COSEWIC
Assessment and Status Report

on the

Eastern Mountain Avens
Geum peckii

in Canada

ENDANGERED
2010

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. 2010. COSEWIC assessment and status report on the Eastern Mountain Avens *Geum peckii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 33 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Previous report(s):

COSEWIC 2000. COSEWIC assessment and update status report on the Eastern Mountain Avens *Geum peckii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 11 pp.

Newell, R.E. 1999. Update COSEWIC status report on the Eastern Mountain Avens *Geum peckii* in Canada, *in* COSEWIC assessment and update status report on the Eastern Mountain Avens *Geum peckii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-11 pp.

Keddy, C. 1986. COSEWIC status report on the Eastern Mountain Avens *Geum peckii* in Canada. Committee on the Status of Endangered Wildlife in Canada. 19 pp.

Production note:
COSEWIC would like to acknowledge Sean Blaney for writing the status report on the Eastern Mountain Avens *Geum peckii* in Canada, prepared under contract with Environment Canada, overseen and edited by Erich Haber, Co-chair, COSEWIC Vascular Plants Species 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 le benoîte de Peck (*Geum peckii*) au Canada.

Cover illustration/photo:
Eastern Mountain Avens — Photo by Sean Blaney, Atlantic Canada Conservation Data Centre.

Catalogue 69-14/147-2010E-PDF
ISBN CW 978-1-100-16041-2

COSEWIC
Assessment Summary

Assessment Summary – April 2010

Common name
Eastern Mountain Avens

Scientific name
Geum peckii

Status
Endangered

Reason for designation
This globally imperiled species is geographically restricted in Canada to three locations of open peatland habitat in Nova Scotia. Its habitat has declined due to encroachment by woody vegetation, exacerbated by artificial drainage of sites. Portions of the habitat have also become degraded by nesting gulls. Threats including all-terrain vehicles, road maintenance and development have also impacted this species. Fewer than 9000 mature individuals remain with most found on private land.

Occurrence
Nova Scotia

Status history
Designated Endangered in April 1986. Status re-examined and confirmed Endangered in April 1999, May 2000, and April 2010.

COSEWIC
Executive Summary

Eastern Mountain Avens
Geum peckii

Species information

Eastern Mountain Avens (*Geum peckii*) is an herbaceous perennial in the rose family. The 15-40 cm flowering stalks bear one to five yellow, five-petalled flowers that produce 30-60 seeds. Leaves are predominantly basal, with one large terminal and several small lateral leaflets. This species is morphologically indistinguishable from the rare Appalachian Avens (*G. radiatum*) of high elevation sites in Tennessee and North Carolina but recent molecular genetic research suggested that patterns of genetic variance between Appalachian Avens and Eastern Mountain Avens support the maintenance of the two as separate species. Features such as the larger flower size, yellow-orange flower centres and peatland habitat of Eastern Mountain Avens distinguish it from Nova Scotia's other *Geum* species.

Distribution

Eastern Mountain Avens occurs only at higher elevations in the White Mountains of central New Hampshire over an area of about 35 km by 65 km and in Canada at Brier Island and Harris Lake, separated by 20 km in Digby County, Nova Scotia. Literature reports from Maine and Cumberland County, Nova Scotia, are in error. In Canada, the range of the two populations extends over about 17 km² with less than 1 km² of habitat actually occupied by the plants.

Habitat

In New Hampshire, Eastern Mountain Avens occurs in open alpine peatlands and meadows at 1200-1830 m elevation, extending down to 425-760 m along steep streams. Nova Scotian sites are at sea level and most plants are in moist to wet *Sphagnum* peat in sparsely treed coastal peatlands, usually where shrubs are lower and sparser than in surrounding areas. Small numbers of plants in non-peatland sites along roadsides and regenerating former pasture may represent colonization of sites opened up by anthropogenic disturbance. The species' success under cultivation in areas with much warmer summers than its natural habitats suggests a biotic factor or limitation of post-glacial dispersal as the cause of its limited distribution.

Biology

In Nova Scotia, peak flowering is from late June to mid-July. Male and female function in individual flowers is spatially and largely temporally separated, although self-pollination from the same flower is briefly possible. Experimental results suggest some depression of seed production associated with selfing. Small flies are probably the primary pollinators in Nova Scotia. Seed dispersal begins in August, with seeds having no obvious means of long-distance dispersal. Seed longevity in the soil is not documented but is probably limited to a few years based on other *Geum* species. Seeds are easily germinated in cultivation following cold treatment. Vegetative reproduction occurs by stout rhizomes that produce new rosettes a short distance from the parent plant. Plants appear long-lived and slow to mature.

Population sizes and trends

Number of mature individuals is estimated to be less than 9,000 within two populations (comprising a total of 18 sub-populations). Near-comprehensive surveys in 2007-08 counted 2,424 plants (represented by flowering stems + vegetative clumps), with the total population unlikely to exceed 2,924. Each of these “plants” may also include multiple, tightly-packed rosettes that represent separate “mature individuals” for the purposes of status assessment. Decline in area occupied by the five sub-populations having over 1,000 rosettes in 1985 is estimated at 64% because of habitat loss from gull nesting and tree and shrub incursion. An unquantified “significant decline” was noted in another sub-population between 1999 and 2006. At least six of nine Brier Island sites with under 1000 plants reported in the 1986 status report have not been found in the past 15 years and may have disappeared. The eight new occurrences found since 1985 likely represent discovery of long-established rather than newly occupied sites, but the largest sub-population (1,327 plants) found in 2008 has likely expanded since 1985, when it was noted as recently burned and lacking plants.

Limiting factors and threats

The species is threatened primarily by habitat degradation and loss caused by tree and shrub incursion and by nesting gulls, which destroy peatland vegetation through nitrification. Impacts of both of these are especially problematic at Big Meadow Bog on Brier Island, the most significant area for the species in Canada, where impacts of both threats are augmented because of artificially low water levels caused by old drainage ditches. All-terrain vehicle use and road maintenance are known to have killed some plants and they, along with housing development and garbage dumping, are threats of lower magnitude or immediacy.

Special significance of the species

Eastern Mountain Avens is one of the most globally rare plants of the Canadian Maritimes and has a unique global distribution. Molecular genetic investigation has shown Canadian populations are genetically different from those in New Hampshire. With its endangered sister species Appalachian Avens, it forms an evolutionary branch quite distinct from all other *Geum* species. The species can be readily cultivated and may be of interest to gardeners because of its large, attractive flowers and rarity.

Existing protection

Based on NatureServe ranks, Eastern Mountain Avens is globally imperiled, critically imperiled in Nova Scotia and imperiled and legally Threatened in New Hampshire. It is Endangered under the Nova Scotia *Endangered Species Act* and was assessed by COSEWIC in May 2000 as Endangered; it is currently listed on Schedule 1 of the *Species at Risk Act*. The species was listed under the United States *Endangered Species Act*, but has been removed from protection under that act because of limited threats in the United States.

TECHNICAL SUMMARY

Geum peckii
Eastern Mountain Avens benoîte de Peck
Range of occurrence in Canada (province/territory/ocean): Nova Scotia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	Conservatively estimated at 5-10 years, potentially longer
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Inferred 64% decline based on estimated decline in area occupied since 1985
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[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.	Portion of post-1985 decline occurring in last 10 years is unclear but perhaps around 64%
Are the causes of the decline clearly reversible and understood and ceased?	Causes understood, not easily reversible and not ceased
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence Calculated in Touratech QV 4.0.72 using the shortest continuous boundary method, excluding ocean area.	17 km²
Index of area of occupancy (IAO) Grid squares from NAD 83 National Topographic Series Maps 21 B/08 - Church Point and 21 B/01 - Meteghan, 2x2 km grid squares aligned from 10x10 km grids on above map sheets. (<1 km² of actual habitat is occupied by plants)	16 km² (2x2 km grid) 8 km² (1x1 km grid)
Is the total population severely fragmented?	No
Number of “locations” (as per definition, in relation to threat) Brier Island: North end of Big Meadow impacted mainly by gull nesting and remainder of Brier Island population impacted by shrub encroachment Harris Lake: spatially much separated from the Brier Island population and its two locations but also impacted by shrub encroachment.	3
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes
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?	Yes (quality and area)
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations (as per definition, in terms of threat)?	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	N Mature Individuals
Number of COSEWIC-defined individuals difficult to determine because of inability to distinguish rosettes and uncertainty regarding their maturity, but probably under 10,000 (see *Abundance*).	
Brier Island – estimated 8,500 COSEWIC-defined individuals; 2,580 – 3,080 flowering stems + vegetative clumps	8,500 (~94% of total)
Harris Lake – estimated under 500 COSEWIC-defined individuals; 44 flowering stems + vegetative clumps	<500
Total	<9,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not calculated - unknown

Threats (actual or imminent, to populations or habitats)

Major threats include:
1) Habitat change caused by nesting gulls
2) Habitat degradation and loss from tree and shrub incursion, enhanced by artificial drainage

Additional lesser threats
3) All-terrain vehicle use
4) Road maintenance and development
5) Garbage dumping

Rescue Effect (immigration from an outside source)

Status of outside population(s)? USA: New Hampshire S2 (Imperiled), Threatened under NH Native *Plant Protection Act*.	
Is immigration known or possible?	Not known and very unlikely
Would immigrants be adapted to survive in Canada?	Possibly, but NH plants subject to much more severe winter temperatures and continuous snow cover vs. Canadian sites.
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (April 2010)
Listed as Endangered under Nova Scotia *Endangered Species Act* in 2000.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	A2c+4c; B1ab(ii,iii)+2ab(ii,iii)
Reasons for designation: This globally imperiled species is geographically restricted in Canada to three locations of open peatland habitat in Nova Scotia. Its habitat has declined due to encroachment by woody vegetation, exacerbated by artificial drainage of sites. Portions of the habitat have also become degraded by nesting gulls. Threats including all-terrain vehicles, road maintenance and development have also impacted this species. Fewer than 9000 mature individuals remain with most found on private land.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2c+4c based on an inferred decline in the population of about 64% due to an estimated decline in area occupied since 1985 and on a decline in past habitat quality that is projected to continue.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B1ab(ii,iii)+2ab(ii,iii); EO and IAO are below thresholds with only three locations and a continuous decline documented and projected in habitat quality and in the IAO.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened C1 with a continuing decline documented and > 2500 but <10,000 mature plants.
Criterion D (Very Small Population or Restricted Distribution): Meets Threatened D2 with only three locations and an IAO below the critical level of 20 km^2 and ongoing serious impacts from shrub encroachment and gull nesting.
Criterion E (Quantitative Analysis): None available

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 (2010)

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

Eastern Mountain Avens

Geum peckii

in Canada

2010

TABLE OF CONTENTS

List of Figures

List of Tables

SPECIES INFORMATION

Name and classification

Scientific name:	*Geum peckii* Pursh
Synonyms:	*Geum radiatum* Michx. var. *peckii* A. Gray *Sieversia peckii* (Pursh) Rydb. *Acomastylis peckii* (Pursh) Bolle *Parageum peckii* (Pursh) H. Hara
English vernacular names:	Eastern Mountain Avens
French vernacular names:	Benoîte de Peck
Family:	Rosaceae, rose family
Major plant group:	Eudicot flowering plant

Eastern Mountain Avens is an herbaceous perennial in the rose family, Rosaceae. It is one of about 56 *Geum* species known worldwide (Gajewski 1957), 13 of which occur in North America (Kartesz 2008). The species is part of a clade of three North American species [Appalachian Avens (*G. radiatum*) and Prairie Smoke (*G. triflorum*) are the others] within the subgenus *Acomastylis* distinguished by their straight, non-jointed style. Eastern Mountain Avens is closely related to the rare southern Appalachian endemic *G. radiatum*, known from just eleven high elevation sites in Tennessee and North Carolina. Eastern Mountain Avens has been considered conspecific with *G. radiatum* by some past authors. An unpublished numerical taxonomic study (Zinck 1996) found that the pubescence characters used by Pursh (1814) to distinguish Eastern Mountain Avens from *G. radiatum*, along with a suite of other characters, did not differ between Eastern Mountain Avens from Brier Island, Nova Scotia and Mount Washington, New Hampshire and *Geum radiatum* from the Roan Mountains of North Carolina. However, a more recent molecular genetic study (Patterson and Snyder 2000) found that genetic variance between Eastern Mountain Avens and *G. radiatum* was an order of magnitude higher than variance between Eastern Mountain Avens populations in Nova Scotia and New Hampshire. They suggested that this degree of variance supported the maintenance of Eastern Mountain Avens and *G. radiatum* as separate species.

