COSEWIC
Assessment and Status Report

on the

Water Pennywort
Hydrocotyle umbellata

in Canada

SPECIAL CONCERN
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the water-pennywort *Hydrocotyle umbellata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 9 pp.

Newell, R.E. 1999. Update COSEWIC status report on the water-pennywort *Hydrocotyle umbellata* in Canada *in* COSEWIC assessment and update status report on the water-pennywort *Hydrocotyle umbellata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-9 pp.

Wilson, S. 1985. COSEWIC status report on the water-pennywort *Hydrocotyle umbellata* in Canada. Committee on the Status of Endangered Wildlife in Canada. 35 pp.

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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Water Pennywort — Photo caption: Water Pennywort (*Hydrocotyle umbellata*) growing as an emergent in shallow water with flowers (flower head is at bottom right). Photograph by Megan Crowley, Parks Canada.

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Water Pennywort

Scientific name
Hydrocotyle umbellata

Status
Special Concern

Reason for designation
This species is known from only three disjunct lakeshore locations in southern Nova Scotia, one of which was discovered since the last assessment. Alterations and damage to shorelines from shoreline development and off-road vehicles are ongoing threats, and water level management is a potential threat at one lake. Increased competition from other plants caused by eutrophication is a potential major future threat.

Occurrence
Nova Scotia

Status history
Designated Endangered in April 1985. Status re-examined and designated Threatened in April 1999. Status re-examined and confirmed in May 2000. Status re-examined and designated Special Concern in May 2014.

COSEWIC
Executive Summary

Water Pennywort
Hydrocotyle umbellata

Wildlife Species Description and Significance

Water Pennywort is a perennial herb with creeping stems that root at the nodes. The round, shallowly lobed leaves are 1-5 cm wide on erect petioles (leaf stems) attaching in the centre of the leaf. Petioles are 5-20 cm in terrestrial plants and up to 150 cm on floating leaves in standing water. The tiny, white flowers are in a round cluster at the tip of a leafless stem. Fruiting has not been seen in Canada.

Water Pennywort co-occurs in southern Nova Scotia with many other disjunct species of the Atlantic Coastal Plain. This group of species is known and appreciated by many cottagers and residents. Populations in Nova Scotia are the northernmost worldwide and 410+ km from the nearest American sites.

Water Pennywort can be used as a salad herb, an aquarium plant or a ground cover in gardens. In the United States it can be a lawn weed and an impediment to navigation in canals. It has been extensively investigated in relation to treatment of nutrient-enriched wastewater, and has potential for use in removing heavy metals from water. It is a traditional treatment for anxiety in South America, and in high concentrations has narcotic effects. Extracts have been shown to have herbicidal effects.

Distribution

Water Pennywort is native from central and northern South America and the Caribbean into California and along the Atlantic coast of the United States north to Massachusetts, with localized, disjunct occurrences in inland areas north to Michigan, Indiana, Ohio, and New York. Occurrence in Canada is limited to two areas of southern Nova Scotia: two sites in southern Yarmouth County and one 70 km northeast in Kejimkujik National Park. It is introduced in Thailand, New Zealand and reportedly Myanmar.

Habitat

In Nova Scotia, Water Pennywort occurs on broad sand and gravel lakeshores within the zone flooded in winter (which protects against cold-induced mortality) and exposed in summer, and on permanently inundated lakeshores in water depths to about 1.5 m. Canadian habitats are acidic and nutrient poor which, along with ice scour and wave action, limits more competitive species. Two of the three subpopulations are on large catchment area lakes with high water level fluctuation, typical of rare Atlantic Coastal Plain flora habitat. Further south, Water Pennywort occupies a wider range of habitats including various nutrient-rich and disturbed, moist sites.

Biology

Water Pennywort is a perennial herb that reproduces sexually and disperses by seed elsewhere, but in Canada is known to reproduce and disperse only through vegetative growth and fragmentation of the creeping stems. Roots are present on all but the most recently produced nodes, so survival of small fragments is possible. In Canada, ice movement is likely a significant cause of fragmentation. “Mature individuals” are thus single stem segments having sufficient roots to survive if severed from the parent plant. Number of leaves is a good metric for “individuals”, assuming each internode has the potential to be a fragment.

Plants flower from late July into September in Canada. Flowering is initiated only in low water and occurs on a very low proportion of nodes; large patches can be completely infertile. Insect pollination is undescribed but likely important outside Canada. Individual stem segments are reported as mostly not exceeding 1.5 years of age in Canada and under optimal conditions growth can be very rapid. Subpopulation size can fluctuate substantially (though under one order of magnitude) with water levels.

Population Sizes and Trends

The Canadian population is estimated in the hundreds of thousands of individuals, with fluctuation between 121,000 and 498,000 (mean 289,000) at Kejimkujik National Park estimated in 2004 to 2012 surveys. Numbers are unknown but likely of a similar order of magnitude at Wilsons Lake and are in the lower thousands (perhaps 10,000 to 20,000) at Springhaven Duck Lake. Populations appear to have been stable since the previous status report, based on annual surveys from 2004 to 2012 at Kejimkujik National Park, repeated comprehensive shoreline surveys at Wilsons Lake, and absence of observed disturbance at Springhaven Duck Lake. Future shoreline development at Wilsons Lake is likely but development impacts are likely to remain small unless future development is of a different nature than existing development.

Threats and Limiting Factors

Eutrophication associated with mink farm waste is a potential future threat at Wilsons Lake and Kejimkujik National Park, where new farms could be built upstream. The mink industry is large and expanding in southern Nova Scotia and mink farms have the potential to affect entire river systems. Despite Water Pennywort’s tolerance of eutrophication in southern areas, eutrophication-induced increases in competition from more common, less stress-tolerant plants would likely threaten Canadian occurrences.

Shoreline development is an ongoing threat only at Wilsons Lake, where 87% of occupied habitat is adjacent to private land. About 40% of occupied shoreline abuts 19 developed and 12 undeveloped cottage lots, and 47% abuts two large private properties with no cottage development, but with a recently completed access road suggesting potential for future development. No new building has occurred in occupied areas on Wilsons Lake over the past decade and numbers within developed areas have appeared stable over that period. New development is likely to have at least some impact on numbers.

A small dam just downstream from Springhaven Duck Lake may be raising lake water levels and reducing Water Pennywort numbers and vigour. Off-highway vehicle impacts are also occurring at Wilsons Lake, where habitat damage was liberally estimated at less than 9% in 2011.

Protection, Status, and Ranks

Water Pennywort is listed as Threatened in Canada by COSEWIC and under Schedule 1 of the *Species at Risk Act* and Endangered in Nova Scotia under the *Nova Scotia Endangered Species Act*. It is Endangered with protection under state law in Connecticut and Ohio. Water Pennywort is Critically Imperilled (N1) in Canada and Nova Scotia (S1) and is At Risk in Nova Scotia and Canada. It is globally secure (G5), nationally secure in the United States (N5), and is SH (Possibly extirpated) in Pennsylvania, S1 (Critically Imperilled) in Connecticut and Ohio, and S3 (Vulnerable) in New York.

TECHNICAL SUMMARY

Hydrocotyle umbellata
Water Pennywort — Hydrocotyle à ombelle
Range of occurrence in Canada:Nova Scotia

Demographic Information

Generation time (usually average age of parents in the population) *Stem segments can survive over winter but are reported to mostly last no more than 1.5 years in Canada. Stem segments can reproduce in weeks.*	Believed to be under 1.5 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *No evidence of recent declines.*	No
Estimated percent of continuing decline in total number of mature individuals within 2 generations. *No suggestion of significant recent declines. Any declines over next 10 years are likely to be small.*	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown, no declines evident
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. *Any declines over next 10 years are likely to be small.*	Potential for small decline
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. *No suggestion of significant recent declines. Any declines over next 10 years are likely to be small.*	Unknown
Are the causes of the decline clearly reversible and understood and ceased? *Eutrophication is potentially reversible over longer term; shoreline development is not readily reversible; OHV damage and dam-induced high water levels are reversible. Causes are understood, but have not ceased.*	Declines not evident; reversibility of threats noted at left
Are there extreme fluctuations in number of mature individuals? *Major population fluctuations associated with water levels documented at Kejimkujik, but these are under one order of magnitude.*	No

Extent and Occupancy Information

Estimated extent of occurrence	469 km²
Index of area of occupancy (IAO) – 2 x 2 km grid *Derived from a 2 x 2 km grid aligned with 10 x 10 km UTM grid squares.*	40 km²
Is the total population severely fragmented?	No
Number of "locations*" *3 locations if defined by watercourse based on threat of eutrophication. If Wilsons Lake locations are defined by threat of shoreline development, total number of Canadian locations is between 5 and 32. See "Number of Locations".*	3, 5 or 32
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of (sub)populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? *Projected future development at Wilsons Lake will reduce habitat to some extent. Future decline in quality with eutrophication is possible.*	Yes, small decline
Are there extreme fluctuations in number of (sub)populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each (sub)population)

(Sub)Population (# = population, see *Defining Populations*)	**N Mature Individuals** (counts are number of leaves, likely a slight overestimate of mature individuals)
1 – Kejimkujik and George lakes, Kejimkujik National Park	Fluctuation between 121,000 and 498,000 (7 year mean 289,000)
2 – Wilsons Lake	Estimated 100,000+
3 – Springhaven Duck Lake	Likely 20,000 or less; estimated at 10,000
Total	231,000+ (using lower value within known range of fluctuation)

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	N/A

Threats (actual or imminent, to (sub)populations or habitats)

- Increased competition caused by eutrophication (potential threat from future upstream mink farm development) at Wilsons Lake and Kejimkujik National Park. Cyanobacterial mats associated with eutrophication could also cover plants.
- Shoreline alteration associated with cottage and residential waterfront development at Wilsons Lake
- Off-highway vehicle damage to plants and habitat at Wilsons Lake
- Water level management at Springhaven Duck Lake

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *From NatureServe (2013): USA: Secure (N5). Secure (S5) in Delaware, North Carolina and Virginia. Apparently Secure (S4) in New Jersey. Vulnerable (S3) in New York, Critically Imperilled (S1) in Connecticut and Ohio. Possibly Extirpated (SH) in Pennsylvania. Not Ranked (SNR, generally because it is considered secure) in Alabama, Arkansas, California, Florida, Georgia, Indiana, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Oklahoma, Oregon, Rhode Island, South Carolina, Tennessee, and Texas. Reported falsely or questionably in Minnesota and New Mexico. Probably Secure in most or all countries of Central America, the Caribbean and northern South America. Introduced in Illinois, New Zealand, Thailand, and probably Myanmar.*	
Is immigration known or possible?	Not known and unlikely
Would immigrants be adapted to survive in Canada? *Uncertain as Canadian subpopulations are 410+ km disjunct from MA where climate is somewhat milder. Sexual reproduction unknown in Canadian populations.*	Possibly
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Data-Sensitive Species

Is this a data-sensitive species?	No

Status History

COSEWIC: Designated Endangered in April 1985. Status re-examined and designated Threatened in April 1999. Status re-examined and confirmed in May 2000. Status re-examined and designated Special Concern in May 2014.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Special Concern	Not applicable

Reasons for designation: This species is known from only three disjunct lakeshore locations in southern Nova Scotia, one of which was discovered since the last assessment. Alterations and damage to shorelines from shoreline development and off-road vehicles are ongoing threats, and water level management is a potential threat at one lake. Increased competition from other plants caused by eutrophication is a potential major future threat.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):
Not met. Declines are below thresholds.

Criterion B (Small Distribution Range and Decline or Fluctuation):
Not met. Comes close to meeting Endangered under B criteria since the EO (469 km²) and IAO (40 km²) are below thresholds and, based on the threat of eutrophication, there may only be 3 locations, along with small habitat declines (2%). However, there may be more than 10 locations based on other threats. The population is not currently considered severely fragmented, and does not undergo extreme fluctuations.

Criterion C (Small and Declining Number of Mature Individuals):
Not met. Number of mature individuals exceeds thresholds.

Criterion D (Very Small or Restricted Total Population):
Not met because the number of individuals exceeds thresholds, and the effects of eutrophication are not believed to be capable of driving this species to become endangered within the next 10 years.

Criterion E (Quantitative Analysis): Not done.

PREFACE

The number of lakes known to be occupied by Water Pennywort in Canada has increased since COSEWIC (2000) from two to three with the 2011 discovery of the species at Springhaven Duck Lake. The subpopulation there is smaller than the other two but is relatively unthreatened, though potentially limited by a small dam. Distribution has been comprehensively documented at all three sites resulting in higher numbers and area of occupancy known, though not necessarily suggesting an increased population. Available data suggests stability at the two long-known sites (Wilsons and Kejimkujik / George lakes). Large annual fluctuation associated with water level changes has been documented by intensive monitoring at Kejimkujik Lake from 2004 to 2012. The apparent stability, since at least 2001, of extensive subpopulations along cottage shoreline at Wilsons Lake has suggested that existing shoreline development and future development of similar intensity are not necessarily a major threat.

Eutrophication resulting from mink farm waste is a newly identified threat to Atlantic Coastal Plain lakeshore flora generally and is a potential future threat to the Wilsons Lake and Kejimkujik National Park subpopulations, but is not believed to be in effect at present.

Signage and restricting access via roped-off areas at Kejimkujik Lake has effectively eliminated trampling by park visitors as a threat to that subpopulation. Landowner contact and education at Wilsons Lake has likely improved stewardship of cottage properties supporting Water Pennywort there, and off-highway vehicle traffic on the shore may be somewhat reduced due to the blockage of an access road, though off-highway vehicle (OHV) impacts were still evident in 2011.

Several recent studies have been undertaken on the species in Canada, adding information relevant to this status report on Water Pennywort's limited genetic diversity (Vasseur 2000, 2002), the longevity of stem segments (Vasseur 2002, 2005; these are "individuals" for the purposes of this report), and growth rates and survival under various water level regimes (Dawe and Reekie 2007; Lusk and Reekie 2007).

The genus *Hydrocotyle* had traditionally been placed in the carrot family Apiaceae, but recent phylogenetic work has shown it to belong in Araliaceae, the ginseng family (Plunkett and Lowry 2001; Wen *et al.* 2001; Chandler and Plunkett 2004; Mitchell and Wen 2004; Plunkett *et al.* 2004).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2014)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Hydrocotyle umbellata* L.

