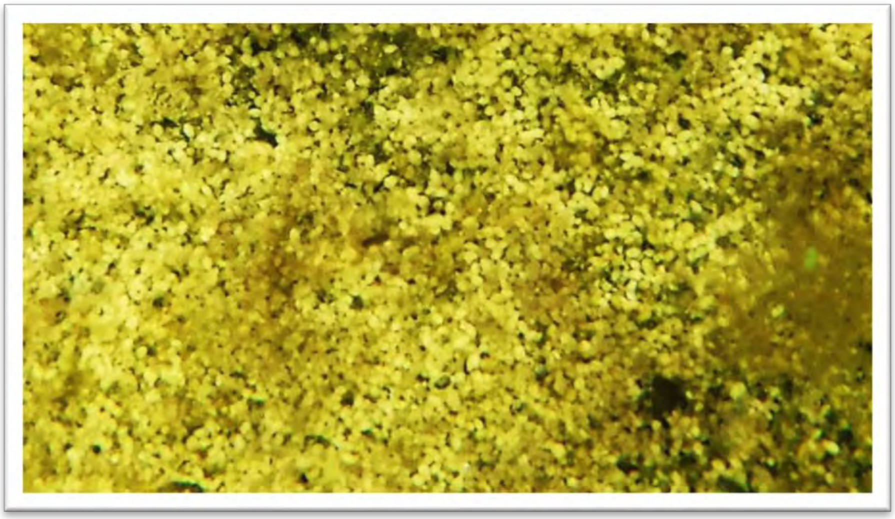


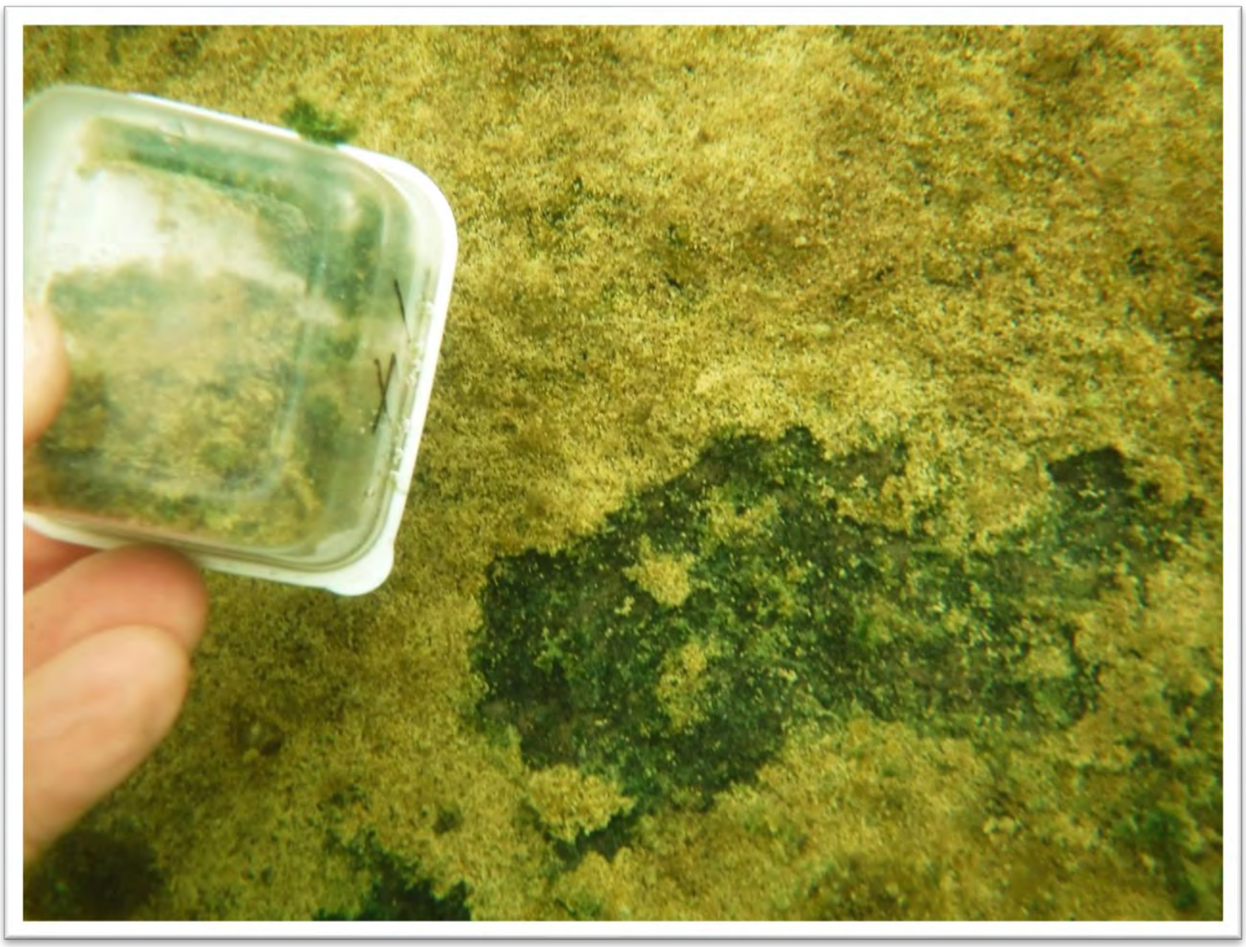
SITE 303: oscillatoria 200x



SITE 314 algal colony draped over water milfoil

SITE 315 carbonate nodules precipitated by an algal colony?

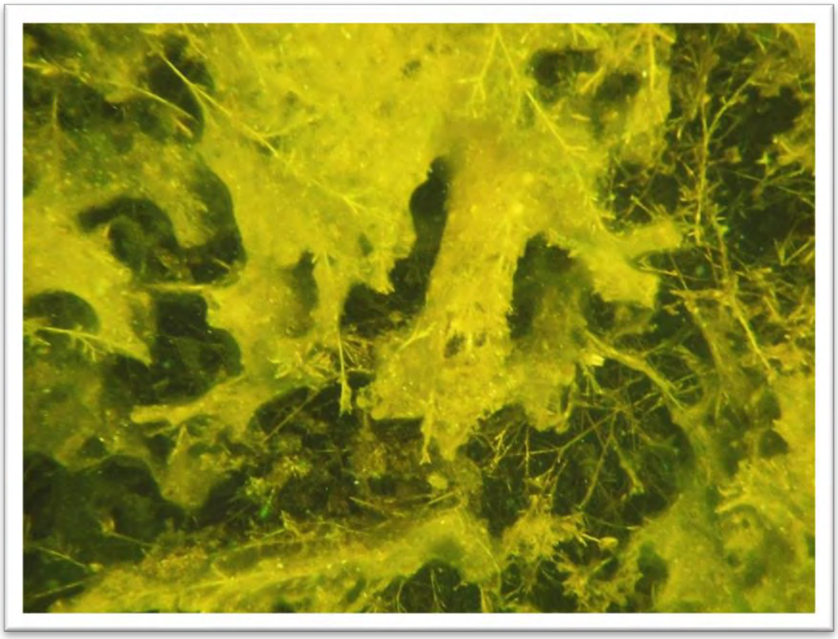




Carbonate secretions which are the by-product of photosynthesis by micro-organisms are referred to as carbonate microbiolites when these are found in the geological record. [1]

[1] Kurt O Knohauser Dept Earth and Stmospheric Sciences, U of Alberta; kurk@ualberta.ca