These three *Geum* species with non-jointed styles were placed in *Sieversia* by Brown in 1838 and *G. peckii* and *G. radiatum* were placed in *Acomastylis* by Bolle (1933) and *Parageum* by Hara (1935), but today they are universally retained in *Geum*.

Morphological description

Eastern Mountain Avens an herbaceous perennial with compound basal leaves having one large (5-10 cm wide), rounded terminal leaflet and one to several very small (<1 cm) lateral ones (Figures 1 and 2). The flowering stalk is 15 to 40 cm tall with small, bract-like, sessile, toothed-laciniate leaves at the stem nodes that become progressively smaller going upwards. Stems bear one to five, five-petalled flowers 2.5 to 3.5 cm wide. Petals are lemon yellow with a darker orange-yellow nectar guide toward their base. Fertilized flowers produce 30-60 seeds (Zinck 1996) in a tight cluster that is partly hidden by the erect sepals. The flattened, ovate-shaped seed body is long-hairy and about 4 mm long with the 5-11 mm style retained on the distal tip of the seed at maturity.

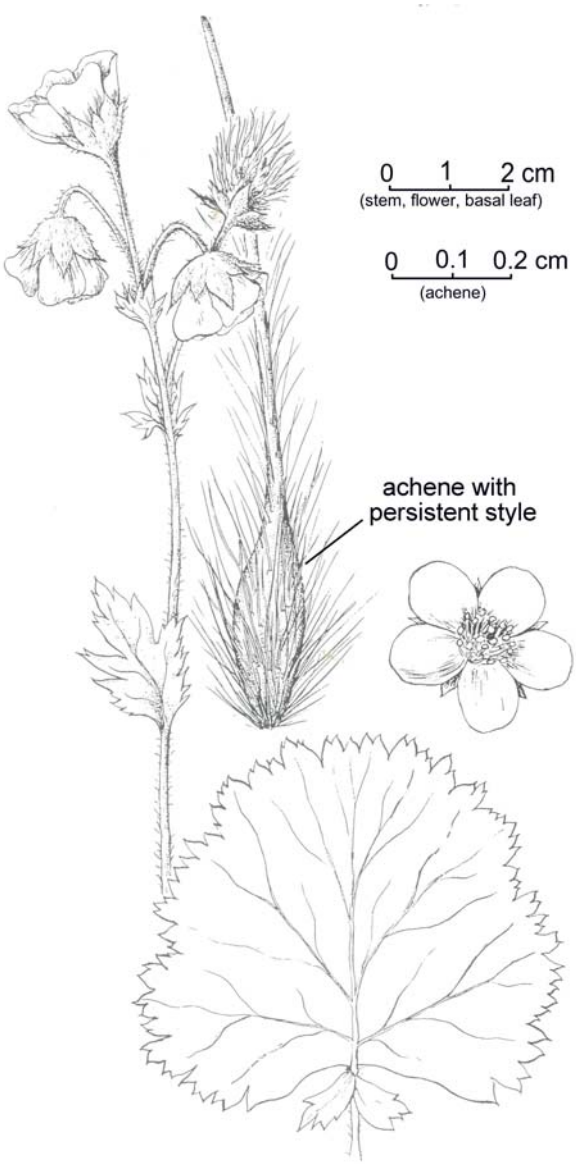

Figure 1. Illustration of Eastern Mountain Avens (*Geum peckii*), adapted from Holmgren (1996), illustrator Anne Rogelberg.

Figure 2. Eastern Mountain Avens (*Geum peckii*) clump and close-up of flower, Brier Island, Nova Scotia. Photos, Sean Blaney, Atlantic Canada Conservation Data Centre.

Eastern Mountain Avens differs from the six other *Geum* species in Nova Scotia by its combination of yellow flowers and a lack of large stem leaves and by its straight, un-jointed styles. The much longer and wider petals of Eastern Mountain Avens also separate it from the other two yellow-flowered *Geum* species [Yellow Avens (*G. allepicum* and Large-leaved Avens (*G. macrophyllum*)], as does the dark orange-yellow colour around the petal bases at the flower centre and the less rounded seed head with erect rather than recurved sepals. Eastern Mountain Avens' basal leaves are fairly similar in size and shape to those of *G. macrophyllum* but have smaller and fewer lateral leaflets, are thicker and tougher, darker green and on average slightly larger (S. Blaney, pers. obs. 2008). *G. macrophyllum* would be unlikely to share the peatland habitats of Eastern Mountain Avens in Canada.

Spatial population structure and variability

Raynor found that Eastern Mountain Avens from the White Mountains of New Hampshire had a somatic chromosome number of 42, the most common chromosome number in the genus (Raynor 1952 and references therein). Paterson and Snyder (2000) analyzed genetic variance within and among North Carolina, New Hampshire and Nova Scotia populations of Eastern Mountain Avens and *Geum radiatum*, using five random amplified polymorphic DNA (RAPD) primers. They found 47 usable genetic markers, of which 7 were monomorphic across all plants, 6 were rare, 4 were monomorphic within species (species-specific), 15 were monomorphic in one species but variable in the other and 15 were variable in both species. They calculated Nei's unbiased genetic distance between Nova Scotia and New Hampshire populations as 0.0462. Nei's distance between two different Nova Scotia populations of Eastern Mountain Avens and North Carolina *G. radiatum* was approximately 10 times greater at 0.4976 and 0.4538. Nei's genetic distances between New Hampshire Eastern Mountain Avens and North Carolina *G. radiatum* were between 0.3472 and 0.3934. Paterson and Snyder (2000) also found that even after removing species-specific loci from their analysis, 49.4% of genetic variation was due to differences between species. They felt that this finding, coupled with the ten times greater amount of between species vs. within species genetic variation, supported the maintenance of Eastern Mountain Avens and *G. radiatum* as separate species.

Paterson and Snyder (2000) also found statistically significant genetic variation in an analysis of molecular variation (AMOVA) between New Hampshire and Nova Scotia populations and significant within-population variance for all Eastern Mountain Avens and *G. radiatum* populations studied.

Designatable units

There is a single designatable unit for Eastern Mountain Avens in Canada, since the populations occur within 20 km of each other within the Atlantic COSEWIC National Ecological Area.

DISTRIBUTION

Global range

Eastern Mountain Avens occurs only at higher elevations in the White Mountains of central New Hampshire over an area of about 35 km by 65 km and in Canada at Brier Island and Harris Lake, separated by 20 km, in Digby County, Nova Scotia (Figure 3). This species is reported by Gleason & Cronquist (1991) to occur in Maine but no records substantiate this report (Cameron, pers. comm.).

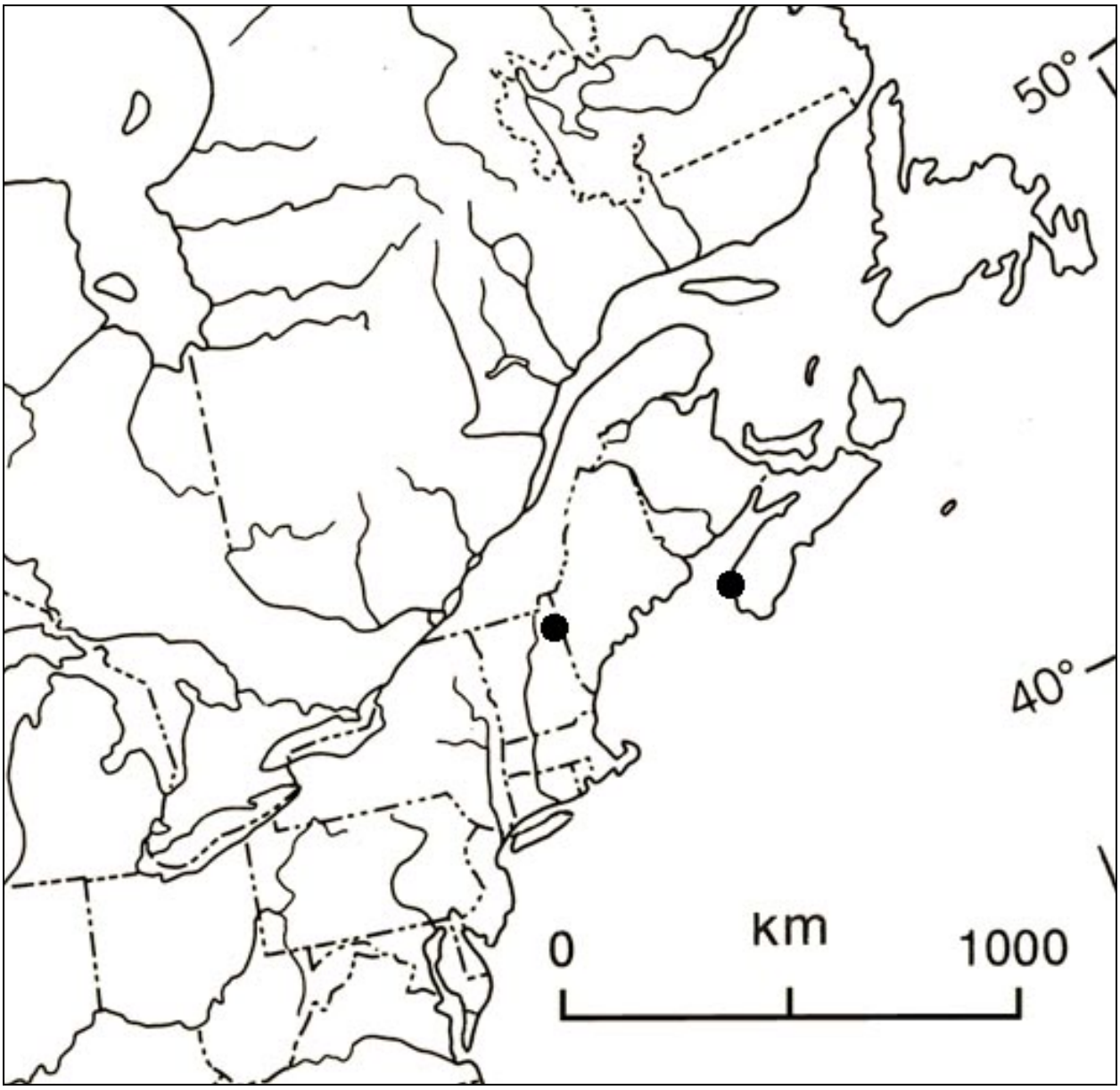

Figure 3. Global range (dots) of Eastern Mountain Avens (Keddy 1986).