Original Description: Linnaeus, Species Plantarum 2 (1753)

Synonym: *Hydrocotyle caffra* Meisner

Hydrocotyle fluitans de Candolle

Hydrocotyle incrassata Rafinesque

Hydrocotyle petiolaris de Candolle

Hydrocotyle polystachya A. Richard

Hydrocotyle polystachya A. Richard var. *quinqueradiata* Du Petit-Thouars ex A. Richard

Hydrocotyle scaposa Steudel

Hydrocotyle umbellata Linnaeus var. *intermedia* Urban

Hydrocotyle umbellata Linnaeus var. *umbellulata* de Candolle

Hydrocotyle umbellata Linnaeus var. *microphylla* Urban

Hydrocotyle umbellata Linnaeus var. *scaposa* (Steudel) Urban

Hydrocotyle umbellulata Michaux

English vernacular names: Water Pennywort

Umbellate Water Pennywort; Many-flowered Water Pennywort; Many-flowered Pennywort; Umbrella Water Pennywort; Dollarweed; Navelwort

French vernacular name: Hydrocotyle à ombelle

Genus: *Hydrocotyle*

Family: Araliaceae

Order: Apiales

Class: Magnoliopsida, asterid clade (APG 2003)

Major plant group: Angiosperms, Eudicotyledons

Hydrocotyle umbellata was first described by Linnaeus in 1753. Seven species and five varieties described in the 1800s (above; references to the descriptions are at Wunderlin and Hansen 2008) have been treated in synonymy with *H. umbellata* in North American treatments back at least to Fernald (1950). The Large-leaf Pennywort (*H. bonariensis*) was treated as *H. umbellata* var. *bonariensis* (Lam.) Spreng. by Sprengel (1820) but has otherwise generally been treated as a separate species in North America since its description in 1789.

The genus *Hydrocotyle* had traditionally been placed in the family Apiaceae, but recent phylogenetic work has shown it to belong in Araliaceae, the ginseng family (Plunkett and Lowry 2001; Wen *et al.* 2001; Chandler and Plunkett 2004; Mitchell and Wen 2004; Plunkett *et al.* 2004).

Morphological Description

Water Pennywort (*Hydrocotyle umbellata*; Figure 1) is a perennial herb with slender, freely branching stems that creep and root at the nodes. Further south the species can form a floating mat, but in Canada plants are always rooted in the soil. The round, shallowly lobed leaves are 1-5 cm wide (to 7.5 cm wide in the United States, Fernald 1950) and are peltate (the petiole attaching in the centre of the leaf underside) on erect petioles. Petioles are sturdy, erect and 5-20 cm in terrestrial plants in Canada, but are flaccid and can elongate to 150 cm on floating leaves (Kejimkujik National Park 2012; DeBarros pers. comm. 2013). The tiny, white, symmetrical, five-petalled flowers are in a globose, 1-3 cm-wide cluster (an umbel) at the tip of an elongate, leafless stem arising from the base of the leaf stalk. Fruit are round,1-2 mm long by 2-3 mm broad, and composed of paired mericarps (hardened, dry, seed-like units of the pistil) adhering to one another by their inner face and separating when ripe. Water Pennywort has a chromosome number of 2n = 40 (Preston and Constance 2012).

Water Pennywort is superficially similar to and sympatric in Canada with the only other eastern Canadian member of the genus, American Marsh Pennywort (*Hydrocotyle americana*). The two species can be easily distinguished by the nature of the petiole’s attachment to the leaf margin in American Marsh Pennywort and in the leaf centre in Water Pennywort. The stem is also fully above ground in American Marsh Pennywort but generally below the soil surface in Water Pennywort. American Marsh Pennywort is also a more terrestrial species.

Figure 1. Water Pennywort (*Hydrocotyle umbellata*) growing as an emergent in shallow water with flowers (left image, flower head is at bottom right; the other similar flower stalks are Water Pipewort - *Eriocaulon aquaticum*), and as a floating-leaved plant with long petioles (right image) at Kejimkujik Lake. Photographs by Megan Crowley, Parks Canada.

Population Spatial Structure and Variability

Water Pennywort is not known to produce viable seed in Canada in the wild (Vasseur *et al*. 2002; Crowley pers. comm. 2013) or in indoor cultivation of plants of wild origin (Vasseur pers. comm. 2013), so genetic exchange even among occurrences in close proximity within Canada is likely very limited or non-existent. Limitation on seed production is not known elsewhere in its range (Patton and Judd 1988; Wetzel *et al*. 2001; DeBarros pers. comm. 2013). The species is restricted to two regions of occurrence in Canada: 1) the hydrologically contiguous Kejimkujik and George Lakes in Kejimkujik National Park, Queens County; and 2) Wilsons and Springhaven Duck Lakes in Yarmouth County. The two areas are separated by 70 km and can reasonably be assumed to be completely genetically isolated from one another.

Kejimkujik and George lakes are contiguous parts of the same water body along the Mersey River. Plant fragments or seeds (if they were produced) of Water Pennywort could likely move downstream from Kejimkujik Lake to George Lake or (less frequently) in the reverse direction. Within Kejimkujik National Park, Water Pennywort is known from ten sites within a 9 km linear distance along the eastern shore of Kejimkujik and George Lakes. Separation distances between sites do not exceed 1.8 km except for a 4.0 km distance from George Lake to the nearest Kejimkujik Lake occurrence. If insect pollination and successful seed set did occasionally occur, occurrences in Kejimkujik National Park are likely close enough that genetic exchange could occur between most sites (*i.e.*, *Bombus* spp. commonly forage over 1500+ m distances, Walther-Hellwig and Frank 2000).

The Wilsons Lake and Springhaven Duck Lake subpopulations are only separated by 1.9 km but are on separate watersheds separated by mostly unsuitable habitat. Animal-mediated dispersal of viable plant fragments between the two watersheds is likely very infrequent. If seeds were produced, they might be more readily dispersed within mud carried on animals. Gaps between areas occupied within the Wilsons and Springhaven Duck subpopulations do not exceed a few hundred metres so movement of vegetative fragments and pollen between areas within a subpopulation is plausible.

Allozyme analysis of Nova Scotia plants showed little genetic variation within and between the Kejimkujik and Wilsons Lake subpopulations with only six genotypes identified in over 40 individuals sampled (Vasseur pers. comm. 2013).

Water Pennywort subpopulations in Canada are composed of large numbers of “individuals” as defined by COSEWIC (2010) within large areas of suitable habitat and appear to have good viability as clonal subpopulations. The species is thus not considered severely fragmented (COSEWIC 2010).

Designatable Units

In Canada, Water Pennywort is restricted to a small portion of the COSEWIC Atlantic Ecological Area in southwestern Nova Scotia and allozyme analysis suggests little genetic variation within Canada, thus Canadian subpopulations should be considered a single designatable unit.

Special Significance

Water Pennywort co-occurs in southern Nova Scotia with a large suite of other disjunct southern species of the Atlantic Coastal Plain, many of which are rare in Canada, including the COSEWIC Endangered Pink Coreopsis (*Coreopsis rosea*), Endangered Plymouth Gentian (*Sabatia kennedyana*) and the Special Concern Long’s Bulrush (*Scirpus longii*). Ongoing stewardship and outreach programs on the lakes most significant for Atlantic Coastal Plain flora has resulted in these rare species being known and appreciated by many cottagers, residents and visitors.

Water Pennywort subpopulations in Nova Scotia are the northernmost worldwide and are separated by 410+ km from the nearest sites in northeast Massachusetts. Disjunct peripheral populations may have a disproportionate genetic significance to the species as a whole (Lesica and Allendorf 1995; Garcia-Ramos and Kirkpatrick 1997; Eckert *et al.* 2008), although in the case of Water Pennywort, genetic diversity in Canada is known to be very low (Vasseur 2002, 2005; Vasseur *et al*. 2002).

Water Pennywort can be used as a salad herb and as an aquarium plant or ground cover in gardens and these uses have resulted in its naturalization in New Zealand (New Zealand Plant Conservation Network 2013) and Thailand (Zungsontisporn 2002), where it is considered a potential invasive species. Within its United States range it can be a significant lawn weed (Yelverton *et al*. 2008; Wells 2009) and an impediment to navigation in canals (Lake County APMS undated). It is considered a noxious weed in Puerto Rico (GRIN 2012), although it is native there. The species has been extensively investigated in relation to treatment of nutrient-enriched wastewater (Reddy and DeBusk 1985; Reddy and Tucker 1985; DeBusk and Reddy 1987; Moorhead and Reddy 1990; Reddy *et al*. 1990; DeBusk and Reddy 1991; Hume *et al*. 2002; Sooknah and Wilkie 2004), and it might be useful for removal of heavy metals in water (Prasad and Freitas 2003; Yongpisanphop *et al.* 2005; Panyakhan *et al*. 2006). It is widely used as a traditional treatment for anxiety in South America (Rocha *et al*. 2011), has medicinal properties associated with brain oxygenation (Bath 1985, in Rojas *et al*. 2009), and in high concentrations has narcotic effects (Laser 1971, in Rojas *et al*. 2009; Rocha *et al*. 2011). Its essential oils were reported upon in Rojas *et al*. (2009), and a novel triterpenoid glycoside extracted from Water Pennywort was shown to have root inhibitory effects on the tropical invasive species *Mimosa pigra* (Chavasiri *et al.* 2005). No evidence of local Aboriginal traditional knowledge of this species was found during the preparation of this report (Hurlburt pers. comm. 2013).

DISTRIBUTION

Global Range

Water Pennywort is native to the New World, occurring from central and northern South America (French Guiana, Guyana, Suriname, Venezuela, Brazil, Colombia, Ecuador, Peru and Chile [possibly not native], GRIN 2012), throughout Central America and the Caribbean (Bahamas, Bermuda, Cuba, Dominica, Dominican Republic, Guadeloupe, Haiti, Jamaica and Puerto Rico [GRIN 2012], and Trinidad [Boyle and Khan 1993 as cited in Lefebvre *et al*. 1989]), into central California and along the Atlantic coast of the United States north to Massachusetts, with a large disjunct area of occurrence in southern Michigan and northern Indiana and localized, disjunct occurrences in more inland localities in Oklahoma, Arkansas, Tennessee, Ohio, Maryland, Pennsylvania and New York (Kartesz 2011; Figure 2). An adventive occurrence is reported for Illinois (Kartesz 2011). Reports from Oregon, Minnesota and New Mexico are questionable or false (Kartesz 2011; Minnesota DNR 2012; Cook and Sundberg 2013; NatureServe 2013) and other false reports in the literature are known from British Columbia[1] and Montana (Kartesz 1999). Occurrence in Canada is limited to disjunct occurrences in two areas of southern Nova Scotia.

Water Pennywort was recorded as naturalized in New Zealand in 2005 (New Zealand Plant Conservation Network 2013) and is extensively established in Thailand (Zungsontiporn 2002). Although no further references to introduced range are readily apparent on the Internet, reports of its use as an Asian salad herb (New Zealand Plant Conservation Network 2013), and the fact that it is widespread in Thailand (Zungsontiporn 2002) suggest it could be more widely introduced in Asia. Herbal medicine studies on the species in Myanmar suggest it is also established there (Aung 2011).

Canada supports less than 1% of the global population.

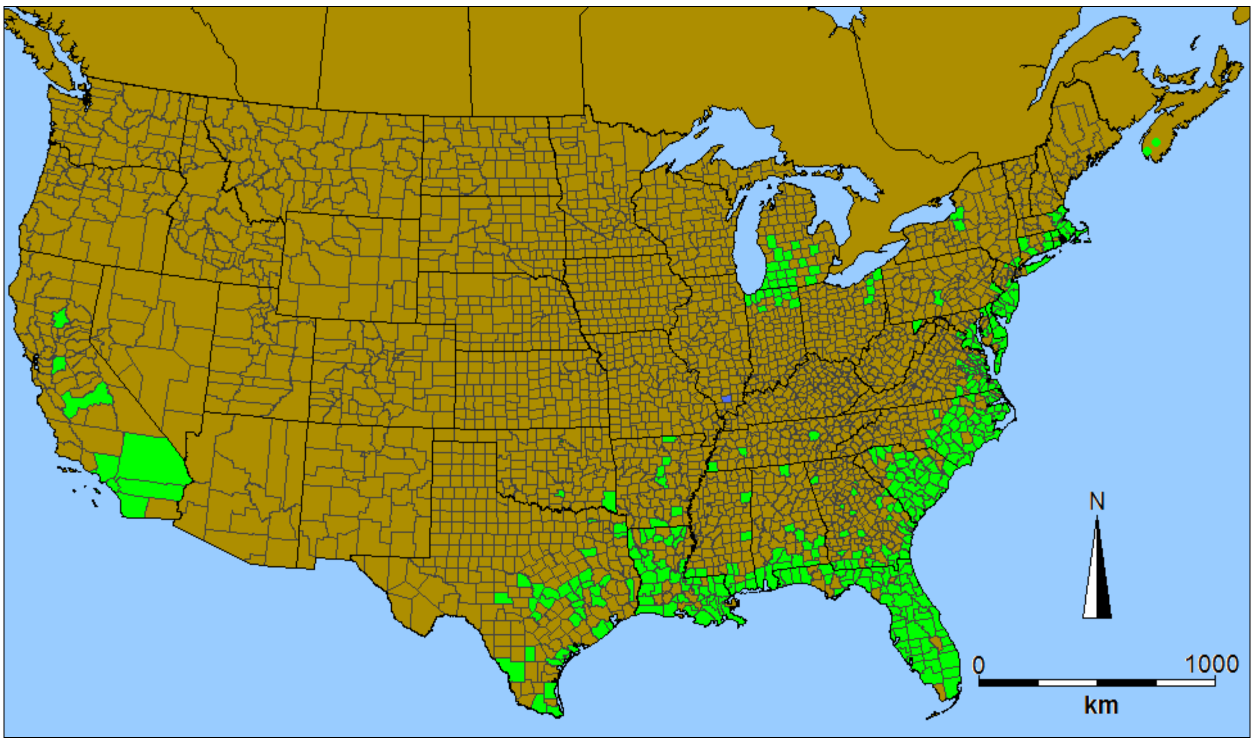

Figure 2. Native range (green shading) of Water Pennywort (*Hydrocotyle umbellata*) in Canada and the United States. The map is modified from Kartesz (2011), with additional counties shaded in Virginia, Georgia and Florida based on Virginia Botanical Associates (2013), Wichmann pers. comm. (2013) and Wunderlin and Hansen (2008) and the single Oregon county occurrence removed, fide Cook and Sundberg (2013). In the United States a whole county is shaded if at least one record is known. Water Pennywort is also native throughout Central America and the Caribbean and in the northern half of South America, and is introduced in Illinois (blue shading), New Zealand and southeast Asia.

[1] Scoggan (1979) notes that Water Pennywort was reported for British Columbia by Macoun (1888, erroneously cited as 1890 by Scoggan) based on Macoun's 1887 collection from ship ballast at Nanaimo, which was later redetermined as Floating Marsh Pennywort (*Hydrocotyle ranunculoides*). This 1888 report is almost certainly the source of Taylor and MacBryde's (1977) unreferenced listing of the species for British Columbia.

Canadian Range

In Canada, Water Pennywort is restricted to the COSEWIC Atlantic National Ecological Area in southwest Nova Scotia (Figure 3). It is known only from Wilsons Lake on the Tusket River watershed and nearby Springhaven Duck Lake on the Kiack Brook watershed in southern Yarmouth County, and from 70 km northeast in a 9 km zone of lakeshore on Kejimkujik and George lakes along the Mersey River in Kejimkujik National Park.