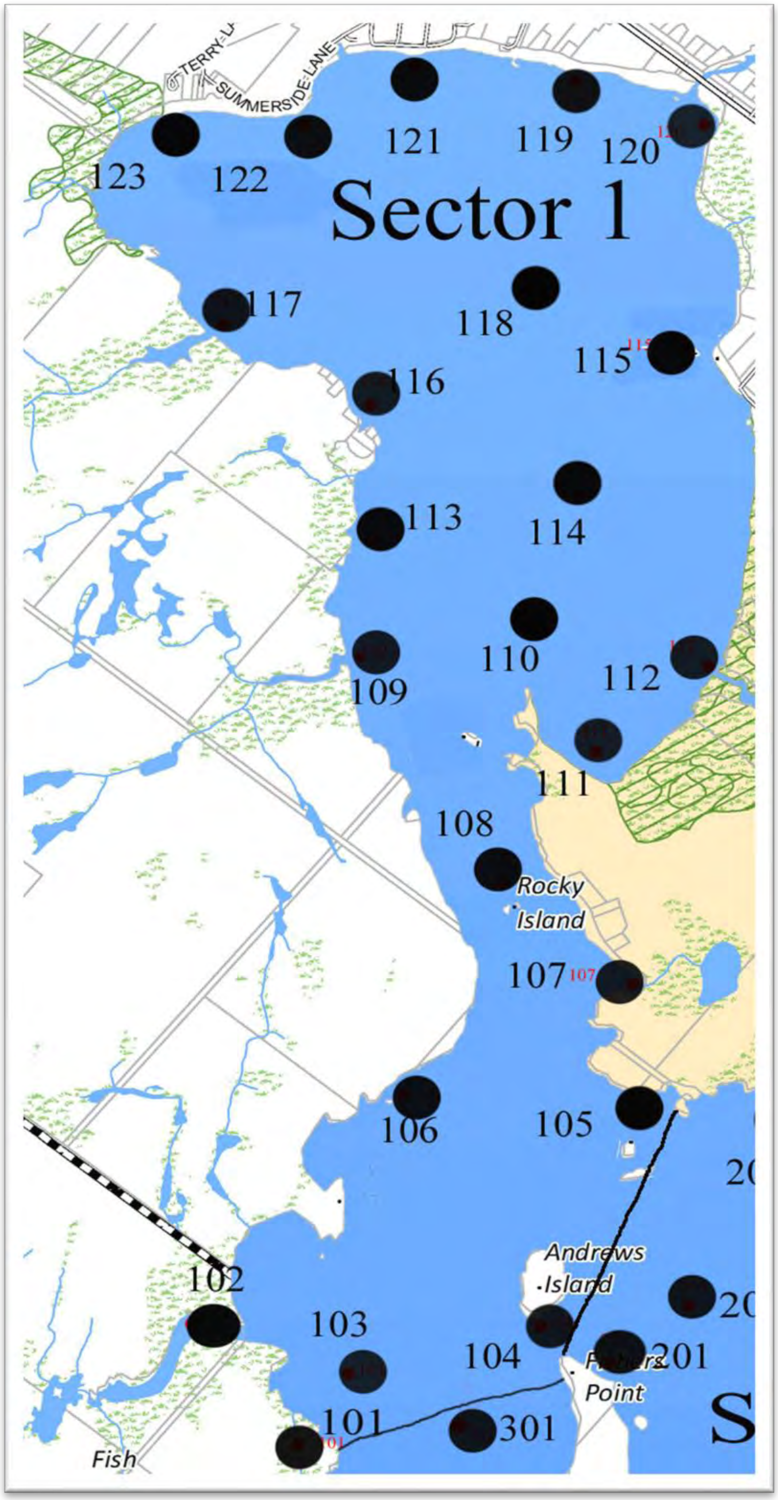
SITE 318 algal colony mat on Slender Water Nymph