Canadian range

Eastern Mountain Avens occurs in Canada only in southwestern Digby County in extreme southwestern Nova Scotia (Figure 4). It was first discovered at Brier Island in 1949 (Atlantic Canada Conservation Data Centre 2008) by a party including A.E. Roland and E.C. Smith and has since been found to be widely distributed on the southern half of that island. The only other site was discovered 20 km to the northeast of Brier Island at Harris Lake on Digby Neck in 1997 (Newell and Proulx 1998). Scoggan (1979) reported the species from Cumberland and Pictou counties in Nova Scotia, but these records are actually Slashed Avens (*Geum laciniatum,* Keddy 1986). The Extent of Occurrence is 17 km² (which excludes 8.1 km² of ocean) using the shortest continuous boundary method (COSEWIC 2007). The Index of Area of Occupancy is 16 km² using a 2 x 2 km grid and 8 km² using at 1 x 1 km grid. Field estimates of actual area of habitat occupied in Canada are less than 1 km^2.

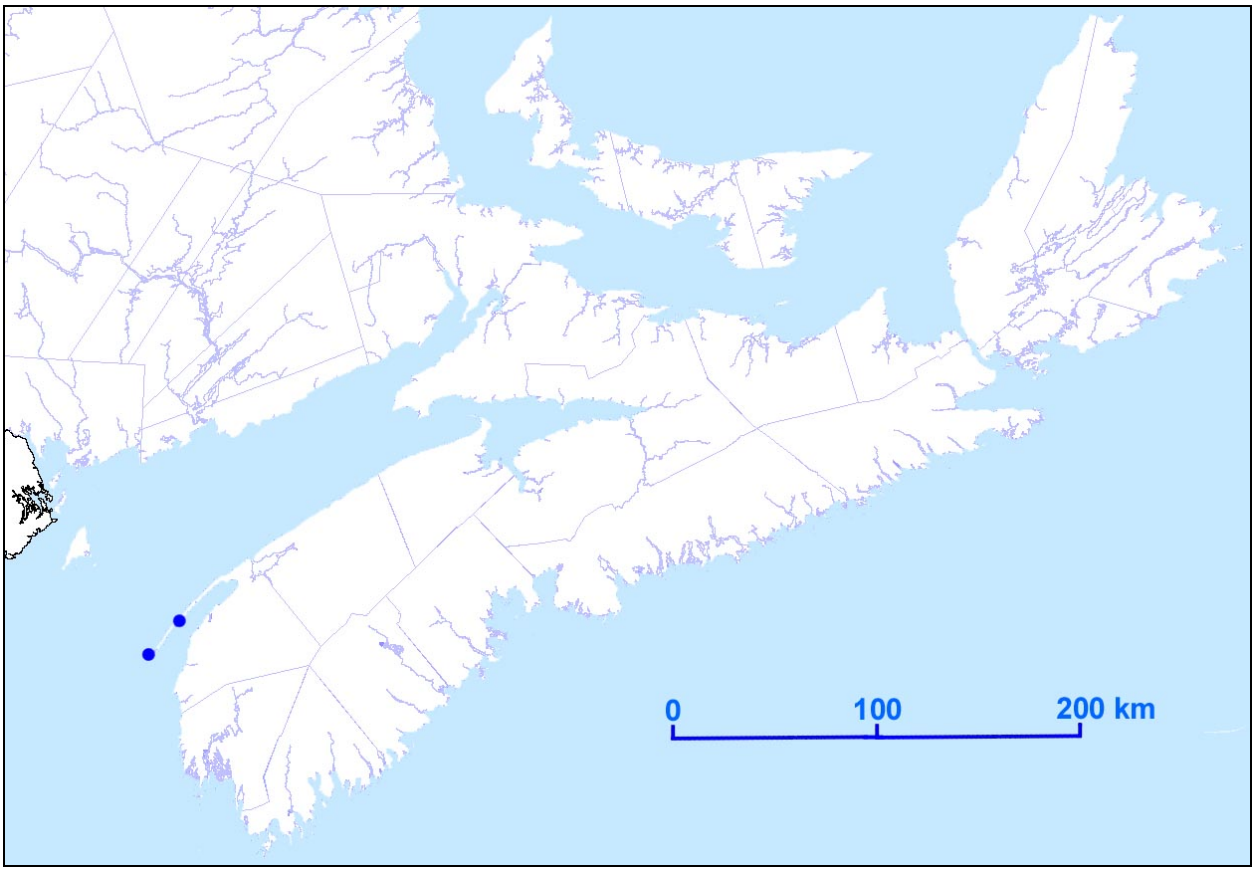

Figure 4. Canadian distribution of Eastern Mountain Avens (*Geum peckii*); southern dot is Brier Island, northern dot is Harris Lake.

The Canadian population is not considered to be severely fragmented, as defined by COSEWIC, because all of the plants occur in two viable populations (Brier Island and Harris Lake) with those on Brier Island representing >90% of all mature individuals. Brier Island plants also occupy most of the species' area of occupancy.

HABITAT

Habitat requirements

Eastern Mountain Avens occurs in sites having cool summers in moist, often peaty soils in full or nearly full sun. Both Nova Scotia and New Hampshire sites are subject to frequent summer fog.

In New Hampshire, Eastern Mountain Avens occurs in rocky wet meadows, along streams, in bogs and peaty depressions at 1200-1830 m elevation in the White Mountains, within the largest expanse of alpine tundra in the eastern United States. It descends to the subalpine zone at 425-760 m along steep streams, especially at cascades (NatureServe 2008). Hadley and Bliss (1964) also note that it tends to be found on lower, sunnier slopes within the high alpine zone. Bliss (1963) classified the alpine communities of the White Mountains and listed Eastern Mountain Avens at 0.7% cover in his Dwarf Shrub-Heath-Rush community, which was dominated by conspicuous clumps of Highland Rush (*Juncus trifidus*) with low, scattered plants of Mountain Cranberry (*Vaccinium vitis-idaea*), Alpine Blueberry (*V. uliginosum*), Three-tooth Cinquefoil [*Sibbaldiopsis (=Potentilla) tridentata*] and smaller amounts of Bigelow's Sedge (*Carex bigelowii*) and Lapland Diapensia (*Diapensia lapponica*). He also noted it in a moist streamside community with Labrador Indian-Paintbrush (*Castilleja septentrionalis*), Mountain Sorrel (*Oxyria digyna*), American Alpine Speedwell [*Veronica wormskjoldii* var. *wormskjoldii* (=*Veronica alpina* var*. unalaschensis*)], Marsh Violet (*Viola palustris*), *Carex bigelowii*, Large-leaved Goldenrod (*Solidago macrophylla*), Harebell (*Campanula rotundifolia* var*. arctica*) and Canada Bluejoint (*Calamagrostis canadensis* var*. scabra*). Sardinero (2000) classified the same communities using a multivariate analysis and listed Eastern Mountain Avens as a "constant" species in an alpine snowbank community characterized by Wavy Hair-Grass (*Deschampsia flexuosa*), Cutler's Alpine Goldenrod (*Solidago cutleri*), False Hellebore (*Veratrum viride*), Dwarf Blueberry (*Vaccinium caespitosum*), *Carex bigelowii*, Goldthread (*Coptis groenlandica*), and Bunchberry (*Cornus canadensis*). He also noted its presence in alpine sedge meadows dominated by *Carex bigelowii* accompanied by *Sibbaldiopsis (=Potentilla) tridentata*, *Solidago cutleri,* Greenland Sandwort (*Minuartia groenlandica*), Arctic Bentgrass (*Agrostis mertensii*), and *Juncus trifidus*.

In Nova Scotia, most plants are in moist to wet *Sphagnum* peat in sparsely treed or untreed peatlands. A diversity of low shrubs is common in these habitats, but Eastern Mountain Avens tends to occur in sites where shrubs are lower and sparser than is typical for the peatlands as a whole. Coast Sedge (*Carex exilis*) and Tufted Leafless-Bulrush [*Trichophorum caespitosum* (=*Scirpus caespitosus*)] are consistent graminoid herbaceous dominants, often with Pickering's Reed-Grass (*Calamagrostis pickeringii*). Slender Sedge (*Carex lasiocarpa* var. *americana*) is a co-dominant at the Harris Lake site. The prostrate dwarf shrubs Small Cranberry (*Vaccinium oxycoccos*) and Black Crowberry (*Empetrum nigrum*) are often abundant. Common low shrubs include Shrubby Cinquefoil (*Dasiphora fruticosa* ssp. *floribunda*, = *Potentilla floribunda*, which seems especially characteristic of suitable habitat), Dwarf Huckleberry (*Gaylussacia dumosa*), Sweet Gale (*Myrica gale*), Labrador Tea (*Ledum groenlandicum*), Leatherleaf (*Chamaedaphne calyculata*) and Bog and Sheep Laurel (*Kalmia polifolia* and *K. angustifolia*). Common Juniper (*Juniperus communis*), which is not generally common in peatlands in Nova Scotia, was also common in several sites (S. Blaney, pers. obs.).

Several Brier Island sites, generally with small numbers of plants, have been found in non-bog sites along roadsides and regenerating former pasture in moist gravelly soils or in thin peaty soils over rocky gravel. At one such site, Eastern Mountain Avens occurred with the Poverty Oat-Grass (*Danthonia spicata*) and Hair Fescue (*Festuca filiformis*) (exotic) and *Calamagrostis pickeringiii*, and the low shrubs Black Huckleberry (*Gaylussacia baccata*), *Juniperus communis*, Green Alder (*Alnus viridis* ssp. *crispa*), Wild Raisin (*Viburnum nudum* var. *cassinoides*), Mountain-Holly (*Nemopanthus mucronatus*) and Bristly Dewberry (*Rubus hispidus*), along with young White Birch (*Betula papyrifera*) and White Spruce (*Picea glauca*) (S. Blaney, pers. obs. 2008). These sites may represent colonization from nearby bog or peaty headland habitats of sites opened up by anthropogenic disturbance, rather than plants persistent from the time before settlement of Brier Island. Roland and Smith (1969) also note Eastern Mountain Avens as occurring in "burned areas" on Brier Island, which could refer to burned peatland or to headland pasture sites similar to those noted above.