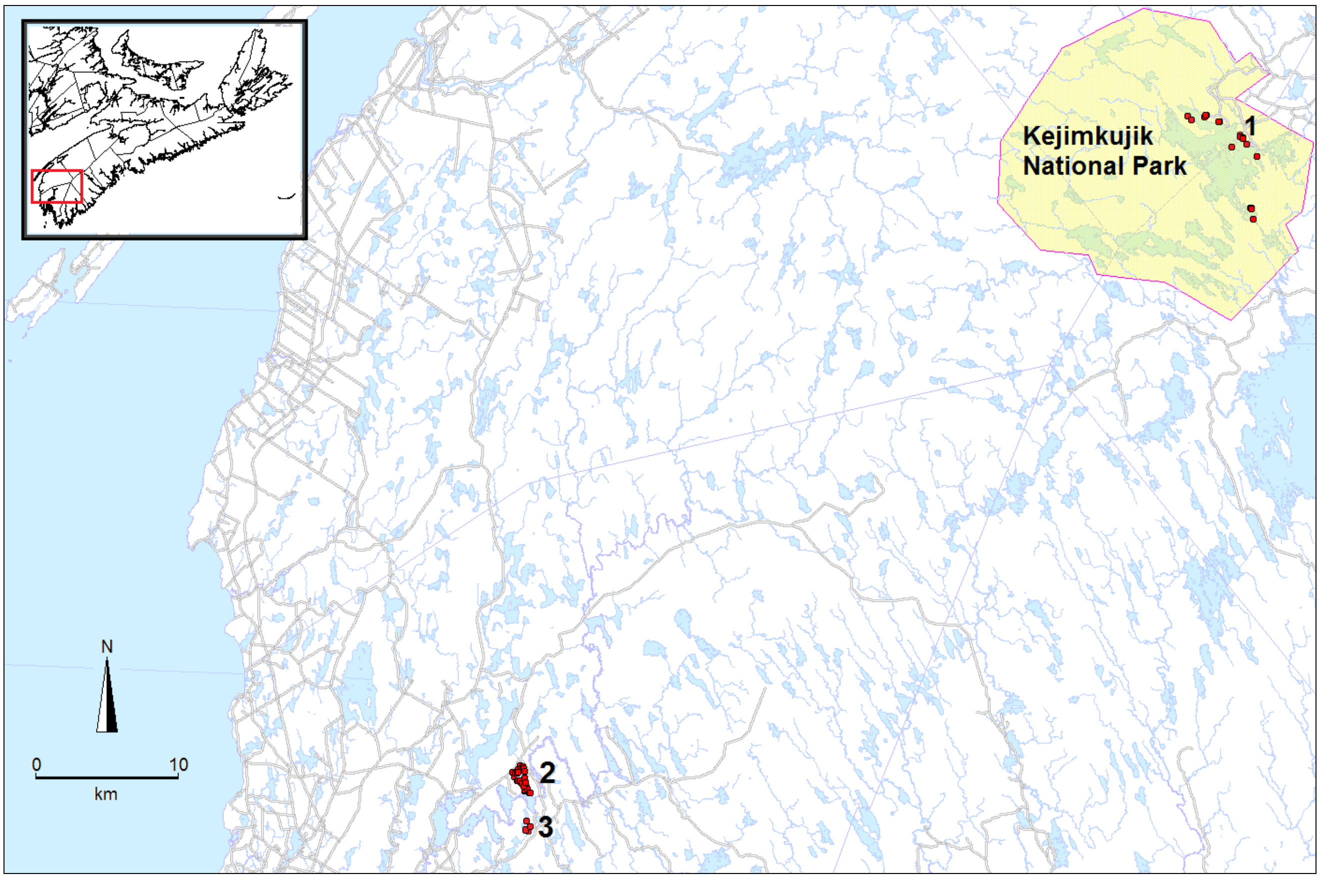

Figure 3. Distribution of Water Pennywort (*Hydrocotyle umbellata*) in Nova Scotia at 1 - Kejimkujik National Park, 2 – Wilsons Lake and 3 – Springhaven Duck Lake. Inset map indicates locality of the larger map within Nova Scotia.

Extent of Occurrence and Area of Occupancy

Under COSEWIC guidelines (COSEWIC 2010), extent of occurrence (EO) for extant sites in Canada is 469 km^2. Index of area of occupancy (IAO) for extant sites, derived using a 2 km x 2 km grid aligned with 10 km x 10 km UTM grid squares, is 40 km^2.

Search Effort

The presence of Atlantic Coastal Plain flora in southern Nova Scotia has been well known since Merritt Fernald's expeditions, which first documented Water Pennywort in Canada at Wilsons Lake (Fernald 1921, 1922). Floristic work focused on coastal plain flora in southern Nova Scotia has continued from the 1950s to the present (see references in COSEWIC 2012a). Academic work on the ecology, distribution and local diversity of Nova Scotian coastal plain flora with a focus on conservation implications has been ongoing since the 1980s (see references in COSEWIC 2012a). Atlantic Canada Conservation Data Centre (AC CDC 2013) database records and COSEWIC (2012a) indicate that up to 2000, when the last status report (COSEWIC 2000) was prepared, herbarium specimens or other records had been documented from 220 lakes within the potential range of Water Pennywort [2]. This is a conservative estimate of the number of lakes visited by botanists because of incomplete databasing of specimens and lakes visited where no data were collected, but it would include a majority of southern Nova Scotia lakes visited by botanists up to 2000.

Since 2000, extensive floristic and conservation work has been conducted annually by AC CDC, Nova Scotia Department of Natural Resources, Nova Scotia Nature Trust and Mersey Tobeatic Research Institute (MTRI) (see references in COSEWIC 2012a) resulting in visits to 172+ lakes within the potential range of Water Pennywort, including 95 lakes not visited by botanists prior to 2000. The majority of these newly visited lakes had comprehensive coverage of their shorelines for rare plants. Among these lakes, five were covered in a 2012 survey specifically focused on finding additional subpopulations of Water Pennywort downstream from Springhaven Duck Lake (Blaney and Mazerolle 2012).

Despite the extensive recent fieldwork, only two new occurrences have been found since Fernald (1922): Kejimkujik and George Lakes in 1975 (Roland 1976; Roland 1980) and Springhaven Duck Lake in 2011, less than 2 km from the Wilsons Lake occurrence. The lack of records of Water Pennywort from 315+ southern Nova Scotia lakes strongly suggests that the very limited nature of the known range is not a result of inadequate survey effort. Although there are hundreds out of the roughly 1,450 lakes and ponds (Natural Resources Canada 2003) within the potential range of Water Pennywort that have never been visited by botanists, survey effort (especially since 2000) has concentrated on lakes with the highest potential for rare Atlantic Coastal Plain flora and no lakes comparable to Wilsons and Kejimkujik in catchment area (see Hill and Keddy 1992; Morris *et al*. 2002 regarding significance of this variable) remain unsurveyed. Nonetheless, occurrence of Water Pennywort on Springhaven Duck Lake demonstrates that smaller headwater lakes can support the species and additional subpopulations could eventually be found.

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[2] The southern Nova Scotia counties of Lunenburg, Queens, Shelburne, Yarmouth, Digby and Annapolis, which closely correspond to the region of highest diversity of Atlantic Coastal Plain flora in Nova Scotia. There are approximately 1,450 named lakes and ponds within this region.

HABITAT

Habitat Requirements

In Nova Scotia, Water Pennywort occurs primarily on lakeshores within the zone flooded in winter and exposed in summer, and in permanently inundated lakeshore zones in water depths to about 1 m (Figures 1 and 4). In these habitats disturbance from waves, ice scour and water level fluctuations reduce occurrence of more competitive plants (Environment Canada and Parks Canada Agency 2010). Winter flooding is likely crucial for preventing cold-induced mortality of Water Pennywort (Hazel 2004, as cited in Lusk and Reekie 2007). Habitats utilized at Wilsons Lake and Kejimkujik and George lakes are similar (Blaney pers. obs. 1999-2012). Wisheu and Keddy (1989) noted occupied lakeshore habitat at Wilsons Lake as broad zones of gently sloping sand and gravel lakeshore and shallow water with a high species diversity (up to 25 species in 0.25m^2 plots), acidic pH and low fertility, as indicated by low organic content (average 8.8%), low silt and clay content (23%), low standing crop (0.4 g to 600 g per m^2, as compared to 2000 g per m^2 in *Typha* stands) and high abundance and diversity of carnivorous plants. Occurrences at Springhaven Duck Lake are somewhat different from Wilsons and Kejimkujik lakes, with most plants in fairly deep water (up to about 1 m), and some plants on saturated lakeshore peat and along a rocky forested stream, including an area where an OHV trail crosses the stream and creates conditions resembling a gravelly lakeshore (Figure 4).

Rare Atlantic Coastal Plain plants of Nova Scotia lakeshores are most diverse and abundant in low biomass areas where low nutrient conditions and flooding, wave action and ice scour limit more competitive, higher biomass species (Keddy and Wisheu 1989; Wisheu and Keddy 1989; Sweeney and Ogilvie 1993; Morris *et al.* 2002). The above disturbances are greatest on larger lakes with large upstream catchment areas (Keddy 1983, 1984, 1985; Holt *et al.* 1995), such as Kejimkujik and Wilsons lakes. The disturbance regimes on those lakes are likely important for the persistence of Water Pennywort, but the species' presence on the small, low catchment area Springhaven Duck Lake (superficially similar to hundreds of other lakes in the region, but likely with a milder climate than more inland areas) suggests that climate and/or poor dispersal may be limiting the species in Nova Scotia as much as specialized lakeshore habitat requirements.

Figure 4. Water Pennywort shoreline and shallow water habitat on Wilsons Lake, with distinct off-highway vehicle damage. In 2011, a well-used OHV trail occupies roughly 25% of the available habitat over 1 to 2 km of the eastern side of Wilsons Lake, with uncertain effects on Water Pennywort. Photograph by Sean Blaney, AC CDC.

In the northern United States, Water Pennywort occupies similar habitats to those in Nova Scotia, *i.e.* “pond shores and outlet margins” (Haines 2011) and “peaty soil of pond shore and in up to 1.5 m of water” (DeBarros pers. comm. 2013). These habitats are also occupied southward in the United States, along with a greater use of disturbed, nutrient rich and/or marginally wet habitats including lawns (Yelverton *et al*. 2008; Wells 2009), sewage pond margins (Hume *et al*. 2002), agricultural and navigational canals (Lake County APMS undated), and “road ditches and wet mineral soils that dry in summer” (Stutzenbaker 1999). Compared to Nova Scotia, Water Pennywort in the southern United States occupies a broader range of wetland types [*i.e.* “…small streams, on or near shores of ponds and lakes, sometimes in floating mats, swamps, ditches, spring runs and seepage areas, wet alluvial outwash” (Godfrey and Wooten 1981), “Emergent to terrestrial, growing on mudflats, shorelines and in shallow water”, (Schummer *et al*. 2012) and “sandy upper edges of salt and brackish marshes” (Tiner 2009), and it shows much greater robustness as a dominant species in standing water (*i.e.* images in Calflora 2013; Clemson Cooperative Extension 2013).

Habitat Trends

As outlined below, Water Pennywort habitat in Nova Scotia is believed to have been stable at Wilsons Lake and Springhaven Duck Lake since the last status report and to have improved somewhat at Kejimkujik Lake with management of trampling by park visitors. Shoreline development is having ongoing minor impacts at Wilsons Lake which could increase in the near future. OHV are causing moderate habitat damage at Wilsons Lake (Figure 4) and may be having very limited impacts at Springhaven Duck Lake. Eutrophication from mink farming could have significant future impacts if farms are developed upstream of Wilsons Lake and Kejimkujik National Park, but it is not known to be a currently active threat at any of the subpopulations.

a) Historical habitat loss

Fernald (1921, 1922) recorded Water Pennywort only on Wilsons Lake in his fairly extensive fieldwork in southern Nova Scotia. Thus there is no evidence that the damming of the Tusket River system for hydroelectricity starting in 1929 (most significantly the dams 10 km downstream from Wilsons Lake at Tusket Falls and 3 km west on the Carleton River branch) eliminated any Water Pennywort occurrences, as was the case with Plymouth Gentian and Pink Coreopsis (COSEWIC 2012a, b). It is possible, however, that undetected subpopulations were lost to hydroelectric damming. Occupied habitat at all three known occurrences appears to be little changed from pre-settlement conditions, with the exception of localized impacts of shoreline development described below.

b) Current habitat trends

Within the last decade eutrophication caused by mink farming has become a major issue threatening Atlantic Coastal plain flora in Nova Scotia (see *Threats and Limiting Factors – Eutrophication*, and note the specific uncertainties regarding Water Pennywort response to eutrophication). No eutrophication impacts on Water Pennywort habitat are known at present, though the most significant eutrophication impacts in Nova Scotia are just 3 km from Wilsons and Springhaven Duck lakes on the adjacent but hydrologically isolated Carleton River system. Development of new mink farms upstream from existing occurrences at Wilsons Lake and Kejimkujik National Park is plausible, or perhaps even likely within a 10 to 20 yr time scale. The extent to which new provincial regulations on mink farm waste management (Government of Nova Scotia 2013) will be effective at preventing future mink farms from causing eutrophication of lakes supporting Water Pennywort is unclear.

As described in detail under *Threats and Limiting Factors – Shoreline Development*, impacts of existing shoreline development are limited to Wilsons Lake and are believed to have been relatively small there (probably eliminating less than 1.7% of existing habitat at the lake). Development impacts are likely to slowly increase in future as new cottages are developed on Wilsons Lake. If private land at Wilsons Lake were fully developed (with an estimated 70 new cottages), direct impacts are estimated to eliminate not more than 6.3% of Water Pennywort habitat on the lake, with ancillary impacts from greater shoreline use and eutrophication likely adding to the effects on Water Pennywort. This level of development is, however, much greater than is likely in the next 10 to 20 yrs. The likely scenario of addition of not more than a few cottages per year is likely to have a relatively limited impact on Water Pennywort habitat.

OHV traffic has been noted as a problem on the Wilsons Lake shore since at least Wisheu and Keddy (1989) and is still having locally significant impacts on Water Pennywort habitat there (Figure 4; see *Population – Threats* for more detailed discussion). The extent to which these are lasting impacts contributing to a long-term habitat trend is unclear and the potential for recovery of Water Pennywort following OHV disturbance seems high. OHV impacts may have lessened in recent years because of public education efforts regarding lakeshore issues and measures to restrict access from a public lane on Wilsons Lake, but future impacts could quickly increase depending on the activity of just a few OHV users (Hurlburt pers. comm. 2013).

BIOLOGY

Life Cycle and Reproduction

Water Pennywort is a perennial herb that reproduces sexually by seed, and vegetatively by growth and fragmentation of creeping stems. Occasional proliferous growth (shoots developing directly from flowers) has also been noted in the United States (Coulter and Rose 1900). In Canada it is not known to produce seeds, so all reproduction is vegetative via stem growth and fragmentation. Seed production is not known to be limited in any other parts of its range (Patton and Judd 1988; Wetzel *et al*. 2001; DeBarros pers. comm. 2013). The horizontal stem segments generally have roots at all nodes except for a few of those most recently produced, and single node stem segments with one leaf and roots survive well when transplanted (Zungsontiporn 2002; Dawe and Reekie 2007; Lusk and Reekie 2007). As with many aquatic plants (Haynes 1988), fragmentation is likely a frequent means of dispersal for Water Pennywort and is the only one known in Canada. Ice movement is likely a significant cause of fragmentation in Canada, as with Plymouth Gentian (COSEWIC 2012a). For this report, “individuals” are thus single stem segments having sufficient roots to survive if severed from the parent plant.

