Nova Scotia Provincial Status Report

on

Spotted Pondweed

(*Potamogeton pulcher* Tuckerm.)

prepared for

Nova Scotia Species at Risk Working Group

by

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EXECUTIVE SUMMARY

TABLE OF CONTENTS

List of tables

List of figures

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name:	*Potamogeton pulcher*
Original Description:	Tuckerman, 1843
Synonyms:	*Potamogeton amplifolius* var. *ovalifolius* Morong ex Benn., 1904 *Potamogeton amplifolius* f. *amphibius* Benn., 1904 *Potamogeton amplifolius* var. *amphibius* (Benn.) Graebn., 1907 *Spirillus pulcher* (Tuckerman) Nieuwl., 1913 *Potamogeton pulcher* f. *amphibius* Hagstr., 1916
English vernacular name:	Spotted Pondweed, Heartleaf pondweed
French vernacular name:	Potamot gracieux
Genus:	*Potamogeton* L. (Pondweed)
Family:	Potamogetonaceae (Pondweed family)
Order:	Najadales
Subclass:	Alismatidae
Class:	Liliopsida (Monocotyledons)
Major plant group:	Magnoliophyta (Angiosperms)

Spotted or Heartleaf pondweed (*Potamogeton pulcher*) was described by American botanist Edward Tuckerman in 1843 from specimens collected in Massachusetts. He must have been quite taken by the species, assigning it a specific epithet that translates to “beautiful” or “handsome”. During the early 20th century, taxonomic revisions of the pondweed family and difficulties in defining taxa in a group prone to hybridization and morphological variation resulted in *P. pulcher* being given several other names. Three of these involved the relegation of this species to a variety or form of Large-leaf Pondweed (*Potamogeton amplifolius*), the species which Spotted Pondweed most closely resembles. Recent treatments of *Potamogeton* have upheld the taxon as a distinct species (BONAP 2010, Haynes and Hellquist 2000, Natureserve 2010).

The pondweed family (Potamogetonaceae) is one of the most common and widespread groups of aquatic vascular plants on the planet (Pip 1987). The pondweed genus (*Potamogeton*) includes approximately 100 species (Haynes and Hellquist 2000, Wiegleb 1988), 33 of which are found in North America (Haynes and Hellquist 2000). Most are of the northern hemisphere and the highest specific densities are found in eastern North America, Western Europe, Siberia and Japan (Wiegleb 1988), where numerous species may co-occur within a site (Pip 1987, see also BONAP 2010, Haynes and Hellquist 2000). Pondweeds are a major source of food and shelter for animals, and are among

the most important vascular plants in aquatic ecosystems (Barrat-Segretain 1996, Newman 1991, Wiegleb *et al.* 1991).

The significant range of environmental variation displayed by pondweeds and the fact that plants often remain infertile (thus lacking fundamental diagnostic features), have made understanding of this group difficult (Ogden 1943). Species are also known to hybridize frequently and hybrids comprise an important part of pondweed diversity (Kaplan and Fehrer 2006, Ogden 1943, Wiegleb and Kaplan 1998). In addition to the ca. 100 species in the genus, Wiegleb and Kaplan (1998) recognize 50 hybrids as being well established and distinguishable from the parent species, while noting that many other hybrids proposed in the literature require further investigation.

Although the genus has been divided into several sections and subsections, these have not been retained in the most recent North American taxonomic treatment (Haynes and Hellquist 2000).

Morphological Description

The description offered below is an amalgamation of those presented by Haynes and Hellquist (2000), Wiegleb and Kaplan (1998) and Ogden (1943), with some additional notes on leaf shape from Scribailo and Alix (2002). Although some technical elements important for the positive identification of specimens are included, many were omitted for the sake of conciseness and simplicity. Figure 1 illustrates the species in its natural habitat and Figure 2 shows line drawings of distinguishing characteristics.

Spotted Pondweed is an aquatic herbaceous plant arising from a slender, often dark-spotted, perennial rhizome 5-1 mm in diameter. Its vertical stems are annual, unbranched, round in cross-section, 1-2.5 mm in diameter, 8-95 cm long and usually conspicuously dark-spotted, particularly near the bottom. Stem nodes do not bear oil glands. Both submersed and floating leaves are produced, arranged alternately or in a spiral along the stem. Floating leaves are roundish-ovate, typically 2-8.5 cm long and 1.5-4.5 cm wide, leathery in texture, petioled (1-16 cm in long), light to dark green on their upper surface, with cordate or roundish bases and15-21 veins. Submersed leaves are of two somewhat distinct types, the upper ones translucent, lance-shaped, tapering at both ends and sometimes undulate and the lower ones thicker, sometimes arched, broadly lance-shaped to oblong with rounded tips. Mid-stem leaves transitional between these two types are also often present. Submersed leaf blades are dark green, typically 4-14 cm long and 1-2.5 cm wide with 7-21 veins, tapering at their base to a short petiole or sometimes almost sessile. Stipules of the submersed leaves are light to dark brown, fairly inconspicuous and decay early in the season while those of the floating leaves are persistent, narrowly triangular and 2-5 cm long. Buoyed by the floating leaves, the inflorescences are held above the water's surface on terminal or axillary peduncles 5-8 cm long and as thick as (or slightly thinner than) the stem. Flowers are bisexual, small (1.5-2.5 mm wide) and

numerous, of 4 greenish tepals and arranged in continuous spikes 2-3.5 cm long and 8-11 mm thick when in fruit. Fruits are drupe-like, sessile, olive-green to dark brown, ovoid to obovoid, 3-4 mm long with a pronounced dorsal keel and an often strongly developed beak.

No chromosome counts seem to have been carried out for this species, as no information on chromosome numbers was found while reviewing pertinent literature. Haynes and Hellquist (2000) state in their Flora of North America treatment of the genus that North American species for which information is available have a chromosome number of x = 13 or 14.

Although of limited use in field identification, several stem anatomy characters are of high diagnostic value and can be especially useful when dealing with poor or intermediate specimens showing signs of hybridization (Ogden 1943). *P. pulcher*, is said to have a stele with a proto-type pattern, an endodermis of O-cells and a pseudo-hypodermis 1 cell thick, with no interlacunar and subepidermal bundles (Ogden 1943). See cited work for additional information on stem anatomy-based identification and terminology.

Field identification

Pondweeds are well-known to exhibit a high degree of morphological plasticity in response to environmental conditions and to hybridize frequently (Kaplan and Fehrer 2006, Spence and Dale 1978, Wiegleb and Brux 1991, Wiegleb and Kaplan 1998). Reproductive features are important in distinguishing species of *Potamogeton* because fruiting specimens tend to be more morphologically consistent within a species (Haynes and Hellquist 2000, Ogden 1943). It is therefore important to collect flowering or fruiting individuals when possible. Unfortunately, fruiting specimens can often be difficult to find and completely vegetative populations are common, perhaps more so in broad-leaved species (Ogden 1943). Identifications are therefore often solely based on rather variable vegetative characters.

A few somewhat reliable vegetative features can be helpful in distinguishing Spotted Pondweed from Large-leaf Pondweed (*P. amplifolius*, the only Nova Scotian species with strong similarity to *P. pulcher*) and other less similar, broad-leaved pondweeds. The most useful being the conspicuously spotted stems and the broadly rounded, cordate-based (heart shaped) floating leaves. The submersed leaves, with their lanceolate shape and rather abrupt tapering near the base, can also be diagnostic. Within Nova Scotia, geography and habitat also provide insight into field identification of the two species. Spotted Pondweed seems to be primarily southern within the province and to be more likely to occur in highly acidic, nutrient-poor environments whereas Large-leaf Pondweed occurs throughout Nova Scotia but is uncommon in the most acidic lakes of the southwest and the Atlantic side of the province.

Modified from Haynes and Hellquist (2000) and Ogden (1943), the characters outlined below are useful in separating Spotted Pondweed from Large-leaf Pondweed.

> Stem not conspicuously dark-spotted; submersed leaves (including upper ones) usually arched, 2.5-7.5 cm wide, with 19-49 veins; floating leaf blades wedge-shaped or rounded at the base with 27-49 veins; fruit wedge-shaped at base
>
> – ***P. amplifolius***

> Stem conspicuously dark-spotted; submersed leaves (especially upper ones) usually not arched, 1-2.5 cm wide, with 7-19 veins; floating leaves cordate or rounded at base with 15-19 veins; fruit rounded or lobed at base
>
> – ***P. pulcher***

Hybridization occurs between these two species and the hybrids (*Potamogeton* x *rhodensis*) have been identified by pondweed expert Barre Hellequist from three Spotted Pondweed populations in Nova Scotia. At each of these sites, Hellequist identified multiple specimens collected from the same patch of plants as being mixed collections of Spotted Pondweed and the hybrid *P. x rhodensis*. At one other location Hellequist identified duplicates as representing a mixed collection of Spotted and Large-leaf Pondweeds. This illustrates the difficulty in making definitive identifications for even the most experienced experts. If specimens are in poor condition or show characters than cannot yield a positive identification, a detailed examination of stem anatomy characters may be necessary for determination. It would be useful to analyze stem anatomy of plants from these mixed collection sites, and from other Nova Scotia sites, to confirm specific identity.

Designatable Units

In a Canadian context, the species is probably best treated as two designatable units (Great Lakes Plains and Atlantic). Canadian Spotted Pondweed populations are found in two highly discrete areas within separate COSEWIC National Ecological Areas (NEAs): 1) extreme southwest Ontario (Great Lakes Plains NEA), and 2) southern Nova Scotia (Atlantic NEA). These are separated by approximately 1300 km, with limited chance of dispersal between them. There has been no evaluation of genetic distinction between Ontario and Nova Scotia populations, or between any other populations. The ecological settings of the two Canadian populations are, however, quite different climatically and ecologically with the Ontario occurrence in a calcareous region and the Nova Scotia occurrences all in acidic regions. The significantly disjunct nature of both Canadian occurrences from the American range of the species (see *Global Range* below) and the fact that Canadian occurrences are on the

periphery of the species' range could mean a heightened chance of significant genetic divergence within and between Canadian populations.

There is no justification for separating Nova Scotia populations into more than one designatable unit.

Special Significance

Spotted Pondweed has a very restricted geographic range in Canada, with its single Ontario occurrence now possibly extirpated and only 12 populations known in the southern half of Nova Scotia. It seems to have a very small area of occupancy in the province with few stands and presumably few individuals.

Occurrences in Nova Scotia are isolated populations at the edge the species' range and they are disjunct by 220+ km from the nearest population in Penobscot County, Maine. This isolation is compounded by the fact that the species is also rare in Maine and the nearest jurisdiction where the species is secure is New Hampshire, over 400 km away. Such isolation can be associated with genetic divergence that may be significant to the species as a whole (REFERENCES – see Baccharis report).

