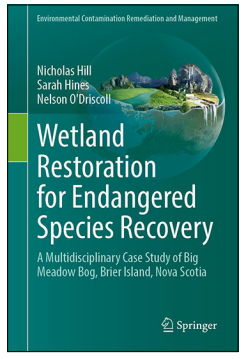
Conservation and Climate Change

Wetland Restoration for Endangered Species Recovery: a Multidisciplinary Case Study of Big Meadow Bog, Brier Island, Nova Scotia

Edited by Nicholas M. Hill, Sarah Hines, and Nelson J. O'Driscoll. 2025. Springer Cham. 353 pages, 95 colour illustrations, and 22 black and white illustrations, 291.95 CAD, Hardcover. Also available as an E-book.



For information about this book and its accessibility go to https://link.springer.com/book/10.1007/978-3-031-71344-6 (a preview is also available on Google Books). It is organized into two primary sections: Section I overviews the restoration work to characterize the biogeochemistry of the bog and the ecological interactions, and Section II examines the post-restoration temporal and spatial changes in the bog and the need for continued monitoring and intervention. The book has 17 chapters, eight in Section I and nine in Section II.

There is substantial variation in the quality of the chapters, but all are useful in providing a helpful list of references as well as some useful, and sometimes novel, perspectives. Overall, the work is an extremely significant conservation achievement.

Chapter 1, Introduction, suggests that a common problem of conservation is the lack of evidence and other knowledge to direct and guide recovery and restoration actions. This book summarizes diverse work and conservation activities that support the recovery of the Endangered (SARA Registry 2025) plant Eastern Mountain Avens (*Geum peckii*). The key factor is the will and interest of researchers, governmental and non-governmental conservation practitioners, and the local community on Brier Island, Nova Scotia. The introduction contains an important overview of the rationale for the restoration project and an outline of the concepts of adaptive management, which shapes the rest of the project and the structure of the book (p. 9, Figure 1.1). In an adaptive management approach, collaborators work cyclically through five steps: (1) concept development, (2) planning and monitoring, (3) implementing actions and monitoring, (4) analyzing and adapting, and (5) sharing what is learned. Information is centred on two main, closely related subjects: *G. peckii* and its major habitat in Big Meadow Bog on Brier Island.

At this point some background may be helpful. Eastern Mountain Avens has been referred to as "a sentinel species for conservation in Canada and globally" (p. 323). It is an attractive plant that can grow up to 0.5 m tall with large yellow flowers with deep orange centres, and it has a story. It is believed to be an ice age relict that may have been common in the glacial parkland below the fluctuating front of the Wisconsin Glacier. This huge mass of mile-deep ice covered most of Canada, extending into the northern United States, more than 10 000 years ago, and for 100 000 years before that. This parkland was a special environment without a definite modern analogue. It had a remarkable combination of elements including Eastern Chipmunks, Thirteen-lined Ground Squirrels from the western prairies, and lemmings now found in the far northern tundra. It was cool and often foggy. As the ice continued to melt, and the new boreal forest extended northward, the environment changed, and the Eastern Mountain Avens populations moved to a higher elevation into a similar bioclimatic zone in the White Mountains of New Hampshire. Probably at the same time, populations of *G. peckii* also moved to parts of the newly exposed coastline of Nova Scotia. Some of the first land in Nova Scotia to appear during deglaciation was Brier Island, which may have been much bigger then. The sea level was lower because a lot of water was still tied up in the continental glacier. The parkland flora moved north following the receding ice, but the climate rapidly changed. Continued warming and the difficulty colonizing a new environment to which they were not adapted resulted in some plants dying out (Courtin *et al.* 2025). Others moved north, but some became isolated in special environments that resembled the parkland. These were mostly cool places but with relatively moderate temperatures. Eastern Mountain Avens in Nova Scotia moved to the cool shoreline of the Bay of Fundy where it currently occurs on Digby Neck and Brier Island. The Minas Basin–Bay of Fundy shoreline region is one of two regions in Nova Scotia where Arctic-alpine plants are isolated and/or disjunct from more extensive cold environments in the north and west (Hounsell and Smith 1966).

