COSEWIC
Assessment and Status Report

on the

Plymouth Gentian
Sabatia kennedyana

in Canada

ENDANGERED
2012

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:

COSEWIC. 2012. COSEWIC assessment and status report on the Plymouth Gentian *Sabatia kennedyana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 46 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the Plymouth gentian *Sabatia kennedyana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 10 pp.

Newell, R.E. 1999. Update COSEWIC status report on the Plymouth gentian *Sabatia kennedyana* in Canada, *in* COSEWIC assessment and update status report on the Plymouth gentian *Sabatia kennedyana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-10 pp.

Keddy, C., and P. Keddy. 1984. COSEWIC status report on the Plymouth gentian *Sabatia kennedyana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 27 pp.

Production note:
COSEWIC would like to acknowledge Sean Blaney and Nicholas Hill for writing the status report on Plymouth Gentian, *Sabatia kennedyana*, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Bruce Bennett, Co-chair of the COSEWIC Vascular Plants Specialist Subcommittee.

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

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Sabatie de Kennedy (*Sabatia kennedyana*) au Canada.

Cover illustration/photo:
Plymouth Gentian — Photo by Sean Blaney.

Catalogue No. CW69-14/246-2013E-PDF
ISBN 978-1-100-22223-3

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Plymouth Gentian

Scientific name
Sabatia kennedyana

Status
Endangered

Reason for designation
This showy perennial lakeshore plant has a restricted global range with a disjunct distribution limited to southernmost Nova Scotia. There is a concern regarding potential widespread and rapid habitat degradation due to recent increases in levels of phosphorus in lakes, tied to a rapidly growing mink farming industry. Though the population size is now known to be larger than previously documented due to greatly increased survey effort, the species is also at risk due to the continuing impacts associated with shoreline development, and historical hydro-development.

Occurrence
Nova Scotia

Status history
Designated Threatened in April 1984. Status re-examined and confirmed in April 1999 and May 2000. Status re-examined and designated Endangered in November 2012.

COSEWIC
Executive Summary

Plymouth Gentian
Sabatia kennedyana

Wildlife Species Description and Significance

Plymouth Gentian is an herbaceous perennial with single, erect, flowering stems 30 to 50 cm tall arising from a basal rosette of narrow (oblanceolate) leaves 3 to 8 cm long. Basal rosettes produce short green stolons which form new rosettes at their tips. Clusters of interconnected rosettes are frequently produced. Erect stems have opposite leaves and one to three (rarely up to five) 5 cm-wide flowers of 7-13 pink petals with yellow bases.

Plymouth Gentian is a globally rare species, co-occurring in southern Nova Scotia with a suite of rare, disjunct species of the Atlantic Coastal Plain. Nova Scotia populations are 400+ km from the nearest sites in Massachusetts. An investigation of genetic diversity suggests that Nova Scotia populations may have a disproportionate significance to the species. The attractive flowers provide cottagers and the public with an easily appreciated reason for good stewardship of habitats supporting rare Atlantic Coastal Plain species.

Distribution

Plymouth Gentian has a very limited global range with three highly disjunct areas of occurrence: 1) along the North Carolina – South Carolina border near the Atlantic Coast; 2) in coastal regions of Massachusetts and Rhode Island; and 3) in extreme southwestern Nova Scotia on the shores of ten lakes in three river systems (Annis, Carleton and Tusket rivers), all of which flow into the Tusket River estuary. Roughly 10% of its global range is in Canada.

Habitat

In Nova Scotia, Plymouth Gentian occurs on lakeshores (rarely river shores) on sand, gravel and peat substrates, within the zone annually or semi-annually exposed in summer but where winter flooding protects plants from freezing. Plymouth Gentian is associated with lakes having especially large upstream catchment areas because the greater fluctuations in water level, wave action and ice scour limit shoreline fertility and inhibit more competitive species. In New England, Plymouth Gentian is mostly found on sandy, gravelly or muddy shores of small kettle ponds. In the Carolinas, the species occurs on river and pond shores and in acidic swamps.

Biology

Plymouth Gentian is a clonal perennial that reproduces by seed, by stolons producing daughter rosettes, and by vegetative fragments moved by ice and water. In Canada, it flowers from mid-July to late September. It is pollinated by a range of generalist pollinators and is self-compatible. Each flower can produce 300-1,400 tiny seeds released in early fall. Dispersal is likely largely by water as seeds can float for at least a day. Seed banks of unknown longevity are reported as very important for persistence in Massachusetts and are present in Nova Scotia, but may be less important there because of more stable habitats. Rosettes grow for two to five or more years and die after flowering, but longevity of genetic individuals is unknown. Generation time, factoring in reproduction by seed and by vegetative means, may be approximately five years.

Population Sizes and Trends

The total Canadian population is estimated at 73,400 to 90,700 flowering stems and 771,400 to 971,500 rosettes, with number of mature individuals in between those totals. There are four extant populations on ten lakes. Two populations on the main branch of the Tusket River are spread over two and six interconnected lakes respectively and support 98% of the total.

Ongoing shoreline development has caused minor declines (<<2.8% total). Eutrophication is likely also causing declines on one lake. Aside from these impacts, populations are believed to have been relatively stable over the past 15 years (three generations).

Threats and Limiting Factors

Eutrophication is the most serious threat to Plymouth Gentian. One small population (Lake Fanning) appears to already be stressed by competition induced by eutrophication associated with mink farming. The nutrient-demanding invasive exotic Reed Canary Grass is established on this lake and is an imminent threat to Plymouth Gentian. Eutrophication (600-800% increases in total phosphorus between 2002 and 2011, possibly from a single mink farm) was detected throughout the Tusket River system in 2011, affecting lakes containing 98% of the Canadian population. No impacts on Plymouth Gentian in Tusket system lakes have yet been observed, but phosphorus levels in some Tusket lakes are approaching those at Lake Fanning.

Shoreline development is a widespread, ongoing threat affecting a small portion of the population. The species occurs on the shorelines of 200+ cottage or residential properties. About 27% of the population is on undeveloped private shorelines. New development continues, including within the densest Canadian population. Population losses from cottage development in the past 15 years (three generations) are likely significantly less than 2.8%. About 38% of occupied habitat and 32% of the population is now in protected areas, somewhat mitigating development threats.

Hydroelectric dams on the lower Tusket River significantly reduced populations around 1929 and may be limiting recovery in affected lakes, but new dams are not a threat. Off-highway vehicles are locally affecting plants but do not appear to have major population effects.

Protection, Status, and Ranks

Plymouth Gentian was assessed by COSEWIC as Endangered in November 2012, and as Threatened in May 2000. It is currently listed on Schedule 1 as Threatened under the *Species at Risk Act*, and provincially under the *Nova Scotia Endangered Species Act*. It is legally protected in Rhode Island (State Endangered), Massachusetts (Special Concern) and North Carolina (Special Concern), and is globally vulnerable (G3) and critically imperilled (N1, S1) and at risk nationally and provincially. It is also a species of regional concern in South Carolina, where there is no legal protection for rare plants.

TECHNICAL SUMMARY

Sabatia kennedyana
Plymouth Gentian — Sabatie de Kennedy
Range of occurrence in Canada (province/territory/ocean): Nova Scotia

Demographic Information

Generation time (usually average age of parents in the population) *Seed to flowering likely at least several years. Time for vegetatively produced rosette to reproduce vegetatively is at least one year.*	Unknown; perhaps 5 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *Small decline observed to present with potential for widespread future decline due to eutrophication.*	Yes
Estimated percent of continuing decline in total number of mature individuals within 2 generations. *Future eutrophication impacts are unclear. Continuing declines over next 10 years due to shoreline development will likely be less than <<2.8% impacts so far.*	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	<<3.0% decline
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. *Eutrophication impacts are unclear. Continuing declines over next 15 years are suspected due to shoreline development but will likely be less than <3.0% impacts so far.*	Decline of unknown magnitude
[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. *Future declines associated with eutrophication could be significant.*	Unknown
Are the causes of the decline clearly reversible and understood and ceased? *Eutrophication is potentially reversible; shoreline development is not readily reversible. Causes are partially understood, but not ceased.*	No
Are there extreme fluctuations in number of mature individuals? *Extreme fluctuations known in Massachusetts but not known in more stable habitats in Nova Scotia.*	No

Extent and Occupancy Information

Estimated extent of occurrence *Extant sites only: 182 km²* *Extant + historical sites, including questionably located Little Tusket Lake site: 520 km²*	182 km²
Index of area of occupancy (IAO) – 2 x 2 km grid *Extant sites only: 112 km²* *Extant + well located historical (probably extirpated) sites: 140 km²* *Maximum IAO including questionably located historical sites: 200 km²*	112 km²

Is the total population severely fragmented?	No
Number of "locations∗" *See "Defining Populations and Locations"*	4-7
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? *Eutrophication impacts could eliminate Lake Fanning population in the next 15 years, which would reduce EO by 12%.*	Possibly
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? *Declines from eutrophication may reduce number of 2 x 2 km grid squares occupied, but ongoing development impacts are not expected to do so.*	Possibly
Is there an [observed, inferred, or projected] continuing decline in number of 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? *Eutrophication is degrading habitat at Lake Fanning, with potential to do so at most other occurrences. Ongoing lakeshore development is degrading habitat, but a very limited proportion affected at present.*	Yes
Are there extreme fluctuations in number of 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 population)

Population (# = population, letter = sub-population; see *Defining Populations*)	**N Mature Individuals** (cannot be determined but is between # flowering stems & # rosettes)	
	N flower stems	N rosettes
1 - Agard Lake	31-570	3,222
2 - Lake Fanning	1,126	4,460
3a - Wilsons Lake	28,100	276,000-289,000
3b - Bennetts Lake	19,700-26,270	193,500-270,200
4a - Travis Lake	100-300	1,200-3,600
4b - Pearl Lake	5,500-6,500	67,300-75,000
4c - Tusket River - Hemlock Run	100-300	500-3,600
4d - Third Lake	6,300-10,500	76,000-126,000
4e - Kegeshook Lake	1,700-4,300	20,100-52,000
4f - Gillfillan Lake	10,600-12,400	128,600-143,300
4g - Lac de l'Ecole	150-300	500-1,000
Total	73,400-90,700	735,900-966,300

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

∗ See definition of location.

Threats (actual or imminent, to populations or habitats)

- Increased competition caused by eutrophication (from mink farming effluent), including from invasive exotic Reed Canary Grass. Cyanobacterial mats associated with eutrophication may also cover plants.
- Shoreline alteration associated with cottage and residential waterfront development
- Off-highway vehicle damage to plants and habitat
- Water level management that prevents re-colonization of occurrences extirpated by dams and limits genetic exchange between Carleton and Tusket River occurrences

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *USA: Vulnerable (N3). Massachusetts (S3), North Carolina (S2), Rhode Island (S1), South Carolina (S2), Virginia (SNA-exotic)*	
Is immigration known or possible?	Highly unlikely
Would immigrants be adapted to survive in Canada? *Canadian populations 400+ km disjunct from MA, so some climatic difference. Genetic differences documented between Canadian & MA populations.*	Possibly
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Status History

Designated Threatened in April 1984. Status re-examined and confirmed in April 1999 and May 2000. Status re-examined and designated Endangered in November 2012.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Threatened	B1ab(iii,v)+2ab(iii,v)

Reasons for designation: This showy perennial lakeshore plant has a restricted global range with a disjunct distribution limited to southernmost Nova Scotia. There is a concern regarding potential widespread and rapid habitat degradation due to recent increases in levels of phosphorus in lakes, tied to a rapidly growing mink farming industry. Though the population size is now known to be larger than previously documented due to greatly increased survey effort, the species is also at risk due to the continuing impacts associated with shoreline development, and historical hydro-development.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met: Declines below thresholds.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened as EO < 5,000km² (182 km²) and IAO <500 km² (112 km²), it is known to exist at 4 locations and there is a continuing decline in the extent and quality of habitat and an inferred decline in the number of individuals.
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): Meets Threatened D2 with 4 locations, and the effects of recent nutrient enrichment could cause declines in a short period.
Criterion E (Quantitative Analysis): Not done.

PREFACE

Since the previous status report (Newell 1999), eutrophication has changed from a theoretical threat to the most significant actual threat. Effluent from upstream mink farming operations is strongly implicated as the cause of eutrophication on the Carleton River, including Lake Fanning, where toxic cyanobacterial blooms have been evident since 2007 and presumed eutrophication-related impacts on Plymouth Gentian habitat and individuals have been noted. Water testing in 2011 shows eutrophication to be a widespread threat, documenting 608% to 819% increases in total phosphorus over 2002 levels throughout the main branch of the Tusket River, possibly also associated with an upstream mink farm. The lakes of the main branch of the Tusket River support 98% of the population. The widespread threat of eutrophication results in all affected lakes on the Tusket system being considered one location rather than seven or more.

Since 2000, there has been extensive new fieldwork precisely documenting areas of Plymouth Gentian occurrence on eight of ten lakes at which extant occurrences are known. These detailed data and new interpretations of the term “mature individuals” have produced total population estimates more than 6.5 times higher than in the previous report. The first non-lakeshore occurrences have been documented at four Tusket River localities downstream from Third Lake, suggesting the possibility of other undiscovered occurrences along the river. However, additional fieldwork since 2000 has not found Plymouth Gentian on any new lakes and has documented the species’ absence from 30 Tusket Region lakes and 5 km of the Tusket River, confirming that Plymouth Gentian is localized in Nova Scotia and suggesting that its distribution is almost entirely known. New information is also presented in this report on the status and actual localities of certain questionable historical records.

Extensive new conservation lands have been designated in seven of eleven sub-populations (Pearl Lake, Third Lake, Gillfillan Lake, Kegeshook Lake, Lac de l’Ecole, Wilsons Lake and Bennetts Lake), raising the proportion of occupied habitat that is not subject to development from 19% to 38%. The proportion of the total population protected from development impacts is now estimated to be 25% to 32%.

Extensive academic and government research on Plymouth Gentian has taken place, including a Ph.D. dissertation on the species in Massachusetts and two M.Sc. theses from Nova Scotia. These have significantly increased understanding of life cycle and demography, pollination biology and inbreeding effects, genetic diversity from local to range-wide scales including the genetic distinctness of Canadian populations, and the potential impacts of shoreline development.