Habitat trends

On Brier Island, habitat is in decline because of tree and shrub incursion and plant community change caused by gull nesting. Both these factors are most severe in Big Meadow Bog on Brier Island, the most important site for the species in Canada. Big Meadow Bog contained four of the five large (1000+ plants) sub-populations noted by Keddy (1986) and contained the only large (1,327 plants of 2,418 observed) sub-population found in 2008. Three 1.2 m deep drainage ditches were dug through Big Meadow Bog and 10 acres of the bog were ploughed and limed by Agriculture Canada in 1958 in a failed attempt to create agricultural land (Keddy 1986). The ditches still drain the bog and the resulting lower water table is probably causing increased tree and shrub cover, especially around the bog margins where Eastern Mountain Avens has been restricted at least since the 1980s (Keddy 1986). Peatland drainage is well documented to increase tree growth rates and tree cover (Paavalainen and Pavainen 1995, Macdonald and Yin 1999, Freléchoux *et al.* 2000). Eastern Mountain Avens is a

species of full or nearly full sun habitats and rarely occurs under over-topping trees or shrubs in Nova Scotia. The extent to which the avens formerly occurred in the central portions of the bog is unclear but Keddy (1986) noted loss of plants there near the main drainage ditch between the 1970s and 1985.

Except for the northern Big Meadow sub-population (BM1), most sites of occurrence tend to be within small openings on the scale of only a few metres to 20 m within otherwise more densely shrubby, semi-treed communities and such sites appear especially susceptible to increased tree and shrub cover. Increased tree and shrub cover is probably the primary cause of the decline of the northern Green Head sub-population from 1000+ plants in 1985 (Keddy 1986) to under 150 in 2008, and for the loss of most of the 4,000+ plants (Keddy 1986) along the east and west margins of the southern and central part of Big Meadow Bog. Decreased avens numbers associated with increased tree and shrub cover have also been anectdotally reported between 1999 and the present for all Big Meadow sub-populations except the northern BM1 and the Camp Road populations. In portions of some of the Green Head and Gull Rock Roads sub-populations, tree and shrub encroachment probably represents regeneration of habitats formerly kept more open by grazing sheep and cattle (Swift, pers. comm. 2009), which may have allowed the avens to colonize areas that would not have otherwise been suitable. There are no longer any livestock within avens habitat on the island.

Gull nesting in Big Meadow Bog is concentrated in the north central portion but extends right to the margin of the only large sub-population seen in 2008, at the north end of Big Meadow (BM1, see Table 1). There appears to be nothing that would prevent the expansion of gull nesting into this sub-population should gull numbers increase, or should something cause a shift in nesting area. Gull nesting in Big Meadow Bog is reported (Keddy 1986, Newell 2000, Environment Canada 2008) to have begun shortly after drainage ditches lowered the water table in 1958, with causation inferred but hard to prove given this was in a period of increasing gull populations (Stenhouse and Montevecchi 1999). At least several hundred pairs of gulls nested in the Big Meadow Bog in 2008 (S. Blaney, pers. obs. 2008), with scattered gulls nesting in the Green Head and Gull Rock Road sub-populations. Data on gull numbers on Brier Island over time provide no clear indication of trends (Chardine, pers. comm. 2009). The nutrient enrichment of gull guano completely changes the plant community over a roughly 1 m diameter area in the vicinity of the nest (probably over multiple years), killing virtually all bog plant species and causing their replacement with weedy, mostly exotic species such as Annual Bluegrass (*Poa annua*), Velvet Grass (*Holcus lanatus*), Tufted Hairgrass (*Deschampsia caespitosa* ssp. *parviflora*), chickweeds (*Cerastium fontanum* ssp. *vulgare* and *Stellaria media*), Sheep Sorrel (*Rumex acetosella*) and White Clover (*Trifolium repens*). The resulting habitat is unsuitable for Eastern Mountain Avens and a large portion of Big Meadow Bog is densely pockmarked with these weedy “holes” in the bog vegetation. The extent to which gulls have eliminated recently occupied avens habitat is unclear but they have probably reduced numbers in Big Meadow sub-populations BM2 and BM3 and they are an obvious threat to remaining plants on Big Meadow Bog, especially to the only large population (BM1) found in 2008.

Table 1. Documented Eastern Mountain Avens (*Geum peckii*) population numbers by sub-population.

Population / Sub-population	Site	Keddy (1986)	Newell & Proulx (1998) [a]	Brown (2003)[a]	Swift (2005)	Proulx (2006), Swift (2006)	Porter & Noel (2007)	NSDNR & ACCDC (2008)
Brier Island South Population								
Green Head 1	GH1	1,000+	N/A	N/A	N/A	N/A	N/A	112
Green Head 2	GH2	<1,000	N/A	N/A	N/A	N/A	N/A	37
Green Head 3	GH3	<1,000	N/A	N/A	N/A	N/A	N/A	0
Green Head 4	GH4	<1,000	N/A	N/A	N/A	N/A	N/A	113
Green Head 5	GH5	<1,000	N/A	N/A	N/A	N/A	N/A	61
Gull Rock Road 1	GR1	<1,000 (x4)[b]	N/A	2,026 rosettes	134	113	N/A	274
Gull Rock Road 2	GR2	<1,000	N/A	N/A	N/A	N/A	N/A	0
Big Meadow 1	BM1	0	N/A	1,200 rosettes	N/A	N/A	N/A	1,327
Big Meadow 2	BM2	1,000+	N/A	252 rosettes	N/A	N/A	N/A	N/A
Big Meadow 3	BM3	1,000+	N/A	186 rosettes	N/A	N/A	N/A	0
Big Meadow 4	BM5	1,000+	N/A	800 rosettes	N/A	N/A	N/A	21
Big Meadow 5	BM6	1,000+	N/A	N/A	N/A	N/A	102[c]	242[c]
Central Brier 1	CB1	N/A	N/A	N/A	N/A	N/A	N/A	8
Central Brier 2	CB2	N/A	N/A	N/A	N/A	N/A	N/A	13
Little Pond	LP	<1,000	N/A	N/A	N/A	N/A	N/A	N/A
Camp Road	CR	N/A	N/A	1,789 rosettes	"significant decline"	190	N/A	166
Western Light	WL	<1,000	N/A	N/A	N/A	N/A	6	6[d]
Harris Lake Population								
Harris Lake	HL	N/A	300 rosettes	N/A	N/A	"same area of occupancy"	N/A	44
TOTAL		minimum 5,450						2,424

[a] These surveys counted individual rosettes, rather than clumps and flowering stems as were counted in 2008.
[b] Keddy (1986) mapped four separate populations of under 1000 plants within this sub-population.
[c] Porter and Noel (2007) found their 102 plants within a slightly different area than was covered in 2008. Their numbers are added to the 140 plants observed in 2008 to get the overall total of 2424.
[d] Not checked in 2008, number based on Porter and Noel (2007) survey. Note: NSDNR=Nova Scotia Department of Natural Resources; ACCDC=Atlantic Canada Conservation Data Centre.

The Nature Conservancy of Canada has studied the possibility of blocking the drainage ditches to restore the original site hydrology (Brown 2003). This would require cooperation of private landowners, who were reported to have some interest in the possibility (Brown 2003), although one large property has since been sold to a developer who is less inclined to conservation efforts. Even if the hydrology were restored however, it is unclear how quickly or even if the effects of gull nesting and tree and shrub incursion would be reversed.

The Harris Lake population has been stable in area occupied and number of rosettes between 1997 and 2006 (Proulx and Swift, pers. comm. 2009). No anthropogenic disturbance was observed at the Harris Lake site in 2008 (S. Blaney, pers. obs. 2009) and the apparent decline in numbers at that site (from 300 in 1997 to 44 in 2008) is almost certainly a result of reduced extent of flowering in 2008 and differences in counting methods, with initial counts reflecting number of basal offshoots rather than clumps.

Habitat protection/ownership

In 1987, the Nature Conservancy of Canada (NCC) purchased a major proportion (approximately 550 ha) of the southwestern end of Brier Island (Maass 1992). This area includes almost half of the area occupied by Eastern Mountain Avens plants on Brier Island, but does not include the largest populations. Surveys in 2007-2008 found 456 plants on NCC land, which represented 17% of the total population. NCC funded a site steward from 1999 to 2001, who monitored Eastern Mountain Avens and attempted to direct all-terrain vehicle traffic away from sensitive areas by roping off certain sites. Management actions relative to Eastern Mountain Avens have been limited since that time. For the avens, NCC ownership provides the opportunity for positive management measures but has had limited impact on the most significant threats of gull nesting and tree and shrub encroachment. ATV use is also still only partially controlled within NCC property.

The remaining 83% of the Canadian population of Eastern Mountain Avens occurs on private land. This includes the northern portion of Big Meadow with at least 51% of plants observed in 2008. Other sites are mostly on land belonging to local people (Swift, pers. comm. 2009) who lack a strong interest in Eastern Mountain Avens (Brown 2003).

BIOLOGY

Life cycle and reproduction

In Nova Scotia, peak flowering is from late June to mid-July (Zinck 1996, S. Blaney, pers. obs. 2008) with Newell (2000) also noting occasional flowers into September. Not all flowers in the field produce nectar. Zinck (1996) recorded no nectar produced before June 24. Hadley and Bliss (1964) recorded similar flowering dates for Mount Washington, New Hampshire, from June 24 to July 7. Zinck (1996) carefully tracked floral phenology in Eastern Mountain Avens and found the following: Most flowers are protogynous (stigma of female organ becomes receptive before pollen is ripe) and herkogamous (male and female organs are spatially separated). The stigmata are generally held above the anthers on long styles. Stigmata were receptive for 24-36 hours after petals separated, with pollen dispersal beginning 30-72 hours after petal separation, meaning there was a six-hour overlap of pollen reception and donation potentially allowing selfing. Under experimental crosses, both selfed and outcrossed flowers produced more achenes per style than controls, with outcrossed flowers

producing the most achenes per style. No significant differences between any two of the six different crossing treatments were detected, but the overall effect of crossing treatments was marginally significant (P=0.10 and P=0.05, depending on how data were grouped), suggesting some depression of seed production associated with selfing.

Zinck (1996) recorded small flies as the only pollinators. At Mount Washington, the major pollinators observed on Eastern Mountain Avens were flies of the genus *Thricops* (Muscidae), including *Thricops spiniger*, *T. septentrionalis*, and *T. hirtulus* (Brackley and Burger 1980). Savage *et al.* (2004) noted that *Thricops* are specialist pollen-feeders and are important pollinators in the arctic and subarctic. Brackley and Burger (1980) also found an anthomyiid fly, *Hylemya aestiva* (=*Nupedia*) and *Chrysotus costalis* (Dolichopodidae) on *Geum radiatum*. There are 14 species of *Thricops* and two species of *Hylemya* in Canada and both genera are noted as "widespread" in Canada (Huckett and Vockeroth 1987, Huckett 1987). *Chrysotus* is a diverse genus across North America (Brooks *et al.* 2008), with about 120 species in Canada (Robinson and Vockeroth 1981). Thus congeners of all documented pollinators of Eastern Mountain Avens and *Geum radiatum*, perhaps including the particular species recorded, could occur on Eastern Mountain Avens in Nova Scotia.