Spotted Pondweed is one of Nova Scotia's suite of Atlantic Coastal Plain Flora, a nationally significant assemblage of disjunct species with a geographic affinity to the lowlands of the eastern and southern United States. Most of these species are rare in Canada and the species and the habitats they occupy in southern Nova Scotia have received considerable conservation attention. Spotted Pondweed's distribution in Nova Scotia is concentrated in a region where federally and provincially protected or nationally rare plant and animal species with affinity to the Atlantic Coastal Plain also occur, and it co-occurs on Carrigan Lake in Queens County with the only known Canadian occurrence of Tall Beakrush (*Rhynchospora macrostachya*).

Figure 1. Spotted Pondweed (*Potamogeton pulcher*) with prominent floating leaves growing in association with Purple bladderwort (*Utricularia purpurea*) and Greater bladderwort (*Utricularia macrorhiza*).

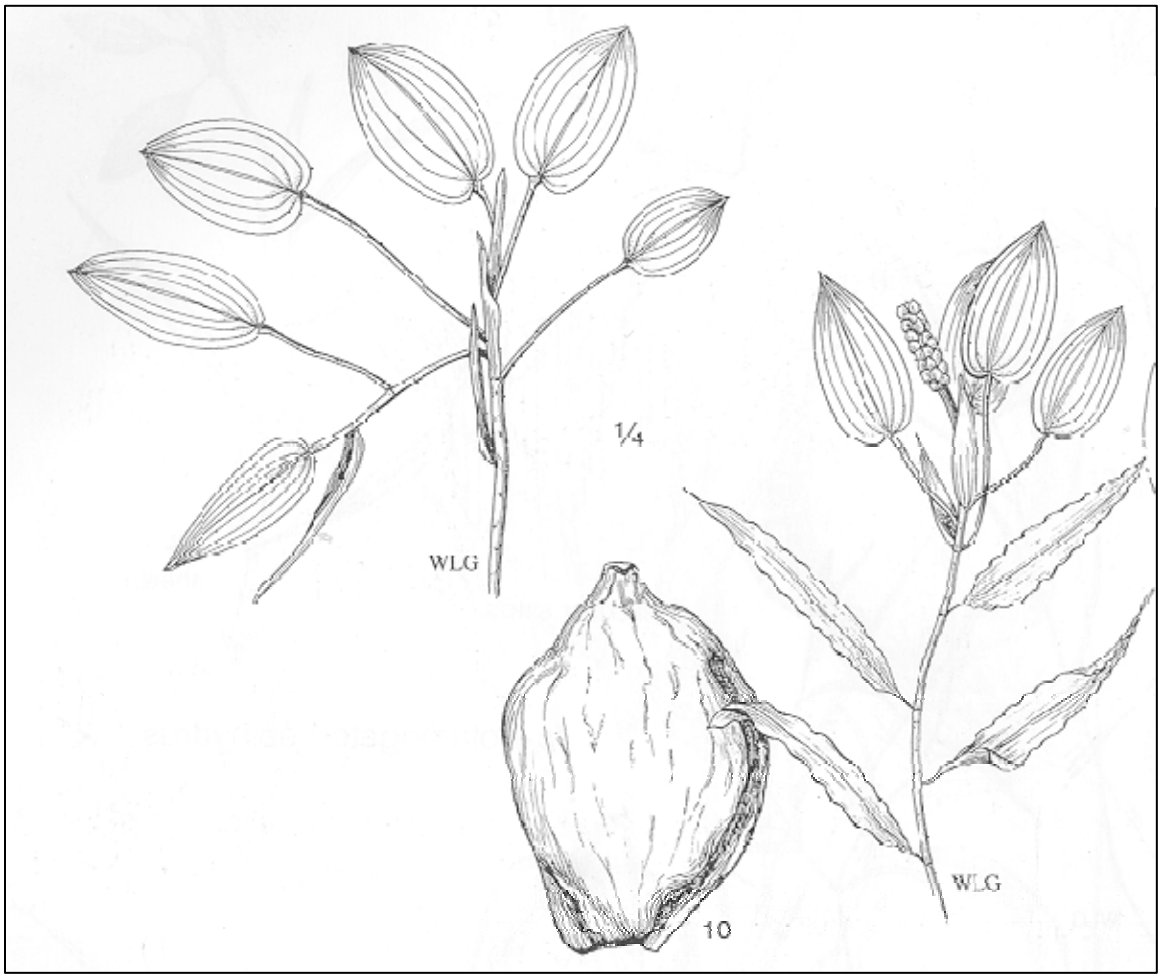

Figure 2. Line drawing of Spotted Pondweed (*Potamogeton pulcher*) showing spotted stem, floating leaf shape, submersed leaf shape, inflorescence and fruit shape (source: Holmgren 1998).

DISTRIBUTION

Global Range

Spotted Pondweed is found along the Atlantic Coastal Plain, from Texas in the southwest to Nova Scotia in the northeast. Inland, it is found on the Mississippi River watershed north to the Great Lakes and has been reported as far west as Oklahoma, Missouri and Minnesota. Its global distribution stretches from latitudes of 25°90'N to 45°10'N and from longitudes of 97°90'W to 62°95'W. Figure 3 illustrates the species' global range.

Although not entirely restricted to it, the species' range occupies the majority of the Atlantic Coastal Plain and it reaches its highest abundance from the Carolinas to Massachusetts. County-level distribution indicates that the species is generally less common to the south and west of this region and

uncommon to rare in jurisdictions inland from the coastal plain (BONAP 2010). The species is scattered and locally abundant in southern New England, gradually becoming extremely rare towards the northeast edge of its range in Maine and Nova Scotia.

Spotted Pondweed is rare in all states of the Great Lakes region, where it is absent from all counties directly adjacent to the international border. In Ontario, the species is only known from one location along the north shore of Lake Erie in Kent County, where it was last observed in 1948 and is considered possibly extirpated. This site is 100-150 km to the north and northeast of the nearest population sites in Summit and Ashtabula counties, Ohio.

Only twelve populations are known to exist in Nova Scotia, most of them concentrated in the southwestern parts of the province. These are a minimum of 220 km northeast of the next nearest sites in Penobscot County, Maine.

Canadian Range

Outside of Nova Scotia, Spotted Pondweed is known in Canada only from a single 1948 collection from Rondeau Bay in Rondeau Provincial Park, Kent County, Ontario (Ontario Natural Heritage Information Centre, 2010). A significant amount of botanical fieldwork has since been carried out in this area, though few efforts specifically targeted submersed aquatics (M. Oldham pers. comm.). Water quality in Rondeau Bay may have declined since the discovery of this occurrence and it is not known if it remains extant (M. Oldham pers. comm.).

The species' range within the province of Nova Scotia is largely restricted to the southwest in the counties of Lunenburg, Queens, Yarmouth and Digby with one outlying occurrence located much further to the northwest in Halifax County (Figure 4). This range largely coincides with the region supporting the greatest diversity of Atlantic Coastal Plain flora species, including nine COSEWIC-listed plants federally protected under the Species at Risk Act.

The most important region of occurrence for the species, with eight of twelve occurrences, is an area roughly 50 km long by 40 km wide comprised of the northeastern half of Queens County and the southwestern half of Lunenburg County. In this region, the species is known to occur in the LaHave, Medway and Mersey watersheds (Figure 5). On the LaHave system, populations are found in Rhodenizer Lake (site 1) and Hirtle Lake (site 3). The location of one historical occurrence in this area (site 2) is uncertain since the site description associated to the specimen collected is not a recognized geographic name. Based on the site name used (Maitland Pond) and the location of other sites visited by the collector on the same date, the most likely locations for this occurrence are Little Lake, Langille Little Lake or Naas Lake near Maitland. In the Medway system, one recently discovered occurrence is located at Shingle Lake (site 7) and three

historical occurrences are found on the lower Medway River at Charleston (site 4), Mill Village (site 5) and Buggy Hole Brook (site 6). Spotted Pondweed is only known to occur at one site in the Mersey River watershed, at Carrigan Lake (site 8).

Nearly 80 km southeast of the main region of occurrence, three confirmed populations are located in Yarmouth and Digby counties (Figure 6). In this second region, two occurrences are found in the Wentworth and Carleton River watershed at Placides Lake (site 9) and Raynards Lake (site 10), and one occurrence is found in the Annis River watershed at Salmon Lake (site 11). A third region of occurrence is Upper Musquodoboit (site 12) in Halifax County, where the species is known from a single location on a small tributary of the Musquodoboit River (Figure 7). This population is significantly isolated, located over 140 km northeast of the closest known population in the LaHave watershed.

Two reported occurrences near Annapolis Royal in Annapolis County and one near Chéticamp in Inverness County do not seem to be supported by specimen collections and could not be verified during the preparation of this status report.

Given Spotted Pondweed's low habitat specificity and the abundance of potential habitat in Nova Scotia, it is likely that other lakes and rivers in the province support the species.