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
(2012)

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.

COSEWIC Status Report

on the

Plymouth Gentian
Sabatia kennedyana

in Canada

2012

TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Sabatia kennedyana* Fernald

Original Description: Fernald (1916)

Synonym: *Sabatia dodecandra* (L.) Britton, Sterns & Poggenb. var. *kennedyana* (Fernald) H.E. Ahles

English vernacular names:
Plymouth Gentian
Plymouth Rose Gentian
Plymouth Sabatia

French vernacular name: Sabatie de Kennedy

Genus: *Sabatia*

Family: Gentianaceae

Order: Gentianales

Class: Magnoliopsida, subclass Asteridae

Major plant group: Angiosperms, Eudicotyledons

Fernald (1916) first described Plymouth Gentian as a taxon distinct from *Sabatia dodecandra* var. *dodecandra*, treating it as the species *Sabatia kennedyana*. Ahles (1964) proposed that the taxon be treated at the varietal level and included it within *S. dodecandra* as *Sabatia dodecandra* var. *kennedyana*. More recent treatments (*i.e.* Gleason and Cronquist 1991; Kartesz 1999; Magee and Ahles 1999, co-authored posthumously by H.E. Ahles who proposed the *S. dodecandra* var. *kennedyana* combination) have followed Fernald (1916) in treating the taxon at the species level as *S. kennedyana*. Fernald described two forms: forma *candida* with white flowers (Fernald 1916) and forma *eucycla* (type from Nova Scotia; Fernald 1922) with broadly obovate (vs. narrowly cuneate-obovate) corolla lobes.

Morphological Description

Plymouth Gentian (*Sabatia kennedyana*; Figure 1) is an herbaceous perennial with single, erect flowering stems 30 to 50 cm high arising from a basal rosette composed of overlapping, oblanceolate leaves 3 to 8 cm long. Basal rosettes produce short green stolons which form new rosettes at their tips, frequently producing a cluster of interconnected rosettes. Erect stems have opposite, lance-shaped leaves 2 to 5 cm long and from one to three (rarely up to five) 5 cm-wide flowers composed of 7-13 pink petals which are yellow at their insertions.

Figure 1. Plymouth Gentian (*Sabatia kennedyana*) flowers and rosettes, with upper right image showing an especially dense patch of rosettes on Wilsons Lake. Photographs by Sean Blaney, AC CDC.

Plymouth Gentian is distinguished from the more southern Swamp Pink Gentian, *Sabatia dodecandra*, with a native range north to New York and Connecticut (NatureServe 2011), in having narrowly linear-lanceolate (vs. oblanceolate to spatulate) leaves with a mucronate tip (Gleason and Cronquist 1991), firm (vs. herbaceous) calyx lobes having one to three (vs. three) nerves (Fernald 1950; Gleason and Cronquist 1991), and by additional minor differences in the calyx tube and corolla lobes (Fernald 1950). Plymouth Gentian has a chromosome number of 2n = 40 (Gleason and Cronquist 1991).

Population Spatial Structure and Variability

Plymouth Gentian populations occur in three highly isolated regions (Carolinas, New England and Nova Scotia; Figure 2) separated by 400 to 800 km, a pattern termed a "double disjunction" (Sorrie 1998).

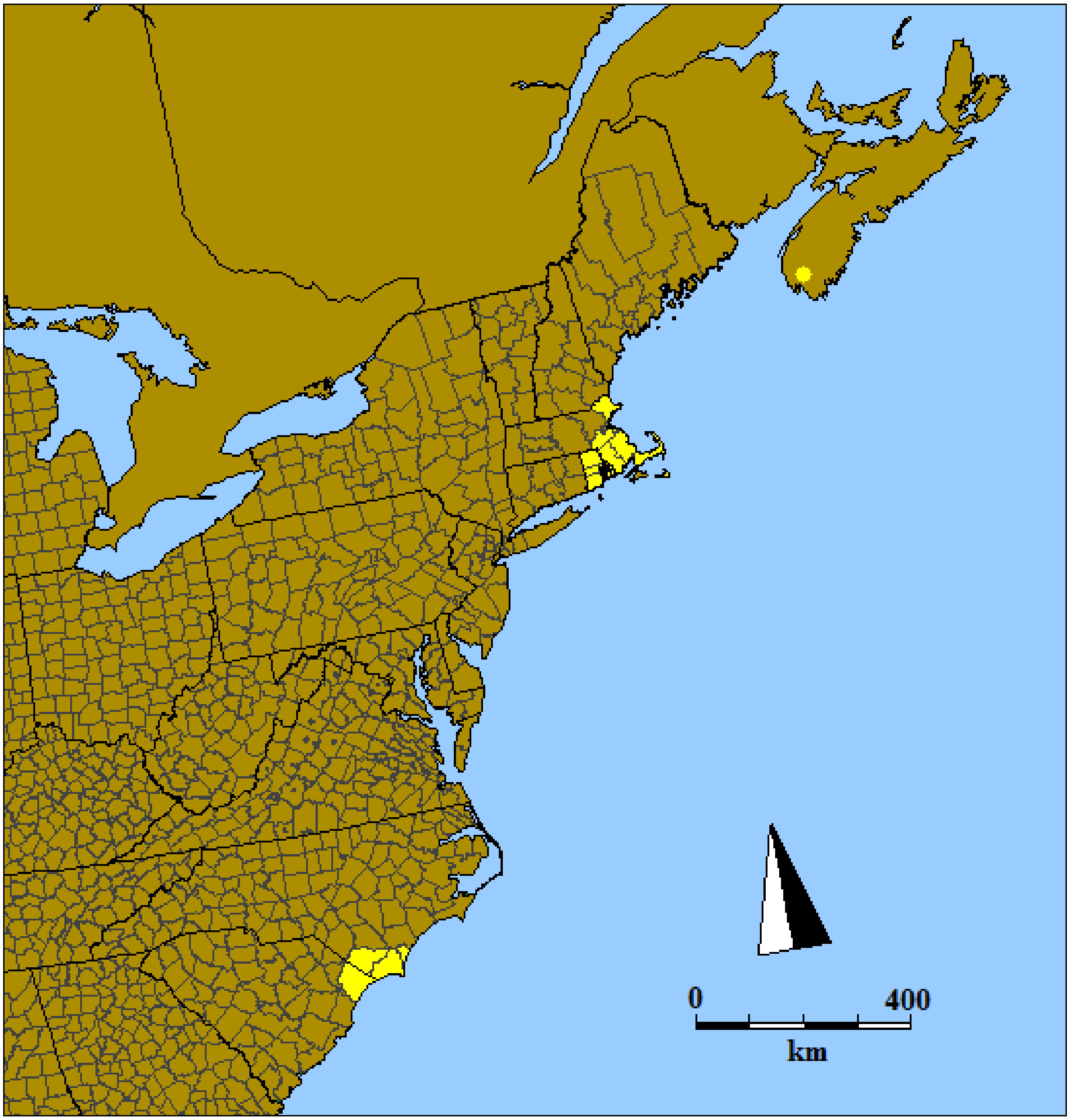

Figure 2. Global native range (pale yellow shading) of Plymouth Gentian (*Sabatia kennedyana*) (modified from Kartesz 2011). Distribution is given by county in the United States so that a whole county is shaded if at least one record is known. The species has also been reported as an established introduced species in Virginia (NatureServe 2011).

In Nova Scotia, known extant Plymouth Gentian populations, except Agard Lake, occur on the Tusket River system and its tributaries within 50 km river distance from the head of tide (Figure 3). Occurrences within a lake are presumed connected by genetic exchange because separation distances between known occurrences on occupied lakes rarely exceed 500 m. Genetic exchange between lakes is most likely in a downstream direction via water-borne propagule dispersal (see *Defining Populations*).

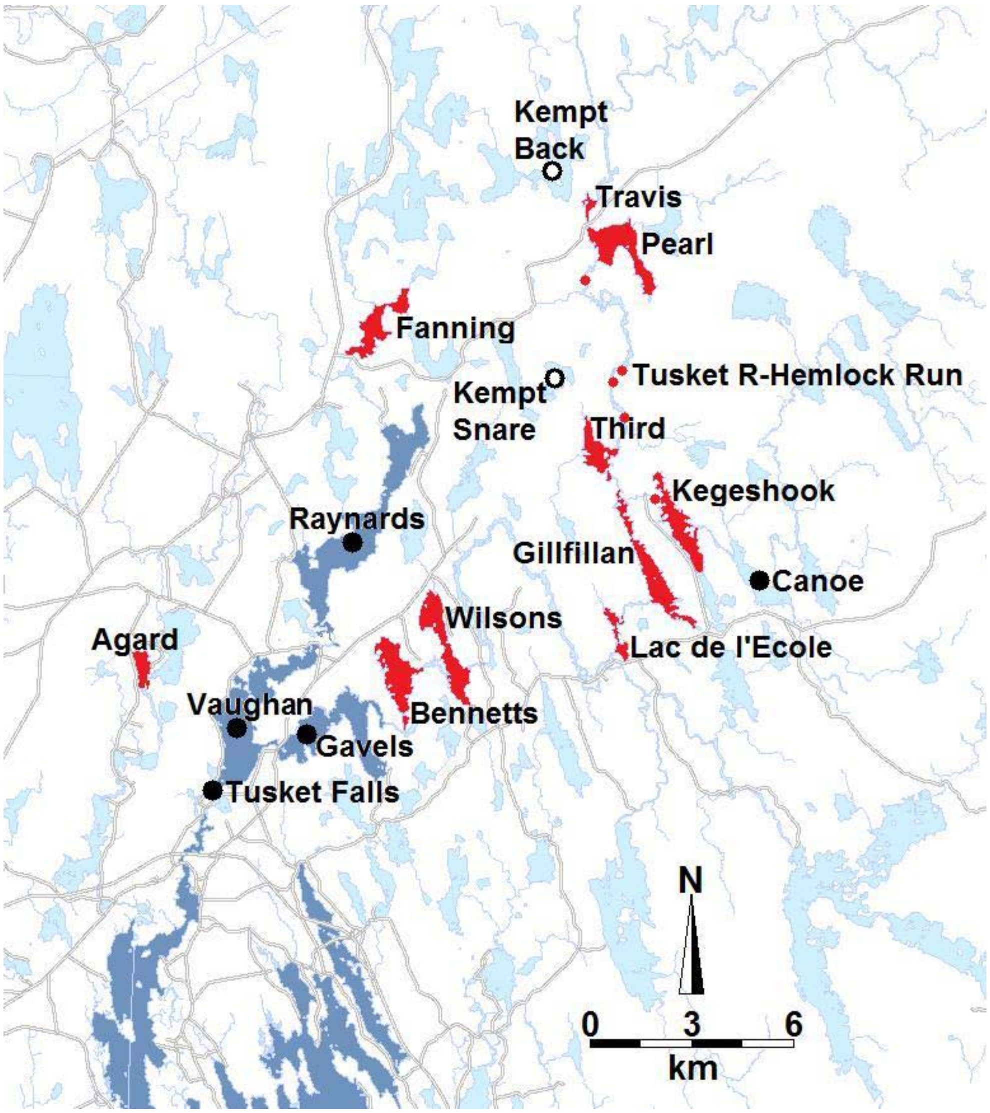

Figure 3. Distribution of Plymouth Gentian (*Sabatia kennedyana*) within the lower Tusket River valley. A reported occurrence at Little Tusket Lake (30 km north of Travis Lake) that was likely actually from Tusket Falls is not shown. Red (dark) shaded lakes support extant populations. Small dots between Pearl and Third lakes are isolated occurrences. Large filled dots are historical occurrences with imprecise localities. Large, unfilled dots (Kempt Snare and Kempt Back lakes) represent a single historical record from “Kempt Lake”, reported from these lakes but likely actually from Travis Lake at Kemptville (Table 2). Shaded water downstream from Raynards and Gavels lakes is unsuitable habitat (saline or brackish waters below Tusket Falls and dam-controlled reservoirs above Tusket Falls).

Sutton (2008) analyzed patterns of genetic diversity in Plymouth Gentian at scales from a few metres to nearly the entire geographic range. She reported relatively high polymorphism in nuclear and chloroplast DNA in each of North Carolina, Massachusetts and Nova Scotia but found much higher chloroplast DNA diversity in Nova Scotia, with more differentiation within Nova Scotia than within Massachusetts and North Carolina. She suggested this indicated that Nova Scotia populations had retained unique polymorphisms from a lineage pre-dating the one that founded the Massachusetts and North Carolina populations. At the local scale, Sutton (2008) found each lake had an array of genotypes and that significant kinship values occurred between plants up to 5 m apart on two of three lakes. Hill *et al*. (2006) also found evidence of relatedness of proximate plants. Artificial crossings using pollen donors from within 10 m produced significant inbreeding depression, expressed through reduced seed germination. Germination of resulting seeds was not affected by pollination of Wilsons Lake plants with pollen from 4 km away on Third Lake (Hill *et al.* 2006).

Plymouth Gentian is not severely fragmented (COSEWIC 2010) because the Canadian population is mostly composed of large, extensive sub-populations that are assumed to be genetically connected to some degree and may have good long-term viability.

Designatable Units

In Canada, Plymouth Gentian is restricted to a small portion of the COSEWIC Atlantic Ecological Area in southwestern Nova Scotia, thus Canadian populations should be considered a single designatable unit.

Special Significance

Plymouth Gentian is a globally rare species with a restricted range. It 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*), Threatened Water Pennywort (*Hydrocotyle umbellata*) and the Special Concern Long’s Bulrush (*Scirpus longii*), which collectively co-occur with Plymouth Gentian on five lakes.

Plymouth Gentian populations in Nova Scotia are separated by 400+ km from the nearest sites in Massachusetts, and support much higher chloroplast diversity than United States populations (Sutton 2008), suggesting they may have a disproportionate significance to the species as a whole (Lesica and Allendorf 1995; Garcia-Ramos and Kirkpatrick 1997; Eckert *et al.* 2008).

Plymouth Gentian serves as a showy flagship for other disjunct Atlantic Coastal Plain plants in southwest Nova Scotia. Its attractive flowers encourage the public to value habitats for these species and provide cottagers with an easily appreciated reason for good stewardship of what they might otherwise consider weeds of their beaches. The species' impressive floral display is recognized in Yarmouth County through the naming of one cottage road "Plymouth Gentian Lane" and through its adoption as the emblem of the Tusket River Environmental Protection Association, a local environmental group.