Fonda and Bliss (1966) recorded seed dispersal on Mount Washington, New Hampshire as occurring "about July 25 and 31", but Hadley and Bliss (1964) noted only young fruits in mid-July with "many fruits beginning to mature on August 17". The limited specimen data and observations in Nova Scotia suggest that the August dates are more accurate for Nova Scotia (S. Blaney, pers. obs. 2008). Data on soil seed banking in *Geum* species are mixed, but the balance of evidence suggests relatively short-lived seeds. Town Avens (*G. urbanum*) is noted as lacking a persistent seed bank in Roberts (1986). The Swiss alpine species *G. reptans* was noted as unlikely to form persistent soil seed banks in Weppler and Stöcklin (2002) based on Schwienbacher and Erschbamer (2002) and Water Avens (*G. rivale*) is noted from some European seed bank studies but at a reduced frequency relative to its vegetative abundance, suggesting limited persistence in soil (Kalamees and Zobel 1998, Falinska 1999). Tsuyazaki (1991) and Tsuyazaki and Goto (2001), however, record 10- and 20-year persistence of *G. macrophyllum* var. *sachalinense* in topsoil buried under deep volcanic deposits in Japan.

Nichols (1934) compared Eastern Mountain Avens germination under greenhouse conditions with and without a two- to three-month outdoor cold treatment and found minimal differences (22 of 300 seeds germinated after cold treatment, 14 of 300 seeds germinated without cold treatment). The New England Wild Flower Society has also determined through germination trials that dried or refrigerated seed will germinate well when sowed outdoors.

Vegetative reproduction occurs by stout rhizomes that produce new rosettes a short distance from the parent plant. Individual plants are probably quite slow to mature and long-lived based on the thick rhizomes of larger plants and the groupings of rosettes apparently derived from multiple years of vegetative reproduction (S. Blaney, pers. obs. 2008), suggesting that five to ten years is a conservative estimate for generation time (average age of reproductive plants) in the field.

Herbivory

No information on effects of herbivory on Eastern Mountain Avens is available. White-tailed Deer (*Odocoileus virginianus*) are present around all populations and Snowshoe Hare (*Lepus americanus*), Meadow Voles (*Microtus pensylvanicus*) and/or Red-backed Voles (*Myodes gapperi*) are likely common at all sites. No evidence of mammalian herbivory was noted in 2008 field surveys (Blaney, pers. obs. 2008). Examination of leaves in 2008 found little or no damage by insect herbivores (Blaney, pers. obs. 2008).

Weppler and Stöcklin (2002) found that seeds of *Geum reptans*, a Swiss alpine species with a similar morphology to Eastern Mountain Avens, were consistently damaged during development by an apparent specialist gall midge larva (*Geomyia alpina*) which significantly reduced seed mass and number of viable seeds in comparison to plants protected by insecticide. Plants with heavily damaged seeds also devoted proportionally more energy to vegetative production through rhizomes, suggesting a trade-off between sexual and clonal reproduction. Population modelling suggested this seed predation would only slightly reduce population growth rates.

Blaney and Kotanen (2001) tested the importance of insect and vertebrate post-dispersal seed predators at the soil surface in two *Geum* species, the native *Geum aleppicum* and the exotic *Geum urbanum*. They found that insect exclusion by a sticky insect trapping substance resulted in significant increase in seed recovery for *Geum aleppicum* but not for *Geum urbanum*, while vertebrate exclusion did not significantly affect seed recovery for either species.

Physiology

Studies in the White Mountains of New Hampshire have demonstrated that, similar to other species examined, Eastern Mountain Avens showed high early season respiration, followed by a roughly 50% drop in respiration rate after the initial rapid spring growth. Early season (3.0 mg CO_2/g/hr) and late season (1.3 mg CO_2/g/hr) respiration rates were found to be highest in Eastern Mountain Avens among the species tested. Eastern Mountain Avens was the only species to reach net positive photosynthesis within the early season period, although it was still negative for that period as a whole. Over the first 26 days of the growing season, it had a daily net loss of 28.4 mg of CO_2/g while over the final 46 days of the growing season it had a daily net gain of 27.3 mg CO_2/g. These values were in a range similar to the other four herb species tested (Bliss 1962, 1963, 1966, Hadley and Bliss 1964, Fonda and Bliss 1966).

The response of Eastern Mountain Avens to light and temperature differed from the other four herbaceous species tested. Maximum net photosynthetic rate was at 20-25^{o}C, while for other species tested the maximum was at 15^{o}C. Eastern Mountain Avens also had a much higher light compensation point (1,200 foot-candles, the light intensity at which photosynthesis equals respiration) than the other species tested, and unlike the other species it showed no light saturation (the point at which greater light intensity does not produce greater photosynthesis) at 64,000 to 80,000 lux (6,400 to 8,000 foot-candles) while other species were saturated at around 24,000 lux (2,400 foot-candles).

Eastern Mountain Avens had the lowest new shoot protein values (15.3%) and highest percentage (8.4%) rhizome and root protein of four herbaceous species on Mount Washington (Hadley and Bliss 1964). They suggested that the low protein values and their uniformity through the growing season indicated that most protein is structural. Eastern Mountain Avens was also noted as maintaining a high carbohydrate level while flowering but was shown to shift carbohydrates from the shoot to the rhizome for storage starting in late July (Fonda and Bliss 1966).

Dispersal

Most other *Geum* species have hooked tips on the persistent styles that extend from their seeds. These hooked tips attach firmly to animal fur and feathers or human clothing and are important to dispersal. Eastern Mountain Avens lacks the jointed styles, the ends of which break off to create the hooked tip after fertilization, and Eastern Mountain Avens seeds do not readily cling to fur, feathers or clothing (Munro, pers. comm. 2008). Examination of the seeds suggests no strong adaptations to promote dispersal and there is no specific mention of Eastern Mountain Avens seed dispersal in the literature. The seed body is covered in long, somewhat spreading hairs that could promote clinging to fur or feathers to some degree. If some seeds were to remain on upright dead stalks into the winter (which does occur in other *Geum* species, S. Blaney, pers. obs. 2008), when shed they could blow for some distance in open bogs over a smooth, icy snow pack surface. Most seed dispersal is likely between August and September (Hadley and Bliss 1964, Fonda and Bliss 1966) and most seeds shed in the absence of such snow cover would likely not move far from the parent plant.

Interspecific interactions

Eastern Mountain Avens probably has vesicular arbuscular mycorrhizae, which are likely ecologically important to the species. The European alpine species *Geum montanum* was reported to be highly mycorrhizal in Read and Haselwandter (1981) with means of 61% and 70% of root distance having vesicular arbuscular mycorrhizae in two populations. *Geum urbanum*, a European forest and forest edge species exotic in North America is also noted as “normally mycorrhizal” with arbuscular mycorrhizae in Harley and Harley (1987). Three species of pathogenic fungi have been reported on native *Geum* in Canada and might occur on Eastern Mountain Avens: the ascomycete *Mycosphaerella caulicola*, the rust *Puccinia urbanis* and the powdery mildew

Sphaerotheca macularis (Ginns 1983). No other information on interspecific interactions, beyond those mentioned above in relation to herbivory and pollination, are known for Eastern Mountain Avens.

Adaptability

As noted above under *Habitat*, evidence from wild occurrences in Canada suggests that Eastern Mountain Avens is able to use certain human-modified habitats (moist, gravelly roadsides, old pasture on peaty headlands and burned peatlands) adjacent to its natural occurrences. Of these, only the burned peatland habitat appears to be significant to the Canadian population as a whole.

Eastern Mountain Avens is cultivated from seed at the New England Wildflower Society's Garden in the Woods at Framingham, Massachusetts and survives and produces seeds well at that location (Brumback, pers. comm. 2008) and it has been cultivated from transplants outdoors at Acadia University at Wolfville, Nova Scotia (Zinck 1996, Priesnitz, pers. comm. 2008), where it also produces seeds. The climate at both these sites is much warmer in the summer than the alpine New Hampshire and coastal Bay of Fundy locations at which Eastern Mountain Avens occurs naturally. In New Hampshire, Eastern Mountain Avens is noted as occurring at lower elevations than other species restricted to the higher parts of the White Mountains (Hadley and Bliss 1964). The information on cultivated plants and the data from the photosynthetic rate studies by Hadley and Bliss (1964) suggest that the species has a broader climatic tolerance than the zones in which it occurs and that its restriction to cooler locations is mediated by some other factor such as competition or predation.

Eastern Mountain Avens may be less tolerant of shading than some other alpine plants tested for light saturation point (see Physiology section).

POPULATION SIZES AND TRENDS

Search effort

Suitable habitat on Brier Island, Long Island and Digby Neck has been extensively searched in the past decade by a number of local botanists (Swift, pers. comm. 2009). Keddy (1986) also searched some of the same potential sites on Long Island. Previous fieldwork for COSEWIC reports (Keddy 1986, Newell 2000), research by Zinck (1996) and Paterson and Snyder (1999), as well as monitoring by the Nature Conservancy of Canada (Brown 2003, Porter and Noel 2007) have also covered Brier Island quite thoroughly. In 2008, staff of the Nova Scotia Department of Natural Resources accompanied by June Swift and Sean Blaney devoted four days to delimiting known populations by GPS; Blaney also spent a half day visiting peatlands on Brier Island not known to support the species. Some undiscovered plants could occur in small openings within otherwise dense and difficult to access shrub and low spruce peatland, but the great majority of plants on Brier Island are likely documented.

Three days of fieldwork were conducted in 2008 looking for new sites on Long Island and Digby Neck and at potentially suitable habitat 150 km northeast of known sites in ocean-influenced peatland near Cape Chignecto, Cumberland County, Nova Scotia. No new sites were discovered.

The nearest unsurveyed coastal bog habitat similar to Digby County sites is in southwestern New Brunswick. Grand Manan Island is only 60 km across the Bay of Fundy from Brier Island, and has a similar cool, foggy summer climate and fairly extensive potentially suitable peatland. The Grand Manan Archipelago is fairly well known botanically (Weatherby and Adams 1945, Weatherby *et al.* 1995) but some of its peatlands are difficult to access and may not have been investigated previously. Potentially suitable habitat probably also exists on New Brunswick's Campobello and Deer Islands and perhaps on larger islands in The Wolves, a group of five small islands well offshore.

Peatlands on the mainland of Nova Scotia, especially in the southwestern part, also offer some potential for new locations. The oceanic temperature moderation and fogginess found at Brier Island and Digby Neck diminish rapidly inland, but the extent to which these are critical to Eastern Mountain Avens occurrence in Nova Scotia is unclear, especially in light of peak photosynthetic rates at 20-25^{o}C (Hadley and Bliss 1964) and the success of cultivated plants at sites with summer-warm, sunnier climates (Brumback, pers. comm. 2008 and Priesnitz, pers. comm. 2008). Michaux's Dwarf Birch (*Betula michauxii*), a provincially rare species co-occurring with Eastern Mountain Avens on Brier Island, was once thought to be restricted to coastal bogs and barrens in Nova Scotia but has recently been found at two inland peatland sites in southern Nova Scotia and a site in eastern New Brunswick (Atlantic Canada Conservation Data Centre 2008). Many peatlands potentially suitable for Eastern Mountain Avens in southern Nova Scotia have been visited by botanists without its discovery, but many others remain unsurveyed.