Under optimal conditions, growth can be very rapid. Cultivated plants in nutrient non-limiting water produced almost 1 kg of dry weight per m^2 over 14 weeks in Florida (Reddy and Tucker 1985) and in Thailand a single leaf transplant produced 174 leaves in 141 days (Zungsontisporn 2002). There is significant annual variation in Canadian population (leaf) counts associated with water level fluctuations, with higher counts in low water years, (e.g., Kejimkujik National Park 2012). Fluctuations in leaf counts probably arise because of rapid proliferation of stem segments and leaves, as opposed to failure of perennial stems to produce leaves under deep water conditions; the latter would not represent population change by the COSEWIC definition.

In subtropical and tropical portions of its range, Water Pennywort grows year-round and can flower at almost any time (Patton and Judd 1988). In Canadian subpopulations, flowering occurs from July into September, with a peak in the first half of August (Crowley pers. comm. 2013), but flowers occur only at a very low proportion of nodes, and many large patches can be completely lacking flowers within a growing season. There is no literature regarding pollination of *Hydrocotyle* species. The floral display suggests insect-mediated pollination, but wind pollination may be possible as airborne *Hydrocotyle* pollen (species unknown, but potentially *H. umbellata*) was detected in Venezuela (Hurtado and Alson 1990).

Seed biology literature on Water Pennywort is limited. A seed bank study in Florida (Wetzel *et al*. 2001) found germination from seed bank samples was much higher under a flooded treatment, but Water Pennywort seed banks were only found in drained pastures that were formerly wet prairies, broadleaf marshes and shrub wetlands, rather than undrained, intact examples of the same community types. Water Pennywort plants were common in undrained examples of each community type suggesting that seed production or persistence was greater in unflooded conditions. Patton and Judd (1988) observed seedlings on floating mats in Florida.

In the absence of seed production, persistence of stem segments under water is the only means of over-winter survival in Canadian subpopulations. Vasseur *et al*. (2002) reports stem segments surviving for only 1.5 years, but further investigation would be needed to confirm this as a general limit to age of individuals in Canada. Given the potential for rapid increase in ramets and the suggestion of a short lifespan for individual stem segments, by the end of the summer much of the population capable of reproduction would be under one year old. Generation time (the average age of individuals capable of reproduction) is thus rather short, and may be under one year.

Physiology and Adaptability

Water Pennywort is considered an obligate wetland plant throughout its Canadian and American range (Reed 1988; USFWS 1997; Blaney 2011), although it does occur commonly in non-wetland disturbed habitats like lawns in the southern United States (Yelverton *et al*. 2008; Wells 2009). Although it is mostly restricted to a few specialized habitats in Canada, it can occur in a wide range of habitats and nutrient conditions elsewhere (see *Habitat Requirements*). Throughout its range, Water Pennywort can survive major water level fluctuations. Lusk and Reekie (2007) note adaptations present in Water Pennywort that are typical of plants in flood-prone habitats, enabling them to cope with low oxygen levels: enlargement of intercellular spaces to form aerenchyma tissue, allowing gas diffusion to and from the roots; upward elongation of roots so that they reach higher oxygen concentrations near the surface; formation of large carbohydrate reserves that can support plants through anaerobic periods; and rapid extension of petioles (likely initiated by elevated ethylene) to send leaf blades to the water surface.

Despite its capacity to persist in permanent shallow water, Water Pennywort in Canada is most successful in soils that in summer are exposed above the water level or flooded by just a few centimetres of water. Density of leaves ("individuals") is much higher in low water or exposed habitats than in deeply summer-flooded habitats (Blaney pers. obs. 1999-2012; Kejimkujik National Park 2012), and flowering in Canadian subpopulations is primarily initiated by plants in very low water levels (Crowley pers. comm. 2013). In a laboratory experiment, Dawe and Reekie (2007) found Canadian Water Pennywort grew twice as fast in exposed conditions as in 15 cm or 30 cm of water as a result of greater photosynthetic efficiency. They documented reduced allocation into reproductive and belowground parts and senescence of terrestrial leaves after flooding. Leaves initiated underwater were fewer, larger and with more stomata on upper than lower surfaces. They also noted that tubers storing carbohydrate, important for surviving flooding when less efficient metabolic pathways are used, were only produced by non-flooded plants. In a field study of transplants, Lusk and Reekie (2007) found that time above water contributed 2 to 3.4 times more to biomass production than time below water, and they suggested 49 to 71 days above water as an appropriate period of exposure in Nova Scotia. Resubmergence in the fall appears important for Canadian Water Pennywort given that Hazel (2004) noted complete mortality of transplants in unsubmerged conditions at a drawn-down reservoir shore.

Investigations of Water Pennywort's use in bioremediation have produced an extensive literature on the species' physiology and growth in variously polluted water (see *Special Significance*). Results are not described in detail here, but they do suggest that any eutrophication effects on Water Pennywort would likely be via competition rather than physiological response.

Water Pennywort occurrence in Nova Scotia may be limited by climate given that it is at the northernmost edge of its range and is restricted to relatively warm regions of the province, although its small extent of occurrence could also be a consequence of dispersal limitations.

Dispersal and Migration

Water Pennywort is not known to produce seed in Canada (Vasseur *et al*. 2002), so dispersal as far as is known is strictly via vegetative means. Vegetative dispersal occurs over short distances by stem growth and is presumed to occur over longer distance via either loose stem segments or sods (soil patches held together by roots) containing the plant, both of which have been observed for the co-occurring Plymouth Gentian (COSEWIC 2012a). Potential dispersal distances would likely be greatest for small fragments and least for sods. All these units are likely dispersed largely by water, although small fragments might also be dispersed in mud on animals or OHV. Waterfowl likely play an important role in dispersal where seeds are produced because Water Pennywort seeds are considered especially favoured waterfowl food (Martin and Uhler 1939; Correll and Correll 1975). Seed dispersal is otherwise poorly understood, but the small seeds have no obvious dispersal adaptations. Work by Janzen (1984) and Ishikawa (2010; see *Interspecific Interactions*) suggests they could be dispersed in the guts of herbivores feeding on the plant's foliage.

Migration of Water Pennywort and other Atlantic Coastal Plain plant species into present-day Nova Scotia occurred after the last glacial retreat. According to the traditional view (Roland and Smith 1969) these plants reached Nova Scotia after having colonized (or having persisted throughout the period of glaciation) on land between present-day southern Nova Scotia and Massachusetts that was exposed by lower sea levels during glaciation, suggesting a slow migration to Nova Scotia via short-distance dispersal events over thousands of years. A recent evaluation (Clayden *et al.* 2009) suggests this scenario may be unlikely for climate-sensitive species like Water Pennywort because offshore land is now known to have had high boreal or arctic climate, and to have been more limited in time and space than previously believed. Thus long-distance dispersal (on the scale of 400 km between southern Nova Scotia and Massachusetts) may be possible for Water Pennywort over geological time.

A very low rate of successful dispersal in Canada is suggested by the absence of Water Pennywort on Bennetts Lake, which is 800 m downstream from subpopulations on Wilsons Lake. It has extensive high quality Atlantic Coastal Plain lakeshore habitat similar to Wilsons Lake that supports the Endangered Plymouth Gentian and Pink Coreopsis that co-occur with Water Pennywort at Wilsons Lake. The species' absence from other lakes in the Kiack Brook watershed, including Long Lake 150 m upstream from Springhaven Duck Lake, further suggest limited dispersal.

Interspecific Interactions

The pollinators of Water Pennywort and other *Hydrocotyle* species appear to be completely unknown in the literature, and there is very little information on herbivory. Stegmaier (1966) documented the generalist leaf-mining midge *Liriomyza munda* from *Hydrocotyle* in Florida. Walsh *et al*. (2010) documented the following feeding on Floating Marsh Pennywort (*H. ranunculoides*) in Argentina: five weevils (Curculionidae: *Helodytes striatus, Listronotus cinnamomeus, Listronotus [=Lixellus] elongatus, Neohydronomus* sp., *Ochetina bruchi*), six flies (Epihydridae - *Hydrellia* sp. 1, and unknown sp.; Chloropidae - *Monochaetoscinella* sp.; Sphaeroceridae - *Parasphaerocera* sp.; Chironomidae - unknown sp.; Stratiomyidae - *Hedriodiscus chloraspis*, *Stratiomys* sp.), one aphid (Aphidae - *Rhopalosiphum nymphaea*), four moths (Arctiidae - *Paracles quadrata*, Noctuidae - *Spodoptera eridania, Spodoptera marima, Condica sutor*), and two gastropods (Planorbidae - *Biomphalaria tenagophila*, Ampullariidae - *Pomacea* sp.). All these species are generalists, except for the weevil *Listronotus* [=*Lixellus*] *elongatus*, a pennywort specialist that fed on six different *Hydrocotyle* species, including Large-leaf Pennywort (*H. bonairiensis*), closely related to Water Pennywort. Cordo *et al*. (1982) also noted that it appeared host-specific on *Hydrocotyle* (*H. ranunculoides* in their study) in Argentina

Water Pennywort seeds are considered especially desirable food for waterfowl (Martin and Uhler 1939; Correll and Correll 1975), and waterfowl are likely important vectors for dispersal. Sorrie (pers. comm. 2013) has noted resident Canada Geese (*Branta canadensis*) on North Carolina pond shores graze Water Pennywort plants "…down to the nubs, preventing normal vegetative growth and precluding flowering". Mammalian herbivory on Water Pennywort is known from Nutria (*Myocastor coypus*) in Louisiana (Kinler *et al*. 1998), and Water Pennywort is listed as having limited resistance to White-tailed Deer (*Odocoileus virginianus*; NPIN 2012). Janzen (1987) suggested that *Hydrocotyle* may be among genera that are adapted to disperse seeds through incidental consumption by ruminant herbivores. Ishikawa (2010) supported this idea, finding that ripened seeds of Nochidome (*Hydrocotyle maritima*) germinated after digestion by Sika Deer (*Cervus nippon*) at similar or greater rates than undigested seeds. Invertebrate herbivory is known to be frequent at Kejimkujik National Park but the herbivores involved are unknown (Crowley pers. comm. 2013).

Mycorrhizae on Water Pennywort have not been investigated, but no vesicular arbuscular mycorrhizae were found in the closely related Large-leaf Pennywort (Logan *et al*. 1989). Different studies have reported the European Umbrella Plant (*Hydrocotyle vulgaris*) as having vesicular arbuscular mycorrhizae and lacking mycorrhizae (Harley and Harley 1987), and vesicular arbuscular mycorrhizae were found in New Zealand Pennywort (*H. novae-zeelandiae*) on the subantarctic MacQuarrie Island (Laursen *et al.* 1997).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

No fieldwork was undertaken specifically for this report. Distribution of Water Pennywort is relatively comprehensively documented at Wilsons Lake and Springhaven Duck Lake (see *Search Effort*) through comprehensive on-foot and near-shore canoe coverage of the shorelines in 2001 and 2011 for Wilsons Lake (AC CDC 2013) and in 2011 for Springhaven Duck Lake (AC CDC 2013; though some deeper water occurrences well away from shore may have been missed at Springhaven Duck Lake). At Wilsons Lake, repeated surveys involving one repeat observer (Sean Blaney) and repeated casual visits by other observers, have allowed qualitative assessments of subpopulation stability, but no attempts have been made to comprehensively count Water Pennywort at Wilsons or Springhaven Duck lakes.

At Kejimkujik and George lakes, distribution is probably also nearly comprehensively known because of:

1) About 50 km of on-foot coverage, mostly within the zones where Water Pennywort is known (Blaney and Mazerolle 2011; MTRI unpubl. 2012; Mazerolle 2012);

2) Survey of 124 shoreline sites spread throughout the lake in a Coastal Plain flora study (Filiatraut and Stewart 2006);

3) Fieldwork specifically focused on Water Pennywort by Liette Vasseur (2000, 2002), including effort to find new localities;

4) Extensive botanical survey on the lake by *Flora of Nova Scotia* author Albert Roland (1976);

5) Extensive observation by park staff and visiting botanists since park establishment in 1974.

The 150+ km of shorelines of Kejimkujik and George lakes with their many islands do, however, mean that comprehensive on-foot and near-shore coverage has not yet been completed, and small undiscovered occurrences may occur.

Kejimkujik National Park initiated a monitoring program for Water Pennywort in 2004, surveying most occurrences annually up to 2012. Monitoring assesses area occupied (initially calculated as triangles, rectangles and circles based on tape measurements, but using GPS-derived polygons since 2009) and number of ramets (using number of leaves as the metric). Information on water level, plant height and proportion of leaf damage by herbivores or other causes is also recorded. For larger occurrences in which complete counts are not practical, counts are derived from $0.25m^2$ quadrats done every other metre on randomly placed transects through the subpopulation, with densities extrapolated over the area occupied. Numbers of quadrats has varied annually but has been between 30 and 184 for larger occurrences and between 191 and 624 for all occurrences (mean 413).

Defining Subpopulations

COSEWIC separates subpopulations if there is typically less than one successful genetic exchange per generation. By this definition, the Kejimkujik National Park occurrence 70 km northeast of the Wilsons Lake and Springhaven Duck Lake occurrences is clearly a separate subpopulation. The minimum distance between plants on Wilsons Lake and Springhaven Duck Lake is 1.9 km, with the distance between occurrences being almost entirely unsuitable upland, deep open water and bouldery lakeshore. The observed absence of sexual reproduction in Canada suggests little or no genetic mixing between the occurrences, and movement and successful establishment of vegetative fragments across the 1.9 km distance between them is likely infrequent. This report thus considers occurrences of Water Pennywort on Wilsons Lake and Springhaven Duck Lake as separate subpopulations.

Water Pennywort on Wilsons Lake occurs fairly continuously over 5.6 km of shoreline in the northern two-thirds of the lake, with no breaks in occurrence exceeding 300 m. Wilsons Lake thus clearly represents a single subpopulation. Occurrence at Kejimkujik Lake is more discontinuous, with nine zones of occurrence known, ranging from a few metres to about 500 m long and separated from others by 330 m to 4000 m. Movement of vegetative fragments by ice and water currents across these distances is here considered plausible enough to justify combining the Kejimkujik National Park occurrences into a single subpopulation.

Abundance

Nearly comprehensive leaf counts (a good metric for the number of mature individuals, as described in *Life Cycle and Reproduction*) have been undertaken at Kejimkujik National Park annually since 2004, but similar counts have never been attempted at Wilsons and Springhaven Duck lakes. At Kejimkujik National Park, total leaf counts since 2004 have been between 121,000 and 498,000 (mean 289,000; Table 1) with most of the variation likely attributable to water level, though some is likely due to differences in observer interpretation of area occupied (Crowley pers. comm. 2013).