No evidence of local Aboriginal traditional knowledge on this species was found during the preparation of this report (Hurlburt pers. comm. 2011).

DISTRIBUTION

Global Range

Plymouth Gentian has a very limited global range (Figure 2) with three highly disjunct areas of occurrence: 1) on either side of the North Carolina – South Carolina border near the Atlantic Coast; 2) in coastal regions of Massachusetts and Rhode Island; and 3) in extreme southwestern Nova Scotia. It was reported as historically present in Connecticut in Keddy and Keddy (1984), but the species is not listed for that state in Fernald (1950), Magee and Ahles (1999) or NatureServe (2011). The species is also reported as established as an introduction in Virginia (NatureServe 2011). An estimated 10% of the global population occurs in Canada.

Canadian Range

In Canada, Plymouth Gentian is restricted to the COSEWIC Atlantic National Ecological Area in southern Yarmouth County in the extreme southwest of Nova Scotia (Figures 3 and 4). It is known only from the lower parts of the Tusket River watershed (including the Carleton River) and at one locality (Agard Lake) in the adjacent Annis River watershed, where it was reported by a local landowner to have been introduced around 1990 from plants taken from Wilsons Lake in the Tusket River system (Webster pers. comm. 2011). The plants at Agard Lake are considered wild for the purposes of this assessment. Even if originally introduced, they are from a native source and have persisted and spread over 20+ years, and COSEWIC follows the IUCN recommendation that self-sustaining populations resulting from translocations be included in wildlife species assessments regardless of the intent or means of the original introduction (Standards and Petitions Working Group 2006).

Confirmed extant populations (Table 1) are found on ten lakes (plus two hydrologically connected river shore areas) within an area 11 km east to west and 18 km south to north. Historical and presumed extirpated occurrences of Plymouth Gentian are known on two lakes affected by dams on the Tusket River and on one undammed lake. Additional historical reports previously mapped at Kempt Back, Kempt Snare, and Little Tusket lakes have not been relocated in comprehensive recent surveys (Blaney and Mazerolle pers. obs. 2012) and were likely actually from other known localities (see Table 2).

Table 1. Extant populations and sub-populations of Plymouth Gentian in Canada, with watershed and details of first observation. Number of mature individuals is somewhere between number of flower stems and number of rosettes. Counts are from 2010 and 2011 unless otherwise noted.

Pop#	Sub-pop	Population/ Sub-population	Watershed (sub-watershed)	First Observer / Year	Flower stems min	Flower stems max	Rosettes min	Rosettes max	Site notes
1		Agard Lake	Annis	Mills 1998	31	570	3,222	3,222	
2		Lake Fanning	Tusket (Carleton)	Fernald 1920	1,126	1,126	4,460	4,460	
3	a	Wilsons Lake	Tusket	Fernald 1920	28,100	28,100	276,000	289,000	
3	b	Bennetts Lake	Tusket	Fernald 1921	19,700	26,270	193,500	270,200	Fernald's "Goven Lake" records are from this lake, called "Coven Lake" on a 1919 map.
4	a	Travis Lake	Tusket	Keddy & Keddy 1982	100	300	1,200	3,600	
4	b	Pearl Lake	Tusket	Fernald 1921	5,500	6,500	67,300	75,000	
4	c	Tusket River - Hemlock Run	Tusket	MacKinnon 1999	100	300	500	3,700	Site not visited since 1999 but presumed extant because no development has occurred in area known to be occupied.
4	d	Third Lake	Tusket	Keddy & Keddy 1982	6,300	10,500	76,000	126,000	
4	e	Kegeshook Lake	Tusket (Cold Stream)	Fernald 1920	1,700	4,300	20,100	52,000	
4	f	Gillfillan Lake	Tusket	[Fernald 1921]	10,600	12,400	128,600	143,300	Fernald visited this lake and undoubtedly saw the species, although no specimen is known.

Pop#	Sub-pop	Population/ Sub-population	Watershed (sub-watershed)	First Observer / Year	Flower stems min	Flower stems max	Rosettes min	Rosettes max	Site notes
4	g	Lac de l'Ecole	Tusket	Keddy & Keddy 1982	150	300	500	1,000	
		TOTALS			**73,407**	**90,666**	**771,382**	**971,482**	

Table 2. Historical populations and sub-populations of Plymouth Gentian in Canada, with watershed, details of observation (first and last in all cases) and notes on status and locality. Populations 6 and 7 would have or may have historically been part of populations 3 and 4 (see Population Spatial Structure and Variability).

Pop #	Sub-pop	Population/Sub-population	Watershed (sub-watershed)	Current Status	First Observer / Year	Notes on Status and Uncertainties Regarding Locality
4	h	Canoe Lake	Tusket (Cold Stream)	probably extirpated	Fernald 1921	Noted as "scarce" at Canoe Lake on 1921 specimen label. Not seen since in repeated surveys.
5		Little Tusket Lake	Tusket - called Silver R. in this upstream section	historical-unknown	Erskine 1953	Specimen label = "Little Tusket Lake, Yarmouth Co." The lake now called "Little Tusket" is in Digby Co., 30 km north of the next nearest Plymouth Gentian record. Erskine may have been there, because on the same day he collected on Wentworth Lake in Digby Co., 18 km south of Little Tusket Lake, Digby Co. and along the same highway that would be used to access it. However, comprehensive 2012 surveys of the Digby Co. lake (Blaney and Mazerolle pers. obs. 2012) found no plants and it is most likely that Erskine was in Yarmouth Co. on a lake no longer called "Little Tusket", most plausibly on the widening in the Tusket River south of Lake Vaughan (formerly called Tusket Lake), which would be contiguous with the Tusket Falls sub-population below.
6	a/b	"Kempt Lake"	Tusket (Carleton)	historical-unknown	Erskine 1956	No such lake name in use today; reported as Kempt Back Lake in Pronych and Wilson (1993) and Kempt Snare Lake by NS DNR. Comprehensive surveys on both these lakes in 2012 (Blaney and Mazerolle pers. obs. 2012) did not find Plymouth Gentian. Suitable habitat is minimal on Kempt Snare Lake and Kempt Back Lake had a low dam affecting water levels until recently. The record was most likely actually from Travis Lake at Kemptville. J.S. Erskine collected a specimen from "Peach Lake, Kemptville" in 1954, obviously an error for Pearl Lake at Kemptville, so his "Kempt Lake" likely does not to refer to Pearl Lake.
7	a	"Reynardton Lake"	Tusket (Carleton)	presumed extirpated	Erskine 1956	No such lake name in use today; either from Lake Vaughan reservoir at the hamlet of Raynardton, or from Raynards Lake reservoir just upstream.
7	b	Lake Vaughan	Tusket (Carleton)	presumed extirpated	Fernald 1920	Called "Tusket (Vaughan) Lake" on Fernald's labels. Historic shoreline flooded by damming.
7	c	Tusket Falls	Tusket	historical-unknown	Roland 1941	Presumed to have occurred in the ~2 km of non-tidal river shore below the Tusket Falls dam. Nearly comprehensive surveys in the area (Blaney and Boates 2004; Blaney *et al.* 2011, Blaney and Mazerolle pers. obs. 2012) have found no plants and limited suitable habitat.
7	d	Gavels Lake	Tusket	presumed extirpated	Fernald 1920	Called "Gavelton (Butlers) Lake" on Fernald's labels. Historic shoreline flooded by damming.

Travis, Pearl, Third, Gillfillan lakes, Hemlock Run, and Lac de l'Ecole are sub-populations of a single large population, connected by downstream flow in that order on the main branch of the Tusket River (Figure 3). The historical and probably extirpated Canoe Lake occurrence and the extant Kegeshook Lake occurrence are connected via Cold Stream into Gillfillan Lake, and are also sub-populations of this upper Tusket River population. Each upper Tusket sub-population is separated from nearest known plants in adjacent sub-populations by no more than 4 km. Occurrences on Wilsons and Bennetts lakes, separated by 750 m, represent sub-populations of a second population 13.5 km downstream from the upper Tusket River population.

Historical and probably extirpated occurrences on Gavels Lake, Lake Vaughan and at Tusket Falls would have been part of this population prior to damming of the lower Tusket River. It is also likely that the now isolated Lake Fanning population on the Carleton River branch of the Tusket River would have been connected to this larger population via Raynards Lake and the Carleton River.

Extent of Occurrence and Area of Occupancy

Under COSEWIC guidelines (COSEWIC 2010), extent of occurrence (EO) for extant sites in Canada is 182 km^2. If historical occurrences that are probably extirpated (Lake Vaughan, Gavels Lake and Canoe Lake), and questionably located (Little Tusket Lake) are included, EO would be about 520 km^2. Index of area of occupancy (IAO) for extant sites, derived using a 2 x 2 km grid aligned with 10 km x 10 km UTM grid squares, is 112 km^2. Well located historical but presumed extirpated occurrences would add approximately 28 km^2 to the IAO, and questionably located historical occurrences would add a maximum of 60 km^2 beyond that.

Search Effort

The presence of Atlantic Coastal Plain flora in southern Nova Scotia has been well known since Merritt Fernald's expeditions (Fernald 1921, 1922), which included the discovery of at least seven Plymouth Gentian occurrences. Extensive floristic work focused on the coastal plain flora in southern Nova Scotia has since been undertaken, starting in the 1950s to the 1970s by Chalmers Smith and students, by Albert Roland, and by John and David Erskine (as documented in Roland and Smith 1969). Paul and Cathy Keddy, Irene Wisheu, Nicholas Hill and their collaborators conducted detailed studies on the ecology, distribution and local diversity of Nova Scotian coastal plain flora with a focus on conservation implications (P.A. Keddy 1984, 1985, 1989; Keddy and Wisheu 1989; Wisheu and Keddy 1991; Hill and Keddy 1992; Wisheu and Keddy 1989; 1994; Wisheu *et al.* 1994; Holt *et al.* 1995; Morris *et al.* 2002). This work included visits to all major lakes through which the lower Tusket River flows and many nearby lakes. More recently, extensive floristic and conservation work has been conducted by Atlantic Canada Conservation Data Centre (AC CDC), Nova Scotia Department of Natural Resources, Nova Scotia Nature Trust and Mersey Tobeatic Research Institute (MTRI) (*e.g.* Eaton and Boates 2003; Blaney 2002, 2004, 2005a, 2005b; MTRI 2010; Blaney and Mazerolle 2009, 2010, 2011; Blaney *et al*. 2011). 2011 and 2012 fieldwork included visits to 23 additional lakes in the vicinity of known Plymouth Gentian occurrences.

There have been hundreds of field days since 1920 spent around lakeshores in Plymouth Gentian's potential range by botanists capable of identifying the species. Search effort is certainly sufficient to say that the species is very restricted within the Atlantic Coastal Plain flora zone of southwestern Nova Scotia. The completeness of the search effort is demonstrated by the fact that despite 58 lakes in or near the Tusket watershed having been visited by botanists since 1983, there have only been two new Plymouth Gentian sites found (small occurrences on the Tusket River around Hemlock Run and one at Agard Lake, which may have originated from a 1990 introduction – see *Canadian Range*) since the original COSEWIC status report (Keddy and Keddy 1984)[1]. Plymouth Gentian records in Nova Scotia are restricted to larger lakes with large watersheds above them, and there are no such lakes around Plymouth Gentian's lower Tusket River area of occurrence that remain unsurveyed. There are, however, still many lakes in southwest Nova Scotia that have seen little or no botanical survey. Plymouth Gentian occurs on small lakes in Massachusetts, and additional populations, though clearly rare, could be found if the species happened to have dispersed to a hydrologically suitable smaller lake. The most likely locality for additional occurrences is the 8.5 km of the Tusket River between Gridiron Lake and Wilsons Lake and the 1.4 km of the river between Lac de l'Ecole and Gillfillan Lake. These are the only portions of the river within Plymouth Gentian's current range in which survey has been minimal. Numbers are unlikely to be high if the species is present given that most river shore habitat is unsuitable and only very small populations occur on the Tusket River near Hemlock Run. A 1956 record from "Raynardton Lake" (either Lake Vaughan at

[1] COSEWIC (1999) reported the Lac de l'Ecole population as a post-1984 discovery. However, Keddy and Keddy (1984) mapped a population from Lac de l'Ecole, though they did not distinguish the lake from the Tusket River on their map.

Raynardton settlement or Raynards Lake, both of which were reservoirs at that time) suggests that Plymouth Gentian may have persisted well after dam construction and that further inventory of reservoir shorelines might reveal small occurrences in isolated pockets of suitable habitat, although limited field surveys between 1982 and 2011 on the Tusket River reservoirs have not located any Plymouth Gentian.

HABITAT

Habitat Requirements

In New England, Plymouth Gentian is mostly found on sandy, gravelly or muddy shores of small kettle ponds (Orrell Elliston 2006). These ponds, formed from the melting of chunks of glacial ice, are frequently hydrologically isolated and are subject to major inter-annual water level fluctuations. In the Carolinas, the species occurs on frequently flooded shores of ponds, rivers or acidic cypress-gum swamps. The species can sometimes occur in logging road ditches or similar disturbed ground within these habitats, and although never brackish, in some cases occupied habitats are influenced by tides (Sutton 2008; Buchanan pers. comm. 2011; Brown pers. comm. 2012).

In Nova Scotia, Plymouth Gentian occurs on lakeshores (rarely river shores) on sand, gravel, peat and small rock substrates, within the zone that is flooded each winter and annually or semi-annually exposed as lake levels recede in summer. Plymouth Gentian and other rare Atlantic Coastal Plain plants of lakeshores are largely restricted to low biomass areas where low nutrient conditions and flooding, wave action and ice scour limit more competitive, higher biomass species (Keddy and Wisheu 1989; Sweeney and Ogilvie 1993; Morris *et al.* 2002).