Number of populations

Brier Island and Harris Lake are clearly separate populations based on the 20 km distance and persistently unsuitable habitat between them. All of the southern Brier Island sub-populations are separated by less than 1 km, generally with potentially suitable habitat between them and are thus considered a single population under NatureServe (2004) guidelines and in relation to the potential for exchange of propagules among them. There are thus two populations.

The determination of number of locations, however, represented by these two populations is equivocal. All sites appear to be threatened or potentially threatened by encroachment from tall shrubs, including Harris Lake, although the latter is spatially quite separate from Brier Island and represents a distinct location. Woody plant encroachment appears to be moderate to high at virtually all sites except perhaps the northern end of the Big Meadow on Brier Island, where the peatland is most open and where impacts of gull nesting are highest. Anecdotal reports (June Swift, pers. comm.

2009) suggest shrub encroachment is reducing populations over a relatively short (10-20 year) time scale. The threat from gull nesting eliminating peatland habitat currently seems relatively low at all sites except for the largest sub-populations at the north end of Big Meadow. The recognition of two locations for Brier Island may be appropriate: the north end of Big Bog Meadow affected by gull nesting and impacts of their droppings and the remaining area of habitat occupied by the species that is impacted primarily by shrub encroachment.

In total, three locations are recognized based on threat: two on Brier Island and one at Harris Lake.

Abundance

Eastern Mountain Avens usually occurs in fairly dense clumps or patches of 20 cm to 1 m wide, often with multiple patches more or less coalescing over a larger area. Within these patches many rosettes of basal leaves overlap extensively. Many of the rosettes in dense clumps are likely derived from vegetative reproduction although extent of reproduction by vegetative means vs. by seed has not been examined. Some vegetative rosettes are small and likely too immature for reproduction (by seed or vegetative means), while others are of a size that suggests they might be capable of flowering or vegetative reproduction despite being infertile in a given year. No data are available on size or resources required for either means of reproduction. Without digging into the peat to determine where basal leaves are attached, it is impossible to count numbers of rosettes and there is no way to assess which rosettes are capable of reproduction. For these reasons 2008 surveys used precise counts of the number of flowering stems and vegetative clumps, while previous surveys (Keddy 1986, Brown 2003) estimated total number of rosettes by extrapolating local plot counts across estimated areas of occurrence. COSEWIC defines number of mature individuals as the number believed to be capable of reproduction, with portions of a clone capable of independent survival counted separately. Counting the number of flowering stems and vegetative clumps likely underestimates the number of COSEWIC-defined individuals because vegetative clumps will tend to include multiple rosettes capable of vegetative or sexual reproduction. Counting every rosette likely over-estimates COSEWIC-defined individuals because some rosettes may be too small for reproduction by any means. For this report, numbers recorded by Keddy (1986) and Brown (2003) are noted as “# rosettes” and 2008 numbers and others derived by similar standards are noted as “# plants”.

Fieldwork in 2008 by Nova Scotia Department of Natural Resources, Atlantic Canada Conservation Data Centre and June Swift (unpublished data, Lawrence Benjamin, NS DNR) plus that of Nature Conservancy Canada in 2007 (Porter and Noel 2007) counted 2,424 flowering stems plus infertile clumps (Table 1). Numbers in 2008 are significantly lower than the 5,450 rosette minimum value[1] derived from Keddy (1986), despite the fact that eight additional sites have been found since 1985. As noted above, numbers recorded in 2008 are not directly comparable to those of Brown (2003), who estimated 6,253 rosettes in the Big Meadow, Camp Road and Gull Rock Road sub-populations by extrapolating numbers in 1 m x 1 m sample plots across measured areas of occurrence. Brown's (2003) survey area covered 70% of total plants observed in 2008. If all his rosettes were reproductively mature and therefore countable as COSEWIC-defined individuals (a questionable assumption) and they represent 70% of the total number of rosettes which would translate to 8,933 COSEWIC-defined individuals. Given the likelihood that Brown's estimate includes immature rosettes and that there have probably been declines since 2003 (Swift, pers. comm. 2009), it seems very likely that the current total population is fewer than 10,000 COSEWIC-defined individuals. A few small areas with plants recorded by Brown (2003) but not in 2008 probably persist but were missed or unsurveyed. The small area involved combined with observed densities in 2008 suggest the number of plants missed is unlikely to exceed 500. Thus the total number of flowering stems plus infertile clumps in 2008 is estimated at between 2,424 and 2,924.

Fluctuations and trends

No significant year-to-year fluctuations in Eastern Mountain Avens populations are known from Nova Scotia or New Hampshire and there is no reason to believe that short-term fluctuations would occur given the plant's apparently long-lived nature and fairly stable habitat. There is, however, evidence that significant shifts in sub-population locations and overall decline in abundance have occurred with habitat changes on Brier Island over 23 years since the fieldwork for the original COSEWIC status report (Keddy 1986). The number of flowering stems at the Harris Lake site was stable between 2006 (36) and 2008 (44) but was significantly reduced from the 300 flowering stems found in 1997 (Newell and Proulx 1998) despite similar area of occupancy and an absence of any obvious habitat change. It is unclear if this represents fluctuation in extent of flowering or a decline in vigour of the population.

Populations were not estimated in Newell (2000). Keddy (1986) also did not provide complete population numbers, but did map areas of occurrence and report five sub-populations of Eastern Mountain Avens having greater than 1000 rosettes each and nine sub-populations having fewer than 1000 rosettes

[1] The five populations given by Keddy (1986) as 1000+ were treated as 1000, and nine populations of less than 1000 were estimated by Sean Blaney to average 50 rosettes, based on present numbers in smaller populations.

Four of the five large sub-populations in Keddy (1986) were within the Big Meadow Bog, where gull nesting is significantly changing community composition and tree and shrub incursion is extensive along the bog margins where plants are concentrated. The area occupied within Keddy's four large Big Meadow sub-populations has declined 80-90% from 14.8 ha in 1985 to between 1.5 ha and 2.9 ha in 2008 (depending on whether sites adjacent to but outside Keddy's mapped area in the southeast corner of the bog are included). These declines in the Big Meadow sub-populations are partially offset by apparent increases in the north end of Big Meadow Bog (sub-population BM1), which Keddy (1986) noted as having been burned in 1984 and where she recorded no plants. In 2008, Eastern Mountain Avens occupied 4.2 ha in this sub-population and 1,327 plants were found, representing 51% of the 2008 Canadian population. The presence of that many plants suggests that some might have been present in the area in 1985, perhaps in a suppressed state from the recent fire, but numbers have probably increased since 1985 as Keddy did cover the area (Keddy, pers. comm. 2009) and would have been unlikely to miss such a large population entirely. Population numbers are not readily comparable because of differences in survey methods, except in three of Keddy's 1,000+ rosette sub-populations in Big Meadow, which experienced a minimum decline of 59% from 3,000+ in 1985 to 1,238 in 2003 (Brown 2003). Additional declines in all Keddy's Big Meadow sub-populations have been anectdotally noted (Swift, pers. comm. 2009) since 2003 as a result of tree and shrub encroachment.

Another line of evidence suggesting population decline is the fact that at least six of Keddy's (1986) nine small (under 1000 plants) Brier Island sub-populations have not been relocated. One of these potentially extirpated small sub-populations is in the centre of Big Meadow Bog where gull nesting is densest and is having the greatest impact. Five are on the thinner peat soils of the Green Head to Gull Rock Ridge along the eastern side of Brier Island where succession on formerly grazed land may have reduced suitable habitat and where roadside ditching has impacted some sub-populations (Newell 2000) and the final one is north of Little Pond where habitat is affected only by natural succession. An overall comparison of the area occupied by Keddy's sub-populations in 1985 and the same sub-populations today shows an 84% decline from 21.1 ha to 3.4 ha. Even if the increase in area at the north end of Big Meadow Bog is factored in, this still represents a 64% decline in area of occupancy. Some of the potentially extirpated populations may still be extant or may have been inaccurately mapped representations of current populations, so the 64% to 84% decline figure represents a maximum value. Nonetheless, about two thirds of this decline is from the Big Meadow Bog sub-populations.

The Harris Lake population on Digby Neck of mainland Nova Scotia was first found in 1997 (Newell & Proulx 1998). Proulx revisited the site in 2006 and found a similar area occupied by plants and similar numbers of rosettes, but a decline in number of flowering stems from 300 to 36 (Proulx, pers. comm. 2009). A total of 44 flowering stems were found in 2008. Whether this decline represents year-to-year fluctuation or a reduction in population health is unknown.

Eight new populations or sub-populations have been discovered since Keddy (1986), but there is no evidence to suggest that any of these other than the northern Big Meadow (BM1) site are newly established sites rather than sites that had been previously overlooked.

Rescue effect

New Hampshire populations of Eastern Mountain Avens are approximately 415 km west of Brier Island across the Gulf of Maine. Human or bird dispersal of seeds are the only conceivable means of immigration from New Hampshire and the probability of such an event is low.

LIMITING FACTORS AND THREATS

It is unclear why Eastern Mountain Avens' distribution is so limited, especially in light of the fact that its climatic tolerance is much broader in cultivation and its peak photosynthetic rate in the field is above the temperature range that is typical in the areas in which it grows. Viable seeds are commonly produced in Nova Scotia and New Hampshire. There is no data on establishment from seed in the field but the apparent large increase in numbers in the northern Big Meadow subpopulation (BM1) since 1985 suggests that it can reproduce well from seed under the right conditions.

Eastern Mountain Avens faces two major, inter-related real threats; habitat change caused by nesting gulls and tree and shrub encroachment reducing the suitability of occupied habitat. Other threats described below are less serious or imminent.

Habitat change caused by nesting gulls

Hundreds of Herring Gulls (*Larus argentatus*) and some Great Black-backed Gulls (*Larus marinus*) nest on Brier Island in open and semi-open peatlands (S. Blaney, pers. obs., 2008). Most nest on the Big Meadow Bog but some also nest in small patches of peatland within the Green Head and Gull Rock Road subpopulations. Gulls likely began to nest on the Big Meadow Bog because of lower water levels after drainage ditches were completed in 1958 (Newell 2000, Environment Canada 2008), but the colonization occurred in a period of regional gull population expansion in association with increased human refuse and fishery discards (Stenhouse and Montevecchi 1999), so causation is unclear.

Canadian Wildlife Service estimates of gull numbers on Brier Island have not been undertaken since 1991. Numbers reported were 2,880 pairs (87% Herring Gulls, 13% Great Black-backed Gulls) in 1987 and lowest were 34 pairs of Herring Gulls reported in 1983 (Chardine *et al.* 2008), but the latter figure undoubtedly did not represent a complete survey (Lock, pers. comm. 2009). The larger figure likely includes numbers from other colonies on Brier Island besides Big Meadow Bog. The area occupied by gulls on Big Meadow Bog seems to have increased somewhat since 1999 (Swift pers. comm. 2009).