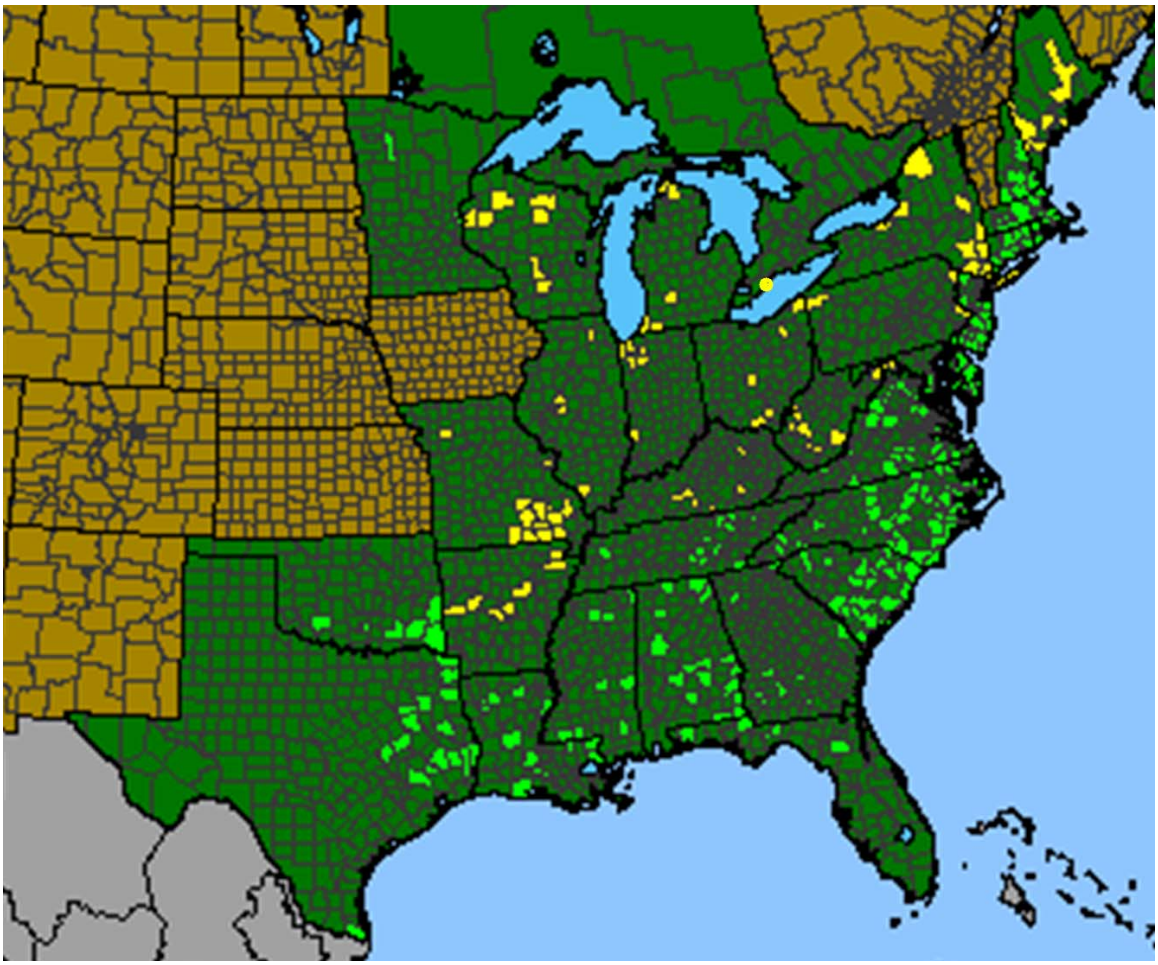

Figure 3. Global distribution of Spotted Pondweed (*Potamogeton pulcher*) outside of Nova Scotia, from BONAP (2010). Dark shaded states support the species and light shaded counties within those states have documented occurrences. Yellow shaded counties indicate state-level rarity. Light green shaded counties indicate non-rare status in that state.

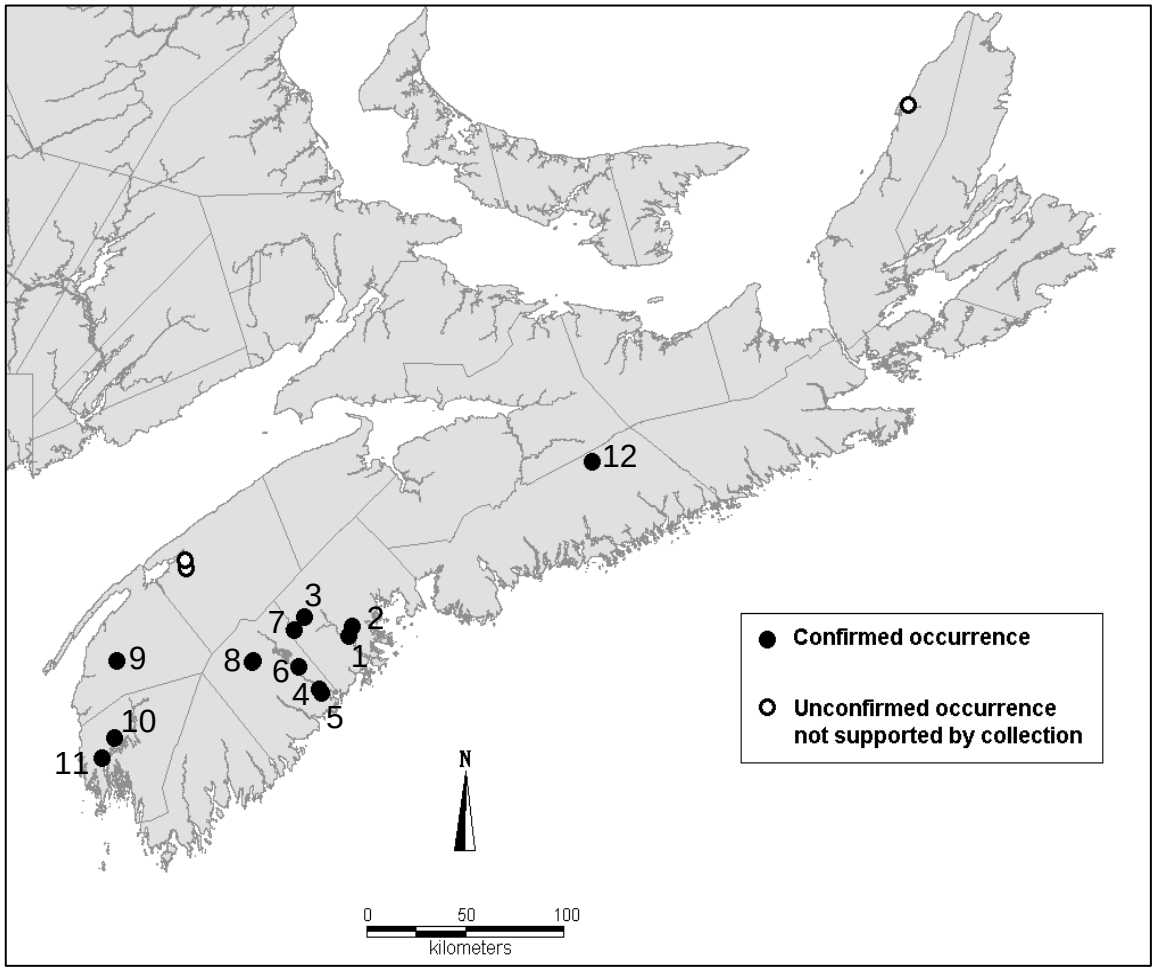

Figure 4. Distribution of Spotted Pondweed (*Potamogeton pulcher*) in Nova Scotia. Numbers refer to those used in Table 1. The twelve confirmed populations are: 1) Rhodenizer Lake, 2) Maitland Pond, 3) Hirtle Lake, 4) Charleston, 5) Mill Village, 6) Buggy Hole Brook, 7) Shingle Lake, 8) Carrigan Lake, 9) Placides Lake, 10) Raynards Lake, 11) Salmon Lake and 12) Upper Musquodoboit. The unconfirmed occurrence mapped in northeast Cape Breton likely does not represent the species.

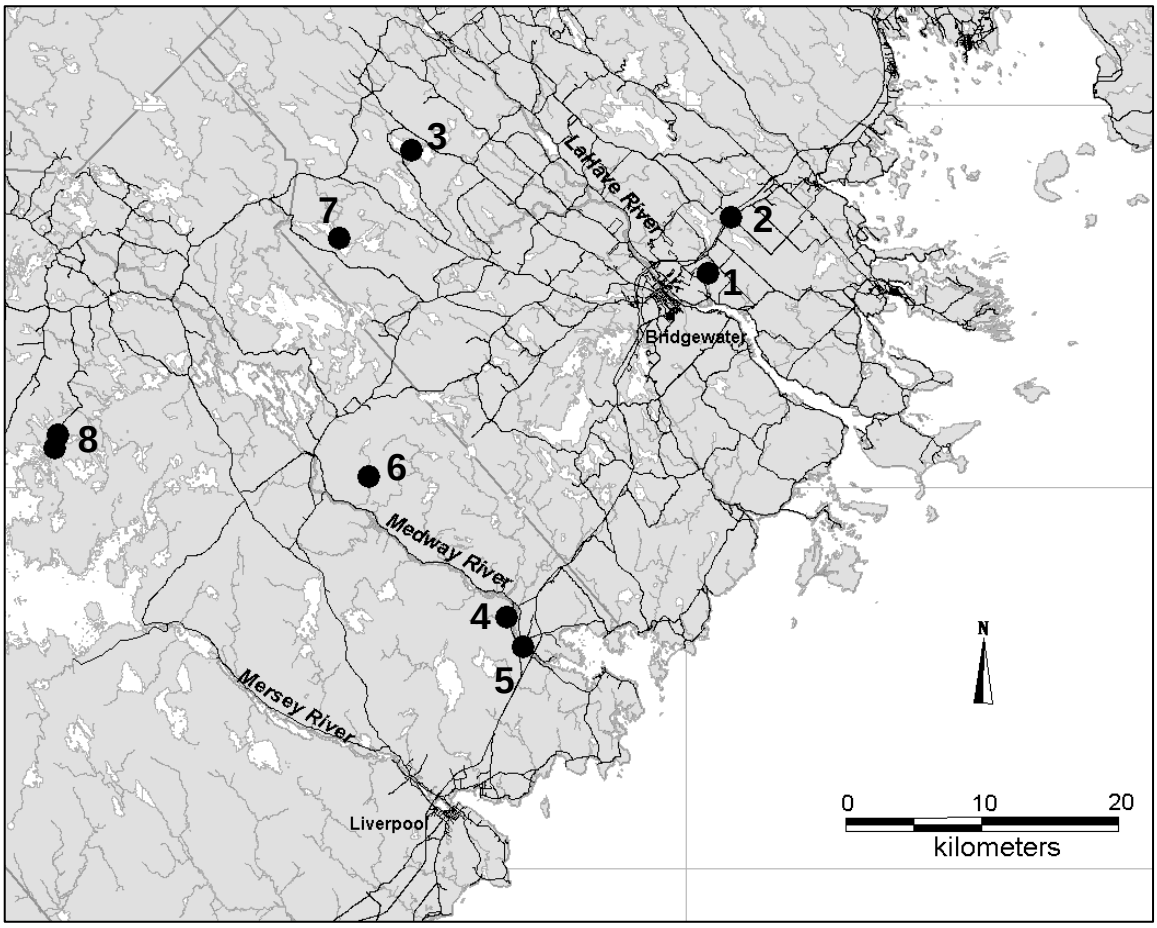

Figure 5. Distribution of Spotted Pondweed (*Potamogeton pulcher*) in Queens and Lunenburg Counties, Nova Scotia. Numbers refer to those used in Table 1. The eight confirmed populations in this region of occurrence are: 1) Rhodenizer Lake, 2) Maitland Pond, 3) Hirtle Lake, 4) Charleston, 5) Mill Village, 6) Buggy Hole Brook, 7) Shingle Lake and 8) Carrigan Lake.