The largest populations of *G. peckii* in Canada are in Big Meadow Bog on Brier Island. Drainage of the bog by ditching in 1958 lowered the water table replacing open habitat with thickets and leading to colonization by thousands of Herring Gulls (*Larus argentatus*). The gulls also eliminated habitat by trampling and changing the plant community through fertilization. There was a substantial decline in the population of Eastern Mountain Avens. A series of status reports (see Chapter 1) resulted in the plant

being listed as Endangered. The most recent of these indicates that fewer than 9000 plants remain localized within an area of 17 km^2, with less than 1 km^2 occupied by the plants, and there has been a 64% decline (COSEWIC 2010). The restoration of the habitat in Big Meadow Bog was a natural result of increasing attention and support. It was Species at Risk legislation that made it possible.

Chapter 2, Big Meadow Bog: a Lost Backyard, outlines the additional major conservation achievement of a protected landscape. Big Meadow Bog served as a common ground for Indigenous Peoples and early European settlers. Here they harvested medicinal plants, berries, and game. This ended in 1958 when it was ditched, dried, and isolated by woody growth. The bog was left ditched for 55 years with barriers of woody vegetation developing on the dry peat and isolating it from local communities. A past Chief of L'sitkuk (Bear River First Nation, which included the first people of the Bay of Fundy region), noted: "We have a responsibility to look after the lands and waters as we will only be as healthy as nature around us" (p. 13). The restoration effort (for the bog and *G. peckii*) and the boardwalk have reconnected local people with the bog, thus renewing appreciation and pride in their immediate natural landscape. This contribution to the community and to the protection of extensive biodiversity started in 1993 with the Nature Conservancy of Canada acquiring and designating the more than 4 km^2 Brier Island Nature Reserve (p. 6). It includes one quarter of the island area, 17% of the total population of *G. peckii*, and critical components of the Brier Island ecosystem.

Chapter 3, Genetic Variation, Clonal Structure, and Mating System of the Imperiled Eastern Mountain Avens (*Geum peckii*) and Its Separation from Spreading Avens (*G. radiatum*), has to do with genetic variation and taxonomy. *Geum peckii* from Nova Scotia and New Hampshire and *Geum radiatum* from the southern Appalachians are supported as separate species based largely on recent molecular evidence (COSEWIC 2010). Nova Scotian *G. peckii* is genetically uniform compared to the New Hampshire population, which has a genetic structure at a scale of 10 km. Ramets of Nova Scotian plants found more than 1 m apart are unlikely to be members of the same clone. *Geum peckii* has a mixed mating system with partial outcrossing and partial self-pollination. The Nova Scotian plants have a very high inbreeding depression but ample genetic variation indicating the importance of maintaining a suitable environment for management and recovery. This study has advantages over previous information based on RAPD (Random Amplified Polymorphic DNA) markers (Paterson and Snyder 1999).

In Chapter 4, Ecology and Conservation of the Eastern Mountain Avens in Nova Scotia, *G. peckii* is found to be a plant of naturally stressed wetland habitats where interspecific competition from shrubs is low. This chapter is very valuable in presenting a great deal of biological information resulting from discussions of: (1) range and habitat; (2) transplantation experiments relating to shrub encroachment and the water table; (3) regenerative biology including pollination, germination, and dispersal; (4) population dynamics; and (5) ecological interventions including shrub removal and facilitating seed germination and growth. It is concluded that without intervention the plant could be eliminated from Canada. An interesting paragraph at the end of the conclusion counters John Harper's argument that conservation is an idea based on nostalgia (Harper was the pioneer of plant population biology; pp. 92–93).

Chapter 5, Climate Change on Brier Island: Prospects for Long-Term Survival of *Geum peckii*, is an exemplary and very relevant chapter based on extensive data and clever analysis. It goes beyond the general subject matter containing (for example) graphs showing climate warming in Nova Scotia with the 1997 and 1998 step change (Figures 5.1 and 5.2). Climate change on Brier Island since the 1960s, following declines of *G. peckii*, is evaluated. The island has warmed 2°C since the 1990s. Brier Island has experienced more climate warming than other parts of Nova Scotia and now has the warmest temperature regime in Atlantic Canada. It is speculated that the warming climate, to which this Arctic-alpine plant may not be well adapted, will limit its general performance, but it may also cause more vigorous shrub growth that would displace *G. peckii*. Climate change is considered a serious threat that will also eliminate populations of *G. peckii* by rising sea levels and more severe storms. The high winds and upwelling of deep, cool water in the Bay of Fundy, which has helped to maintain cool conditions on Brier Island, may be changing along with the general oceanic warming. There is evidence from cultivation that *G. peckii* 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 (COSEWIC 2010: 18). This makes climate change seem a little less threatening, but is *G. peckii* likely to survive without being looked after (cultivated) in gardens (which are watered)? The plant may need a foggy, moist, and disturbed habitat. Many plants that can survive in cultivation may not survive in a nearby natural habitat. The ease of cultivation is an important management consideration, but perhaps not a good reason to downgrade the threat of climate change. The stronger evidence for a lack of impact of

increasing temperature may be that *G. peckii* survived the warmer temperatures of the postglacial hypsithermal interval, but data to support this have not been critically reviewed.