Table 1. Area occupied and subpopulation totals from Kejimkujik National Park Water Pennywort monitoring data, 2004 to 2012 (Kejimkujik National Park 2012). Area values were calculated by Kejimkujik National Park. Areas for 2005 to 2008 were calculated as rectangles, triangles or circles based on tape measure values. Areas for 2009 to 2012 were GPS-derived polygons. Subpopulation values were calculated based on densities derived from raw quadrat data multiplied by area occupied, plus other separately counted ramets, with calculations by Sean Blaney.

	Area Occupied (m^2)									Subpopulation (# ramets)								
Occurrence	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
1. Ell Islan0d													~200					
2. George Lake		177	36	108	159	32	247	52	135		9116	619	7056		463	113	410	764
3. Indian Point		4824	2445	3237	3590	3286	3573	3479	3166		155096	66178	146070		68426	58159	89028	215384
4. Jim Charles		400	57	254	544	313	414	358	276		23153	970	37305		4838	9385	13804	24994
5. Meadow Beach		223	109	509	607	434	555	3916	1014		9160	3626	19321		2509	8137	63417	46093
6. Merry-makedge		1924	659	1289	1360	1275	2710	2475	1964		284265	50253	211679		43714	38233	56352	68576
7. Mersey River	3									32								
8. Mill Bay			168	120	145							3155	10007					
9. Petroglyphs		276	251	851	1334	796	1700	849	1167		16853	9734	66238		17166	7143	15441	41415
TOTAL		7823	3725	6368	7739	6136	9199	11130	7723		497643	134537	497877		137116	121169	238451	397226
Average water level (cm)	25	12	53	6	17	52	50	24	8	25	12	53	6	17	52	50	24	8

The subpopulation at Wilsons Lake is clearly many thousands and may be of a similar size to Kejimkujik Lake given a longer distance of shoreline occupied. Most occurrences at Wilsons Lake, however, appear less dense than the densest occurrences at Kejimkujik Lake (Blaney pers. obs. 1999-2012; Crowley pers. comm. 2013). Numbers at Springhaven Duck Lake are much lower, because there are very limited areas of dense terrestrial occurrence as occur at the other lakes and the total area occupied is much smaller (Blaney pers. obs. 2011). The subpopulation at Springhaven Duck Lake is likely in the thousands or low tens of thousands. Total Canadian population is thus a minimum of about 231,000 if the lowest value within the known range of fluctuation at Kejimkujik is used for that subpopulation (Table 2).

Table 2. Estimated number of mature individuals at the Canadian subpopulations of Water Pennywort. Counts are of number of leaves, which is a good approximation of number of mature individuals but is likely a slight overestimate (see *Biology* and *Abundance*).

Subpopulation	Number of Leaves
1 – Kejimkujik and George lakes, Kejimkujik National Park	Fluctuation between 121,000 and 498,000 (7 year mean 289,000)
2 – Wilsons Lake	Visual estimate 100,000+
3 – Springhaven Duck Lake	Likely 20,000 or less; Visual estimate 10,000
Total	231,000+ (if lower value within known range of fluctuation is used)

Fluctuations and Trends

Although subpopulation counts were not documented in COSEWIC (2000), more individuals are now known than was the case in 2000. Detailed surveys in Kejimkujik National Park have extended the areas of Kejimkujik Lake shoreline that are known to support the species to a limited degree. It was suggested in COSEWIC (2000) that the species had increased at Kejimkujik due to low water levels associated with warm, dry summers. A long-term increasing trend would make sense given climate change and Water Pennywort's tropical affinities; however, significant annual fluctuations documented in 2004 to 2012 Kejimkujik monitoring data mask any underlying trend (Table 1). Occurrence at Wilsons Lake is now known to be much more widespread than the two occupied zones of 800 m and 100 m reported in Wilson (1985) and COSEWIC (2000). A comprehensive survey in 2011 found widespread occurrence over 5.65 km of shore in the northern half of the lake, within which Water Pennywort was recorded over at least 2.2 km of shoreline. Increase at Wilsons Lake may have occurred between 1985 and 2000 but any increase in shoreline occupancy over the COSEWIC (2000) report appears to be largely or entirely due to more intensive survey effort, given that comprehensive AC CDC shoreline surveys in 2001 documented a distribution almost identical to that in 2011 (AC CDC 2012). The 2011 discovery of the new occurrence at Springhaven Duck Lake further adds to the known population, though it does not necessarily represent an increase in actual population because the extensive subpopulation there suggests the species is not a recent arrival at that site.

One other line of evidence suggestive of long-term subpopulation change is worth noting. Fernald (1922) reported Water Pennywort at Wilsons Lake to be "very rare and local and appearing like a waif washed down from some as yet undiscovered station farther up the valley of the Tusket". The species could have increased since the 1920s, but it is also possible that he was reporting on a small peripheral occurrence at the south end of the lake (where Water Pennywort is absent today) while missing larger occurrences at the lake's north end (where large occurrences currently occur). Had Fernald accessed the lake on foot via the long-standing road just south of Wilsons Lake (the most likely scenario for travel from the Tusket – Yarmouth area where he was staying), he would have had difficulty reaching the north end of the lake where dense occurrences are found today because of the in-flowing and out-flowing rivers on either side of the lakeshore halfway up toward the north end.

Large inter-annual fluctuations are known from monitoring at Kejimkujik National Park, with low water years producing much higher leaf counts (Table 1). The subpopulation has varied between 121,000 and 498,000 (4.1 times difference) and year to year variations have been as much as 363,000 (between 2006 and 2007, the highest and lowest water levels during the nine years of surveys). The subpopulation at Wilsons Lake has the potential to vary similarly with water level given their similar habitat, but the species cannot be said to have “extreme fluctuations” because variation is less than an order of magnitude. Additionally, some of the variation in counts may reflect lower detectability of small plants in deep water, and/or live stem segments (individuals) that are still present but do not produce leaves. The assertion in Vasseur *et al*. (2002) that stem segments do not survive more than 1.5 years suggests, however, that most inter-annual variation is a result of different rates of production of new stem segments and leaves.

Available evidence does not suggest significant change in the overall population in Canada over the past 10 years and as outlined in *Threats* there are no strong indications suggesting major population change over the next 10 years.

Rescue Effect

The 410+km disjunction across the open Atlantic Ocean between Canadian sites and the next nearest populations in northeast Massachusetts means that there is a negligible chance of any rescue from occurrences in the United States.

THREATS AND LIMITING FACTORS

Eutrophication

Since the last status report (COSEWIC 2000), eutrophication has changed from a theoretical threat to Atlantic Coastal Plain flora in Nova Scotia (Moore *et al.* 1989; Eaton and Boates 2003; Environment Canada and Parks Canada Agency 2010; Brylinsky 2011) to one of the most significant actual threats to the suite of rare flora as a whole.

The potential impacts of eutrophication on Water Pennywort are less clearly negative than for other rare Atlantic Coastal Plain species with which it co-occurs such as Plymouth Gentian and Pink Coreopsis (COSEWIC 2012a, b). Those species are restricted throughout their range to acidic, nutrient-poor habitats while Water Pennywort can thrive in nutrient-rich habitats in southern areas (see *Habitat Requirements*) and has been extensively investigated for water remediation in sewage treatment (see *Special Significance*). In Canada, however, Water Pennywort is only known from nutrient-poor, relatively low-biomass habitats and likely has a much reduced competitive ability compared to plants in more southern sites. Treating eutrophication as a threat to Water Pennywort that could favour more competitive common shoreline species is thus a reasonable precautionary approach.

Mink farming is the most significant source of inland nutrient pollution within the Atlantic Coastal Plain flora region of Nova Scotia (Brylinsky 2011, 2012). It is an especially large source of phosphorus pollution because mink feed is treated with superphosphate to increase shelf life and to reduce the occurrence of kidney stones in mink (Brylinsky 2011). Phosphorus sources may also include residential fertilizers and municipal waste water (Conley et al. 2009). Once phosphorus has entered a lake, the recovery from eutrophic conditions following a reduction in the external phosphorus loading may be slow as the phosphorus is stored in the lake sediments (Marsden 1989; White *et al*. 2002). Eutrophication from residential and agricultural sources negatively affects coastal plain shoreline flora primarily through increased competition from more common, robust plant species (Ehrenfeld 1983; Zaremba and Lamont 1993). Rafts of condensed cyanobacterial colonies observed in nutrient-enriched southern Nova Scotia lakes (COSEWIC 2012a) could also cover low-growing shoreline flora.

Very large increases (608% to 819% over 2002 values) in total phosphorus were reported from Wilsons Lake and elsewhere in the lower Tusket River in MTRI (2011-2012) and this was cited in COSEWIC (2012a, b). Subsequent water testing by MTRI in Wilsons Lake has found no evidence of eutrophication there and the results on Wilsons Lake and possibly elsewhere on the main branch of the Tusket River are suspected to have been the result of sample contamination or some other error (Beals pers. comm. 2012).

Nonetheless, the potential for eutrophication to impact Water Pennywort is illustrated by the situation on the Carleton River. The Carleton is a branch of the Tusket River that is hydrologically separated from the branch supporting Water Pennywort at Wilsons Lake, but is only 2 km from Water Pennywort occurrences. Expansion of large mink farms in the Carleton watershed has caused major cyanobacterial blooms since 2007 that have significantly impaired recreational activity on some lakes (COSEWIC 2012a). Lake Fanning on the Carleton River supports the Endangered Plymouth Gentian and has seen a 1000% increase in total phosphorus since 2002 (MTRI 2011-2012)[3]. Effects on Plymouth Gentian have not been quantified, but subpopulations appear to be suffering from increased competition from the native Golden Pert (*Gratiola aurea*; COSEWIC 2012a). The invasive exotic Reed Canary Grass (*Phalaris arundinacea*), a species rarely seen on nutrient-poor southern Nova Scotia lakes, is also present and is a potential near-future threat (COSEWIC 2012a).

Mink farming has undergone rapid expansion in Nova Scotia over the past decade and is the province's largest agricultural export with 1.4 million pelts produced annually by 152 farms, about 75% of which are in Yarmouth and adjacent Digby counties

[3] The accuracy of MTRI results on Lake Fanning is supported by the fact that it had very low phosphorus and ultra-oligotrophic chlorophyll A levels in 1986 (Brylinsky 2011b) and oligotrophic conditions in 2002 (Eaton and Boates 2003), but has had major cyanobacterial blooms each summer since at least 2007 (Taylor 2010).

(Flemming pers. comm. 2011). Future expansion of mink farming is plausible on any private land outside heavily settled areas in southern Nova Scotia because it is one of very few expanding industries (Flemming pers. comm. 2011) in an economically depressed region. It is thus a potential threat to Water Pennywort at Kejimkujik National Park (where farms could be developed upstream on the Mersey River system) and at Wilsons Lake. At present, however, mink farming upstream from known Water Pennywort subpopulations is limited to a single smaller farm 32 km upstream from Wilsons Lake at Kemptville. Mink farms are unlikely to affect Springhaven Duck Lake because it is a near-headwater lake with much of its watershed within a nature reserve. Mink farming is treated in this report as the most significant threat to Water Pennywort because of the ongoing rapid expansion of the industry in southern Nova Scotia, because of its potential to affect entire subpopulations of lakeshore plants on a time scale of one decade or less and because shoreline development is only a threat at Wilsons Lake and does not appear to have significantly impacted Water Pennywort there since the last status report (discussed below). It is important to note, however, that new provincial fur farm regulations specify requirements for solid and liquid feces storage structures, provide minimum distance requirements from watercourses and specify maximum allowable nutrient levels for ground and surface water coming off fur farms (Government of Nova Scotia 2013). If these regulations are effectively enforced, impacts of future mink farm development on the lakeshore habitats supporting Water Pennywort are likely to be less than the impacts seen from current mink farms on the Carleton River.

Shoreline Development

Shoreline development is considered a significant threat to Atlantic Coastal Plain flora communities on lakeshores (Wisheu and Keddy 1994; Eaton and Boates 2003; Environment Canada and Parks Canada Agency 2010) but is not a threat to Water Pennywort at Kejimkujik National Park because of its protected status, nor to the Springhaven Duck Lake subpopulation because most of the Water Pennywort is either within the Nova Scotia Nature Trust's Jack and Darlene Stone Conservation Lands, or is in permanent water deep enough for development impacts to be limited. The only Springhaven Duck Lake occurrence potentially susceptible to development is at the lake's inlet stream and would be protected by watercourse alteration regulations, although the small portion of the occurrence at that site within an OHV trail could be impacted if the trail were upgraded.

Shoreline development directly impacts Water Pennywort through modifications of beach habitat associated with either new cottage development or with existing cottages. Existing cottage properties (representing about 26% of the 5.6 km of occupied shoreline at Wilsons Lake) do not appear to be having a large effect on Water Pennywort habitat, which is somewhat protected by its occurrence below the water line for most of the year. Direct development impacts on the species are thus primarily limited to docks, breakwaters, boat launch and boat storage sites, trails and fire pits, which represent only a small portion of the habitat. The average length of Water Pennywort habitat lost to development impacts per cottage is less than 5 m (Blaney pers. obs. 1999-2012), amounting to a loss of not more than 95 m out of 5.6 km (1.7%) of shoreline on the lake. There is some additional suppression of Water Pennywort by cottager activity outside the zones of complete loss, but the level of this effect appears to have been stable in the past 10 years. All Wilsons Lake cottages within the zone of Water Pennywort occurrence pre-date 2000 (Blaney pers. obs. 1999-2012; Hurlburt pers. comm. 2013) and comprehensive shoreline surveys in 2001 by Sean Blaney and collaborators (AC CDC 2013), show Water Pennywort distribution essentially identical to that derived from similar surveys in 2011 by Blaney and David Mazerolle (AC CDC 2013). Although not quantified, abundance and habitat quality did not appear significantly different between 2001 and 2011 (Blaney pers. obs. 2011). Thus the total loss of Water Pennywort population since shoreline development began may be quite small. Population lost to development in the past 10 years relevant for status assessment is much smaller again, because no new cottages have been built within the zone of Water Pennywort occurrence on Wilsons Lake since 2001 (Blaney pers. obs. 1999-2012; Hurlburt pers. comm. 2013).

Some near-future development seems likely on a large private property at the northeast end of Wilsons Lake with 860 m of occupied Water Pennywort habitat. Four cottage lots have previously been subdivided from this property and a new lakeshore access road was built in about 2007. This property represents about 15% of occupied Water Pennywort habitat at the lake. There are also 12 undeveloped cottage-sized lots (about 17% of occupied habitat at the lake) and an additional 1.6 km of shoreline (29% of occupied habitat at the lake) at another large private property. If all undeveloped shoreline within the zone occupied by Water Pennywort were developed with 50 m of shoreline frontage per cottage (existing subdivided lots average 70 m of shoreline frontage), there could be 70 additional cottages. New cottages tend to have a larger terrestrial footprint than older ones (Blaney pers. obs. 1999-2012) but impacts of new cottages within the frequently submerged zone occupied by Water Pennywort are unlikely to be very much larger than those of existing cottages. Better owner understanding of, and compliance with, the shoreline alteration permitting regime also means that impacts observed in the past (such as the large area of shoreline habitat bulldozed on the northeast shore of Wilsons Lake (Wisheu and Keddy 1989) are now somewhat less likely to occur.