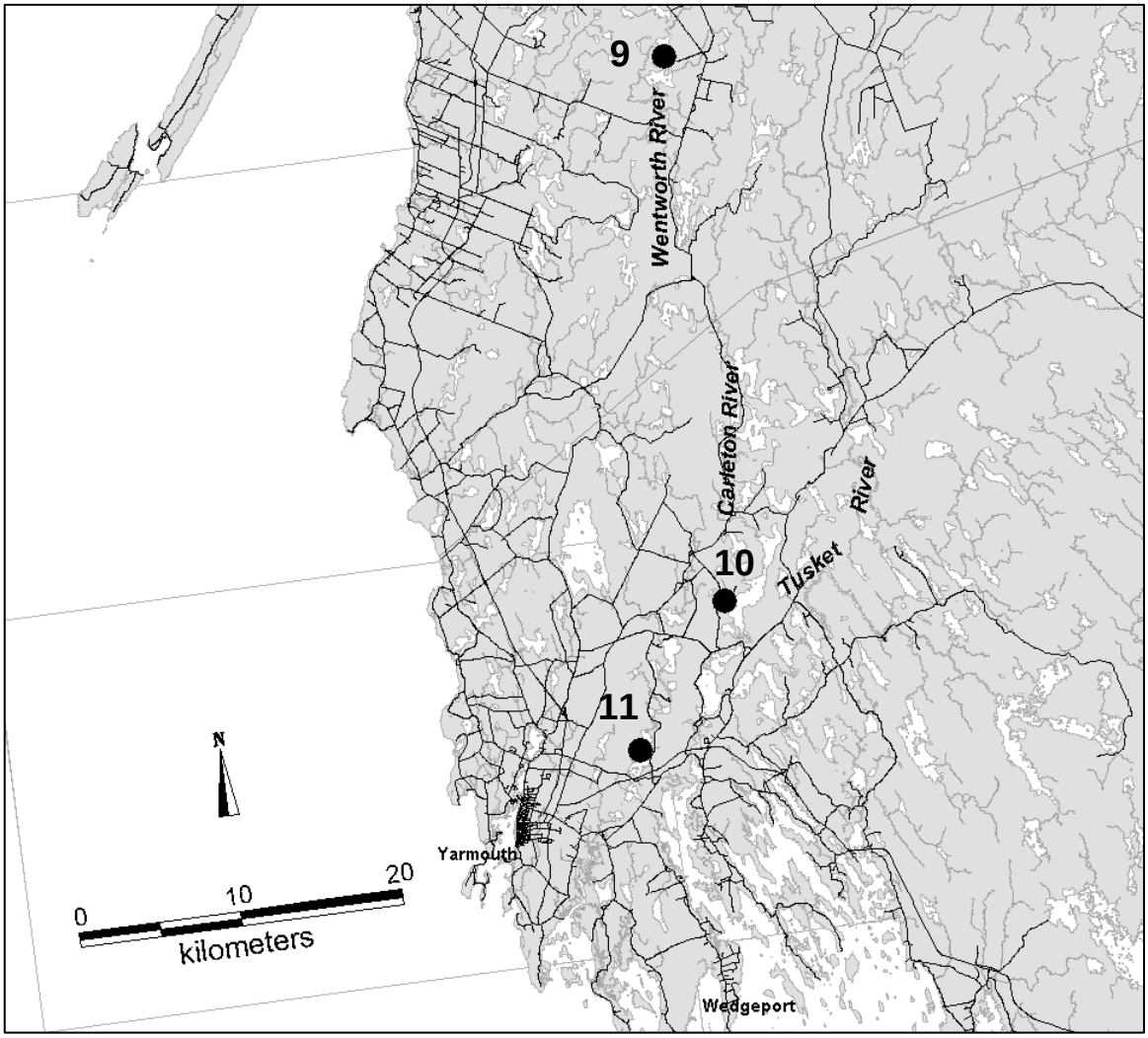

Figure 6. Distribution of Spotted Pondweed (*Potamogeton pulcher*) in Yarmouth County and Digby County, Nova Scotia. Numbers refer to those used in Table 1. The three confirmed populations in this region of occurrence are: 9) Placides Lake, 10) Raynards Lake and 11) Salmon Lake.

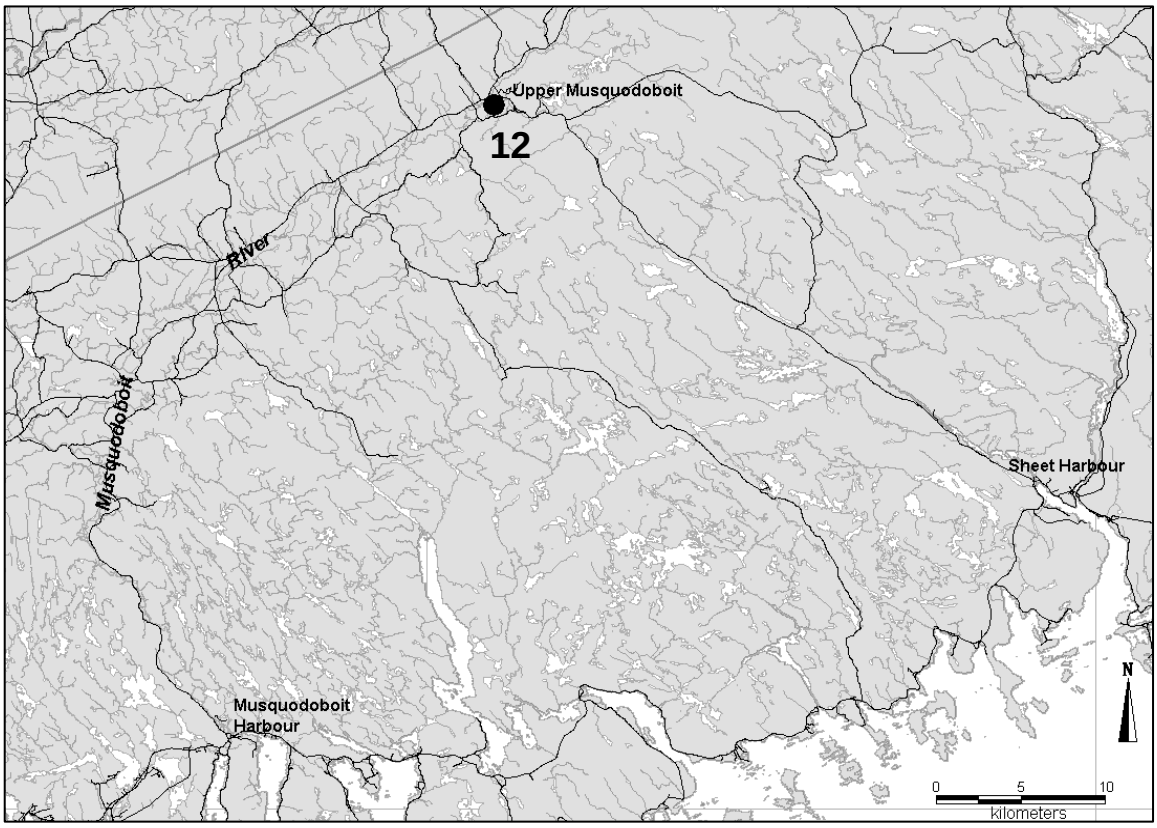

Figure 7. Distribution of Spotted Pondweed (*Potamogeton pulcher*) in Halifax County, Nova Scotia. Number refers to that used in Table 1. The only confirmed population in this region of occurrence is at Upper Musquodoboit (12).

Search Effort

Historic effort to document aquatic plants in Nova Scotia has been fairly significant, with Fernald *et al.* (1921, 1922), Roland and Smith and collaborators (documented in Roland and Smith 1969) and especially the M.Sc. thesis of David Webster (REFERENCE) contributing to collections of *Potamogeton* species on well over XX different lakes in Nova Scotia, including XX in the counties south and west of Halifax (AC CDC 2010) where the occurrences of Spotted Pondweed are concentrated.

Over the past decade, the Atlantic Canada Conservation Data Centre has carried out extensive botanical surveys on numerous lakes and rivers in southwestern Nova Scotia, driven by prevalence of suitable habitat for Atlantic Coastal Plain flora and a high potential for the discovery of federally and provincially rare species populations. Most significantly, from 2007 to 2010 surveys were carried out at over 60 sites within Spotted Pondweed's main region of occurrence in the Mersey, Medway and LaHave watersheds (Figure 8). These included two field days specifically focused on locating historical occurrences of the species. On August 12th 2007, sections of the Medway River were surveyed from Charleston (site 4) to Mill Village (site 5) and at the mouth of Buggy Hole Brook (site 6) by Sean Blaney *et al.* Spotted Pondweed was not found during these surveys. On August 27th 2009, a significant portion of Rhodenizer Lake in Luneburg County was searched by Sean Blaney and David Mazerolle and the population at this site was confirmed to be extant.

Despite the considerable survey effort of AC CDC and other botanists capable of identifying the species, only eight older records exist and new populations have only been discovered at Shingle Lake (Lunenburg Co.), Hirtle Lake (Lunenburg Co.), Carrigan Lake (Queens Co.), Raynards Lake (Yarmouth Co.) and Salmon Lake (Yarmouth Co.). New sites represent less than 10% of lakes recently visited, which strongly suggests that the species is genuinely quite infrequent in Nova Scotia. However, Spotted Pondweed can be difficult to detect at low densities and is easily mistaken for Large-leaf Pondweed (*P. amplifolius*), so earlier botanists may have missed some occurrences in lakes they visited. There is also still a very high proportion of southern Nova Scotia lakes that have never been visited by botanists knowledgeable enough to find and identify the species. If even 1% of the many hundreds of potentially suitable lakes of southern Nova Scotia supported Spotted Pondweed, there could be a significant number of undiscovered sites in the province.