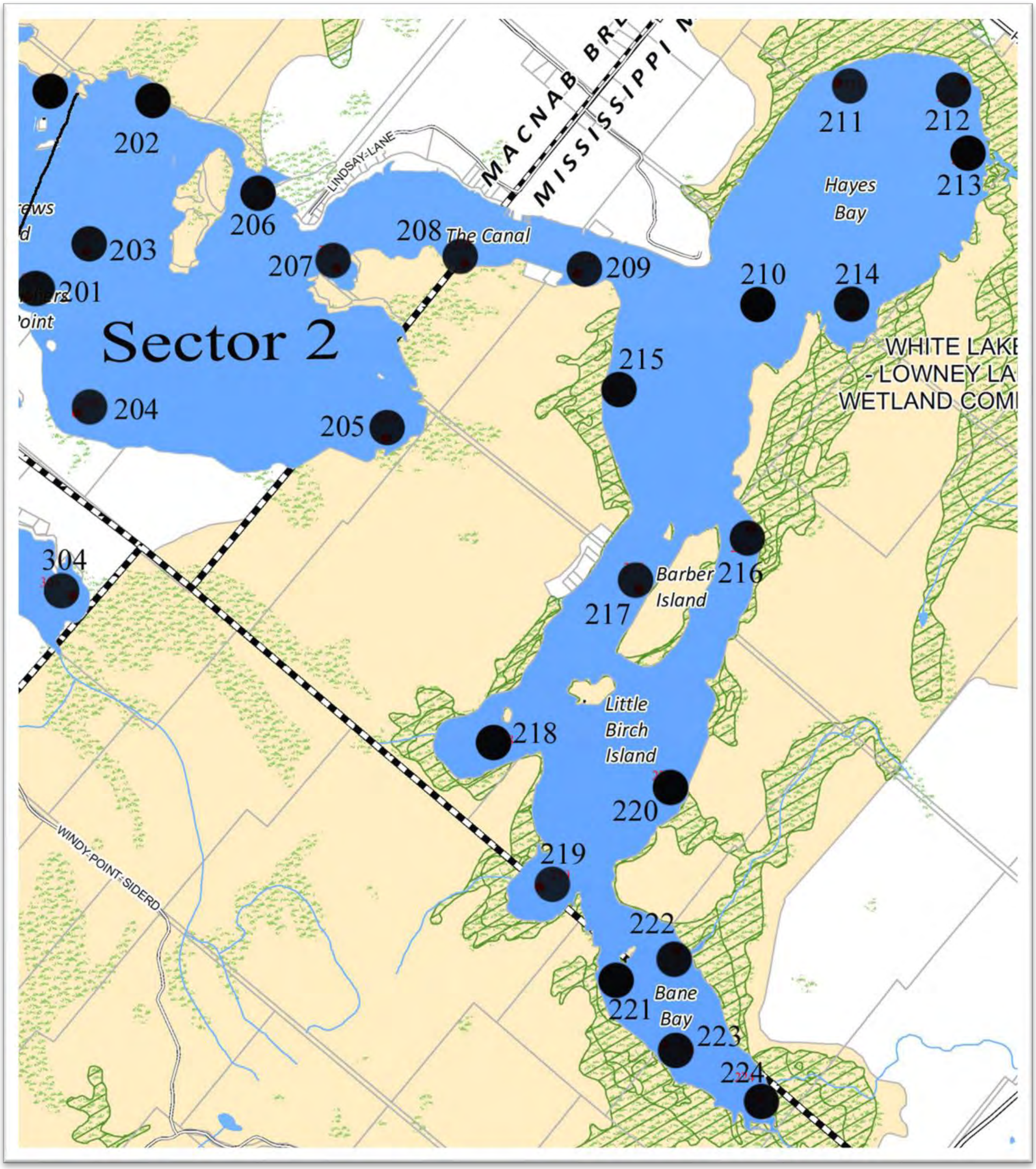