Even though direct losses of Water Pennywort to future cottage development (assuming not more than 5 m lost per cottage as above) would still be relatively small (6.3% of the 5.6 km of occupied shoreline at the lake), cumulative impacts of nutrient enrichment from septic systems and increased human traffic on shorelines could be significant. This level of development is, however, unlikely to occur within the next ten years. The most likely progression of development in that period is continuing development of not more than a few cottages per year amounting to a relatively small loss of the Water Pennywort population.

Limited Genetic Diversity and Lack of Seed Production

Water Pennywort is not known to produce viable seed in Canada. This has not been documented in any populations to the south and could be associated with lack of genetic diversity given that it has failed to produce seed even under indoor conditions (Vasseur pers. comm. 2013). Genetic diversity is known to be very limited in Canadian Water Pennywort populations, with only six genotypes found (Vasseur pers. comm. 2013) in over 40 plants sampled. These data suggest that, despite high numbers of individuals per population, most of these plants are clones of a low number of parent genotypes.

Limited genetic diversity may limit the ability of Water Pennywort in Nova Scotia to adapt to novel environmental conditions, diseases or predators (Frankham *et al*. 2010), and lack of seed production would limit dispersal potential if vegetative fragments were less efficient at dispersal than were seeds. However, neither limited genetic diversity nor lack of seed production appears likely to pose an imminent threat. The species has persisted since its discovery over 90 years ago at Wilsons Lake and almost 40 years ago at Kejimkujik National Park, and the limited genetic diversity observed today could be a founder effect (Mayr 1963; Nei *et al*. 1975) present right from the species' establishment in Canada hundreds or thousands of years ago. Additionally, having migrated to Nova Scotia from a more southern area and with a range extending to South America, it is reasonable to speculate that Canadian plants already have the genetic potential to respond to a predicted warmer climate caused by global climate change (IPCC 2007).

Artificial Regulation of Water Levels

The artificial regulation of water levels through dam construction can directly eliminate coastal plain shoreline species through flooding. It can also alter community composition as loss of natural fluctuations allows shrubs and other competitive, high biomass species to displace less competitive species (Keddy 1989; Wisheu and Keddy 1994; Nilsson and Jansson 1995; Hill *et al.* 1998; Merritt and Cooper 2000). Low winter water levels on reservoirs are also a factor in preventing Water Pennywort from utilizing otherwise suitable reservoir shoreline habitat, because the species seems to require significant winter flooding to insulate rosettes against freezing (Hazel 2004, in Lusk and Reekie 2007).

Kejimkujik, George and Wilsons lakes are not regulated by dams and are unlikely to be affected by damming in the foreseeable future. There is a roughly 1 m high earth dam roughly 20 or more years old, 440 m (stream distance) downstream from the outlet of Springhaven Duck Lake (Blaney pers. obs. 2011). The extent to which this dam influences the lake level is unclear, but an unnaturally high water level would explain the extensive occurrence of Water Pennywort well away from the lakeshore in fairly deep water conditions at the south end of the lake. Occurrence of Water Pennywort in shoreline sites at Springhaven Duck Lake in addition to deeper water sites mitigates any threat that the existing dam poses.

Off-highway Vehicle Traffic

Off-highway vehicle (OHV) traffic is considered a threat to several coastal plain flora species in Nova Scotia (Wisheu and Keddy 1991; Environment Canada and Parks Canada Agency 2010). OHV traffic has been noted as a problem on the Wilsons Lake shore since at least Wisheu and Keddy (1989) reported it, and is still having locally significant impacts on Water Pennywort habitat (Figure 4). In 2011 a well-used OHV trail at Wilsons Lake passed in or near dense Water Pennywort subpopulations, damaging about 25% of shoreline habitat over not more than 2 km of the 5.6 km of occupied lakeshore (Blaney pers. obs. 2011; Figure 4), suggesting a maximum of 9% habitat damage on the lake in 2011. Actual damage to Water Pennywort is likely significantly less than 9% because the trail is frequently higher on the shore than Water Pennywort occurrence. The extent to which these are lasting impacts contributing to a long-term habitat trend is unclear. The potential for recovery of Water Pennywort following OHV disturbance seems high. At a very local scale, OHV impacts observed in 2011 (Blaney pers. obs. 2011) are probably of similar intensity to ice scouring events in terms of depth of soil disturbance and width of shoreline affected. The impacts are, however, spread over a longer distance than would typically be disturbed by ice. A small portion of the Springhaven Duck Lake subpopulation occurs on a gravelly OHV trail at a stream crossing, where disturbance has created habitat mimicking lakeshore conditions, but the threat from OHV there appears non-significant. OHV impacts may have lessened in recent years because of public education efforts regarding lakeshore issues and measures to restrict access from a public lane on Wilsons Lake, but the level of impact can vary significantly between years depending on the activity of just a few OHV users (Hurlburt pers. comm. 2013).

Invasive Species

Coastal Plain lakeshore habitats in Nova Scotia are generally inhospitable to exotic plants (Hill and Blaney 2010). Eaton and Boates (2003) documented no significant invasive alien plants on Bennetts, Wilsons, Lac de l'Ecole, Gillfillan, Third and Pearl lakes, and no significant invasives are known in or near Water Pennywort lakeshore habitat at Springhaven Duck Lake or Kejimkujik National Park. Water Pennywort habitat in Nova Scotia is too wet and heavily ice-scoured for Glossy Buckthorn (*Frangula alnus*), a significant invasive species rapidly spreading in southern Nova Scotia (Hill and Blaney 2010) and having potential to impact some other Atlantic Coastal Plain Species at Risk (COSEWIC 2011). The invasive species with the most potential to outcompete Water Pennywort may be Reed Canary Grass, which is present in southern Nova Scotia but seemingly restricted to more nutrient-rich lakes (COSEWIC 2012a). This species and perhaps other invasives like European Common Reed (*Phragmites australis* ssp. *australis*) seem likely to become problematic for Water Pennywort only if eutrophication were also affecting habitat.

Number of Locations

COSEWIC "locations" are defined at the scale of the most significant threat to each (sub)population (COSEWIC 2010). Differences in watershed, land ownership and land use mean threats vary at each of the three lakes at which Water Pennywort is known in Canada, and these must represent at least three locations. The only significant threat at Springhaven Duck Lake is the possibly artificially high water levels maintained by a small dam. Occurrences there are thus considered a single location. Eutrophication, although not currently in effect at either Wilsons Lake or Kejimkujik National Park, is arguably the most significant threat to both these sites (see *Threats – Eutrophication*). Eutrophication would act relatively uniformly across a whole lake subpopulation but would be acting independently at the two sites, making them two separate locations.

If one considered shoreline development the most significant threat at Wilsons Lake, number of locations there would be a minimum of three based on land ownership and development potential (nature reserve, private already developed, and private undeveloped) and a maximum of 32 (there are 31 private properties within the zone of Water Pennywort occurrence, and individual landowners are making independent decisions on land management; remaining occupied shoreline is in a nature reserve which could be affected by eutrophication and thus represents one more location).

Total number of Water Pennywort locations in Canada is thus three, five or a total not more than 32, depending on interpretation of the most significant threat and the scale at which the threat of shoreline development is considered.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Water Pennywort is currently listed as Threatened in Canada by COSEWIC and under Schedule 1 of the *Species at Risk Act* (Government of Canada 2011). It was first designated Endangered in April 1985. Its status was re-examined and designated Threatened in April 1999 and that status was re-examined and confirmed in May 2000. It is also listed as Endangered under the *Nova Scotia Endangered Species Act* (Nova Scotia DNR 2013).

Water Pennywort is Endangered in Connecticut under the *Connecticut Endangered Species Act* (Connecticut DEEP 2013), and Endangered in Ohio under *Ohio Chapter 1518: Endangered Species* (Ohio DNR 2012) but has no legal protection elsewhere in its non-Canadian range.

Non-Legal Status and Ranks

Water Pennywort is Critically Imperilled (N1) in Canada and in Nova Scotia (S1) and is ranked as At Risk in Nova Scotia and Canada (Canadian Endangered Species Conservation Council 2011). It is globally secure (G5) and nationally secure in the United States (N5) and has no special non-legal designations within its range outside Canada except for being ranked SH (Extirpated) in Pennsylvania, S1 (Critically Imperilled) in Connecticut and Ohio and S3 (Vulnerable) in New York (NatureServe 2013).

Habitat Protection and Ownership

Kejimkujik National Park occurrences of Water Pennywort are entirely within federal Crown land managed by Parks Canada. Actual ownership of almost all other Water Pennywort occurrences is with the province (LIANS 2008), because the species grows almost entirely below the annual high water mark on lakeshores (Blaney pers. obs. 1999-2012; Crowley pers. comm. 2013). However, relative to impacts on the species it is ownership of adjacent land rather than the shoreline itself that is most relevant because landowners generally treat exposed beaches at their waterfront as their own property. The analysis below thus describes shore ownership based on the land ownership immediately up from the shore.

About 0.77 km (13%) of the 5.74 km of shoreline occupied by Water Pennywort at Wilsons Lake is on provincial Crown land within the Tusket River Nature Reserve. Of the remainder, 2.28 km (40%) of occupied shoreline is within 32 small privately owned lakefront properties (19 with existing cottages, 12 undeveloped), and 2.69 km (47%) is within two large private properties with no cottage development (but a recently completed access road to one).

At Springhaven Duck Lake, much of the area occupied is well into the lake (owned by the province), beyond the area likely to be affected by any shoreline development. The shoreline occurrences are within the Jack and Darlene Stone Conservation Lands owned by the Nova Scotia Nature Trust, with the exception of the occurrence along the inlet stream at the north end of the lake, which is on private land.

It is important to note that occurrence on Crown or nature reserve land does not necessarily protect Water Pennywort from OHV or other human-caused impacts, including eutrophication. OHV impacts, although noted at the Wilsons Lake portion of the Tusket River Nature Reserve in the past (MacKinnon pers. comm. 2012), were not noted in 2011 surveys (Blaney and Mazerolle pers. obs. 2011).

Water Pennywort habitat is afforded indirect protection from provincial laws and policies regulating shoreline development and pertaining to the protection of water quality, watercourses, wetlands and riparian buffers, although these regulations do not always provide protection in practice. The *Nova Scotia Wetlands Conservation Policy*, *Activities Designation Regulations* and *Environmental Assessment Regulations*, all under the *Environment Act*, the *Forest Act* - *Wildlife Habitat and Watercourses Protection Regulations*, and the *Off Highway Vehicle Act* all may apply. Projects involving lakeshore or wetland alterations are required to go through a permitting process, though not all private landowners acquire necessary permits and enforcement is strictly complaint-based.

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INFORMATION SOURCES

Angiosperm Phylogeny Group (APG). 2003. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. Botanical Journal of the Linnean Society 141: 399-436.

Aung, E.E. 2011. Country Presentation of Myanmar to 12th Myanmar Traditional Medicine Practitioners' Conference. Department of Traditional Medicine, Ministry of Health, Myanmar. Website: http://www.slideserve.com/rosa/ms-ei-ei-aung-branch-officer-department-of-traditional-medicine-ministry-of-health-myanmar [accessed February 14, 2013].

Atlantic Canada Conservation Data Centre (AC CDC). 2013. Digital database of rare species locations for Nova Scotia. Atlantic Canada Conservation Data Centre, Sackville, NB.

Bath, K. 1985. *Herbolario Tropical. Una Manera Sencilla de Vivir Mejor*. p. 173, Editorial texto, Caracas, Venezuela.

Beals, L., pers. comm. 2012. *Email conversation with Sean Blaney regarding water quality data for Wilsons Lake and other Tusket River lakes*. December 14, 2012. Aquatic Health Researcher, Mersey Tobeatic Research Institute, Kempt NS.

Blaney, C.S. 2011. Nova Scotia Wetland Plant Indicator List. Nova Scotia Department of Environment. Online document: http://www.gov.ns.ca/nse/wetland/indicator.plant.list.asp [accessed February, 2013].

Blaney, C.S., pers. obs. 1999-2012. Personal observations on Atlantic Coastal Plain flora in southern Nova Scotia. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., pers. obs. 2011. Personal observations on Wilsons Lake and Springhaven Duck Lake shoreline plants and plant communities. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S. and D.M. Mazerolle. 2011. Lakeshore surveys for rare Atlantic Coastal Plain vascular plants in Kejimkujik National Park, with notes on overall diversity and new park records. Unpublished report to Kejimkujik National Park, Parks Canada. Atlantic Canada Conservation Data Centre, Sackville NB. 36 pp.

Blaney, C.S., and D.M. Mazerolle, pers. obs. 2011. Personal observations on Wilsons Lake and Springhaven Duck Lake shoreline plants and plant communities. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., and D.M. Mazerolle. 2012. 2012 botanical fieldwork completed under the Critical Habitat Schedule of Studies for Plymouth Gentian, Golden Crest, Water Pennywort and Van Brunt's Jacob's-Ladder. Unpublished report to Environment Canada, Canadian Wildlife Service. Atlantic Canada Conservation Data Centre. Sackville NB. 18 pp.

Boyle, C., and J. Khan. 1993, National report on the status of the West Indian manatee population in Trinidad and Tobago. Manatee Subcommittee, Trinidad and Tobago Field Naturalist Club. Unpublished report.

Brylinsky, M. 2011. An assessment of the sources and magnitudes of nutrient inputs responsible for degradation of water quality in seven lakes located within the Carleton River watershed area of Digby and Yarmouth counties, Nova Scotia. Prepared for the Nova Scotia Department of Environment. 25 pp.

Brylinsky, M. 2012. Results of the 2011 Water Quality Survey of Ten Lakes Located in the Carleton River Watershed Area of Digby and Yarmouth Counties, Nova Scotia. Prepared for Nova Scotia Environment. Acadia Center for Estuarine Research, Acadia University, Wolfville NS. 37 pp.

Calflora. 2013. The Calflora Database: Information on California plants. http://calphotos.berkeley.edu/cgi-bin/img_query?rel-taxon=begins+with&where-taxon=Hydrocotyle+umbellatapatial Structure and Variability [accessed: Feb 15, 2013].

Canadian Endangered Species Conservation Council. 2011. Wild Species 2010: The General Status of Species in Canada. National General Status Working Group. 302 pp.

Chandler, G.T., and G.M. Plunkett. 2004. Evolution in Apiales: nuclear and chloroplast markers together in (almost) perfect harmony. Botanical Journal of the Linnean Society 144: 123-147.

Chavasiri, W., W. Prukchareon, P. Sawasdee, and S. Zungsontiporn. 2005. Allelochemicals from *Hydrocotyle umbellata* Linn. Proceedings of the 4th World Congress on Allellopathy. http://regional.org.au/au/allelopathy/2005/2/1/2628_warinthorn.htm [accessed February 14, 2013].