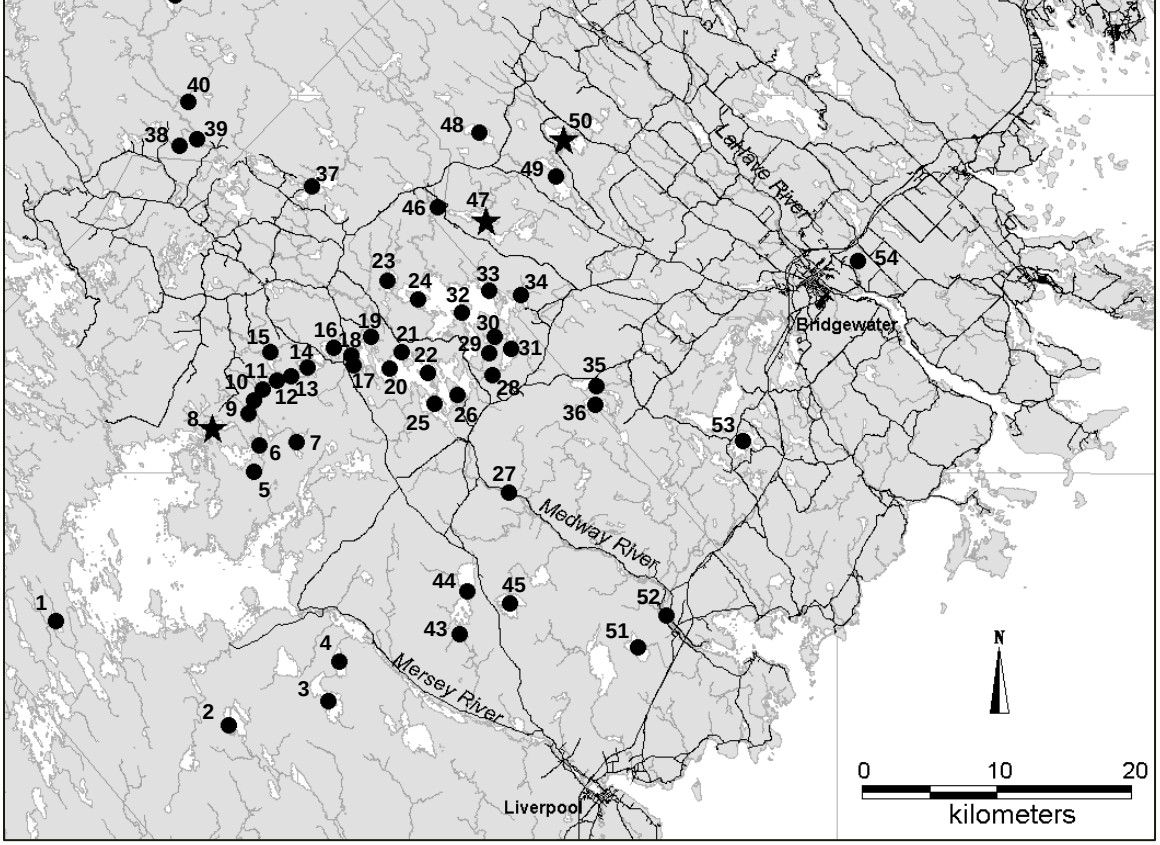

Figure 8. Atlantic Canada Conservation Data Centre rare plant survey sites visited in Queens, Lunenburg and Annapolis counties from 2007 to 2010. Stars indicate survey sites where previously unknown Spotted Pondweed (*P. pulcher*) populations were discovered (8 - Carrigan Lake, 47 – Shingle Lake, 50 – Hirtle Lake).

1) Caduesky Lake (2010), 2) Broad River Lake (2010), 3) Toney Lake (2009), 4) Eagle Lake (2009), 5) Little rocky Lake (2010), 6) Moccasin Lake (2010), 7) Bull Moose Lake (2009), 8) Carrigan Lake (2009), 9) Appletree Lake (2010), 10) Telfer Lake (2010), 11) Fourth Christopher Lake (2010), 12) Third Christopher Lake (2008), 13) Laurel Lake (2008, 2010), 14) Second Christopher Lake (2007, 2010), 15) Russel Lake (2008), 16) First Christopher Lake (2010), 17) Beartrap Lake (2007), 18) Cameron Lake (2007), 19) Medway River north of Ponhook (2007), 20) western section of Ponhook Lake (2007), 21) Wildcat River (2007), 22) north section of Ponhook Lake (2010), 23) Hog Lake (2010), 24) western section of Molega Lake (2010), 25) southern section of Ponhook Lake (2010), 26) southwestern section of Ponhook Lake (2010), 27) mouth of Buggy Hole Brook (2007), 28) Whynott Lake (2008), 29) Beaverdam Lake (2007), 30) Black Rattle Lake (2007), 31) Beavertail Basin (2007), 32) Hanley Point area of Molega Lake (2007), 33) northwestern section of Molega Lake (2010), 34) western section of Molega Lake (2007), 35) Long Lake (2008), 36) Elizabeth Lake (2008), 37) Tupper Lake (2008), 38) Medway River north of New Albany (2010), 39) Mill Brook (2010), 40) Perch Lake (2010), 41) Medway Lake (2010), 42) Alma Lake (2010), 43) Little Ten Mile Lake (2009), 44) Ten Mile Lake (2009), 45) Eight Mile Lake (2008), 46) Pleasant River (2009), 47) Shingle Lake (2007, 2009), 48) Smith Lake (2010), 49) Seven Mile Lake (2008), 50) Hirtle Lake (2008), 51) Crane Lake (2009), 52) lower Medway River from Charleston to Mill Village (2007), 53) Crooked Lake (2009), 54) Rhodenizer Lake (2009), 55) East Stoney Lake (2009).

HABITAT

Habitat Requirements

The distribution of freshwater macrophytes is primarily a function of abiotic factors such as bottom substrate and water chemistry parameters including pH, alkalinity and nutrient availability (Hutchinson 1975, Pip 1987, Schiemer and Prosser 1976). Since species differ in their photosynthetic response to light (Spence and Chrystal 1970), depth and factors influencing light penetration within the water column also play an important role in distribution and zonation (Barrat-Segretain 1996, Chambers 1987).

Pondweeds as a group exhibit a wide ecological flexibility, as evidenced by the widespread distribution of many species, their high degree of morphological plasticity and ability to employ various growth forms and life-cycle strategies (Ogden 1943, Pip 1987, Wiegleb and Brux 1991).

Little is known of Spotted Pondweed's specific habitat requirements and available information is largely based on qualitative field observations. Throughout its global range, Spotted Pondweed is reported to occur in various types of stagnant to slow-flowing aquatic habitats including lakes, ponds, muddy or peaty pools, rivers, slow-flowing streams and runnels in bogs. It is generally a species of acidic waters (Crow and Hellquist 2000), but can also be found in waters with nearly neutral pH levels (Williams 1997).

Most confirmed populations in Nova Scotia are found in lakes, with the exception of two historical occurrences on the lower Medway River at Buggy Hole Brook and Mill Village. Even along these watercourses, populations were likely found in slow-flowing pools or stillwaters. Data collected in recent surveys indicates that the species is mainly found growing on muddy substrates at depths of approximately 10 cm to over 2 m, often within fairly dense stands composed of several submersed and emergent species. At Carrigan Lake, Spotted Pondweed was observed in various situations, in moderately deep water with little competition from other species as well as in very shallow water growing on muddy and peaty shoreline mats formed by abundant emergent macrophytes (D.M. Mazerolle, pers. obs.). Commonly associated species include Pickerel weed (*Pontederia cordata*), Algae-like pondweed (*Potamogeton confervoides*), Purple bladderwort (*Utricularia purpurea*), Greater bladderwort (*Utricularia macrorhiza*), Seven-angled pipewort (*Eriocaulon aquaticum*), Yellow cowlily (*Nuphar lutea ssp. variegata*), American water-lily (*Nymphaea odorata*), Floating-heart (*Nymphoides cordata*), Nuttall pondweed (*Potamogeton epihydrus*) and Water lobelia (*Lobelia dortmanna*) (C.S. Blaney pers. obs., D.M. Mazerolle pers. obs., N.M. Hill pers. obs., Williams 1997). All recently surveyed populations occur in oligotrophic to mesotrophic water bodies in clear to moderately turbid conditions.

Although the majority of known populations are located at sites subjected to natural water level fluctuations, the recent discovery of *P. pulcher* at the Raynards Lake reservoir suggests that such fluctuations are not a necessary element of the species' habitat.

Habitat Trends

The majority of habitat occupied by Spotted Pondweed in Nova Scotia is not likely to have changed significantly due to anthropogenic disturbances. Large-scale mink farming and aquaculture, however, have been identified as major sources of nutrient enrichment and linked to major changes in several water bodies in the Wentworth and Carleton River watersheds (Nova Scotia Environment 2009, 2010). Hyper-eutrophic conditions were observed at Placides Lake (site 9) and eutrophic conditions were observed at Lake Fanning, which is located just upstream of Raynards Lake (site 10) (Nova Scotia Environment 2010). One of the fastest growing agricultural sectors in the province, fur farming could lead to further habitat degradation. Eutrophication of water bodies is a well documented driver of macrophyte declines and local extinctions (Hough *et al.* 1978, Phillips *et al.* 1978, Sand-Jensen *et al.* 2000, Wiegleb *et al.* 1991).

Human impacts on Spotted Pondweed are not known elsewhere, but residential and recreational development along shorelines are extensive enough on several lakes to potentially create nutrient enrichment and local sediment changes at Rhodenizer Lake (site 1), Hirtle Lake (site 2), and Salmon Lake (site 11). Significant residential development on the lower Medway River at Charleston (site 4) and Mill Village (site 5) is less likely to have drastically altered aquatic habitats along this fast-flowing section of river, but historic dams that are no longer present may have affected Medway River sites. The majority of waterfront land where populations occur is privately owned and highly subdivided. Development is therefore likely to continue and potentially impact other population sites in the future.

Over recent decades, surface waters in the Maritimes have undergone fluctuations in pH level due to acidification from acid rain and gradual attenuation of this acidification through stricter emissions regulations (Whitfield *et al.* 2006). These changes are unlikely to have affected Spotted Pondweed populations since the species tolerates a wide range of pH levels and most often grows in acidic waters.

BIOLOGY

The life cycle, reproduction and ecology of Spotted Pondweed have not been studied in detail, as little information was uncovered during a literature review. The following is therefore general in nature and largely based on genus-

level information and findings concerning morphologically similar pondweed species.

Life Cycle and Reproduction

Although typically referred to as perennial plants, most pondweeds are better described as facultative perennials, having the capacity to adopt annual and perennial life-cycle characteristics based on environmental conditions at a particular site (Philbrick and Les 1996).

Reproduction in pondweeds consists of both sexual and vegetative mechanisms (Cook 1988, Hutchinson 1975, Wiegleb and Brux 1991). Along with other life-history traits, reproductive strategies employed by pondweed species are closely associated to specific growth forms (emergent, floating or submergent) which represent different degrees of adaptation to aquatic environments (Philbrick and Les 1996).

Flowering in *P. pulcher* occurs in summer from June to September, with fruits maturing in late summer to early fall (Wisconsin Department of Natural Resources 2009). Pondweed species such as *P. pulcher*, which form floating leaves and emersed flowering spikes, are dependent on wind for the dispersal of their spherical pollen grains and exhibit strong protogyny, with stigmas becoming receptive before anthers release pollen but remaining receptive during pollen dissemination (Cook 1988). Protogyny suggests a species is facultatively autogamous (self-pollinating), with an initial phase that allows outcrossing followed by a second phase during which selfing occurs (Philbrick 1984).

In many pondweed species, the large majority of individuals in a population typically remain sterile and achenes only contribute minimally to overall reproduction (Barrat-Segretain 1996, Muenscher 1936, Ogden 1943). This would seem to be the case for *P. pulcher*, since lack of flowering parts in most collected specimens and rarity or absence of flowering in populations (C.S. Blaney pers. obs., D.M. Mazerolle pers. obs., Scribailo and Alix 2002) suggest infrequent sexual reproduction.

The dominant mode of reproduction and spread in floating and submerged aquatic plants is by vegetative means (Cook 1993, Hutchinson 1975, Spencer and Bowes 1993, Philbrick and Les 1996, Wiegleb *et al.* 1991). Pondweeds can achieve rapid reproduction and spread through rhizomes, stolons and continuously growing vertical shoots (Muenscher 1936, Sculthorpe 1967, Van Wijk 1988, Wiegleb and Brux 1991). They also commonly form specialized structures called turions, which function as vegetative propagules capable of long-distance dispersal (Sculthorpe 1967, Van Wijk 1988, Wiegleb and Brux 1991, Wiegleb *et al.* 1991). Often referred to as winter buds, these structures consist of dormant vegetative buds which are enclosed by numerous specialized leaves (Philbrick and Les 1996). Formation of turions most often occurs in late

summer and fall, as environmental conditions become less favorable (Barrat-Segretain 1996). As is common in macrophytes, pondweeds also possess the ability to regenerate from vegetative fragments such as stem or root sections (Barrat-Segretain 1996, Philbrick and Les 1996).