Chapter 6, Geological History and Ecosystems Evolution at Big Meadow Bog, Brier Island, Nova Scotia, provides some useful information, but the conclusion may benefit from additional work. For example, the comparison with a wide-ranging turtle (p. 130) does not seem informative. Late Holocene environmental change including dry periods with forest cover that were open bog during wetter periods are an interesting revelation. Perhaps the plants have a degree of resilience on a very local scale and can move over the landscape (assisted by unusually high winds; p. 114). It may be possible to discover more precisely the sites occupied by *G. peckii* in the past using macrofossils (seeds, etc.) preserved in dated peat layers (e.g., Landry and Cwynar 2005). The difficulty with this idea is that the seeds of *G. peckii* may be scarce and short-lived (p. 82).

Chapter 7, Pre and Post Restoration Hydrology of Big Meadow Bog, indicates that the restoration was successful in raising water levels overall, but parts of bog had poor water level recovery. It is important to consider that the rise in water level in some areas was not beneficial to *G. peckii* because it led to an increase in Sweet Gale shrubs from 5 to 85% cover (p. 85).

Chapter 8, Differences in Shallow Groundwater Dynamics Between Disturbed and Undisturbed Peatlands on Brier Island, Nova Scotia: Implications for Persistence of *Geum peckii* in Big Meadow Bog, provides some foundation for understanding the hydrologic niche of *G. peckii*. There has always been a general agreement that a return to the original (preditching) hydrology of Big Meadow Bog would benefit the plant.

Chapter 9, Greenhouse Gas Emissions from Big Meadow Bog: Influence of Gull-Derived Phosphate as a Biogeochemical Driver, reports that the long-term goal of reducing gull numbers could return Big Meadow Bog to a carbon sink, but in the short-term greenhouse gas emissions (CO_2, CH_4, N_20) have been exacerbated by the changing hydrology and eutrophication.

Chapter 10, Restoration of Wetland Hydrology at Big Meadow Bog, is well grounded with scientific information from other studies, e.g., from the extensive work done on peatland restoration in Yorkshire, England. The restoration design was implemented for Big Meadow Bog from 2016 to 2018. It included blocking ditches with regularly spaced dams, re-profiling ditch edges, and woody plant removal. It was followed by an assessment of effectiveness in 2023, which indicated that ditch-blocking structures were mostly functioning well.

Chapter 11, Baseline and 3-Year Post-restoration Bird Communities at Big Meadow Bog, Brier Island, Nova Scotia, indicates that much longer post-restoration periods are needed before restoration will be complete. Herring Gull abundance is associated with major deterioration of the breeding bird community in northeastern Big Meadow Bog, and it "is likely to take several decades" to repair the damage (p. 241).

Chapter 12, Effects of Avian Biotransport of Industrial Wastes to a Bog Ecosystem, reports that over 3000 Herring Gulls, using the bog as one of the largest nesting sites in the Maritimes, bring nutrients to the ecosystem. The gulls are largely subsidized by human activity (fish processing plants and American Mink farms, etc.) where they scavenge waste and carcasses.

Chapter 13, A Multi-Year Study of Methylmercury and Nutrient Export in Surface Water from Big Meadow Bog, Brier Island, Nova Scotia, notes that water table restoration in 2013 resulted in increased outflow of methylmercury, but it declined thereafter to a stable state of lower levels.

Chapter 14, Foliar Endophytic Fungi from *Geum peckii* in Canada, provides the first survey of this group in Eastern Mountain Avens including important new information. Although the results, along with additional study, may be helpful to conservation, the extent is unclear.

Chapter 15, *Ex Situ* Conservation of the Globally Imperiled Eastern Mountain Avens (*Geum peckii*) in Nova Scotia, Canada, indicates that Eastern Mountain Avens was successfully retrieved from seedbank storage, propagated by tissue culture, and returned to a natural habitat. It was confirmed for the first time that *G. peckii* grows in association with arbuscular mycorrhizal fungi and can be inoculated with these fungi. This was the first time in Nova Scotia that an endangered plant species was successfully retrieved from seedbank storage. This chapter is a very helpful outline of *ex situ* conservation methods. Thousands of *G. peckii* seeds are stored long term in the Acadia Seed Bank, with thousands more to be collected routinely and sustainably in the future. This work illustrates the value of seed banks and of tissue culture techniques to the conservation of biodiversity.