The areas of Big Meadow bog in which gulls nest densely have altered plant communities in patches around gull nests with typical peatland species locally eliminated and replaced by weedy native and exotic species. The densest portion of the gull colony is in the north end of the Big Meadow peatland and gulls have likely reduced the area occupied by the largest Canadian population of Eastern Mountain Avens there. Gull nests were present in 2008 within about 50 m of plants in sub-population BM1 (51% of Canadian population in 2008) and there appears to be nothing preventing gull colony expansion into that population. Habitat change caused by nesting gulls has likely also reduced area of occupancy and numbers of Eastern Mountain Avens in Big Meadow subpopulations BM1, BM2 and BM3. Gulls roost and fly over portions of the bog beyond those in which they nest and nitrogen enrichment from guano may be contributing to encroachment by native trees, shrubs and weedy herbaceous species elsewhere in the Big Meadow peatland and potentially in other portions of the island as well, as has been noted in European peatlands as a consequence of increasing atmospheric deposition of nitrogen (Bobbink *et al.* 1998, Chambers *et al.* 1999).

Tree and shrub encroachment

Increasing cover of tall shrubs and trees within areas occupied by Eastern Mountain Avens is a threat to all Brier Island sub-populations, except perhaps for the largest sub-population at the northern end of Big Meadow Bog (BM1). Other than this site, most sites of occurrence tend to be within small openings on the scale of only a few metres to 20 m within otherwise more densely shrubby or semi-treed habitats. Such sites appear especially susceptible to increased tree and shrub cover. The fact that the species has no light saturation point (Hadley and Bliss 1964) suggests it is adapted to full sun conditions and its clearly noted tendency to occur in the more open portions of peatlands where woody plants are primarily very low-growing shrubs (S. Blaney, pers. obs. 2009) supports the idea that it suffers in competition with taller woody species.

Increased tree and shrub cover is probably the primary cause of the possible decline of the northern Green Head sub-population from 1000+ plants in 1985 (Keddy 1986), and for the loss of most of the 4,000+ rosettes (Keddy 1986) along the east and west margins of the southern and central part of Big Meadow Bog. Decreased avens numbers associated with increased tree and shrub cover have also been anectdotally reported by June Swift between 1999 and the present for all Big Meadow sub-populations except the northern BM1 and the Camp Road sub-population. In portions of some of the occurrences in the Green Head and Gull Rock Road sub-populations, tree

and shrub encroachment probably represents a return to more natural conditions of habitats formerly kept open by grazing sheep and cattle (Swift, pers. comm. 2009, S. Blaney, pers. obs. 2008), but elsewhere on Brier Island ingrowth is occurring in non-anthropogenic communities.

In Big Meadow Bog, tree and shrub encroachment is likely associated with the construction of three 1.2 m deep drainage ditches in 1958 in a failed attempt to convert the land to agricultural use. Peatland drainage is well-documented to increase tree cover and tree growth (Paavalainen and Pavainen 1995, MacDonald and Yin 1999, Freléchoux *et al.* 2000). The drainage ditches remain functional today. Even if the hydrology were restored however, it is unclear how quickly or even if a positive response in avens numbers would result.

All-terrain vehicle use

All-terrain vehicles (ATVs) are widely used for transportation and recreation by Brier Island residents and ATV trails are present in and near most sub-populations. The Nature Conservancy of Canada has attempted to direct ATV traffic on their properties onto particular paths and away from Eastern Mountain Avens populations using ropes. ATVs have the potential to significantly damage or even eliminate small occurrences but to this point only small numbers of plants have been observed to have been directly affected.

Development and road maintenance

The Western Light sub-population and most of the Camp Road, Green Head and Gull Rock Road sub-populations are located immediately along or within about 100 m of existing roads and as such might fall within the footprint of future development. A series of small cottages are present near the Camp Road sub-population and two residences are already present along the road near the Green Head sub-populations.

Ditching and road maintenance have been noted to have removed some plants in the past (Newell 2000) and the Western Light sub-population and some plants in the Green Head and Gull Rock Road sub-populations could be affected by road widening and ditching.

Dumping

There are several garbage piles of construction waste, old cars and other materials along the road running through the Green Head and Gull Rock Road sub-populations. Any Eastern Mountain Avens plants near the road or along drivable side trails might be subject to such dumping.

Other threats

Fire, sheep grazing, peat mining and increased peatland drainage were all cited as potential threats in Keddy (1986) but all are either not clearly negative for Eastern Mountain Avens or are no longer likely. Eco-tourism and potential for picking flowers or digging plants were also raised as potential threats by Newell (2000), but there is no evidence that these are significant.

The Brier Island shoreline tends to rise relatively rapidly, and with the exception of portions of the north and south ends of Big Meadow on Brier Island, sites are >10 m elevation above sea level. The north and south ends of Big Meadow are probably just under 10 m elevation based on the placement of topographic lines on the National Topographic System maps (Natural Resources Canada 1999, 2000). Thus direct threat by sea level rise in the short term as a consequence of climate change is unlikely.

SPECIAL SIGNIFICANCE OF THE SPECIES

Eastern Mountain Avens is one of the most globally rare plants occurring in the Canadian Maritimes. It is interesting biogeographically because its restriction to alpine New Hampshire and sea level Nova Scotia sites is unique among vascular plants. Molecular genetic investigation has shown Canadian populations to have genetic differences from those in New Hampshire (Paterson and Snyder 2000). With its endangered southern Appalachian sister species *G. radiatum*, it forms a clade quite distinct from all other *Geum* species. The species may be of interest to specialist alpine rock gardeners because of its large, attractive flowers and its rarity, and because it can be readily cultivated (Brumback pers. comm. 2008; Priesnitz, pers. comm. 2008). No other human uses appear to be known for the species.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Eastern Mountain Avens is ranked as globally imperiled (G2, NatureServe 2008), critically imperiled (S1) in Nova Scotia and imperiled (S2) in New Hampshire (New Hampshire Natural Heritage Bureau (2006). COSEWIC assessed this species as Endangered in May 2000 and is currently listed on Schedule 1 of SARA. It is listed as Endangered under the Nova Scotia *Endangered Species Act*, giving the species and its habitat legal protection on all land, in addition to the protection it would receive on federal land under the federal Species at Risk Act. The species was listed under the United States *Endangered Species Act*, but has since been removed from protection under that act because its habitats were not considered to be under significant threat there (Keddy 1986). This might be re-evaluated in future as a result of climate change. In New Hampshire, it is listed as Threatened under the state's Native Plant Protection Act.

ACKNOWLEDGEMENTS

June Swift provided invaluable direction to sites of occurrence in the field and extensive comments on many issues relevant to the report. Pamela Mills and Lawrence Benjamin, Nova Scotia Department of Natural Resources, Wildlife Division, assisted with 2008 field surveys and compiled and provided information collected from those surveys. Ruth Newell of E.C. Smith Herbarium, Acadia University provided several key references and allowed access to herbarium specimens. Paula Noel, Phil Greyson, Kendra MacDonald and Laurel Bernard of The Nature Conservancy of Canada, provided information from monitoring efforts on Nature Conservancy land. Marian Munro of the Nova Scotia Museum of Natural History shared her observations on seed dispersal. Melissa Coppola of New Hampshire Division of Forest & Lands, Natural Heritage Bureau supplied data on New Hampshire occurrences. John Burger, Professor, Department of Zoology, University of New Hampshire provided information on pollinators of Eastern Mountain Avens and *G. radiatum.* Don Cameron and Lisa St. Hilaire, Maine Natural Areas Program, provided confirmation of the species' absence from Maine and data compiled for NatureServe on the species. Julie McKnight of Environment Canada provided the proposed recovery strategy for the species. William Brumback of New England Wild Flower Society and Melanie Priesnitz, of the K.C. and Harriet Irving Botanical Gardens, Acadia University shared their experience with the species in cultivation. John Chardine and Bradley Toms, Environment Canada, Canadian Wildlife Service, provided information on nesting gull numbers on Brier Island. Karen Timm and Erich Haber of the COSEWIC secretariat handled contracting and initial review of content and formatting.

AUTHORITIES CONSULTED

William Brumback, Conservation Director, New England Wild Flower Society (experience with the species in the field in New Hampshire and in cultivation).

John Burger, Professor, Department of Zoology, University of New Hampshire (studied pollinators of Eastern Mountain Avens and *G. radiatum*).

Don Cameron and Lisa St. Hilaire, Maine Natural Areas Program (experts on flora of Maine; Lisa wrote a NatureServe compilation of data on the species).

Melissa Coppola, Environmental Information Specialist, New Hampshire Division of Forest & Lands-Natural Heritage Bureau (manager of data on New Hampshire occurrences).

Tony Lock (retired), John Chardine and Bradley Toms, Environment Canada, Canadian Wildlife Service (colonial waterbird experts with database of numbers over time and experience on Brier Island).

Julie McKnight, Species at Risk Biologist, Environment Canada (primary author of recovery strategy for the species).

Pamela Mills and Lawrence Benjamin, Nova Scotia Department of Natural Resources, Wildlife Division (maintain Nova Scotia rare species data and visited the sites in 2008).

Marian (Zinck) Munro, Botanist, Nova Scotia Museum of Natural History (completed an Honours' Thesis on Eastern Mountain Avens).

Ruth Newell, Curator, E.C. Smith Herbarium, Acadia University (author of previous COSEWIC status report on Eastern Mountain Avens).

Paula Noel, Phil Greyson, Kendra MacDonald and Laurel Bernard, Nature Conservancy of Canada (knowledge of and direct experience with monitoring efforts on Nature Conservancy Land).

Melanie Priesnitz, Horticulturalist, K.C. and Harriet Irving Botanical Gardens, Acadia University (experience with cultivation of transplanted individuals).

June Swift, local naturalist, Brier Island (has monitored many of the sites as Nature Conservancy site steward and informally since 1999).

INFORMATION SOURCES

Atlantic Canada Conservation Data Centre. 2008. Nova Scotia Rare Species Database (digital database, accessed December 5, 2008).

Blaney, C.S. & P.M. Kotanen. 2001. Post-dispersal losses to seed predators: an experimental comparison of native and exotic old field plants. *Canadian Journal of Botany* 79: 284-292.

Bliss, L.C. 1962. Caloric and Lipid Content in Alpine Tundra Plants. *Ecology* 43: 753-757.

Bliss, L.C. 1963. Alpine Plant Communities of the Presidential Range, New Hampshire. *Ecology* 44: 678-697

Bliss, L.C. 1966. Plant productivity in alpine microenvironments on Mt. Washington, New Hampshire. *Ecological Monographs* 36:125-155.

Bobbink, R., M. Hornung & J.G.M. Roelofs. 1998. The effects of air-borne nitrogen pollutants on species diversity in natural and semi-natural European vegetation. *Journal of Ecology* 86: 717-738.

Bolle, F. 1933. Ein Ubersicht uber die Gattung Geum L. und ihr nahestehenden Gattungen. *Repert. Sp. Nov. Fedde, Beih*. 72:1-119.

Brackley, F.E. & J.F. Burger, 1980. Occurrence of two anthophilous Diptera (*Hylemya aestiva, Chrysotus costalis*) on *Geum radiatum* (Rosaceae) in North Carolina. *Entomological News* 91: 110-112.