The occurrence of Plymouth Gentian and many other lakeshore Atlantic Coastal Plain species is strongly correlated with large upstream catchment areas, ranging from 66,000 to 107,000 ha, except for Lake Fanning, on the Carleton branch of the Tusket, with a catchment of 26,000 ha. Biomass and shoreline fertility (organic matter and nitrogen and phosphorus content) decrease from headwater lakes to lakes near the river mouth (Holt *et al.* 1995) because flooding, waves, river current and ice scour remove fine particles and nutrients from the soil to a greater degree downstream (Keddy 1983, 1984, 1985). Habitat also tends to increase downstream because of increased average shoreline width. In addition to reducing competition, high water levels also appear critical for Plymouth Gentian in providing winter insulation from freezing. Hazel (2004) found 100% mortality of young Plymouth Gentian when plants were exposed to winter temperatures above water.

Habitat Trends

The most significant threat to Plymouth Gentian habitat is eutrophication associated with mink farming and perhaps with other unknown sources (see *Threats and Limiting Factors*). There are many small, local anthropogenic disturbances within

Plymouth Gentian habitat associated with cottages (or less frequently permanent residences), and these will increase as development continues. Off-highway vehicles (OHV) are also damaging habitats at Wilsons Lake and Pearl Lake. Neither of these two threats are currently affecting a high proportion of the total population or of any sub-populations, nor are they expected to do so in the next 15 years (three generations).

a) Historical habitat loss

In 1929 and the following few years, Plymouth Gentian on at least two and probably four or more lakes was extirpated by construction of hydroelectric and headpond dams at Lake Vaughan, Raynards Lake, and Gavels Lake. These dams flooded the original shores and altered water level variation. Fernald (1921, 1922; AC CDC 2011) documented Plymouth Gentian at Lake Vaughan and Gavels Lake. Plymouth Gentian likely also occurred at Kings and Raynards lakes given its presence immediately upstream and downstream, and modelling that has confirmed the habitat would have been hydrologically suitable (Hill *et al.* 1998). Precise maps of the area from prior to 1929 are not available, but water depth data (Nova Scotia Power 2009) suggests that prior to damming there were more than four lakes connected by narrow river segments. The proportion of original Canadian Plymouth Gentian habitat lost may have been as much as 47%, given that the current shoreline on the reservoir lakes is about 63 km and Plymouth Gentian currently occupies about 72 km of shoreline. This value would be even higher if plants had been on Ogden, Parr, and Petes lakes on the Carleton River near Lake Fanning, where water levels were controlled by smaller, non-hydroelectric dams up to 1960.

b) Ongoing habitat loss and degradation

Eutrophication is a major new issue threatening Plymouth Gentian habitat (see *Threats and Limiting Factors*). The primary impact of eutrophication is increased competition from more common shoreline plants. Presumed eutrophication-induced impacts have been observed on Lake Fanning but not yet on other Plymouth Gentian lakes. These include greater abundance and density of competing native vegetation (especially Golden Hedge-hyssop, *Gratiola aurea*) and local occurrence (but not yet direct competition from) the invasive exotic Reed Canary Grass (*Phalaris arundinacea*, a species almost never seen in nutrient-poor lakes). It has expanded on Lake Fanning since 1988 to become fairly common on the lakeshore, including one case where it is within 1 m of Plymouth Gentian.

Eaton and Boates (2002) suggested the greatest threat to Plymouth Gentian habitat was shoreline development. They analyzed human impacts on shoreline buffer vegetation within 100 m of Plymouth Gentian lakes and found 2.7% loss of that buffer zone between 1945 and 2000. Actual loss of Plymouth Gentian habitat over the same period is clearly much less than 2.7% because almost all the footprint of cottage development is outside the shoreline zone occupied by Plymouth Gentian and there is little shoreline impact that is not associated with development. There are approximately 200 cottages or homes on Plymouth Gentian lakes (see *Habitat Protection and Ownership*). If each one completely eliminated Plymouth Gentian over 10 m of shoreline that would amount to 2.8% loss (2.0 km out of 72 km of occupied shoreline). Actual habitat loss in the past three generations (15 years) is much less than 2.8% based on Blaney (pers. obs. 2002-2011) because: 1) a very high proportion of existing development occurred more than 15 years ago; 2) most cottages alter less than 10 m of Plymouth Gentian habitat; and 3) Plymouth Gentian sometimes persists in altered habitat. New shoreline development and intensification of existing shoreline development is ongoing, however, especially at Third, Gillfillan, and Bennetts lakes, and potentially at the north end of Wilsons Lake, where a new access road to the shore was recently completed on a property having 1 km of shoreline and supporting the densest Plymouth Gentian occurrence in Canada. Future development impacts cannot be predicted, but if the current pace and average impact of new development is maintained, it is unlikely that resulting declines of Plymouth Gentian habitat would reach 10% in the next 10 to 15 years, especially if current management actions (i.e. landowner education and shoreline monitoring efforts, enforcement of shoreline regulations) are continued. The threat posed by future development is also somewhat mitigated by the relatively high proportion (38%) of Plymouth Gentian habitat within protected areas and Crown land (see *Habitat Protection and Ownership*).

Off-highway vehicle traffic (OHV) is having locally significant impacts on Plymouth Gentian habitat on Wilsons Lake (Figure 5) and Pearl Lake. In both cases well used OHV trails traverse dense Plymouth Gentian populations, damaging habitat and crushing or killing many plants. On Wilsons Lake, this represents about 25% damage of shoreline habitat over not more than 2 km of the 11.1 km of lakeshore (Blaney *et al.* pers. obs. 2011), suggesting a maximum of 5% habitat damage on the lake in 2011, and damage at Pearl Lake is roughly of the same magnitude (Hill pers. obs. 1988-2011; observations in 1993 and 2011). Heavy OHV damage reported at Gillfillan Lake in Wisheu and Keddy (1991), Newell (1999) and Sutton (2008) was not evident in 2011 but only two-thirds of the lakeshore was visited.

BIOLOGY

Life Cycle and Reproduction

Plymouth Gentian is a clonal perennial that reproduces from seed, from the vegetative production of daughter rosettes at the tips of green stolons, and from vegetative fragments moved by ice and water.

In Nova Scotia, flowering occurs from middle or late July into late September. Rosettes produce a single flowering stem, typically with one or two flowers (less commonly up to five flowers). Average flowers per stem ranged from 1.22 to 1.40 on five Nova Scotia lakes in 2011 (Hill, unpubl. 2011). Flowers are protandrous (male fertile first) and as the flower develops, the stigma swings from a position appressed to the base of the petals and it passes through the flower to become upright as the stigmatic surface becomes receptive. The style arms open to expose the stigmatic surface, at which point the flower may receive pollen from a variety of insect pollinators. Plymouth Gentian is self-compatible (Hill *et al*. 2006; Sutton 2008).

The majority of the rosettes in healthy Plymouth Gentian populations in Nova Scotia are in large interconnected clones. At Wilsons Lake, 90% of all rosettes are in interconnected groupings of 10-300 rosettes (Hill, unpubl. 2011). The smaller the grouping of rosettes, the larger the flowering rate (30% of rosettes flower when in groupings of 1 to 10 rosettes, 8% flower in groups of 10 to 50, and 4% flower in groups of 50 to 300; Hill, unpubl. 2011).

Seed set occurs in late summer and capsules release from 300 to 1400 tiny seeds in September (Hill *et al*. 2006). The tiny dimpled (punctate) seeds can float at least one day (Hill *et al*. 2006) but dispersal distances have not been tracked. Cold stratification is required for germination (Brumback 1983; Hazel 2004; Orrell Elliston 2006; Hill *et al*. 2006) and germination likely occurs during the late spring drawdown in lake water levels. Orrell Elliston (2006) documented complete local loss of adult plants after several high-water years, followed by recovery from seed to near initial population levels. She concluded that seed banking was very important for the long-term persistence of Plymouth Gentian in Massachusetts kettle ponds. With 156 seeds/m^2, Plymouth Gentian was the eighth most abundant of 36 species detected in the July seed bank in a dense population on Wilsons Lake, but it was under-represented in the seed bank relative to above ground numbers (Wisheu and Keddy 1991). Seed banking may be less significant in Nova Scotia than in Massachusetts because of Nova Scotia's more consistent range of water level fluctuation on lakes vs. Massachusetts' precipitation-fed ponds. Longevity of seed in the seed bank is unknown. Hill *et al.* (2006) found 69% germination of fresh seed in laboratory cultivation on wet peat after two months of cold stratification. Upon germination small rosettes form, which can reproduce sexually after two years (very rarely one year) under ideal conditions, but which generally grow for at least three to five years before flowering (Orrell Elliston 2006). Rosettes die after flowering (Orrell Elliston 2006; Hill pers. obs. 1988-2011), but it is unclear how long entire plants, which may be composed of many connected rosettes, can live. Vegetative reproduction by stolon growth and formation of new rosettes can begin in a plant's second year (Orrell Elliston 2006) in Massachusetts but could be somewhat slower in the cooler conditions of Nova Scotia. If the majority of rosette death is from flowering, and death of rosettes is balanced by new rosette formation, the ratios of rosettes to flowering stems would suggest that Nova Scotia rosettes could live as long as 12 years (Table 1), but the extent to which these assumptions are met is unclear.

Generation time is not known, but given that vegetative reproduction seems to predominate in Nova Scotia and that rosettes may reproduce vegetatively in their second year, the average age of reproductive individuals is likely in the range of five years or less.

Physiology and Adaptability

Plymouth Gentian is an obligate wetland plant throughout its range (Reed 1988; Blaney 2011). In Nova Scotia Plymouth Gentian is only able to occupy a narrow zone of seasonally flooded, low biomass lakeshore because it is limited both by its poor competitive ability and its requirement for winter submergence to avoid freezing temperatures (Hazel 2004). Occurrence in Nova Scotia may also be limited by climate given that it is at the northernmost edge of its range, although its small extent of occurrence could also be a consequence of dispersal limitations.

Keddy (2010) describes Plymouth Gentian as a stress-tolerator (*sensu* Grime 2001) because it inhabits a nutrient-poor habitat and has the nutrient conserving strategy of evergreen leaves. It is not known to have the special mechanisms for the uptake of carbon dioxide from the water column found in co-occurring species when their rosettes are submerged (e.g. quillworts - *Isoetes* spp., Water Lobelia - *Lobelia dortmanna,* Pipewort - *Eriocaulon aquaticum* and Golden Hedge-hyssop; Boston *et al.* 1987). The resulting carbon physiology advantage would not be as important a factor in competitive relations where mineral nutrients are limiting, but could become more significant with eutrophication, as at Lake Fanning, where Golden Hedge-hyssop appears to be having a competitive impact on Plymouth Gentian (see *Threats and Limiting Factors – Eutrophication*).

Dispersal and Migration

Plymouth Gentian disperses by seed and by vegetative means. Vegetative dispersal occurs over short distances by stolon growth and establishment of new rosettes and over longer distance via plant fragments, either loose rosettes or sods (soil patches held together by roots) containing the plant, both of which are observed on Nova Scotia lakes (Hill pers. obs. 1988-2011). Potential dispersal distances would likely be greatest for the tiny seeds and least for sods. All these units are likely dispersed largely by water, although seeds could also be dispersed by strong winds and in mud on animals or OHV. The seeds are tiny, dimpled, and can float for at least a day because of small volumes of trapped air in each dimple. Seed release occurs in September and large seedling populations were observed in October 2001 (Hill pers. obs. 1988-2011). Stems do not remain standing through the winter, so dispersal across ice is likely limited. Lake to lake dispersal would likely be predominantly downstream via the connecting rivers, but wind, waves and ice movement (which is the primary force moving sods) could disperse propagules in any direction within a lake.

Migration of Plymouth Gentian 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 Plymouth Gentian 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 Plymouth Gentian over geological time. The only possible major dispersal of Plymouth Gentian known in contemporary time is the suspected anthropogenic introduction of Plymouth Gentian in sod from Wilsons Lake to Agard Lake (8.5 km) in the 1990s (see *Canadian Range*). A low rate of upstream dispersal is demonstrated by the failure of Plymouth Gentian to colonize good habitat on Parr and Ogden lakes (where a dam was removed in 1960) that is only 4 km by water and 2 km by land from occurrences on Lake Fanning (Hill *et al.* 1998).

Interspecific Interactions

<u>a) Competition</u>

Plymouth Gentian requires shoreline habitats with limited competition from other plants and is therefore restricted to shores where acidic, naturally infertile conditions are reinforced by flooding, wave wash and ice scour (see *Habitat Requirements*). Gaudet and Keddy (1995) found that Plymouth Gentian was 36th out of 44 wetland species in its ability to suppress Purple Loosestrife (*Lythrum salicaria*) when the two species were grown in a single pot. Gaudet and Keddy (1988) suggested that plant size was an important determinant of competitive dominance in pairwise comparisons. The small stature of Plymouth Gentian rosettes and the species’ poor competitiveness (Gaudet and Keddy 1995; Keddy *et al*. 1998) suggest that most species overtopping the rosettes would outcompete them.

b) Other interactions

Mutualism with generalist pollinating insects ensures cross-pollination. It is not essential in the short-term because Plymouth Gentian is self-compatible (see *Life Cycle and Reproduction*), but may be important in relieving inbreeding depression such as occurs at Wilsons Lake (Hill *et al*. 2006). Pollinators documented in Nova Scotia are primarily flower flies (Syrphidae), sweat bees (Halictidae), European Honeybee (*Apis mellifera*) and *Bombus* bumblebees (Trant *et al.* 2010; Hill *et al.* 2006). Casual observation in 2011 documented a *Bombus* species (either *B. ternarius* or *B. rufocinctus*), the syrphid fly *Meliscaeva cinctella* and an unidentified small muscoid fly on Plymouth Gentian flowers (Blaney *et al.* pers. obs. 2011, identifications by John Klymko, AC CDC). Orrell Elliston (2006) recorded various other potential pollinators in Massachusetts, noting the Banded Longhorn Beetle (*Typocerus velutinus*) as the most frequently observed pollinator, as well as ladybird beetles (*Coleomegilla maculata* and an unidentified species), the syrphid fly (*Toxomerus marginatus*, reported as *Episyrphus* species with revised identification by John Klymko, AC CDC), and scarab beetles (*Popillia japonica* and *Anomala* species). A wide range of generalist pollinating insects, especially other bees and wasps, may be involved in pollination of Plymouth Gentian because leaf-cutter bees (Megachilidae), andrenid bees (Andrenidae), small carpenter bees (Anthophoridae) and sand wasps (Sphecidae) are known from the similar flowers of Common Rose Pink (*Sabatia angularis*) (Dudash 1990, 1993; Spigler *et al*. 2009). Crab spiders, including Goldenrod Crab Spider (*Misumena vatia*; Harriet Irving Botanical Gardens 2011), a *Misumenops* species (Orrell Elliston 2006), and perhaps other species in the genera *Misumenoides* and/or *Mecaphasa* appear to be especially common predators of insects in Plymouth Gentian flowers (Hill *et al*. 2006).