Dependence on any particular life-cycle strategy can vary significantly in accordance with habitat conditions (Philbrick and Les 1996).

In broad-leaved pondweed species, life expectancy at the genet level (set of shoot complexes sharing a genetic identity) can vary significantly depending on environmental conditions, from annual to a virtually unlimited number of years (Wiegleb and Brux 1991).

Physiology and Adaptability

Pondweeds are generally highly adaptable species, exhibiting a high degree of morphological plasticity and an ability to utilize various growth forms and life cycle strategies depending on habitat conditions (Philbrick *et al.* 1996, Wiegleb and Brux 1991). In Sago Pondweed (*Stuckenia pectinata*, formerly *P. pectinatus*) for example, Van Wijk (1988) observed that individuals survived through the winter months as vital vegetative plants in deep and sheltered sites while individuals growing in shallower and more exposed sites only persisted as tubers or tuber fragments. Through changes in morphology and reproductive strategies, some pondweed species can persist in habitats having undergone rapid and drastic changes in water chemistry or physical characteristics (Van Wijk 1988, Wiegleb *et al.* 1991).

Both pondweed individuals and their propagules, including seeds and turions, can also undergo extended periods of dormancy during winter months or when habitat conditions become unfavorable, germinating or resuming growth when suitable conditions return (Barrat-Segretain 1996, Haag 1979). Potential for vigorous vegetative reproduction and capacity to employ various dispersal mechanisms such as rhizomes, fragments, turions and seeds enable macrophytes to maximize their dispersal and establishment into available habitats (Barrat-Segretain 1996, Muenscher 1936, Philbrick and Les 1996, Sculthorpe 1967).

Because of their increased capacity to capture light, floating-leaved macrophytes such as *P. pulcher* have a competitive advantage over submerged species. By the same token, they are also better adapted to withstand decreased light availability in the water column caused by increases in the abundance of other macrophytes, algae or suspended sediments. In a study investigating the response of Spotted Pondweed and two submergent macrophytes (*Elodea* and *Myriophyllum*) to algal competition, Spotted Pondweed was the least affected due to its fibrous stems and leaves floating above the algae (Ryan *et al.* 1972).

Dispersal and Migration

The drupes and achenes produced by pondweed species can float for considerable lengths of time, with flotation periods varying from a few days to 18 months (Spence *et al.* 1971). Seed buoyancy is thought to be assisted by gases produced by photosynthesis in green fruits and captured by the cuticle and pericarp (Spence *et al.* 1971). Though the flotation periods of *P. pulcher* fruits and achenes are unknown, it is presumed that wave action and water flow play a major role in dispersing seeds within water bodies and watersheds. Similarly, vegetative propagules such as plant fragments and turions can float in the water column and are therefore potentially carried by water over considerable distances. Spotted Pondweed can also disperse over short distances by rhizomes or stolons which spread away from parent plants and form new vertical shoots.

Animals are the principal agents of long-distance dispersal for most aquatic macrophytes (Sculthorpe 1967). Both the sexual and vegetative propagules of aquatic plants are known to be transported internally and/or externally by birds, large and small mammals, reptiles and amphibians (Hutchinson 1975, Sculthorpe 1967). The role of water birds in the dispersal of propagules is well documented and may be of particular importance for pondweeds, as the passage of seeds through the digestive tracts of waterfowl has been shown to facilitate germination in several species (Guppy 1906, Smits *et al.* 1989; Van Wijk 1989). The discovery in Ohio of a Spotted Pondweed population in ponds recently created by sand-mining (Scribailo and Alix 2002) attests to *P. pulcher*'s capacity for animal or human-mediated dispersal.

Human activity, through the transfer of watercraft, boat trailers and commercial or recreational equipment between water bodies, is also recognized as an important vector in the propagation of macrophytes and a facilitator of invasion by exotic species (Johnstone *et al.* 1985, Les and Mehrhoff 1999, Scales and Bryan 1979).

Interspecific Interactions

Pondweed stands play a significant role in the structure and function of many aquatic ecosystems by contributing to primary production, sediment fixation and nutrient cycling as well as creating habitat and food sources for animals and periphyton (Barrat-Segretain 1996, Sand-Jensen *et al.* 1989, Wiegleb *et al.* 1991). Macrophytes in general represent important invertebrate habitats, providing refuge from predation and substratum for periphyton and epiphytic algae (Hutchinson 1975, Newman 1991). Berg (1949) states that pondweeds support a particularly large and diverse assemblage of invertebrates, some of

which may be obligatorily associated with certain pondweed species. Floating-leaved macrophytes can suffer significant damage from invertebrate herbivores (Jacobsen and Sand-Jensen 1994, Otto and Wallace 1989, Setala and Makela 1991), and pondweeds can be injured from attack or infestation by aquatic snails (Sheldon 1987, Lodge 1991) and various insect groups including Lepidoptera, Trichoptera, Chironomidae (Diptera), Epihydridae (Diptera) and Donaciinae (Chrysomelidae - Coleoptera) (Berg 1949).

The larvae of Obscure Pondweed Moth (*Parapoynx obscuralis*) and Waterlily Borer (*Munroessa gyralis*), two generalist lepidopteran species, are known to use Spotted Pondweed as a host plant (Stoops *et al.* 1998). The range of these species is not well understood but both are said to occur in Nova Scotia (BugGuide.net 2010).

Moose herbivory can reduce plant height and stand density of various pondweeds (Aho and Jordan 1979, Crete *et al.* 2001) but the scarcity of Moose in mainland Nova Scotia means they are unlikely to be impacting Spotted Pondweed populations.

Pondweeds are also known to be a food source for waterfowl (Anderson and Low 1976, McKnight 1995), Muskrat (Ching and Chih-Tang 1965, Takos 1947) and Beaver (Milligan and Humphries 2010).

POPULATION SIZES AND TRENDS

Abundance

Wiegleb and Brux (1991) suggest the basic independent unit of growth in the genus *Potamogeton* is the shoot complex, defined as all connected shoots (both vertical and horizontal) and reproductive structures (both asexual and sexual). This unit can vary greatly in size and complexity, from a small root system with a single vertical shoot in its most simple expression, to a dense and extensive stand. Following COSEWIC standards, however, each separate shoot would be considered a separate individual and a shoot complex would include multiple individuals. However one defines an individual of Spotted Pondweed, it is difficult to count individuals in the field since more than one “shoot complex” can be interwoven together (potentially including both the hybrid *P.* x *rhodensis* and Spotted Pondweed in barely distinguishable masses) and since one has to look down to the mucky substrate underwater to accurately count shoots. Area of occupancy and descriptions of abundance thus tend to be more useful measures of population size in this species.

Data on population size is lacking for most occurrences, due to lack of

recent surveys in many sites, difficulties in field identification vs. co-occurring hybrids and the inherent difficulty in counting individuals underwater. Data collected at recently surveyed population sites indicates that the species is very localized with few stands, a limited area of occupancy and likely few genetically distinct individuals. All available data on Nova Scotia populations is presented in Table 1.

Table 1. Location, observer and survey date for all confirmed Spotted Pondweed (*Potamogeton pulcher*) populations, with notes on abundance and habitat.

Population	**Watershed**	**Collector / observer**	**Date(s) of discovery / survey** (Y/M/D)	**Notes on habitat and abundance**
1. Rhodenizer Lake (Lunenburg Co.)*	LaHave River	1) Fernald, M.L.; B. Long 2) Blaney, C.S.	1) 192x/xx/xx 2) 2009/08/27	2) Abundance: dense 3x4m patch Habitat: 10-20cm water in organic muck over sand
2. Maitland Pond (Lunenburg Co.)*†	LaHave River or Mushamush River†	Erskine, J.S.	1952/08/23	
3. Hirtle Lake (Lunenburg Co.)*	LaHave River	Blaney, C.S.	2008/09/10	1) Abundance: one patch ~3m x 5m Habitat: 0.2-1.0m of water; rock/boulder bottom with some peat accumulation 2) Abundance: one patch 3-5m diameter Habitat: in relatively deep water, 1.5-2m+
4. Charleston (Queens Co.)*	Medway River	Dore, W.G.; Gorham, E.	1945/08/02	Habitat: pool on marshy gravelly drained shore of Medway River above
5. Mill Village (Queens Co.)*	Medway River	Donly, J.F.	1958/09/26	Habitat: in pond
6. Buggy Hole Brook (Queens Co.)*	Medway River	Donly, J.F.	1956-1962	Habitat: in brook

7. Shingle Lake (Lunenburg Co.)*	Medway River	Blaney, C.S.	2007/09/07	Abundance: one large stand 3-5m in diameter Habitat: relatively deep water, 1.5-2m+
8. Carrigan Lake (Queens Co.)*	Mersey River	1) Blaney, C.S. 2) Mazerolle, D.M.	2009/08/28	1) Habitat: sheltered bay; 2) Abundance: two small patches ~2m in diameter Habitat: shallow to moderately deep water in sheltered cove on muddy bottom
9. Placides Lake (Digby Co.)	Wentworth River – Carleton River	Fernald, M.L.; B. Long	192x/xx/xx	
10. Raynards Lake (Yarmouth Co.)*	Carleton River	Newell, R.E.; Peck, J.	2009/08/14	Habitat: small coves with an abundance of aquatic vegetation
11. Salmon Lake (Yarmouth Co.)	Annis River	Hill, N.M.	2010/08/23	Abundance: two stands, 25 m^2 and 10 m^2 Habitat: small bay with inflowing stream
12. Upper Musquodoboit (Halifax Co.)*	Musquodoboit	Smith, E.C.; Taylor, J.C.; Webster, D.H.; Slipp, L.B.	1953/08/10	Habitat: runnel of alkaline bog; Abundance: abundant; Flowering

* Specimen identification confirmed or specimen annotated by C. B. Hellquist, 2010.
† Exact location of this occurrence is not known since “Maitland Pond” is not a recognized geographic name. The most likely locations for this occurrence are Little Lake, Langille Little Lake or Naas Lake.

Fluctuations and Trends

Existing data is insufficient to detect fluctuations in population size or area of occupancy. With the exception of one population at Rhodenizer Lake (Lunenburg Co.), where the species has persisted from about 1920 to the present, most populations have only been surveyed once and available data is limited to notes taken at the time of their discovery.