Brooks, S.E., J.M. Cumming & M.A.A. Pollet. 2008. Checklist Of Dolichopodidae s.str. (Diptera) of America North of Mexico (1st Edition). 18 pp. http://www.nadsdiptera.org/Doid/Checklist/Dolichopodidae%20Checklist.pdf (accessed December 5, 2008).

Brown, P. 2003. Big Meadow Bog and *Geum peckii*: Preliminary Restoration Plan. Nature Conservancy of Canada, Fredericton (unpublished document). 14 pp.

Brumback, W. pers. comm. 2008. Email correspondence to Sean Blaney. December 2008. Conservation Director, New England Wildflower Society. Framingham, MA.

Cameron, D. pers. comm. 2008. Email correspondence to Sean Blaney, December 2008. Botanist, Maine Natural Areas Program, Augusta, ME.

Chambers, F.M., D. Mauquoy & P.A. Todd. 1999. Recent rise to dominance of *Molinia caerulea* in environmentally sensitive areas: new perspectives from palaeoecological data. *Journal of Applied Ecology* 36:719–733.

Chardine, J. pers. comm. 2009. Telephone conversation with Sean Blaney, January 2009. Seabird Biologist, Canadian Wildlife Service, Environment Canada, Sackville, NB.

Chardine, J.W., *et al.* 2008. Colonial Waterbird Database. Canadian Wildlife Service, Sackville, NB. 2699 sites, 9623 recs (7882 obs).

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2007. Instructions for the Preparation of COSEWIC Status Reports. Online document. http://www.cosewic.gc.ca/htmldocuments/instructions_2008_e.htm#4.

Environment Canada. 2008. Recovery Strategy for the Eastern Mountain Avens (*Geum peckii*) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. 25 pp.

Falinska, K. 1999. Seed bank dynamics in abandoned meadows during a 19 year period in the Bialowieza National Park. *Journal of Ecology* 76: 350-364.

Freléchoux, F., A. Buttler & F. Gillet. 2000. Dynamics of bog-pine-dominated mires in the Jura Mountains, Switzerland: A tentative scheme based on synusial phytosociology. *Folia Geobotanica* 35: 273-288.

Fonda, R.W. & L.C. Bliss. 1966. Annual Carbohydrate Cycle of Alpine Plants on Mt. Washington, New Hampshire. *Bulletin of the Torrey Botanical Club* 93: 268-277.

Gajewski W. 1957. A Cytogenetic Study on the Genus *Geum*. *Monographiae Botanicae* 4: 1–157.

Ginns, J.H. 1983. *Compendium of Plant Disease and Decay Fungi in Canada*. 1960-1980. Publication 1813. Research Branch, Agriculture Canada, Ottawa. 416 pp.

Gleason, H. A. & A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. New York Botanical Garden, New York. 910 pp.

Hadley, E.B. & L.C. Bliss. 1964. Energy Relationships of Alpine Plants of Mt. Washington, New Hampshire. *Ecological Monographs* 34: 331-357.

Hara, H. 1935. Preliminary report on the flora of southern Hidaka, Hokkaido (Yezo) VI. *Bot. Mag. Tokyo* 49: 124-125.

Harley, J.L. & E.L. Harley. 1987. A check-list of mycorrhiza in the British Flora. *New Phytologist Supplement* 105: 1-102.

Holmgren, N.H. 1996. *Illustrated Companion to Gleason and Cronquist's Manual. Illustrations of the Vascular Plants of Northeastern United States and Canada.* New York Botanical Garden, New York. 937 pp.

Huckett, H.C. 1987. Anthomyiidae *in* Manual of Nearctic Diptera, Volume 2. pp. 1099-1114. Monograph No. 28, Research Branch, Agriculture Canada, Ottawa.

Huckett, H.C. & J.R. Vockeroth.1987. Muscidae *in* Manual of Nearctic Diptera, Volume 2. pp. 1115-1131. Monograph No. 28, Research Branch, Agriculture Canada, Ottawa.

Kalamees, R. & M. Zobel. 1998. Soil seed bank composition in different successional stages of a species rich wooded meadow in Laelatu, western Estonia. *Acta Oecologica* 19: 175-180.

Kartesz, J. 2008. Floristic Synthesis of North America (CD-ROM). Biota of North America Program. Chapel Hill, NC.

Keddy, C. 1986. COSEWIC status report on the Eastern Mountain Avens *Geum peckii* in Canada. Committee on the Status of Endangered Wildlife in Canada. 19 pp.

Keddy, C. 2009. Email correspondence to Sean Blaney. January 2009. Consulting Ecologist, Ponchatoula, LA.

Lock, T. pers. comm. 2009. Telephone conversation with Sean Blaney. January 2009. Seabird Biologist (retired), Canadian Wildlife Service, Environment Canada, Dartmouth, NS.

Maass, O. 1992. Management of the Nature Conservancy of Canada's Brier Island property, Nova Scotia: Issues, options and recommendations. The Nature Conservancy of Canada (unpublished report).

Munro, M. pers. comm. 2008. Email correspondence with Sean Blaney. December 2008. Botanist, Nova Scotia Museum of Natural History, Halifax.

NatureServe. 2004. Habitat-based Plant Element Occurrence Delimitation Guidance. http://www.natureserve.org/explorer/decision_tree.htm.

Macdonald, S.E. & F. Yin. 1999. Factors influencing size inequality in peatland black spruce and tamarack: evidence from post-drainage release growth. *Journal of Ecology* 87: 404–412.

Natural Resources Canada. 1999. National Topographic System Map 21 B/1 – Meteghan. Centre for Topographic Information, Natural Resources Canada, Ottawa.

Natural Resources Canada. 2000. National Topographic System Map 21 B/8 – Church Point. Centre for Topographic Information, Natural Resources Canada, Ottawa.

NatureServe. 2008. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: December 5, 2008).

Newell, R.E. & G. Proulx. 1998. Documentation of the occurrence of *Lophiola aurea* (Golden Crest) on Digby Neck, Digby County, Nova Scotia. Nova Scotia Museum, Halifax, Nova Scotia (unpublished report).

Newell, R.E. 2000. Update COSEWIC status report on the Eastern Mountain Avens *Geum peckii* in Canada, *in* COSEWIC assessment and update status report on the eastern mountain avens *Geum peckii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-11 pp.

New Hampshire Natural Heritage Bureau. 2006. Rare Plant List for New Hampshire. . Department of Resource and Economic Development. Concord, NH. 18 pp.

Nichols, G.E. 1934. The influence of exposure to winter temperatures upon seed germination in various native American plants. *Ecology* 15: 364-373.

Paterson, I.G. & M. Snyder. 1999. Genetic evidence supporting the taxonomy of *Geum peckii* (Rosaceae) and *G. radiatum* as separate species. Rhodora. 101: 325-340.

Paavilainen, E. & J. Paivanen. 1995. *Peatland Forestry: Ecology and Principles*. Berlin, Germany: Springer.

Porter, C. & P. Noel. 2007. Brier Island Nature Preserve Monitoring Report, July 9-10, 2007. Nature Conservancy of Canada, Fredericton. Unpublished document. 6 pp.

Priesnitz, M. pers. comm. 2008. In-person conversation with Sean Blaney. December 2008. Horticulturalist, K.C. and Harriet Irving Botanical Gardens, Acadia University, Wolfville, NS.

Proulx, G. 2009. Email correspondence to Sean Blaney. Naturalist, Clementsvale, NS.

Pursh, F.T. 1814. *Florae Americae Septentrionalis*. White, Cochrane & Co. London, 2 vols.

Raynor, R.A. 1952. Cytotaxonomic Studies of *Geum*. *American Journal of Botany* 39: 713-719.

Read, D.J. & K. Haselwandter. 1981. Observations on the Mycorrhizal Status of Some Alpine Plant Communities. *New Phytologist* 88: 341-352.

Roberts, H.A. 1986. Seed persistence in soil and seasonal emergence in plant species from different habitats. *Journal of Applied Ecology* 23: 639-656.

Robinson, H & J.R. Vockeroth. 1981. Dolichopodidae *in* Manual of Nearctic Diptera, Volume 1, pp. 625-639. Monograph No. 27, Research Branch, Agriculture Canada, Ottawa.

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

Sardinero, S. 2000. Classification and ordination of plant communities along an altitudinal gradient on the Presidential Range, New Hampshire, USA. *Plant Ecology* 148: 81–103

Savage, J., T.A. Wheeler & B.M. Wiegmann. 2004. Phylogenetic analysis of the genus *Thricops* Rondani (Diptera: Muscidae) based on molecular and morphological characters. *Systematic Entomology* 29: 395–414

Schwienbacher, E. & B. Erschbamer. 2002. Longevity of seeds in a glacier foreland of the Central Alps - a burial experiment. *Bulletin of the Geobotanical Institute ETH Zürich* 68: 63-71.

Scoggan, H.J. 1978. The Flora of Canada, Part 3. Saururaceae to Violaceae. *National Museum of Natural Sciences Publications in Botany* 7 (3). National Museums of Canada, Ottawa. 1115 pp.

Stenhouse, I., & W.A. Montevecchi. 1999. Indirect effects of the availability of capelin and fishery discards: gull predation on breeding storm-petrels. *Marine Ecology Progress Series* 184: 303–307.

Swift, J. pers. comm. 2009. Telephone conversation with Sean Blaney. January 2009. Naturalist, Westport, Brier Island, NS.

Tsuyazaki, S. 1991. Survival characteristics of buried seeds 10 years after the eruption of the Usu volcano in northern Japan. *Canadian Journal of Botany* 69: 2251–2256.

Tsuyazaki, S. & M. Goto. 2001. Persistence of seed bank under thick volcanic deposits twenty years after eruptions of Mount Usu, Hokkaido Island, Japan. *American Journal of Botany* 88:1813–1817.

Weatherby, C.A. & J. Adams. 1945. *A list of the vascular plants of Grand Manan, Charlotte County, New Brunswick*. Gray Herbarium, Harvard University, Cambridge, MA.

Weatherby, C.A. & J. Adams; revised by H.R. Hinds and G.H. Flanders. 1995. *The Flora of the Grand Manan Archipelago*. Grand Manan Historical Society. 156 pp., 12 drawings.

Weppler, T & J. Stöcklin. 2006. Does pre-dispersal seed predation limit reproduction and population growth in the alpine clonal plant *Geum reptans*? *Plant Ecology* 187: 277–287.

Zinck, M.C. 1996. Numerical Evaluation of *Geum radiatum* and preliminary studies of the pollination biology of its Nova Scotian population. Honours Thesis, Acadia University, Wolfville, Nova Scotia.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

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 discovered dozens of new provincial records for vascular plants and documented several thousand rare plant locations during extensive fieldwork across the Maritimes region. Sean is also 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 several 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.

COLLECTIONS EXAMINED

Specimens at the E.C. Smith Herbarium, Acadia University (ACAD) were examined in relation to phenology. All specimens of the species from the E.C. Smith Herbarium, the Nova Scotia and New Brunswick Museums (NSPM, NBM) and the Connell Memorial Herbarium at University of New Brunswick (UNB) have already been documented in the Atlantic Canada Conservation Data Centre database (AC CDC 2008).