Limited herbivory by White-tailed Deer (*Odocoileus virginianus*) on the flowering stalks was seen in 2011 (Hill pers. obs. 2011), but significant insect herbivory was not noted. The moth Shortlined Chocolate (*Agyrostrotis anilis*) is reported as a specialist herbivore of Common Rose Pink (Hilty 2011) but must also feed on other genera, because its range extends beyond that of Common Rose Pink at least to Ottawa, Ontario (BugGuide 2011). It does not appear to have been reported feeding on Plymouth Gentian in Canada or the United States, although the moth occurs in coastal Massachusetts (BugGuide 2011).

The importance of mycorrhizal associations with fungi is unknown for Plymouth Gentian, but most genera of Gentianaceae have mycorrhizae (Struwe and Albert 2002).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The occurrence of Plymouth Gentian in Canada, in terms of lakes on which the species occurs and distribution within those lakes, was fairly completely understood prior to this report so the 12 person-days of fieldwork in 2011 for this report concentrated on understanding population numbers, checking unsurveyed lakes in close proximity to occupied lakes (Long Lake, Springhaven Duck Lake, English Clearwater Lake, Lac à Pic), and searching for an historical population (Canoe Lake). Populations were counted comprehensively on Wilsons Lake and Lake Fanning and over about two-thirds of Gillfillan Lake by walking shorelines. Small populations were counted individually or estimated directly, and large populations (typically at the scale of 20 m to 500 m of shoreline) were estimated based on counts per metre of shoreline multiplied by shoreline distances measured by GPS. The population estimate on Lake Fanning should be quite accurate because of the low numbers involved. Huge numbers on other lakes means greater uncertainty associated with population estimates, but this uncertainty was not quantified mathematically. On the lakes on which the species was not found, shorelines were walked completely (Canoe Lake), or were covered completely (Springhaven Duck Lake, Long Lake, Lac à Pic) or within the most promising habitats (English Clearwater Lake) by a combination of canoeing and walking. Similar methods were used by AC CDC and MTRI in 2012 (Blaney and Mazerolle pers. obs. 2012) to comprehensively cover 11 additional lakes.

For other lakes, populations were derived from various field surveys unrelated to this report.

Defining Populations

COSEWIC separates populations if there is typically less than one successful genetic exchange per generation. Because both genetic exchange rates and generation time are hard to quantify for Plymouth Gentian, populations are defined in this report using standards in NatureServe (2004), under which occurrences meeting one of the following conditions are grouped into a single population: 1) occurrences separated by less than 1 km, 2) occurrences separated by 1 to 3 km with no break in suitable habitat between them exceeding 1 km, 3) occurrences separated by 3 to 10 km but connected by linear water flow with no break in suitable habitat between them exceeding 3 km. Under these standards, five populations occur in Canada (Table 1; Figure 4), the first four of which are known to be extant: 1) Agard Lake; 2) Lake Fanning; 3) Wilsons and Bennetts lakes; 4) middle Tusket River, including Travis Lake, Pearl Lake, the Hemlock Run area along the river, Third Lake, Kegeshook Lake, Gillfillan Lake, Lac de l'Ecole and Canoe Lake; 5) Raynards Lake, Lake Vaughan and Gavels Lake reservoirs plus the Tusket Falls area, all of which may be extirpated (see *Population Spatial Structure and Variability* for relation between population 5 occurrences and populations 2 and 3 above). Historical reports from Kempt Back, Kempt Snare and Little Tusket Lakes were likely actually from sites listed above (Table 2).

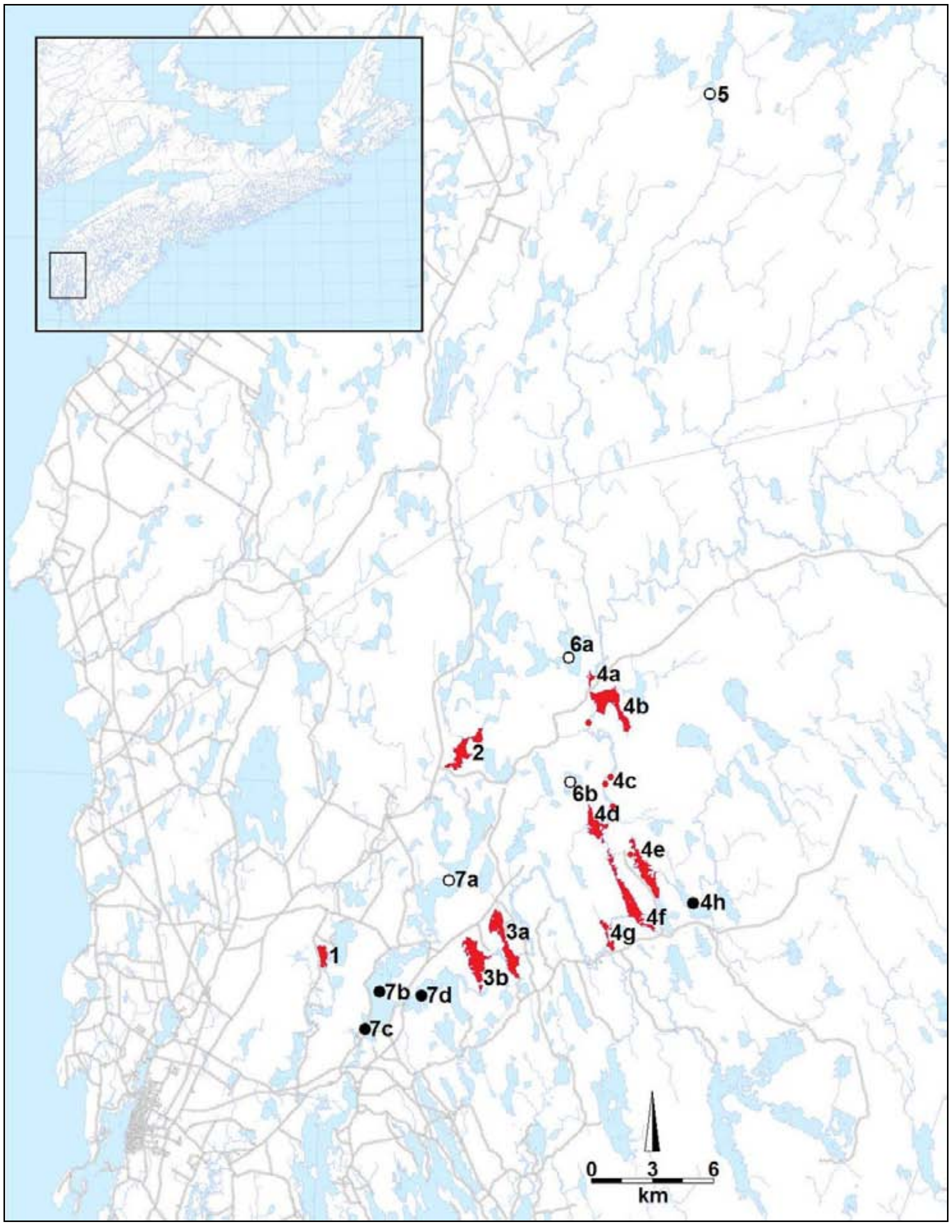

Figure 4. Distribution of Plymouth Gentian (*Sabatia kennedyana*) populations (numbers) and sub-populations (letters following numbers) in Nova Scotia. Shaded lakes support extant populations. Small red dots (*i.e.* at 4c) are isolated occurrences on river shores. Filled dots are historical occurrences with imprecise localities within a known lake. Unfilled dots (5, 6a, 6b and 7a) are historical occurrences with uncertain localities as to lake (see Table 2). Numbering corresponds to Table 1. Inset map shows sites in Nova Scotia.

Abundance

It is difficult to count "mature individuals" (those capable of sexual or vegetative reproduction, COSEWIC 2010) for Plymouth Gentian. Number of flowering stems and number of rosettes are easily counted, providing a good index of abundance, but neither equate to number of COSEWIC mature individuals. Number of "mature individuals" is greater than the number of flowering stems (because larger rosettes are capable of producing daughter rosettes, and larger rosettes are likely capable of survival when severed by ice or other disturbance), but is less than the number of rosettes (because first year and perhaps many other rosettes are too small for vegetative or sexual reproduction). The total Canadian population is roughly estimated to include between 73,400 and 90,700 flowering stems and 771,400 and 971,500 rosettes, with number of mature individuals between those values (Table 1).

Although major fluctuation in numbers is not known in Nova Scotia (see *Fluctuations and Trends*), detectability varies significantly with water levels. High water reduces flowering, making plants less visible from a distance and often obscuring rosettes at depths below about 15 cm because of naturally dark, tannic lake water (Blaney *et al*. pers. obs. 2011). This is important to understand when evaluating counts in Table 1 against any future survey values. It is also important to note that estimates of larger populations have large confidence intervals.

Extant Canadian occurrences comprise two small populations (Agard Lake and Lake Fanning, each under 5,000 rosettes) and two very large, extensive populations on the main Tusket River and its Cold Stream tributary. The Wilsons and Bennetts lakes population on the lower Tusket River contains between 55% and 63% of the Canadian population, with each lake estimated to have 155,000 to 289,000 rosettes. The extensive upper Tusket River population includes large populations (estimated at 20,000 to 143,000 rosettes) on Pearl, Third, Gillfillan and Kegeshook lakes and small populations (estimated to have no more than 3,600 rosettes) on Travis Lake, the Tusket River near Hemlock Run (between Pearl and Third lakes) and on Lac de l'Ecole (Tables 1 and 4).

Fluctuations and Trends

Extreme population fluctuations of Plymouth Gentian have been documented from glacial kettle pond shorelines in Massachusetts (Orrell Elliston 2006). Counts of vegetative rosettes plus flowering plants declined at five different ponds by 70% to 96% (Orrell Elliston 2006) between 1996 and 1999 in association with multiple years of high water levels and limited exposed shoreline. Complete demographic monitoring in 2 x 2 m plots showed that small scale, dense occurrences could decline to zero and then recover from seed to approximately original density over a five-year period. No such dramatic population fluctuations are known in Nova Scotia, perhaps because the lakeshore habitat in Nova Scotia has much more consistent water level fluctuation than the glacial kettle ponds in Massachusetts. Kettle ponds are fed exclusively by precipitation and may experience minimal summer drawdown in wet years, or dry up completely during drought. Sutton (2008) reported an 87% decline in flower (but not rosette) density in her plots on Gillfillan Lake between 2005 and 2006 associated with high water levels. Casual observations from Wilsons and Gillfillan lakes (Blaney pers. obs. 2002-2011) suggested similar high water effects on numbers of flowering individuals (but not necessarily rosettes), especially lower on the shoreline, where plants are closer to their maximum depth tolerance.

Available survey data are insufficient for direct assessment of fluctuations or long-term trends in Canadian populations; however, populations appear to have been relatively stable between 1984 and 2011. All, or almost all, the occurrences mapped as extant in Keddy and Keddy (1984) seem to remain extant. Extensive observations by various botanists over multiple years (*i.e.* Nick Hill 1988 to 2011, Sean Blaney 2002 to 2011, Ruth Newell 1980 to 2010, Pamela Mills 1997 to 2008) have not produced anecdotal accounts of major declines or increases, with the possible exception of Agard Lake where a possible expansion in numbers and area has been noted between 1999 and 2010 (Pamela Mills data in AC CDC 2011; MTRI 2010). This increase would be consistent with ongoing expansion after deliberate introduction, which is reported to have occurred in 1990 (see *Population Spatial Structure and Variability*). The much higher reported numbers in this report compared to those in Keddy and Keddy (1984) are almost certainly a result of more comprehensive and detailed surveys and the counting of rosettes as well as flowering plants.

Declines relative to historical population and distribution have obviously occurred. Plymouth Gentian is no longer known on three lakes on which it was recorded by Fernald (1921, 1922). Two of these, Lake Vaughan and Gavels Lake (called “Tusket (Vaughan) Lake” and “Gavelton (Butlers) Lake” on Fernald’s labels), have been subject to dam-controlled water levels since about 1929. The now flooded lower Tusket lakes could have supported hundreds of thousands of rosettes, as currently occur at nearby Bennetts and Wilsons lakes, given that current lakeshore distance on the reservoir lakes is about 63 km (vs. 72 km of currently occupied shoreline in Canada). Fernald also noted Plymouth Gentian as “scarce” on Canoe Lake in 1921 (Gray Herbarium label data in AC CDC 2011). The species is probably extirpated on Canoe Lake as it has not been documented there since 1921, despite thorough surveys by Paul and Cathy Keddy in 1982 (Keddy and Keddy 1984), Dave MacKinnon in 1995, Pamela Mills in 2003 (AC CDC 2011; Mills pers. comm. 2011) and a complete shoreline survey on foot by Sean Blaney, David Mazerolle and Nicholas Hill in 2011. Cause of extirpation on Canoe Lake is unclear. It may represent natural loss of a small population, disturbance from one of the relatively small number of cottages or perhaps flooding by a short-lived dam from the river-driving era (although no evidence of a dam was visible during 2011 survey around the outlet). The 1941 Tusket Falls occurrence, presumably just below the dammed portion of the river, may also now be extirpated. Partial surveys in that area have found no Plymouth Gentian and little suitable habitat (Blaney pers. obs. 2002-2011; Blaney *et al.* pers. obs. 2011).

Observations of high flower to rosette ratio and unusually robust competitors (see *Threats and Limiting Factors*) suggest the small Lake Fanning population may be suffering from increased competition induced by eutrophication. Data is, however, insufficient to demonstrate population decline. Eutrophication documented on the Tusket River lakes (MTRI 2011) that support 98% of the Canadian population of Plymouth Gentian could represent the early stages of a significant negative habitat and population trend. Local, small-scale losses from cottage construction and associated impacts and through OHV use are also ongoing (see *Threats and Limiting Factors*).