Attempts made in 2007 by AC CDC botanists and Sherman Boates (NS DNR) to locate three historical occurrences, at Charleston (site 4), Mill Village (site 5) and Buggy Hole Brook (site 6), were unsuccessful, though this does not necessarily indicate loss of those populations. Precise locations of the original

collections were not known to the surveyors, so surveys may not have focused on the right areas. Aquatic habitats on the lower Medway River are not known to have changed significantly over the past six decades. Eutrophication of water bodies from agricultural nutrient loading could have caused declines in the Wentworth and Carleton River watersheds. Since data indicates that Nova Scotia populations are generally small, local fluctuations or extinctions may have resulted from stochastic events.

Rescue Effect

Rescue effect between populations found within the same watershed is possible, as sexual or vegetative propagules can be carried downstream by water flow. Upstream transfer of propagules is less likely and would depend on animal or human-mediated dispersal.

Exchange between populations in different watersheds is possible but likely to be infrequent. Since the three known regions of occurrence in Nova Scotia (Yarmouth/Digby counties, Queens/Lunenburg counties and Halifax County) are separated by distances of 70 km and 150 km, any natural exchange between them would rely entirely on dispersal of seeds by migrating birds, which may be extremely infrequent given the inconsistent flowering seen in *P. pulcher*.

The significant disjunction of Nova Scotian populations from the nearest populations in Maine (220 km away) also make any cross-border rescue effect unlikely.

THREATS AND LIMITING FACTORS

The most imminent threat to Spotted Pondweed populations in Nova Scotia is the eutrophication of water bodies resulting from large agriculture or aquaculture operations. Anthropogenic eutrophication is known to be occurring at the Picoides Lake site and just upstream from the Raynards Lake site. Effects on Spotted Pondweed at those sites are not well understood, but nutrient loading from effluent and surface runoff containing fertilizers and manure can lead to algal blooms and eutrophic conditions, which have been linked to macrophyte population declines and local extinctions (Hough *et al.* 1989, Phillips *et al.* 1978, Sand-Jensen *et al.* 2000, Wiegleb *et al.* 1991). Although floating leaved macrophytes are better adapted than submergent species to withstand eutrophic conditions, algal competition has been shown to lower productivity in Spotted Pondweed (Ryan *et al.* 1972). It is also plausible that since Spotted Pondweed appears to be a specialist of acidic, nutrient-poor waters, eutrophication could cause it to suffer from increased competition from other vascular species less tolerant of low nutrient conditions. Competitors could include the closely related

Large-leaf Pondweed (*P. amplifolius*), which has been shown to respond positively to increased sediment nutrients by Cronin and Lodge (2003). That species would compete directly with Spotted Pondweed and could also reduce pure populations through hybridization.

Fur farming, mainly with mink, is one of the fastest growing agricultural sectors in Nova Scotia (Nova Scotia Department of Agriculture 2009). In its 2006 Census of Agriculture, Statistics Canada reported that Nova Scotia was the largest producer of mink fur in the country, with an 89% increase in provincial mink farming from 2001 to 2006. Nearly 80 mink farms are presently operating in the province, most in Yarmouth and Digby counties.

In water quality surveys in the Wentworth and Carleton River watershed area, eutrophic conditions were observed in a number of water bodies including Placides Lake (site 9) (Nova Scotia Environment 2009) and Lake Fanning (Nova Scotia Environment 2010), which is located just upstream of Raynards Lake (site 10). In a report summarizing the findings, mink farms and an aquaculture operation were identified as major nutrient sources in the area's water bodies (Nova Scotia Environment 2009, 2010). The aquaculture operation identified in the report is located on Hourglass Lake, approximately 3 km upstream of Placides Lake.

Though populations are not likely to be directly disturbed by lakeshore cottage and residential development, nutrient enrichment from faulty septic systems and surface runoff can contribute to changes in trophic levels and have a cumulative impact. Deforestation and removal of shoreline vegetation often associated with development can also increase sedimentation and siltation, potentially modifying underwater substrates, increasing water turbidity and decreasing light availability in the water column. Field observations and aerial photography indicate that development is considerable on Rhodenizer Lake (site 1), Hirtle Lake (site 2), and Salmon Lake (site 11). Given the fact that lakeshore properties are generally in high demand both for cottage development and for recreational purposes, the level of impact from this threat and the number of populations affected will undoubtedly increase in the future.

Through habitat alteration and deliberate or accidental transport of species, disturbances related to shoreline development and recreational activities typically lead to increases in the number and abundance of exotic species present at a given site. Nutrient-poor lakes typically occupied by Spotted Pondweed appear quite resistant to aquatic and shoreline invasive plants (Hill and Blaney 2010) but if coupled with eutrophication, exotic species such as Yellow Floating-heart (*Nymphoides peltata*), Eurasian Water-milfoil (*Myriophyllum spicatum*) and Curly Pondweed (*Potamogeton crispus*) might pose some threat to Spotted Pondweed. The first occurs in Nova Scotia, while the latter two are considered absent in the province but are known from New Brunswick, Quebec and the northeast United States.

Given that available information indicates that Spotted Pondweed is rare at most known sites with few stands and likely few separate individuals, populations in Nova Scotia could be highly vulnerable to even very localized disturbance and stochastic events. Random fluctuations in small populations could also lead to extirpation at some sites.

Since knowledge on the biology and ecology of Spotted Pondweed is limited, additional threats and limiting factors can only be speculative.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The species is not presently afforded legal protection under any provincial or federal act in Canada. In the United States, it has been granted legal state-level protection in Illinois, Indiana, Kentucky, Maine, Michigan, New York, Ohio, Pennsylvania and Wisconsin (USDA 2010).

Non-Legal Status and Ranks

Spotted Pondweed is listed as globally secure (G5) but is considered rare throughout a large portion of its range (Natureserve 2010). In Canada, it is ranked as critically imperiled (N1), with a subnational status of S1 in Nova Scotia (with a revision to S2 likely at the next review based on number of occurrences, which would change the N-rank to N2) and SH (possibly extirpated) in Ontario (NatureServe 2010). It has been assigned a National General Status rank of May Be At Risk, which equates to a “Red” rank under the NS DNR provincial ranks.

Subnational status ranks in the United States, as listed by Natureserve (2010), are: Alabama (SNR), Arkansas (S3), Connecticut (SNR), Delaware (S5), Florida (SNR), Georgia (SNR), Illinois (S1), Indiana (S1), Kentucky (S1S2), Louisiana (SNR), Maine (S1), Maryland (SNR), Massachusetts (SNR), Michigan (S2), Minnesota (SNR), Mississippi (SNR), Missouri (S2S3), New Hampshire (SNR), New Jersey (S3S4), New York (S2), North Carolina (S4), Ohio (S2), Oklahoma (SNR), Pennsylvania (S1), Rhode Island (SNR), South Carolina (SNR), Tennessee (SNR), Texas (SNR), Vermont (SNR), Virginia (S4), West Virginia (S1), Wisconsin (S1). The exact status of the species remains undetermined in most states to the south and west of the Carolinas but available county-level distribution suggests it is locally common to uncommon or rare in these jurisdictions (BONAP 2010).

Habitat Protection and Ownership

Given that Spotted Pondweed is an aquatic species of lakes and rivers, it receives indirect protection from laws and policies regulating shoreline development and pertaining to the protection of water quality, watercourses, wetlands and riparian buffers. In Nova Scotia, pertinent laws and regulations include the *Activities Designation Regulations* and *Environmental Assessment Regulations* under the *Environment Act* as well as the *Forest Act*'s *Wildlife Habitat and Watercourses Protection Regulations*.

No occurrences are within protected areas, although the population at Salmon Lake is situated just offshore of a crown property which has been considered for designation as a nature reserve. The majority of populations in Nova Scotia clearly occur on crown land since they are situated in large permanent lakes and in the Medway River. Historical populations at Buggy Hole Brook (population 6) and Upper Musquodoboit (population 12) may however be located in smaller and possibly ephemeral water bodies or watercourses, which could be on private land. A substantial majority of land at population sites is privately owned and heavily subdivided. Three of the lakes in which the species is found have some crown land frontage: approximately 75% of total shoreline on Carrigan Lake (site 8), 25% on Hirtle Lake (site 3), 30% on Shingle Lake (site 7) and less than 5% on Salmon Lake (site 11).

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INFORMATION SOURCES

Aho, R.W. and P.A. Jordan. 1979. Production of aquatic macrophytes and its utilization by moose on Isle Royale National Park. Pages 341-348 in Proceedings of the First Conference on Science Research in the National Parks. National Parks Service, Washington, D.C., USA.

Anderson, M.G. and J.B. Low. 1976. Use of Sago pondweed by waterfowl on the Delta Marsh. Manitoba Journal of Wildlife Management 40: 233–242.

Barrat-Segretain, M.H. 1996. Strategies of reproduction, dispersion, and competition in river plants: a review. Vegetatio 123: 13–37.

Berg, C.O. 1949. Limnological relations of insects to plants of the genus *Potamogeton*. Transactions of the American Microscopical Society 68: 279-291.

BONAP (Biota of North America Program). 2010. North American Plant Atlas - *Potamogeton*. Website: http://www.bonap.org/BONAPmaps2010/Potamogeton.html. [Accessed November 10, 2010].

BugGuide.net. 2010. Website: http://bugguide.net/node/view/15740 [Accessed December, 2010].

Cook. C.D.K. 1988. Wind pollination in aquatic angiosperms. Annals of the Missouri Botanical Garden 75: 768-777.

Cook, C.D.K. 1993. Origin, autecology, and spread of some of the world's most troublesome aquatic weeds. Pages 31-38 in Pieterse AJ, Murphy KJ, eds. Aquatic weeds: the ecology and management of nuisance aquatic vegetation. New York, Oxford University Press.

Chambers, P.A. 1987. Light and nutrients in the control of aquatic plant community structure. II. *In situ* observations. Journal of Ecology. 75: 621-628.

Ching, C. and Y. Chih-Tang. 1965. Foods and food bases of the muskrat, *Ondatra zibethica* Linnaeus. Acta Zoologica Sinica 17: 352-363.

Crête, M., J.-P. Ouellet and L. Lesage. 2001. Comparative effects on plants of Caribou/Reindeer, Moose and White-tailed deer herbivory. Arctic 54(4): 407-417.

Cronin, G. and D.M. Lodge. 2003. Effects of light and nutrient availability on the growth, allocation, carbon/nitrogen balance, phenolic chemistry, and resistance to herbivory of two freshwater macrophytes. Oecologia 137: 32-41.

Guppy, H.B. 1906. Observations of a naturalist in the Pacific between 1891 and 1899. Vol. 2. Plant dispersal. Macmillan Co., London, UK.

Haag, R.W. 1979. The ecological significance of dormancy in some rooted

aquatic plants. Journal of Ecology 67: 727-738.

Haynes, R.R. and C.B. Hellquist. 2000. *Potamogeton*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 12+ vols. New York and Oxford. Vol. 22, pp. 47-74.