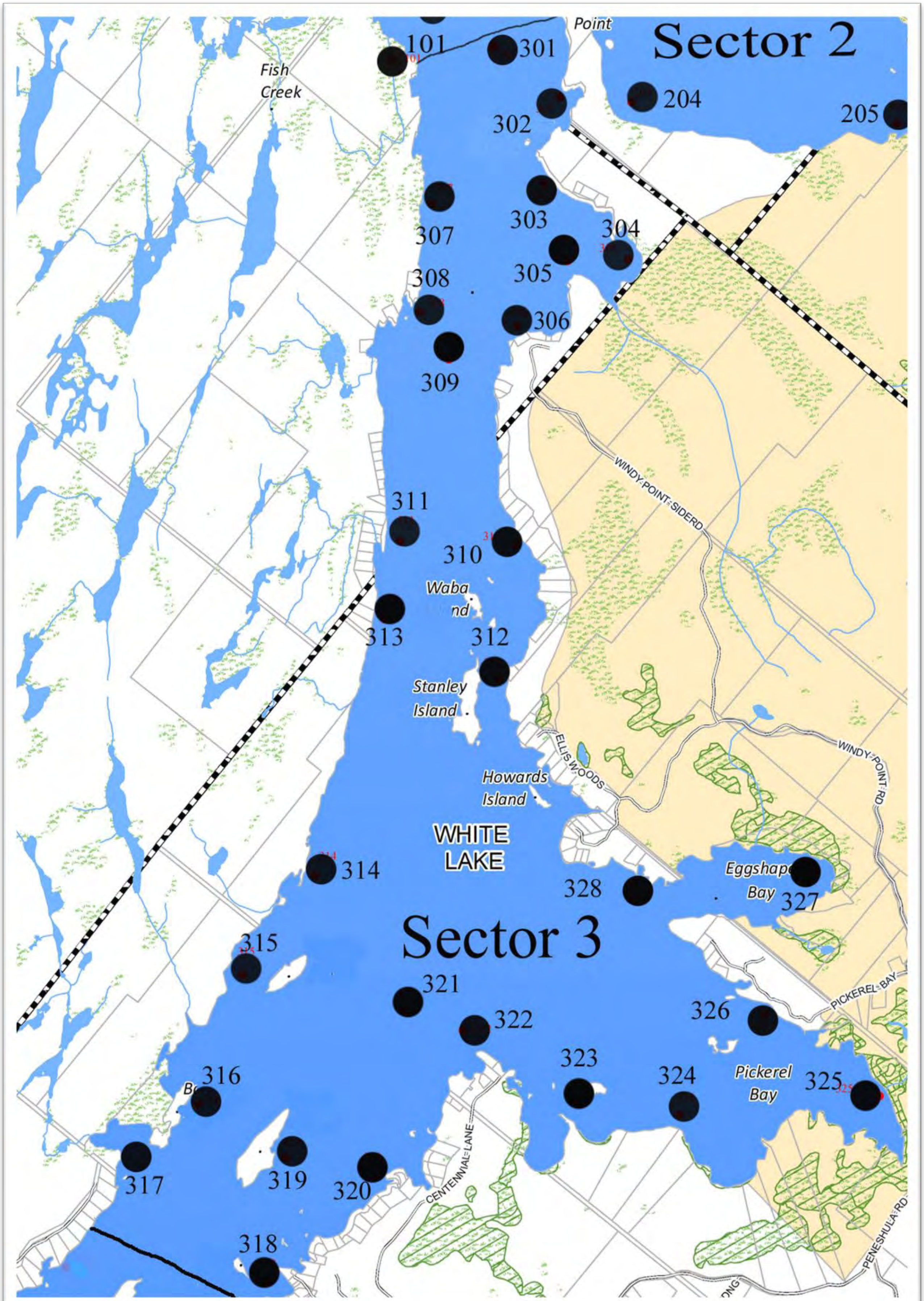
SITE 318 algal colony forming "clouds"