Clayden, S.R., M.C. Munro, C.S. Blaney, and S.P. Vander Kloet *et al*. 2009. Vascular flora of the Atlantic Maritime Ecozone: some new perspectives. Ch. 10, pp. 197-214 *in* D.F. McAlpine, and I.M. Smith (eds.). Assessment of Species Diversity in the Atlantic Maritime Ecozone. NRC Research Press, Ottawa, ON. 785 pp.

Clemson Cooperative Extension. 2013. Aquatic Plant Profiles: *Hydrocotyle umbellata*. http://www.clemson.edu/extension/horticulture/nursery/remediation_technology/constructed_wetlands/plant_material/water_pennywort.html [accessed February 15, 2013].

Conley. D.J., H.W. Paerl, R.W. Howarth, D.F. Boesch, S.P. Seitzinger, K.E. Havens, C. Lancelot, and G.E. Likens. 2009. Controlling eutrophication: nitrogen and phosphorus. Science 323:1014-1015.

Connecticut Department of Energy and Environmental Protection (DEEP). 2013. Endangered, Threatened & Special Concern Plants. http://www.ct.gov/deep/cwp/view.asp?a=2702&q=323482&deepNav_GID=1628 [accessed February 12, 2013].

Cook, T., and S. Sundberg. 2013. Oregon Flora Project, Checklist – Araliaceae. http://www.oregonflora.org/family_treatments/Araliaceae.pdf [accessed February 26, 2013].

Cordo, H.A., C.J. DeLoach and R. Ferrer. 1982. The weevils *Lixellus, Tanysphiroideus* and *Cyrtobagous* that feed on *Hydrocotyle* and *Salvinia* in Argentina. The Coleopterist's Bulletin 36: 279-286.

Correll, D.S., and H.B. Correll. 1975. Aquatic and Wetland Plants of Southwestern United States, Volume 1. Stanford University Press, Palo Alto CA.

COSEWIC. 2000. COSEWIC assessment and update status report on the water-pennywort *Hydrocotyle umbellata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 9 pp.

COSEWIC. 2010. COSEWIC's Assessment Process and Criteria. Online document: http://www.cosewic.gc.ca/pdf/assessment_process_e.pdf [accessed February 22, 2013].

COSEWIC. 2011. COSEWIC assessment and update status report on Goldencrest *Lophiola aurea* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012a. COSEWIC assessment and update status report on Plymouth Gentian *Sabatia kennedyana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

COSEWIC. 2012b. COSEWIC assessment and update status report on Pink Coreopsis *Coreopsis rosea* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Coulter, J.M., and J.N. Rose. 1900. Monograph of the North American Umbelliferae. Contributions from the United States National Herbarium 7: 9-256.

Crowley, M. pers. comm. 2013. *Telephone conversation regarding monitoring methods, population status and ecology of Water-pennywort in Kejimkujik National Park*. February 27, 2013. Species at Risk Biologist, Parks Canada, Kejimkujik National Park.

Dawe, C.E., and E.G. Reekie. 2007. The effects of flooding regime on the rare Atlantic coastal plain species, *Hydrocotyle umbellata*. Canadian Journal of Botany 85:167-174.

DeBarros, N., pers. comm. 2013. Email conversations between Nelson DeBarros and Sean Blaney regarding Water-pennywort in Connecticut. February 25, 2013. Plant Ecologist, Connecticut Bureau of Natural Resources, Hartford CT.

DeBusk, T.A., and K.R. Reddy. 1987. BOD Removal in Floating Aquatic Macrophyte-Based Wastewater Treatment Systems. Water Science & Technology 19: 273–279.

DeBusk, T.A., and K.R. Reddy. 1991. Wastewater treatment and biomass production by floating aquatic macrophytes *in* Methane from community wastes. (R. Isaacson, ed.) pp. 21-36. Elsevier Applied Science, London. 215 + x pp.

Eaton, S.T., and J.S. Boates. 2003. Securing the science foundation for responsible stewardship and recovery of ACPF species at risk. NS Department of Natural Resources, Kentville, NS.

Eckert, C.G., K .E. Samis, and S.C. Lougheed. 2008. Genetic variation across species' geographical ranges: the central–marginal hypothesis and beyond. Molecular Ecology 17:1170–1188.

Ehrenfeld, J.G. 1983. The effects of changes in land use on swamps of the New Jersey Pine Barrens. Biological Conservation 25: 353-375.

Environment Canada and Parks Canada Agency. 2010. Recovery Strategy and Management Plan for Multiple Species of Atlantic Coastal Plain Flora in Canada. *Species at Risk* Act Recovery Strategy Series. Environment Canada and Parks Canada Agency. Ottawa. 96 pp. + appendices.

Fernald, M.L. 1921. The Gray Herbarium expedition to Nova Scotia 1920. Rhodora 23: 89-111, 130-152, 153-171, 184-195, 233-245, 257-78, 284-300.

Fernald, M.L. 1922. Notes on the flora of western Nova Scotia. Rhodora 24: 157-164, 165–181, 201-208.

Fernald, M.L. 1950. Gray's Manual of Botany. A handbook of the flowering plants of the central and northeastern United States and adjacent Canada. 8th Edition. American Book Company. New York. 1632 pp.

Filiatrault, M., and H. Stewart. 2006. Assessment of Atlantic Coastal Plain Flora in Kejimkujik National Park. Year 1: Shorelines of Kejimkujik Lake. Applied Geomatics Research Group, Centre of Geographical Sciences, Middleton NS. v + 112 pp.

Flemming, J., pers. comm. 2011. December 7, 2011. *Telephone conversation with Sean Blaney regarding mink farming in southern Nova Scotia*. Permitting officer, Laboratory Services Section, Nova Scotia Department of Agriculture, Truro NS.

Frankham, R., J.D. Ballou, and D.A. Briscoe. 2010. Conservation Genetics. Cambridge University Press, Cambridge, UK. 618 pp.

García-Ramos, G., and M. Kirkpatrick. 1997. Genetic models of rapid evolutionary divergence in peripheral populations. Evolution 51: 21-28.

Germplasm Resources Information Network (GRIN). 2012. United States Department of Agriculture Agricultural Research Service, Beltsville Area. http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?102108 [Accessed February 13, 2013]

Godfrey, R.K., and J.W. Wooten. 1981. Aquatic and Wetland Plants of Southeastern United States: Dicotyledons, Volume 2. University of Georgia Press, Athens, GA. 933 pp.

Government of Canada. 2011. Species at Risk Public Registry. Website: http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=219 [accessed November 2011].

Government of Nova Scotia. 2013. Fur Industry Regulations made under Section 36 of the Fur Industry Act S.N.S. 2010, c. 4 O.I.C. 2013-2 (January 11, 2013), N.S. Reg. 4/2013 http://www.gov.ns.ca/just/regulations/regs/furindustry.htm [accessed February 14, 2013].

Haines, A. 2011. New England Wild Flower Society's Flora Novae Angliae: A Manual for the Identification of Native and Naturalised Higher Vascular Plants of New England. Yale University Press, New Haven CT. 992 pp.

Harley, J.L., and E.L. Harley. 1987. A checklist of mycorrhiza in the British flora. New Phytologist 155: 1-102.

Haynes, R.R. 1988. Reproductive Biology of Selected Aquatic Plants. Annals of the Missouri Botanical Garden 75: 805-810.

Hazel, S.N. 2004. Hydrological alterations and rare species of the Atlantic Coastal Plain Flora in Nova Scotia. M.Sc. Thesis, Acadia University, Wolfville, NS.

Hill, N.M., and C.S. Blaney. 2010. Invasive Vascular Plants in the Maritime Atlantic Ecozone: Plague or Symptom of Anthropogenic Habitat Disturbance? Ch. 11 in *Assessment of Species Diversity in the Atlantic Maritime Ecozone*. D. McAlpine, ed., NRC Press. 17 pp.

Hill, N.M., and P.A. Keddy. 1992. Prediction of rarities from habitat variables: coastal plain plants on Nova Scotian lakeshores. Ecology 73: 1852-1859.

Hill, N.M., P.A. Keddy, and I.C. Wisheu. 1998. A hydrological model for predicting the effects of dams on the shoreline vegetation of lakes and reservoirs. Environmental Management 22: 723-736.

Holt, T.D., I. Blum, and N.M. Hill. 1995. A watershed analysis of the lakeshore plant community. Canadian Journal of Botany 73: 598–607.

Hurlburt, D., pers. comm. 2013. *Telephone communication with Sean Blaney regarding aboriginal traditional knowledge of Water-pennywort (Hydrocotyle umbellata) and its status on Wilsons Lake.* March 1, 2013. COSEWIC Aboriginal Traditional Knowledge Specialist Committee representative to the COSEWIC Vascular Plants Species Specialist Committee, and Wilsons Lake cottager, Yarmouth, NS.

Hume, N.P., M.S. Fleming, and A.J. Horne. 2002. Plant carbohydrate limitation on nitrate reduction in wetland microcosms. Water Research 36: 577-584.

Hurtado, I., and J. Alson. 1990. Air pollen dispersal in a tropical area. Aerobiologia 6: 122-127.

Intergovernmental Panel on Climate Change (IPCC). 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri, R.K. and Reisinger, A. (eds.). IPCC, Geneva, Switzerland. 104 pp.

Ishikawa, H. 2010. Effects of ingestion of seeds by sika deer (*Cervus nippon*) and dung presence on their germination in a herbaceous community. Ecological Research 25: 591-598.

Janzen, D.H. 1984. Dispersal of small seeds by big herbivores: foliage is the fruit. American Naturalist 123, 338–353.

Kartesz, J.T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada and Greenland. First Edition. *In*: Kartesz, J.T. and C.A. Meacham. Synthesis of the North American Flora, Version 1.0. North Carolina Botanical Garden, Chapel Hill NC.

Kartesz, J.T. 2011. *North American Plant Atlas*. Website: http://www.bonap.org/MapSwitchboard.html [maps generated from Kartesz, J.T. 2010. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). Chapel Hill, NC. [accessed February 2013].

Keddy, P.A. 1983. Shoreline vegetation in Axe Lake, Ontario: effects of exposure on zonation patterns. Ecology 64:331-344.

Keddy, P.A. 1984. Quantifying a within-lake gradient of wave energy in Gillfillan Lake Nova Scotia. Canadian Journal of Botany 62: 301–309.

Keddy, P.A. 1985. Lakeshores in the Tusket River Valley, Nova Scotia: distribution and status of some rare species, including *Coreopsis rosea* Nutt. and *Sabatia kennedyana* Fern. Rhodora 87: 309–319.

Keddy, P.A. 1989. Effect of competition from shrubs on herbaceous wetland plants: a 4-year field experiment. Canadian Journal of Botany 67: 708–716.

Keddy, P.A., and I.C. Wisheu. 1989. Ecology, biogeography, and conservation of coastal plain plants: some general principles from the study of Nova Scotian wetlands. Rhodora 91: 72–94.

Kinler, N., G. Linscombe, and S. Hartley. 1998. A survey of Nutria herbivory damage in coastal Louisiana in 1998. Fur and Refuge Division, Louisiana Department of Wildlife and Fisheries. 29 pp. http://dnrucm.dnr.state.la.us/ucm/groups/coastalprotectionrestoration/documents/ocpr/3891531.pdf [accessed February 12, 2013].

Kejimkujik National Park. 2012. Monitoring data for Water-pennywort, 2004 to 2012. Unpublished digital data. Parks Canada, Kejimkujik National Park.

Lake County Aquatic Plant Management Section. (no date). Aquatic Plant Management Procedures. http://www.lakecountyfl.gov/pdfs/Public_Works/mosquito_and_aquatic_plants/aquatic_plants_management_procedures.pdf [accessed February 11, 2013].

Laser, T. 1971. Flora de Venezuela. Instituto Botánico, Caracas, Venezuela.

Laursen, G.A., R. Treu, R.D Seppelt, and S.L. Stephenson. 1997. Mycorrhizal assessment of vascular plants from subantarctic Macquarie Island. Arctic and Alpine Research 29:483–491.

Lefebvre, L.W., T.J. O'Shea, G.B. Rathbun, and R.C. Best. 1989. Distribution, status, and biogeography of the West Indian manatee. In: C.A. Woods and F.E. Sergile (eds.). Biogeography of the West Indies. Gainesville, FL: Sandhill Crane Press. pp. 567-610.

Lesica, P., and, F.W. Allendorf. 1995. When Are Peripheral Populations Valuable for Conservation? Conservation Biology 9: 753-760.

LIANS (Lawyer’s Insurance Association of Nova Scotia). 2008. The Ebb and Flow of Water Law in Nova Scotia. Online document: http://www.lians.ca/documents/EbbAndFlowOfWaterLaw-CorsanoRisk_(00012380).PDF [accessed September 12, 2013].

Logan, V.S., P.J. Clarke, and W.G. Allaway. 1989. Mycorrhizas and Root Attributes of Plants of Coastal Sand-dunes of New South Wales. Aust. J. Plant Physiol. 16:141-146.

Lusk J.M., and Reekie E.G. 2007. The effect of growing season length and water level fluctuations on growth and survival of two rare and at risk Atlantic coastal plain flora species, *Coreopsis rosea* and *Hydrocotyle umbellata*. Canadian Journal of Botany 85:119-131.

MacKinnon, D., pers. comm. 2012. *Phone conversation with Sean Blaney about off-highway vehicle impacts at Tusket River Nature Reserve, Wilsons Lake.* November, 2012. Protected Areas Planner, Nova Scotia Department of Environment and Labour, Halifax, NS.

Macoun, J.M. 1888. Catalogue of Canadian Plants, Part IV – Endogens. Geological Survey of Canada. Dawson Brothers, Montreal. 295 pp.

Marsden, M.W. 1989. Lake restoration by reducing external phosphorus loading: the influence of sediment phosphorus release. Freshwater Biol. 21:139–162.

Martin, A.C., and F.M. Uhler. 1939. Food of game ducks in the United States and Canada. Technical Bulletin No. 634. United States Department of Agriculture, Washington D.C. 147 pp.

Mazerolle, D.M. 2012 (in prep.). Rare plant fieldwork on Kejimkujik Lake. Unpublished report to Kejimkujik National Park, Parks Canada. Atlantic Canada Conservation Data Centre.

Mayr, E. 1963 *Animal Species and Evolution.* Harvard University Press, Cambridge, MA.

Merritt, D.M., and D.J. Cooper. 2000. Riparian vegetation and channel change in response to river regulation: A comparative study of regulated and unregulated streams in the Green River Basin, USA. Regulated Rivers: Research and Management 16:543-564.

Mersey Tobeatic Research Institute (MTRI). 2012. Rare coastal plain species surveys by Alain Belliveau on Kejimkujik Lake. [unpublished data, held at Kejimkujik National Park, NS]. Mersey Tobeatic Research Institute, Caledonia, NS.

Mersey Tobeatic Research Institute (MTRI), unpubl. 2011-2012. Water quality monitoring in Tusket River region. Unpublished data, Mersey Tobeatic Research Institute, Caledonia, NS.