Holmgren, N.H. 1998. Illustrated companion to Gleason and Cronquist's Manual: illustrations of the vascular plants of northeastern United States and adjacent Canada. New York botanical Garden, Bronx, New York.

Hough R.A., M.D. Fornwall, B.J. Negele, R.L. Thompson and D.A. Putt. 1989. Plant community dynamics in a chain of lakes: principal factors in the decline of rooted macrophytes with eutrophication. Hydrobiologia 173: 199–217.

Hutchinson, G.E. 1975. A Treatise on Limnology, vol. 3: Limnological Botany. Wiley, New York.

Jacobsen, D. and K. Sand-Jensen. 1994. Invertebrate herbivory on the submerged macrophyte Potamogeton perfoliatus in a Danish stream. Freshwater Biology 31: 43-52.

Johnstone, I.M., B.T. Coffey and C. Howards-Williams. 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand study. J. Environ. Manage. 20: 263-279.

Kaplan, Z. and J. Fehrer. 2006. Comparison of natural and artificial hybridization in Potamogeton. Preslia 78: 303-316.

Les, D.H., and L.J. Mehrhoff. 1999. Introduction of nonindigenous aquatic vascular plants in southern New England: a historical perspective. Biological Invasions 1: 281–300.

Lodge D.M. 1991. Herbivory on freshwater macrophytes. Aquatic Botany 41: 195-224.

McKnight, S.K. and G.R. Hepp. 1995. Potential effect of Grass carp herbivory on waterfowl foods. The Journal of Wildlife Management 59(4): 720-727.

Milligan, H.E. and M.M. Humphries. 2010. The importance of aquatic vegetation in Beaver diets and the seasonal and habitat specificity of aquatic-terrestrial ecosystem linkages in a subarctic environment. Oikos 119(12): 1877-1886.

Muenscher, W.C. 1936. The germination of seeds of Potamogeton. Annals of Botany 50: 805-821.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: December 13, 2010).

Newman, R.M. 1991. Herbivory and detritivory on freshwater macrophytes by invertebrates: a review. Journal of the North American Benthological Society 10(2): 89-114.

Nova Scotia Environment. 2009. A water quality survey of nine lakes in the Carleton River watershed area, Yarmouth County, Nova Scotia. Prepared by the Water and Wastewater Branch, (D. Taylor, project lead). 16 pp. +app.

Nova Scotia Environment. 2010. A water quality survey of ten lakes in the Carleton River watershed area, Yarmouth and Digby counties, Nova Scotia. Prepared by the Water and Wastewater Branch, (D. Taylor, project lead). 16 pp. +app.

Ogden, E.C. 1943. The broad-leaved species of Potamogeton. Rhodora 45: 57-105, 119-163, 171-214.

Ontario Natural Heritage Information Centre. 2010. Response to data request on Spotted Pondweed (*Potamogeton pulcher*) in Ontario. Information requested and received in April 2010.

Otto, C. and J.B. Wallace. 1989. Life cycle variation and habitat longevity in waterlily leaf beetles. Holarctic Ecology 12:144-151

Philbrick C.T. 1984. Aspects of floral biology, breeding system, and seed and seedling biology of *Podostemum ceratophyllum* (Podostemaceae). Systematic Botany 9: 166-174.

Philbrick, C.T., and D.H. Les. 1996. Evolution of aquatic angiosperm reproductive systems. Bioscience 46: 813–826.

Phillips G.L., D. Eminson and B. Moss. 1978. A mechanism to account for macrophyte decline in progressively eutrophical freshwaters. Aquatic Botany 4: 103-126.

Pip, E. 1987. The ecology of *Potamogeton* species in central North America. Hydrobiologia 153: 203-216.

Ryan, J.B., D.M. Riemer and S.J. Toth. 1972. Effects of fertilization on aquatic plants, water and bottom sediments. Weed Science. 20: 482-486.

Sand-Jensen K., E. Jeppesen, K. Nielsen, L. Bijl, L. Hjermind, L. W. Nielsen and T. M. Iversen. 1989. Growth of macrophytes In lowland streams and ecosystem consequences. Freshwater Biology 22: 15-32.

Sand-Jensen, K., T. Riis, O. Vestergaard and S. E. Larsen. 2000. Macrophyte decline in Danish lakes and streams over the past 100 years. Journal of Ecology 88:1030-1040.

Scales, P. and A. Bryan. 1979. Transport of *Myriophyllum spicatum* fragments by boaters and assessment of the 1978 boat quarantine program. Studies on Aquatic Macrophytes 27. Water Investigations Branch, British Columbia Ministry of Environment.

Sheldon, S.P. 1987. The effects of herbivorous snails on submerged macrophyte communities in Minnesota lakes. Ecology 68: 1920-1931.

Schiemer, F. and M. Prosser. 1976. Distribution and biomass of submerged macrophytes in Neusiedlersee. Aquatic Botany 2: 289-307.

Scribailo, R.W. and M.S. Alix. 2002. New Records with ecological notes for rare aquatic vascular plants in Indiana. Part I. Rhodora 104: 373-395.

Sculthorpe, C.D. 1967. The biology of aquatic vascular plants. New York, St. Martin's Press.

Setälä, H. and I. Mäkelä. 1991. *Galerucella nymphaeae* (Col, Chrysomelidae) grazing increases *Nuphar* leaf production and affects carbon and nitrogen dynamics in ponds. Oecologia 86: 170-176.

Smits, A.J.M., R. van Ruremonde and G. van der Velde. 1989. Seed dispersal of three nymphaeid macrophytes. Aquatic Botany 35: 167-180.

Spence, D.H.N. and H.M. Dale. 1978. Variations in the shallow water form of Potamogeton richardsonii induced by some environmental factors. Freshwater Biology 8:251-268.

Spence, D.H.N. and J. Chrystal. 1970. Photosynthesis and zonation of freshwater macrophytes II: adaptability of species of deep and shallow water. New Phytologist 69: 217-227.

Spence, D.H.N., T.R. Milburn, M. Ndawula-Senyimba and E. Roberts. 1971. Fruit biology and germination of two tropical *Potamogeton* species. New Phytologist 70:207-212.

Spencer W. and G. Bowes. 1993. Ecophysiology of the world's most troublesome aquatic weeds. Pages 39-73 in Pieterse AJ, Murphy KJ, eds. Aquatic

weeds: the ecology and management of nuisance aquatic vegetation. New York, Oxford University Press.

Stoops, C.A., P.H. Adler and J.W. McCreadie. 1998. Ecology of aquatic Lepidotera (Crambidae: Nymphulinae) in South Carolina, USA. Hydrobiologia 379: 33-40.

Takos, M.J. 1947. A semi-quantitative study of Muskrat food habits. Journal of Wildlife Management 5: 1-12.

van Wijk, R.J. 1988. Ecological studies on *Potamogeton pectinatus* L. I. General characteristics, biomass production and life cycles under field conditions. Aquatic Botany 31: 211-258.

Van Wijk, R.J. 1989. Ecological studies on *Potamogeton pectinatus* L. III. Reproductive strategies and germination ecology. Aquatic Botany 33: 271-299.

Whitfield, C.J., J. Aherne, S.A. Watmough, P.J. Dillon and T.A. Clair. 2006. Recovery from acidification in Nova Scotia: temporal trends and critical loads for 20 headwater lakes. Canadian Journal of Fish and Aquatic Sciences 63: 1504-1514.

Wiegleb, G. 1988. Notes on pondweeds - outlines for a monographical treatment of the genus *Potamogeton* L. Feddes Repertorium 99: 249-266.

Wiegleb, G. and H. Brux. 1991. Comparison of life history characters of broad-leaved species of the genus *Potamogeton* L. I. General characterization of morphology and reproductive strategies. Aquatic Botany 39: 131-146.

Wiegleb, G., H. Brux and W. Herr. 1991. Human impact on the ecological performance of *Potamogeton* species in northwestern Germany. Vegetatio 97: 161-172.

Wiegleb, G. and Z. Kaplan. 1998. An account of the species of *Potamogeton* L. (*Potamogetonaceae*). Folia Geobotanica 33: 241–316.

Williams, K.K. 1997. A new site in Maine for Spotted Pondweed (*Potamogeton pulcher* Tuckerm.). Northeastern Naturalist 4(2): 103-104.

Wisconsin Department of Natural Resources. 2009. Endangered Resources Program Species Information: Spotted Pondweed (*Potamogeton pulcher*). Website:http://dnr.wi.gov/org/land/er/biodiversity/index.asp?mode=info&Grp=20&SpecCode=PMPOT030W0 [Accessed December 2010].

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

David Mazerolle completed an undergraduate degree with a major in biology and a minor in geography, and a Master's degree in environmental studies, at the Université de Moncton. For his M.Sc. he studied the geography of exotic vegetation in Kouchibouguac National Park and created a strategy for the management of the park's exotic invasive flora. David has worked as a botanist at the Atlantic Canada Conservation Data Centre since 2007. Prior to this he was coordinator for rare plant survey and monitoring projects at the Bouctouche Dune Irving Eco-Centre from 2003 to 2006, where his work focused on the rare coastal plants of New Brunswick's Northumberland Coast. He has over ten years experience working on various research, survey and monitoring projects and has authored and coauthored numerous status reports and technical reports pertaining to rare plants in Atlantic Canada.

Sean Blaney is the Botanist and Assistant Director of the Atlantic Canada Conservation Data Centre (AC CDC), where he is maintains status ranks and a rare plant occurrence database for plants in the three Maritime provinces. Since beginning with the AC CDC in 1999, he has discovered dozens of new provincial records for vascular plants and documented thousands of rare plant locations during extensive fieldwork across the Maritimes. Sean is a member of the COSEWIC Vascular Plant Species Specialist Committee, the Nova Scotia Atlantic Coastal Plain Flora Recovery Team, and has co-authored several COSEWIC and provincial status reports. Prior to employment with AC CDC, Sean received a B.Sc. in Biology from the University of Guelph and an M.Sc. in Plant Ecology from the University of Toronto, and worked on a number of biological inventory projects in Ontario as well as spending eight summers as a naturalist in Algonquin Park, where he co-authored the park's plant checklist.

COLLECTIONS EXAMINED

All Spotted Pondweed specimens housed at the E.C. Smith Herbarium (Wolfville, Nova Scotia) and the Nova Scotia Museum of Natural History Herbarium (Halifax, Nova Scotia) were examined, along with a number of specimens possibly misidentified as Large-leaf pondweed (*P. amplifolius*).

Specimens were sent in September 2010 to C. Barre Hellquist at the Massachusetts College of Liberal Arts, a co-author of the Flora of North America's treatment of the Pondweed family (FNA 2000). During his examination of material sent, several specimens previously misidentified as Spotted Pondweed were annotated to other taxa including Large-leaf Pondweed (*P. amplifolius*), Large-leaf Pondweed / Spotted Pondweed hybrids (*P. x rhodensis*) and Grassy Pondweed (*P. gramineus*).