Available evidence suggests that the overall population trend for Canada over the past 15 years (3 generations) is likely a minor decline of less than 2%. The magnitude of the presumed population decline over the next 15 years cannot be predicted but will likely be largely determined by the extent to which eutrophication continues to impact Plymouth Gentian.

Rescue Effect

The 400+km disjunction across the open Atlantic Ocean between Canadian sites and the next nearest populations in Massachusetts means that there is a negligible chance of any rescue effect from occurrences in the United States.

THREATS AND LIMITING FACTORS

Eutrophication

Since the last status report (Newell, 1999), eutrophication has changed from a theoretical threat (Moore *et al.* 1989; Eaton and Boates 2003; Environment Canada and Parks Canada Agency 2010; Brylinsky 2011a) to the most significant actual threat. Eutrophication from residential and agricultural sources can have a detrimental impact on coastal plain shoreline flora, primarily through increased competition from more common, robust plant species (Ehrenfeld 1983; Zaremba and Lamont 1993). The threat of eutrophication has recently become significant because of expansion of large mink farms on the upper Carleton River watershed, making it the most immediate threat to Plymouth Gentian on Lake Fanning. Except for Kegeshook Lake and possibly Agard Lake (where no water quality testing has taken place), it is also now the most immediate threat to all extant sub-populations. Very large (608% to 819%) increases in total phosphorus have been documented in Wilsons, Bennetts and Pearl lakes on the main branch of the Tusket River since 2002 (MTRI 2011). Third Lake and Lac de l'Ecole in between these lakes, and Travis Lake (contiguous with Pearl Lake just upstream; Figure 3) are likely also affected to a similar degree. One mink farm is present just upstream from Pearl Lake, but it is not known if it is causing the observed eutrophication in the Tusket system. Kegeshook Lake, which is on the Cold Stream branch of the Tusket River, is the only other Plymouth Gentian lake for which nutrient level information is available, and it has not changed significantly since 2002. Future testing will be required to determine if 2011 results were an anomaly. Collectively, lakes known or probably subject to eutrophication impacts contain 89% of Plymouth Gentian habitat in Canada as measured by shoreline distance of occupied lakes.

Effects are most advanced on Lake Fanning, where major cyanobacterial blooms caused by a 1000% increase in total phosphorus since 2002 (MTRI 2011) have been evident since at least 2007 (Taylor 2010; Brylinsky 2011a, 2011b, 2012; Table 3). Algal blooms occur with the addition of nitrogen and phosphorus to the river system. The decay of the algae depletes oxygen, kills fish and bottom-dwelling animals, and thereby creates “dead zones” in the body of water (Carpenter 2008). In the other lakes on the main branch of the Tusket River, more work is needed to confirm that the increased phosphorus levels of 2011 are not an anomaly and to confirm the nutrient source(s), but the results appear robust. Nutrient values were obtained by averaging repeated measurements taken in the same deeper portions of the lakes across whole summers. The fact that the trend in nutrient levels was in a uniform direction and of similar magnitude across all lakes on the main Tusket system, but that Kegeshook Lake on a different river branch was unaffected, also strongly suggests that results were real. Although no impacts on Plymouth Gentian or shoreline communities on the main branch of the Tusket River have yet been documented, concern over eutrophication impacts is justified because:

1) Plymouth Gentian is a poor competitor adapted to low nutrient shorelines and is likely to fare poorly under increased competition;
2) All Plymouth Gentian lakes would likely have been oligotrophic (low nutrient) under natural conditions (Eaton and Boates 2003);
3) Comparison of 2011 (MTRI 2011) and 2002 (Eaton and Boates 2003) nutrient values show that since 2002, Wilsons Lake has changed from oligotrophic to eutrophic, Bennetts Lake has changed from oligotrophic to mesotrophic and Pearl Lake has changed from mesotrophic to eutrophic (trophic status based on Carlson 1977);
4) Changes of the magnitude observed from 2002 to 2011 are unlikely to be of natural origin (Brylinsky pers. comm. 2011);
5) It is likely that Plymouth Gentian occurrences on the Tusket River system between Pearl and Wilsons lakes (Tusket River – Hemlock Run, Third Lake, Gillfillan Lake and Lac de l’Ecole) are experiencing similarly increased nutrient levels;
6) Changes in lake ecology and effects on Plymouth Gentian that are likely related to eutrophication are being observed on Lake Fanning at similar phosphorus levels to those recorded on Pearl Lake in 2011 and can be expected throughout the main branch of the Tusket River if high nutrient levels continue. Collectively, affected lakes on the main branch of the Tusket River support 98% of the Canadian population.

Table 3. Water quality data for Plymouth Gentian lakes from 2002 (Eaton and Boates 2003) and 2011 (MTRI 2011). Carlson's trophic status index value for total phosphorus = 14.42 (ln(TP)+4.15)) (Carlson 1977).

Parameter	Lake				
	Bennetts	**Fanning**	**Kegeshook**	**Pearl**	**Wilsons**
Total phosphorus 2002	9.67	10.33	5.67	11.67	8.33
Total phosphorus 2011	77.00	103.33	1.00	95.50	50.67
Total phosphorus proportion increase 2002-2011	796.55	1000.00	17.65	818.57	608.00
Carlson's trophic status index value for TP 2002	36.86	37.83	29.16	39.58	34.72
Carlson's trophic status index value for TP 2011	66.79	71.03	4.15	69.89	60.75
TROPHIC STATUS (Carlson 1977) 2002	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic
TROPHIC STATUS (Carlson 1977) 2011	Eutrophic	Eutrophic	Oligotrophic	Eutrophic	Mesotrophic

Mink farming has undergone rapid expansion in Nova Scotia over the past decade and there are now about 1.4 million pelts produced annually by 152 farms, about 75% of which are in Yarmouth and Digby Counties (Flemming pers. comm. 2011). There are documented problems with effluent from mink farms upstream from Lake Fanning (Wendland 2010; Shelburne County Today 2011), and the high concentration of mink farms in the Carleton River headwaters has been identified as the cause of eutrophication in the Carleton River system (Brylinsky 2012). Phosphorus entering the headwater lakes is carried downriver to Lake Fanning, which 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). "Most of the phosphorus was present in the dissolved inorganic form which is not typically found in high concentrations in aquatic ecosystems because of its rapid assimilation by aquatic plants. This suggests that the major source of phosphorus is most likely to be a result of mink farm operations that utilize superphosphate, a substance used to increase the shelf of mink feed and to reduce the occurrence of kidney stones in mink livestock" (Brylinsky 2011a). Total phosphorus in Lake Fanning increased 1000% between 2002 and 2011 (Table 3). Once phosphorus has entered the system, the recovery of eutrophic lakes 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). Large rafts of condensed blue-green bacterial colonies were observed in 2011 (Hill pers. obs.), and these could cover Plymouth Gentian rosettes if they become more extensive. The Lake Fanning shoreline also supports exceptionally luxuriant mats of Golden Hedge-hyssop that are dense enough to make counting Plymouth Gentian rosettes difficult at several sites (Blaney *et al*. pers. obs. 2011), suggesting a strong competitive effect. Golden Hedge-hyssop (which is common on most Plymouth Gentian lakes at lower densities) is likely responding more successfully to higher nutrient levels on Lake Fanning than is Plymouth Gentian. In 2011, Plymouth Gentian on Lake Fanning also had especially low rosette to flowering stem ratios (average of three vegetative rosettes per flowering stalk, vs. 13, nine and seven vegetative rosettes per flowering stalk on Gillfillan, Pearl and Wilsons lake plots (Hill, unpubl. 2011)), with many flowering stems having few or no non-flowering rosettes nearby. Because rosettes die after flowering, this could indicate low population vigour and a declining population, especially if establishment from seed is limited by increased competition.

Shoreline Development

Shoreline development is considered a significant threat to Atlantic Coastal Plain flora communities on lakeshores (Wisheu and Keddy 1994; Eaton and Boates 2002; 2003; Environment Canada and Parks Canada Agency 2010). There are 221 small lakefront properties bordering shoreline known or presumed occupied by Plymouth Gentian, and these support about 36% of the Canadian Plymouth Gentian population (Table 4). Based on limited aerial photography analysis in Google Earth (Blaney, unpubl. 2011), 60% or more of those properties currently have cottages. An additional 31% of the Plymouth Gentian population is on the shorelines of larger, privately owned parcels, some of which have cottages already, but most of which are undeveloped and potentially subject to future development. Shoreline development is ongoing on Plymouth Gentian lakes, with development in the past 10 to 15 years most active on Bennetts Lake, Gillfillan Lake and particularly on Third Lake, where about 17 of 46 lots in a cottage subdivision have been developed since the late 1990s. This subdivision occupies 4.3 km (45%) of the lake’s shoreline and 2.2 km of Tusket River frontage (the latter perhaps partially occupied by Plymouth Gentian because there are records on the opposite shore, but not included in the “presumed occupied” totals above). Another area of high potential impact is a property at the north end of Wilsons Lake, where a new access road to the lake was built about 2008. That property has the densest population of Plymouth Gentian in Canada, with about 82,000 rosettes over 1 km of shoreline.

Table 4. Ownership statistics for all extant Canadian Plymouth Gentian occurrences.

As used below, “Protected” means non-government or provincial nature reserve, provincial Crown land or provincial park. For sites where Plymouth Gentian occurrence is sparse or restricted (*), shoreline distances refer only to occupied shoreline. Otherwise shoreline distances represent the whole lake, including islands. For Bennetts, Third and Pearl lakes “# Private Property Parcels” values were derived assuming occupancy of all lakeshore parcels. Values for other lakes represent known occupied parcels from more or less comprehensive inventories. Where number of rosettes is given as a range estimate (Table 1), value below is a mean of the range extremes. The Tusket River – Hemlock Run sub-population has only been surveyed on one side of the river, so values are incomplete.

		Shoreline Distance (km) by Ownership Class				# Private Property Parcels				Shoreline Proportion by Ownership Class			
Pop#	**Population / Sub-population**	**Nature Reserve**	**Crown (incl. Prov. Park)**	**small private**	**large private**	**#small private parcels**	**#large private parcels**	**Total shore distance (km)**	**Total shore protected (km)**	**% protected**	**% in small private**	**% in large private**	**# rosettes**
1	Agard Lake*	-	0.47	0.17	-	2	-	0.64	0.47	73%	27%	0%	3222
2	Lake Fanning*	-	-	0.92	0.19	11	2	1.11	-	0%	83%	17%	4460
3a	Bennetts Lake	4.02	0.30	6.01	2.63	52	2	12.96	4.32	33%	46%	20%	231900
3b	Wilsons Lake	2.04	-	3.89	5.16	42	5	11.09	2.04	18%	35%	47%	282500
4a	Lac de l'Ecole*	0.16	-	0.26	0.25	3	2	0.67	0.16	24%	39%	37%	750
4b	Gillfillan Lake	1.22	5.77	6.03	5.18	57	12	18.2	6.99	38%	33%	28%	136000
4c	Third Lake	2.35	2.60	3.25	1.35	28	3	9.55	4.95	52%	34%	14%	101000
4d	Tusket River - Hemlock Run*	-	0.22	?	?	?	?	[0.22]	[0.22]	[100%]	[0%]	[0%]	2100
4e	Pearl Lake	2.06	0.80	2.24	4.48	20	6	9.58	2.86	30%	23%	47%	71200
4f	Travis Lake*	-	-	0.3	0.1	3	1	0.4	-	0%	75%	25%	2400
4g	Kegeshook Lk *	2.28	3.40	0.48	1.36	3	1	7.54	5.70	76%	6%	18%	36100
	TOTAL	**14.13**	**13.56**	**23.55**	**20.7**	**221**	**34**	**71.96**	**27.71**	**39%**	**33%**	**29%**	**871432**
Population Proportion (lake population x shoreline proportion by ownership class)										**32%**	**41%**	**27%**	

A strong majority of existing shoreline development on Plymouth Gentian lakes occurred before 2000, and Eaton and Boates (2002) determined that cottage and residential development had caused a 2.7% loss of natural vegetation in the 100 m buffer zone around the eight lakes supporting Plymouth Gentian between 1945 and 2000. Most shoreline development occurred more than 15 years ago, so loss of shoreline buffer over the past 15 years would be much less than 2.7%. Loss of shoreline buffer is a useful index of population loss, but probably overestimates actual loss because in the absence of direct shoreline impacts plants typically persist (Blaney pers. obs. 2002-2011) and cottagers typically alter less Plymouth Gentian habitat along shorelines than habitat within the 100 m shoreline buffer. Observations of the same cottage shorelines on Wilsons and Gillfillan lakes in 2002 and 2011 do not suggest significant changes in population (Blaney, unpubl. 2011).

Two recent theses (Trant 2004 and Sutton 2008) have investigated effects of cottage-related shoreline disturbance on Plymouth Gentian. Trant *et al.* (2010) found that disturbance did not affect the diversity of pollinators but that disturbance was associated with significantly reduced pollinator visitation rate and handling time per flower. However, rate of viable seed production was actually significantly higher in disturbed sites on two of three lakes investigated, perhaps because disturbance was reducing inbreeding effects at the local scale by increasing the ratio of sexual vs. vegetative reproduction. Sutton (2008) documented reduced kinship coefficients for adjacent plants in disturbed sites that would be consistent with this hypothesis.

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 like Plymouth Gentian (P.A. Keddy 1989; Wisheu and Keddy 1994; Nilsson and Jansson 1995; Hill *et al.* 1998; Merritt and Cooper 2000). For Plymouth Gentian, low winter water levels on reservoirs are likely also a crucial factor, because it seems to require significant winter flooding to insulate rosettes against freezing (see *Habitat Requirements*).