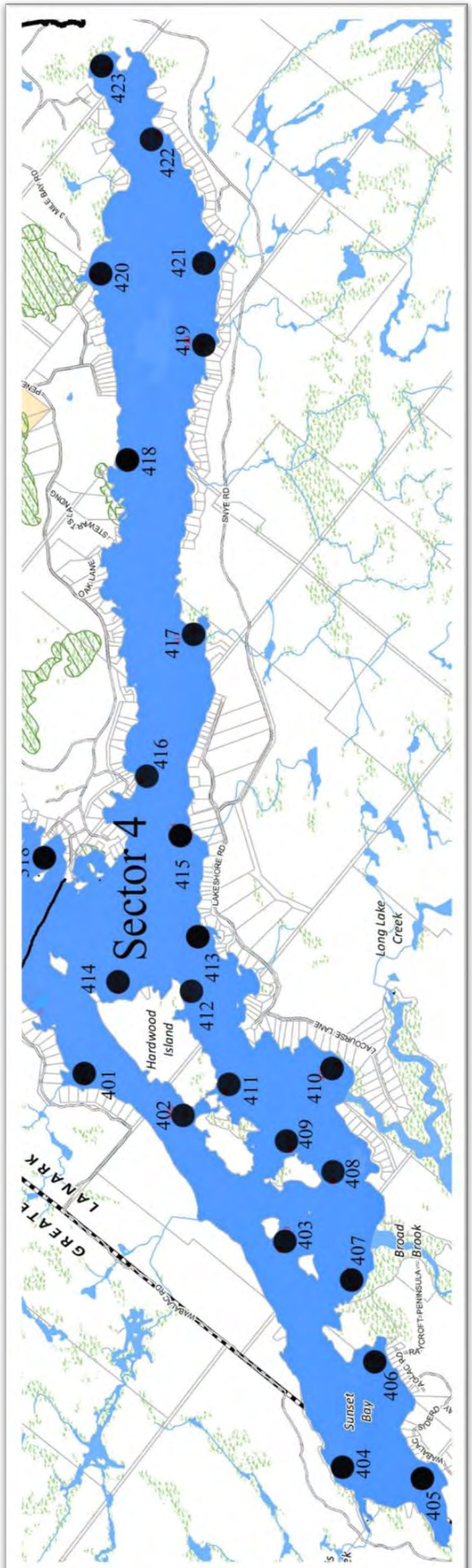
SITE 318 Eurasian Water-milfoil draped in filamentous algal colonies

II APPENDIX: SAMPLING STATION LOCATIONS ON WHITE LAKE




Sector 2
201
202
203
204
205
206
207
208
The Canal
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
304
Hayes
Bay
Barber
Island
Little
Birch
Island
Bane
Bay
LINDSAY-LANE
WINDY-POINT-SIDERD
MACNAB BR
MISSISSIPPI
WHITE LAKE
- LOWNEY LA
WETLAND COM


Sector 2
Point
101
301
204
205
Fish
Creek
302
307
303
304
305
308
306
309
311
310
Waba
nd
313
312
Stanley
Island
Howards
Island
WINDY POINT SIDERD
ELLIS WOODS
WINDY POINT RD
WHITE
LAKE
314
328
Eggshape
Bay
327
Sector 3
315
321
322
326
PICKEREL BAY
323
324
Pickerel
Bay
325
316
317
319
320
CENTENNIAL LANE
318
PENESHULA RD


Sector 4
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
Hardwood Island
Long Lake Creek
Broad Brook
Sunset Bay
LANARK
SNYE RD
LAKESHORE RD