Minnesota Department of Natural Resources (DNR). 2012. Minnesota Plant Checklist, June 2012. Digital document. http://www.dnr.state.mn.us/eco/mcbs/plant_lists.html [accessed February 20, 2013].

Mitchell, A., and J. Wen. 2004. Phylogenetic utility and evidence for multiple copies of granule-bound starch synthase I (GBSSI) in the Araliaceae. *Taxon* 53: 29-41.

Moore, D.R.J., P.A. Keddy, C.L. Gaudet, and I. Wisheu. 1989. Conservation of Wetlands: Do Infertile Wetlands Deserve a Higher Priority? Biological Conservation 47: 203-217.

Moorhead, K.K., and K.R. Reddy. 1990. Carbon and nitrogen transformations in wastewater during treatment with *Hydrocotyle umbellata* L. Aquatic Botany 37: 153-161.

Morris, P.A., N.M. Hill, E.G. Reekie, and H.L. Hewlin. 2002. Lakeshore diversity and rarity relationships along interacting disturbance gradients: catchment area, wave action and depth. Biological Conservation 106: 79-90.

Natural Resources Canada. 2003. Canadian Geographical Names. Geomatics Canada, Earth Sciences Sector, Centre for Topographic Information, Geographical Names Section. Ottawa ON. http://geobase.ca/geobase/en/data/cgn/cgn1.html [Downloaded 2007; sorted for “lake” and “pond” and by latitude and longitude to produce list of relevant waterbodies].

NatureServe. 2013. NatureServe Explorer – *Hydrocotyle umbellata*. Web site: http://www.natureserve.org/explorer [accessed February 2013].

Nei, M., T. Maruyama and R. Chakraborty. 1975. The bottleneck effect and genetic variability in populations. Evolution 29: 1-10.

New Zealand Plant Conservation Network. 2013. Flora: *Hydrocotyle umbellata*. http://www.nzpcn.org.nz/flora_details.aspx?ID=4202 [accessed February 11, 2013].

Nilsson, C., and R. Jansson. 1995. Floristic differences between riparian corridors of regulated and free-flowing boreal rivers. Regulated Rivers: Research and Management 11: 55-66.

Nova Scotia Department of Natural Resources. 2011. Species at Risk List Regulations made under Sections 10 and 12 of the Endangered Species Act. Website: http://www.gov.ns.ca/just/regulations/regs/eslist.htm [accessed November 2011].

Native Plant Information Network (NPIN). 2013. *Hydrocotyle umbellata*. http://www.wildflower.org/plants/result.php?id_plant=HYUM. Lady Bird Johnson Wildflower Center, University of Texas at Austin. [accessed February 15, 2012].

Ohio Department of Natural Resources (DNR), Wildlife Division. 2012. Wildlife That are Considered to be Endangered , Threatened , Species of Concern, Special Interest, Extirpated, or Extinct in Ohio. http://www.dnr.state.oh.us/Portals/9/pdf/pub356.pdf [accessed February 12, 2013].

Panyakhan, S., M. Kruatrachue, P. Pokethitiyook, V. Soonthornsarathoon, and S. Upatham. 2006. Toxicity and Accumulation of Cadmium and Zinc in *Hydrocotyle umbellata*. Science Asia 32: 6 pp.

Patton, J.E., and W.S. Judd. 1988. A Phenological Study of 20 Vascular Plant Species Occurring on the Paynes Prairie Basin,Alachua County, Florida. Castanea 53:149-163.

Plunkett, G.M., and P.P. Lowry II. 2001. Relationships among “ancient Araliads” and their significance for the systematics of Apiales. Molec. Phylogen. Evol. 19:259-276.

Plunkett, G.M., G.T. Chandler, P.P. Lowry II, S.M. Pinney, and T.S. Sprenkle*.* 2004. Recent advances in understanding Apiales and a revised classification. South African Journal of Botany 70:371–381.

Prasad, M.N.V., and H.M.D. Freitas. 2003. *Metal Hyperaccumulation in Plants – Biodiversity Prospecting for Phytoremediation Technology*. Electron. J. Biotechn. 6:285–321.

Preston, R.E., and L. Constance. 2012. *Hydrocotyle* in Jepson Flora Project (eds.) *Jepson eFlora*, http://ucjeps.berkeley.edu/cgi-bin/get_IJM.pl?tid=28610 [accessed February 8, 2013].

Reddy, K.R., E.M. D'Angelo, and T.A. DeBusk. 1990. Oxygen Transport through Aquatic Macrophytes: The Role in Wastewater Treatment. Journal of Environmental Quality 19:261-267.

Reddy, K.R., and W.F. DeBusk. 1985. Nutrient Removal Potential of Selected Aquatic Macrophytes. Journal of Environmental Quality 14:459-462.

Reddy, K.R., and J.C. Tucker. 1985. Growth and nutrient uptake of Pennywort (*Hydrocotyle umbellata* L.), as influenced by the nitrogen concentration of the water. J. Aquat. Plant Manage. 23:35-40.

Reed, P.B. Jr. 1988. National List of Plant Species that Occur in Wetlands: National Summary. US Fish and Wildlife Service, National Wetlands Inventory Project, Washington, DC, Biological Report 88 (24). 244 pp.

Rocha F.F., C.S. Almeida, R.T. Dos Santos, S.A. Santana, E,A, Costa, J.R. De Paula, F.A. Vanderlinde. 2011. Anxiolytic-like and sedative effects of *Hydrocotyle umbellata* extract in mice. *Rev. Bras. Farmacogn.* 21: 115-120.

Rojas, L.B., A. Usubillaga, J. Rondón, and P. Vit. 2009. Essential Oil Composition of *Hydrocotyle umbellata* L. From Venezuela. Journal of Essential Oil Research 21:253-254.

Roland, A.E. 1976. The Coastal Plain Flora of Kejimkujik National Park. Unpublished Report to Parks Canada.

Roland, A.E. 1980. *Hydrocotyle umbellata* in Nova Scotia. Rhodora 82: 517-518.

Roland, A.E., and E.C. Smith. 1969. The Flora of Nova Scotia. Nova Scotia Museum, Halifax. 743 pp.

Schummer, M.L., M.H. Hagy, K.S. Fleming, J.C. Cheshier, and J.T. Callicutt. 2012. A Guide to Moist-Soil Wetland Plants of the Mississippi Alluvial Valley. University Press of Mississippi, Jackson, MS. 256 pp.

Scoggan, H.J. 1979. The flora of Canada Part 4. Dicotyledons (Loasaceae to Compositae). Nat. Mus. of Natural Science Publication in Botany No. 7., pp. 1117 – 1711. National Museum of Natural Sciences, Ottawa.

Sooknah, R.D., and A.C. Wilkie. 2004. Nutrient removal by floating aquatic macrophytes cultured in anaerobically digested flushed dairy manure wastewater. Ecological Engineering 22: 27–42.

Sorrie, B., pers. comm. 2013. *Email conversation with Sean Blaney regarding Water Pennywort distribution and ecology in the Carolinas*. February 25, 2013. Inventory Biologist, North Carolina Natural Heritage Program, Whispering Pines, NC.

Sprengel, K.P.J. 1820. *Hydrocotyle bonariensis*, in C. von Linné (ed.) Systema Vegetabilium, 6th Edition. Stuttgart, Germany.

Stegmaier, Jr., C.E. 1966. Host Plants and Parasites of *Liriomyza munda* in Florida (Diptera: Agromyzidae). The Florida Entomologist 49:81-86.

Stutzenbaker, C.D. 1999. Aquatic and Wetland Plants of the Western Gulf Coast. University of Texas Press, Austin, TX. 465 pp.

Sweeney, S., and R. Ogilvie. 1993. The conservation of coastal plain flora in Nova Scotia. Maine Naturalist 1(3):131-144.

Taylor, R.L., and B. MacBryde. 1977. Vascular plants of British Columbia. Bot. Gard. Tech. Bull. No. 4. U.B.C. Press, Vancouver, BC. 754 pp.

Tiner, R.W. 2009. Field Guide to Tidal Wetland Plants of the Northeastern United States and Neighboring Canada. Vegetation of Beaches, Tidal Flats, Rocky Shores, Marshes, Swamps, and Coastal Ponds. University of Massachusetts Press, Amherst, MA. 459 pp.

United States Fish and Wildlife Service (USFWS). 1997. National List of Vascular Plant Species that Occur in Wetlands: 1996 National Summary. USFWS Ecology Section, National Wetlands Inventory. http://library.fws.gov/Pubs9/wetlands_plantlist96.pdf [accessed February 13, 2013].

Vasseur, L. 2000. Distribution and ecology of *Hydrocotyle umbellata* in Kejimkujik National Park. Preliminary research report. Kejimkujik National Park. 18 pp.

Vasseur, L. 2002. Abstracts for *Botany 2002*, *Botany in the Curriculum: Integrating Research and Teaching*. University of Wisconsin, Madison. http://2002.botanyconference.org/section3/abstracts/3.shtml [accessed February 12, 2012].

Vasseur, L. 2005. Monitoring populations of *Hydrocotyle umbellata* (water pennywort) in Kejimkujik National Park and National Historic Site. Research report for Kejimkujik National Park, Parks Canada, N.S.

Vasseur, L. pers. comm. 2013. *Telephone conversation with Sean Blaney regarding her research and observations on Water-pennywort genetics and ecology in Nova Scotia.* February 28, 2013. Professor of Biology, Brock University, St. Catherines ON.

Vasseur, L., Drysdale, C., and Potter, K. 2002. National recovery plan of *Hydrocotyle umbellata* (water-pennywort) Volume II: Background and recovery and conservation action plan. Parks Canada and COSEWIC. N.S.

Virginia Botanical Associates. 2013. Digital Atlas of the Virginia Flora http://www.vaplantatlas.org. Virginia Botanical Associates, Blacksburg VA. [accessed March 1, 2013].

Walsh, W.C., M. Maestro, D. Djeddour, M. Seier, and D. Shaw. 2010. Biocontrol study for *Hydrocotyle ranunculoides.* USDA Agriculture Research Service. http://afrsweb.usda.gov/SP2UserFiles/Place/02110000/Annual%20Report%202011%20Part%2010%20WATER%20PENNYWORT.pdf [accessed February 2013].

Walther-Hellwig, K., and R. Frank. 2000. Foraging distances of *Bombus muscorum*, *Bombus lapidarius*, and *Bombus terrestris* (Hymenoptera, Apidae). J. Insect Behav. 13: 239–246.

Wells, W. 2009. Pennywort (Dollarweed) Control. Turf Tips Newsletter, Mississippi University Forestry and Agricultural Experimental Station, Mississippi University Extension Service. http://msucares.com/lawn/lawn/turf/09/0706.html [accessed February 18, 2013].

Wen, J., G.M. Plunkett, A.D. Mitchell, and S.J. Wagstaff. 2001. The evolution of Araliaceae. A phylogenetic analysis based on ITS sequences of nuclear ribosomal DNA. Syst. Bot. 26:144-167.

Wetzel, P.R., A.G. van der Valk, and L.A. Toth. 2001. Restoration of wetland vegetation on the Kissimmee River Floodplain: Potential role of seed banks. Wetlands 21:189-198.

White, D.J., J.C. Makarewicz, and T.W. Lewis. 2002. The significance of phosphorus released from the sediment under anoxic conditions in Sodus Bay, N.Y. Environmental Sciences Program, Department of Biological Sciences SUNY Brockport Brockport, New York, 33 pp.

Wichmann, B., pers. comm. 2013. *Email conversation with Sean Blaney with spreadsheet attachment regarding county distribution of Water-pennywort in Georgia based on University of Georgia herbarium specimens*. Collections Manager, University of Georgia Herbarium, Athens GA.

Wilson, S. 1985. Status Report on the Water-Pennywort *Hydrocotyle umbellata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 28 pp.

Wisheu, I.C., and P.A. Keddy. 1989. The conservation and management of a threatened coastal plain plant community in eastern North America (Nova Scotia, Canada). Biological Conservation 48:229-238.

Wisheu, I.C. and P.A. Keddy. 1991. Seed banks of a rare wetland plant community: distribution patterns and effects of human-induced disturbance. *Journal of Vegetation Science* 2: 81–88.

Wisheu, I.C., and P.A. Keddy. 1994. The low competitive ability of Canada's Atlantic Coastal Plain shoreline flora: implications for conservation. Biological Conservation 68:247–252.

Wisheu, I.C., C.J. Keddy, P.A. Keddy, and N.M. Hill. 1994. Disjunct Atlantic coastal plain species in Nova Scotia: distribution, habitat and conservation priorities. Biological Conservation 68:217–224.

Wunderlin, R.P., and B.F. Hansen. 2008. Atlas of Florida Vascular Plants – *Hydrocotyle umbellata*. S. M. Landry and K. N. Campbell (application development), Florida Center for Community Design and Research. Institute for Systematic Botany, University of South Florida, Tampa. http://florida.plantatlas.usf.edu/Plant.aspx?id=3906 [accessed February 27, 2013].

Yelverton, Y., B.R. Lassiter, G.G. Wilkerson, L. Warren, T. Gannon, J.J. Reynolds, and G.S. Buol. 2008. Dollarweed (Pennywort) [*Hydrocotyle* spp.] Info Sheet. Center for Turfgrass Environmental Research and Education, North Carolina State University. http://www.turffiles.ncsu.edu/PDFFiles/004367/Dollarweed.pdf [accessed February 18, 2013].

Yongpisanphop, J., M. Kruatrachue, and P. Pokethitlyook. 2005. Toxicity and accumulation of lead and chromium in *Hydrocotyle umbellata*. J. Environ. Biol. 26:79–89.

Zaremba, R.E., and E.E. Lamont. 1993. The status of the Coastal Plain Pondshore community in New York. Bulletin of the Torrey Botanical Club 120:180-187.

Zungsontiporn, S. 2002. Global invasive plants in Thailand and its [*sic*] status and a case study of *Hydrocotyle umbellata* L. Food and Fertilizer Technology Centre for the Asia and Pacific Region. http://www.docstoc.com/docs/48557363/Global-invasive-plants-in-Thailand-and-its-status-and [accessed February 11, 2013].

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Sean Blaney is the Botanist and Assistant Director of the Atlantic Canada Conservation Data Centre (AC CDC), where he is responsible for status ranks and rare plant occurrence databases for each of the three Maritime provinces. Since beginning with the AC CDC in 1999, he has documented dozens of new provincial records for vascular plants and thousands of rare plant localities 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 authored or co-authored numerous COSEWIC and provincial status reports. Prior to employment with AC CDC, Sean received a B.Sc. in Biology (Botany Minor) from the University of Guelph and an M.Sc. in Plant Ecology from the University of Toronto, and worked on biological inventory projects in Ontario as well as spending eight summers as a naturalist in Algonquin Park, where he co-authored the second edition of the park's plant checklist.

COLLECTIONS EXAMINED

No specimens were examined during preparation of the report. Specimens from the E.C. Smith Herbarium, Acadia University (ACAD) and the Nova Scotia Museum of Natural History (NSPM) were already documented in the Atlantic Canada Conservation Data Centre database (AC CDC 2013) prior to the preparation of the report.