Damming on the lower Tusket River in 1929 is known to have eliminated Plymouth Gentian occurrences on two lakes (Lake Vaughan and Gavels Lake) and the species likely also occurred on Raynards and Kings lakes prior to regulation of their water levels. Dams disrupted what was historically a more or less continuous population on the Carleton and Tusket rivers, isolating the Lake Fanning population. New dams affecting Plymouth Gentian are now unlikely to be approved under federal or provincial environmental impact assessment processes so they are no longer a major threat, but water level regulation by Nova Scotia Power on the four lower Tusket River lakes above is still probably a limiting factor for Plymouth Gentian populations. The large population of Plymouth Gentian on Bennetts Lake is likely sending large numbers of floating seeds 700 m downstream into Kings Lake. Inadequate drawdown in summer and/or large drawdowns in winter, which cause lethal freezing of rosettes, likely prevent Plymouth Gentian from recolonizing these lakes naturally. The possibility of changes to water-level management that would favour Atlantic Coastal Plain flora has been discussed with Nova Scotia Power, but no significant changes in operation have yet resulted.

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). The typically slow growth rates of coastal plain species increase their vulnerability to disturbance (Sharp and Keddy 1985; Keddy and Wisheu 1989) and even infrequent vehicle traffic could allow more common species (especially rushes, *Juncus* spp.) which are frequently abundant in the seed bank to colonize areas once occupied by rare species (Keddy and Wisheu 1989).

Wisheu and Keddy (1991) recorded local reductions of Plymouth Gentian populations by 90% due to heavy OHV use on Gillfillan Lake, and Sutton (2008) also noted heavy local OHV disturbance on Gillfillan Lake. However, within the 12.1 km surveyed in 2011 (of the 18.6 km total lakeshore) only about 100 m of OHV trail and minimal impacts on Plymouth Gentian were noted. OHV use is currently impacting Plymouth Gentian primarily on Wilsons Lake and Pearl Lake. At Wilsons Lake, a well-used OHV trail extends through dense Plymouth Gentian for 1 to 2 km on the northeast shore. This has caused significant local loss of Plymouth Gentian plants in the tire ruts (Figure 5), but probably less than 5% of plants on Wilsons Lake are affected (see *Habitat Trends*). OHV use is also significant at Pearl Lake, especially in the northeast end near the year-round settlement of Kemptville. The proportion of plants affected at Pearl Lake has not been quantified but is likely not more than the 5% maximum estimated for Wilson's Lake (Hill pers. obs. 2011). Other lakes are undoubtedly affected occasionally or to limited degrees on an ongoing basis, but there is no evidence of major effects at present. OHV impacts may have lessened in recent years because of public education efforts regarding lakeshore issues and because of measures to restrict access from public lanes on Wilsons and Gillfillan lakes.

Figure 5. Plymouth Gentian habitat (shallowly sloped, seasonally flooded shoreline zone dominated by grass-like plants) on Wilsons Lake, with distinct off-highway vehicle damage. In 2011, a well-used OHV trail occupied roughly 25% of the available habitat over 1 to 2 km of the eastern side of Wilsons Lake, visibly reducing Plymouth Gentian abundance. Photograph by Sean Blaney, AC CDC.

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. Reed Canary Grass, the only potentially problematic invasive co-occurring with Plymouth Gentian, was found at Lake Fanning (Blaney *et al.* 2011), where patches were scattered fairly frequently around the lake, including cases where it was rooting at the nodes in the water and one site where a patch was within one metre of Plymouth Gentian. Reed Canary Grass is a major invasive of shoreline communities (Lavergne and Molovsky 2004; IPANE 2011), and it was not noted during a 1988 survey of Lake Fanning by Hill and Keddy, or at any other Plymouth Gentian lakes during 2010 and 2011 surveys (AC CDC 2011). Among Plymouth Gentian lakes, Lake Fanning is the most obviously enriched by anthropogenic inputs (from mink farming, see *Eutrophication* above) and it had dam-controlled water levels from 1910 to 1965 (Hill *et* *al*. 1998). Both of these factors increase susceptibility of shorelines to invasion by exotics (Wisheu and Keddy 1994; Hill *et al.* 1998; Environment Canada and Parks Canada Agency 2010). As noted above, eutrophication appears to be a serious, new threat in all Plymouth Gentian lakes along the main Tusket River. Further eutrophication, coupled with additional development bringing new exotic species, could increase the threat of Reed Canary Grass and other invasive species to Plymouth Gentian beyond the currently limited level.

Number of Locations

There are four Plymouth Gentian locations in Canada (as defined by the scale of the most immediate threat at each site, COSEWIC 2010). Eutrophication, which can lead to competitive exclusion of coastal plain flora by more common native and exotic species, is clearly the most significant threat to Plymouth Gentian at all extant sub-populations. Different sources and states of eutrophication serve to define the following locations for Plymouth Gentian: 1) Lake Fanning on the Carleton River, where mink farming is clearly the cause of major eutrophication over the past decade; and 2) the main branch of the Tusket River from Travis and Pearl lakes downstream to Bennetts Lake (population 3 and all sub-populations of population 4 except Kegeshook Lake; Table 1), where there is limited mink farming and recent documentation of eutrophication on lakes at the upper and lower ends of the area, but where no significant impacts have yet been observed. Eutrophication impacts are relatively uniform within these two areas, thus they represent two locations.

Mink farm expansion continues throughout the region of Plymouth Gentian occurrence, and potential future expansion of mink farm-related eutrophication to Agard and Kegeshook Lake watersheds is considered a more significant threat than cottage development. Eutrophication is not currently known to be affecting Agard Lake (population 1; Table 1) or Kegeshook Lake (sub-population 4a; Table 1). These lakes represent two additional locations for a Canadian total of four.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Plymouth Gentian was assessed by COSEWIC as Endangered in November 2012, and as Threatened in May 2000. It is currently listed on Schedule 1 as Threatened under the *Species at Risk Act*, and provincially under the *Nova Scotia Endangered Species Act* (Government of Canada 2011). It was first designated Threatened in April 1984. Its status was re-examined and confirmed Threatened in April 1999 and May 2000. It is also listed as Threatened under the *Nova Scotia Endangered Species Act* (Nova Scotia DNR 2011). The species receives legal protection in three of the four states in which it is native through the following status designations and acts: State Endangered under the Rhode Island State *Endangered Species Act* (Enser 2007), Special Concern under the *Massachusetts Endangered Species Act* (Massachusetts

NHESP 2011) and Special Concern under the *North Carolina Plant Protection and Conservation Act* (Buchanan and Finnegan 2010). It is not legally protected in South Carolina where there is no legal protection for rare plants (South Carolina DNR 2011).

Non-Legal Status and Ranks

Plymouth Gentian is rare throughout its range and is considered Vulnerable (G3) globally (NatureServe 2011). It is ranked as Critically Imperilled (N1) in Canada and in Nova Scotia (S1). Plymouth Gentian is ranked as At Risk in Nova Scotia and Canada (Canadian Endangered Species Conservation Council 2011). In the United States, it is Vulnerable (N3) nationally, and is ranked as Vulnerable (S3) in Massachusetts, Imperilled (S2) in North Carolina and South Carolina, and Critically Imperilled (S1) in Rhode Island (NatureServe 2011). Plymouth Gentian is also listed by the New England Plant Conservation Program as a Division 1 species (globally rare species occurring in New England, Brumback and Mehrhoff 1997), and by South Carolina Department of Natural Resources (2011) as a species of regional concern.

Habitat Protection and Ownership

Actual ownership of almost all Plymouth Gentian occurrences is with the province, because the species grows almost entirely below the annual high water mark on lake and river shores (Blaney *et al*. pers. obs. 2011). However, relative to impacts on Plymouth Gentian it is ownership of adjacent land rather than the shoreline itself that is most relevant since 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.

New Nature Conservancy of Canada (NCC) and Nova Scotia Nature Trust (NSNT) nature reserves on Bennetts, Wilsons, Lac de l’Ecole, Gillfillan, Kegeshook, Pearl, and Third lakes, and a Provincial Nature Reserve on Gillfillan Lake have all been acquired and designated since the previous status report (Newell 1999). Currently about 38% of the roughly 72 km of shoreline occupied by Plymouth Gentian is on land that is not directly subject to development, compared to only 19% in 2000. Protected and Crown lands include multiple parcels in the provincial Tusket River Nature Reserve (2.1% of shoreline distance occupied by Plymouth Gentian), private nature reserves of NCC (14.3%) and NSNT (3.2%), Ellenwood Provincial Park (0.6%) and provincial Crown land (18.2%) (Table 4). Of the remainder, 32.7% of occupied shoreline is within about 221 small privately owned lakefront properties (average shore frontage 107 m) and 28.8% is within about 34 larger privately owned lakefront properties (average shore frontage 608 m).

Applying lake-specific values for ownership category and population allows better estimation of the proportion of the population in each ownership category (Table 4), suggesting about 32% of the population is in nature reserves or on Crown land, 41% is in small privately owned parcels and 27% is in larger privately owned parcels. The actual proportion of the population that is not subject to development is likely closer to 25% because large new nature reserves within the extensive Plymouth Gentian populations on Wilsons and Bennetts Lake, and extensive Crown land at Gillfillan Lake, are in portions of the lakes having lower densities of the species. The proportion on private land is thus likely about 75%. It is important to note that occurrence on Crown or nature reserve land does not necessarily protect Plymouth Gentian from OHV or other human-caused impacts, including eutrophication, but these impacts were not extensive on Crown and nature reserve sites in 2010-2011 surveys (MTRI 2010; Blaney *et al*. 2011).

The habitat of Plymouth Gentian receives 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. These include 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*. Though projects involving lakeshore or wetland alterations are required to go through a permitting process, not all private landowners make efforts to acquire necessary permits and enforcement is strictly complaint-based.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Lelia Orrell Elliston provided her Ph.D. thesis on Plymouth Gentian in Massachusetts and offered useful insights on the species' biology. Pamela Mills of the Nova Scotia Department of Natural Resources provided details of her Kegeshook and Canoe lakes fieldwork, as did Alain Belliveau, Tom Neily and Brad Toms of Mersey Tobeatic Research Institute (MTRI) for fieldwork on several other lakes. Lindsay Notzl of MTRI provided crucial data from their water quality monitoring program. Emily Wood and Michaela Schmull of the Gray Herbarium, Harvard University, provided details of M.L. Fernald's Nova Scotia specimens and Marian Munro of the Nova Scotia Museum of Natural History Herbarium provided details on a questionably located specimen from Little Tusket Lake. Misty Buchanan of the North Carolina Natural Heritage Program and Herrick Brown of the South Carolina Heritage Trust Program provided habitat information for their states. Michael Brylinsky, Acadia Centre for Estuarine Research, Acadia University provided very important interpretation of water quality data. David MacKinnon of the Nova Scotia Department of Environment provided GIS data on protected areas and information on Tusket River occurrences. Julia Flemming, Nova Scotia Department of Agriculture, provided statistics on mink farming. Fieldwork was partially supported by the Mersey Tobeatic Research Institute via Environment Canada's Habitat Stewardship Fund, by the Nova Scotia Crown Share Land Legacy

Trust and by Nova Scotia Power. Sherman Boates, Manager, Biodiversity Wildlife Division, Department of Natural Resources, Government of Nova Scotia, provided additional information on eutrophication.

INFORMATION SOURCES

Ahles, H.E. 1964. New combinations for some vascular plants of southeastern United States. J. Elisha Mitchell Sci. Soc. 80: 172-173.

Atlantic Canada Conservation Data Centre (AC CDC). 2011. Digital database of rare species locations for Nova Scotia. Atlantic Canada Conservation Data Centre, Sackville, NB.

Blaney, C.S. 2002. 2001 Rare plant surveys on Bowater Mersey Woodlands land. Report to Bowater Mersey, Inc. Liverpool, NS. Atlantic Canada Conservation Data Centre, Sackville, NB. 31 pp.

Blaney, C.S. 2004. A vascular plant inventory and *Pseudocyphellaria* lichen survey on Bowater property at Bog Lakes, Lunenburg County, Nova Scotia. Atlantic Canada Conservation Data Centre, Sackville, NB. 15 pp.

Blaney, C.S. 2005a. 2004 Vascular Plant Surveys in Yarmouth and Shelburne Counties, Nova Scotia. Report to NS DNR. Atlantic Canada Conservation Data Centre, Sackville, NB. 28 pp.

Blaney, C.S. 2005b. 2005 Vascular Plant Surveys in Yarmouth and Shelburne Counties, Nova Scotia. Report to NS DNR. Atlantic Canada Conservation Data Centre, Sackville, NB. 38 pp.

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 December 2, 2011].

Blaney, C.S., pers. obs. 2002-2011. Personal observations on Plymouth Gentian (*Sabatia kennedyana*) in southern Nova Scotia. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., unpubl. 2011. Unpublished data on plant species associated with Plymouth Gentian (*Sabatia kennedyana*) in southern Nova Scotia. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., N.M. Hill, and D.M. Mazerolle, pers. obs. 2011. Personal observations on Plymouth Gentian (*Sabatia kennedyana*) in southern Nova Scotia made in association with COSEWIC fieldwork. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., and D.M. Mazerolle. 2009. Rare Plant Inventory of Lakes in the Ponhook-Molega Lakes region, Nova Scotia. Report to the Endangered Species Recovery Fund and Nova Scotia Species at Risk Conservation Fund. Atlantic Canada Conservation Data Centre, Sackville, NB. 27 pp.

Blaney, C.S., and D.M. Mazerolle. 2010. Rare Plant Inventory of Nova Scotia Lakes in the Ponhook-Molega Lakes Region and Potential Eastern Lilaeopsis sites. Report to the Endangered Species Recovery Fund and Nova Scotia Species at Risk Conservation Fund. Atlantic Canada Conservation Data Centre, Sackville, NB. 16 pp.

Blaney, C.S., and D.M. Mazerolle. 2011. Rare Plant Inventory of Lakes in the Ponhook-Molega Lakes region and tidal rivers with potential for Eastern Lilaeopsis. Report to the Endangered Species Recovery Fund. Atlantic Canada Conservation Data Centre, Sackville, NB.

Blaney, C.S., and D.M. Mazerolle, pers. obs. 2011. Personal observations on potential Plymouth Gentian (*Sabatia kennedyana*) lakes in Yarmouth County, Nova Scotia. Botanist and Assistant Director, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., D.M. Mazerolle, and N.M. Hill. 2011. Preliminary Report on 2011 Plymouth Gentian (*Sabatia kennedyana*) and Pink Coreopsis (*Coreopsis rosea*) Fieldwork for COSEWIC. Atlantic Canada Conservation Data Centre, Sackville NB. 11 pp.

Boston, H.L., M.S. Adams, and T.P. Pienkowski. 1987. Models of the use of root-zone CO_2 by selected North American isoetids. Annals Botany 60: 495-503.

Brown, H., pers. comm. 2012. *Email communication with Sean Blaney regarding Plymouth Gentian habitat in South Carolina*. January 4, 2012. Assistant Botanist, South Carolina Department of Natural Resources, Heritage Trust Program. Columbia, SC.

Brumback, W.E. 1983. Propagating endangered plants, theory and practice. *Wild Flower Notes and News,* New England Wild Flower Society 1: 4-5.

Brumback, W.E., and L.J. Mehrhoff. 1997. Flora Conservanda: New England. The New England Plant Conservation Program List of Plants in Need of Conservation. *Rhodora* 98: 233-361. Online document: http://www.newfs.org/docs/docs/fcne97.pdf [accessed November 29, 2011].

Brylinsky, M. 2011a. 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. 2011b. Water Quality Survey of Ten Lakes Located in the Carleton River Watershed Area of Digby and Yarmouth Counties, Nova Scotia. Prepared for Nova Scotia Department of the Environment. Acadia Center for Estuarine Research, Acadia University, Wolfville Nova Scotia. 78 pp.

Brylinsky, M., pers. comm. 2011. *Telephone communication with Nicholas Hill regarding eutrophication issues.* November 2011. Research Associate, Acadia Center for Estuarine Research, Acadia University, Wolfville Nova Scotia

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.

Buchanan, M.F., pers. comm. 2011. *Email communication with Sean Blaney regarding Plymouth Gentian habitat in North Carolina*. December 30, 2011. Natural Areas Inventory Manager, North Carolina Natural Heritage Program, Raleigh, NC.

Buchanan, M.F., and J.T. Finnegan (eds.). 2010. Natural Heritage Program List of Rare Plant Species of North Carolina 2010. North Carolina Natural Heritage Program, Raleigh NC. Online document: http://www.ncnhp.org/Images/2010%20Rare%20Plant%20List.pdf [Accessed December 8, 2011].

BugGuide. 2011. Short-lined Chocolate (*Argyrostrotis anilis*). Website: http://bugguide.net/node/view/294450 (Ottawa, ON) http://bugguide.net/node/view/367397 (Cape Cod National Seashore) [accessed December 2, 2011].

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

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Carpenter, S.R. 2008. Phosphorus control is critical to mitigating eutrophication. PNRS. 105(32):11039-11040. Website: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2516213/ [accessed Dec. 2012].

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.

COSEWIC. 2010. COSEWIC's Assessment Process and Criteria. Online document: http://www.cosewic.gc.ca/pdf/assessment_process_e.pdf [accessed November 2011].

Dudash, M.R. 1990. Relative fitness of selfed and outcrossed progeny in a self-compatible, protandrous species, *Sabatia angularis* L. (Gentianaceae): a comparison in three environments. Evolution 44: 1129–1139.

Dudash, M.R. 1993. Variation in pollen limitation among individuals of *Sabatia angularis* (Gentianaceae). Ecology 74: 959-962.

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.

Enser, R.W. 2007. Rare Native Plants of Rhode Island. Rhode Island Natural History Survey, Providence, RI. 17 pp. Online document: http://www.rinhs.org/wp-content/uploads/ri_rare_plants_2007.pdf [accessed November 2011]

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. 1916. The genus *Sabatia* in New England. Rhodora 18: 145-152.

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.

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.

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

Gaudet, C.L., and P.A. Keddy. 1988. A comparative approach to predicting competitive ability from plant traits. Nature 334: 242-243.

Gaudet, C.L., and P.A. Keddy. 1995. Competitive performance and species distribution in shoreline plant communities: A comparative approach. Ecology 76: 280-291.

Gleason, H.A., and A. Cronquist. 1991. Manual of the Vascular Plants of Northeastern United States and Adjacent Canada, 2nd Edition. New York Botanical Garden, New York.

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

Grime, J.P. 2001. Plant strategies, vegetation processes, and ecosystem properties, 2nd Edition. John Wiley & Sons, Chichester, England. 419 pp.

Harriet Irving Botanical Garden. 2011. Plymouth Gentian (*Sabatia kennedyana*) [photograph with Goldenrod Crab Spider from Tusket River region]. Website: http://botanicalgardens.acadiau.ca/sabatia.html [accessed November 27, 2011].

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., pers. obs. 1988-2011. Personal observations on Plymouth Gentian (*Sabatia kennedyana*) in southern Nova Scotia. Botanical Consultant, Fern Hill Institute for Plant Conservation, Berwick NS.

Hill, N.M., pers. obs. 2011. Personal observations on Plymouth Gentian (*Sabatia kennedyana*) in southern Nova Scotia, made during COSEWIC fieldwork. Botanical Consultant, Fern Hill Institute for Plant Conservation, Berwick NS.

Hill, N.M., unpubl. 2011. Unpublished data on Plymouth Gentian (*Sabatia kennedyana*) in southern Nova Scotia, made during monitoring work for Nova Scotia Power. Botanical Consultant, Fern Hill Institute for Plant Conservation, Berwick NS.

Hill, N.M. & 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.

Hill, N.M., M.T.D. Myra, and M.O. Johnson. 2006. Breeding system and early stage inbreeding depression in a Nova Scotian population of the global rarity, *Sabatia kennedyana* (Gentianaceae). Rhodora 108: 307–328.

Hilty, J. 2011. Illinois Wildflowers - Common Rose Pink, *Sabatia angularis*. Website: www.illinoiswildflowers.info/prairie/plantx/cm_rosepink.htm [accessed November 28, 2011].

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. 2011. *Email communication with Sean Blaney regarding aboriginal traditional knowledge of Plymouth Gentian (Sabatia kennedyana) and its status on Wilsons Lake.* November 24, 2011. COSEWIC Aboriginal Traditional Knowledge Specialist Committee representative to the COSEWIC Vascular Plants Species Specialist Committee, and Wilsons Lake cottager, Yarmouth, NS.

Invasive Plant Atlas of New England (IPANE). 2011. Reed Canary Grass (*Phalaris arundinacea*) Website: http://nbii-nin.ciesin.columbia.edu/ipane/icat/browse.do?specieId=84 [accessed November 30, 2011].

Kartesz, J.T. 1999. A synonymized checklist of the vascular flora of the U.S., Canada, and Greenland. In: Kartesz, J.T.; Meacham, C.A., editors. 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 January 2011]

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. 2010. Wetland Ecology: Principles and Conservation. Second Edition, Cambridge University Press. New York.

Keddy, P.A, L.H. Fraser, and I.C. Wisheu. 1998. A comparative approach to examine competitive response of 48 wetland plant species. Journal of Vegetation Science 9: 777-786.

Keddy, P.A., and C.J. Keddy. 1984. Status report on the Plymouth Gentian *Sabatia kennedyana* in Canada. COSEWIC, Ottawa, ON. 18 pp.

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.

Lavergne, S., and J. Molovsky. 2004. Reed canary grass (*Phalaris arundinacea*) as a biological model in the study of plant invasions. Critical Reviews in Plant Sciences 23: 415-429.

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

Magee, D. W., and H. E. Ahles. 1999. Flora of the Northeast: A Manual of the Vascular Flora of New England and Adjacent New York. University of Massachusetts Press, Amherst, MA, USA.

Marsden, M.W. 1989. Lake restoration by reducing external phosphorus loading: the influence of sediment phosphorus release. Freshwater Biology 21(2):139-162.

Massachusetts Natural Heritage & Endangered Species Program (NHESP). 2011. Massachusetts List of Endangered, Threatened and Special Concern Species. Online document: http://www.mass.gov/dfwele/dfw/nhesp/species_info/mesa_list/mesa_list.htm#PLANTS [accessed November 15, 2011].

MacKinnon, D., pers. comm. 2011. *Phone conversation with Sean Blaney about distribution of Plymouth Gentian along Tusket River between Pearl and Third Lakes.* November 30, 2011. Protected Areas Planner, Nova Scotia Department of Environment and Labour, Halifax, NS.

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). 2010. Rare coastal plain species surveys in southwestern Nova Scotia [unpublished data, held in Atlantic Canada Conservation Data Centre database, Sackville NB]. Mersey Tobeatic Research Institute, Caledonia, NS.

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

Mills, P., pers. comm. 2011. *Email communication to Sean Blaney regarding distribution of Plymouth Gentian on Kegeshook and Canoe Lakes*. November 25, 2011. Wildlife Technician, Biodiversity, Nova Scotia Department of Natural Resources, Kentville NS.

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.

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.

NatureServe. 2004. Habitat-based Plant Element Occurrence Delimitation Guidelines. Web site: http://www.natureserve.org/explorer/decision_tree.htm [accessed January 2008].

NatureServe. 2011. NatureServe Explorer – *Sabatia kennedyana*. Web site: http://www.natureserve.org/explorer [accessed November 2011].

Newell, R.E. 1999. Update COSEWIC status report on the Plymouth Gentian *Sabatia kennedyana* in Canada, in COSEWIC assessment and update status report on the Plymouth Gentian *Sabatia kennedyana* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 10 pp.

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].

Nova Scotia Power. 2009. Bathymetry map of Raynards Lake. Unpublished digital map. Nova Scotia Power, Halifax.

Orrell Elliston, L.C. 2006. Natural history, genetics and population biology of *Sabatia kennedyana* (Plymouth gentian): An endangered plant of Atlantic coastal plain pondshores. Ph.D. thesis, University of Massachusetts Boston. 138 pp.

Pronych, G., and A. Wilson. 1993. Atlas of rare vascular plants in Nova Scotia, Volume 2. Curatorial Report Number 78. Nova Scotia Museum of Natural History, Halifax NS. 331 pp.

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.

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

Sharp, M. J., and P. A. Keddy. 1985. Biomass accumulation by *Rhexia virginica* and *Triadenum fraseri* along two lakeshore gradients: a field experiment. Canadian Journal of Botany 63: 1806-1810.

Shelburne County Today. 2011. Small fine in mink stink offense. Website: http://shelburnecountytoday.wordpress.com/2011/09/06/small-fine-in-mink-stink-offense/ [accessed December 7, 2011].

Sorrie, B. A. 1998. Distribution of *Drosera filiformis* and *D. tracyi* (Droseraceae): Phylogenetic implications. Rhodora 100: 239–261.

South Carolina Department of Natural Resources (DNR). 2011. South Carolina Rare, Threatened, and Endangered Species Inventory. Website: www.dnr.sc.gov/pls/heritage/county_species.list?pcounty=all [accessed November 14, 2011].

Spigler, R.B., J.L. Hamrick, and S.M. Chan. 2009. Increased inbreeding but not homozygosity in small populations of *Sabatia angularis* (Gentianaceae). *Plant Syst. Evol*. 284: 131–140.

Standards and Petitions Working Group. 2006. Guidelines for using the IUCN Red List Categories and Criteria. Version 6.2. Prepared by the Standards and Petitions Working Group of the IUCN SSC Biodiversity Assessments Sub-Committee in December 2006.

Struwe, L., and V.A. Albert. 2002. Gentianaceae: Systematics and natural history. Cambridge University Press, Cambridge UK. 539 pp.

Sutton, J. 2008. Effects of latitude and habitat disturbance on morphology, fruit and seed set, genetic variation, spatial genetic structure and gene flow in a rare Atlantic Coastal Plain flower *Sabatia kennedyana* Fern. M.Sc. Thesis, Acadia University, Wolfville, NS. 115 pp.

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

Taylor, D. 2010. A water quality survey of ten lakes in the Carleton River watershed area, Yarmouth and Digby Counties Nova Scotia. Water & Wastewater Branch, Nova Scotia Department of Environment, Halifax NS. 55 pp. + appendices.

Trant, A.J. 2004. Effects of lakeshore development on pollination service, seed bank composition, and stewardship of Atlantic coastal plain flora in the Tusket River Watershed, Nova Scotia, Canada. M.Sc. Thesis, Acadia University, Wolfville, NS.

Trant, A.J., T.B. Herman, and S.V. Good-Avila. 2010. Effects of anthropogenic disturbance on the reproductive ecology and pollination service of Plymouth gentian (*Sabatia kennedyana* Fern.), a lakeshore plant species at risk. Plant Ecology 210: 241–252.

Webster, C., pers. comm. 2011. In-person discussion with Nicholas Hill regarding Plymouth Gentian (*Sabatia kennedyana*) on Agard Lake. August 2010. Cottager on Agard Lake, Agard Lake, NS.

Wendland, S. 2010. Communities Rally to Defend their Water, Tension grows over mink farming in Yarmouth County. Halifax Media Co-op, Halifax NS. Website: http://halifax.mediacoop.ca/story/3153 [accessed December 7, 2011].

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.

Wisheu, I.C., and P.A. Keddy. 1989. Species richness-standing crop relationships along four lakeshore gradients: constraints on the general model. Canadian Journal of Botany 67: 1609–1617.

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.

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.

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 maintaining status ranks and a rare plant occurrence database for plants in 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 a number of biological inventory projects in Ontario as well as spending eight summers as a naturalist in Algonquin Park, where he co-authored the second edition of the park's plant checklist.

Nicholas Hill is a private ecological consultant and part-time academic at Acadia, St. Francis Xavier, and Dalhousie universities who has conducted research on the Atlantic Coastal Plain Flora since his post-doctorate with Paul Keddy in 1988. As associate professor at Mount Saint Vincent University, he published several papers on rare species of Maritime Canada and continues to do so. He is a scientific advisor to the NS Atlantic Coastal Plain Flora Recovery Team and in 2011 was instrumental, with the Nova Scotia Department of Natural Resources, in establishing a rare plant monitoring program for 10 lakes in the Tusket River area. This was particularly aimed at getting better information on the natural dynamics of the rare coastal plain plant populations and instating a system that can alert conservation and land managers to population and habitat trends of concern.

COLLECTIONS EXAMINED

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 2011) prior to the preparation of this report. One questionably labelled specimen from Little Tusket Lake was examined by Marian Munro (NSPM) on behalf of the report writers. Data from all Nova Scotia specimens at the Gray Herbarium, Harvard University (GH), were received in digital form during preparation of the report.