Chapter 16, Managing Gull Numbers: History and Challenges, begins with a review of general problems with gulls. The experiments with preventing gulls from nesting near Eastern Mountain Avens are discussed. The use of bamboo poles and egg removal was not effective.

Chapter 17, Summary and Conclusions, includes a helpful summary of the conclusions of each chapter

(pp. 345–349). In many situations we look past landscape disturbances and threats to find alternative sites for conservation. In this case an endangered species was threatened by wetland alteration, and people chose to fix the problem with a concerted conservation effort. Restoration and recovery are relatively new sciences developing from ecology, and there is much still to learn, making this book a valuable case study. The specific problems that remain to be resolved with Nova Scotian *G. peckii* and Big Meadow Bog are outlined here, providing valuable directions for future conservation efforts.

This is a long book with diverse conservation and restoration subjects, all of which are of some interest. Two important questions are:

1) What is missing from one of the most complete and extensive research efforts to protect an endangered plant in Canada?
2) What is next?

Regarding the first question, I noticed the following, which I do not consider definitely limiting to the conservation effort in this case:

a) Information on pollination and dispersal has not been studied in a sufficiently detailed manner.
b) Mathematical methods of determining survival likelihood have not been used.
c) Habitat diversity deserves more consideration. Where was *G. peckii* before the bog developed 700 or 1700 years ago (pp. 18, 58), or even when the freshwater peatland developed 2500 years ago (p. 18)? Presumably the plant was present in some of its other habitats including successional sheep pasture (8% of current occurrences; pp. 58, 61, 90, 346, etc.), perhaps previously grazed and disturbed by other mammals, or burned areas (where populations were increased by fire). Over several thousand years in Nova Scotia, it may have benefitted from natural fire, disturbance by mammals, and later activities of Indigenous Peoples including the use of fire.
d) Fire, although associated with increasing populations of *G. peckii* (p. 89), was not used in restoration experiments.
e) The disturbance requirement may have been under-emphasized despite the presence of seedlings in ATV trails, deer paths (pp. 80, 81), and sheep pastures. Over many thousands of years, Eastern Mountain Avens evolved in the cool, highly disturbed environment of fluctuating ice lobes, erosion, deposition, and megafauna (mastodons, mammoths, various Muskoxen, various very large ground sloths, giant beavers, horses, Stag Moose, Caribou, tapirs, etc.) that may have had much more impact on the landscape than ATVs of today. When the climate rapidly changed, the megafauna and many other plants died out (Courtin *et al.* 2025), but *G. peckii* remained. This may help to develop a realistic view of the evolutionary ecology of this fascinating plant.

Regarding question two, there are a few important future actions:

a) The gulls need to be reduced in number and moved. An obvious solution is the enforcement of some of the regulations having to do with the dumping of organic waste on the landscape. There are a number of actions that may not have been tested adequately yet, such as noisemakers and regular disturbance at key times.
b) Everyone seems to agree that *ex situ* conservation methods are an essential insurance for plant survival. It is probably a good time to cross provincial boundaries, cooperate with Newfoundland and Labrador, and establish *ex situ* plantings on coastal streamsides north of Bellburns and on Belle Isle.
c) Should consideration be given to improving the genetic variation in the Canadian population by introducing plants from the White Mountains?
d) Without continuing interventions this species may be lost from Canada. It is time now for a new plan.

Reading and writing is not that difficult, certainly not as difficult as it is to indulge in endless meetings and communications, extensive data gathering and analysis, to create hundreds of proposals and plans, and to carry out the heavy work of restoration. This has been a very big job, but it has also been very successful. Many hundreds of people, from Nova Scotia and beyond, have been involved. In particular, the people of Nova Scotia—including Indigenous Peoples, local community members, researchers, consultants, and government employees, who worked together to protect Eastern Mountain Avens and restore Big Meadow Bog—deserve our admiration and sincere appreciation. Dr. Nicholas M. Hill, adjunct professor at St. Francis Xavier University and Acadia University, played a major role.

Literature Cited

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2010. COSEWIC assessment and status report on the Eastern Mountain Avens *Geum peckii* in Canada. COSEWIC, Ottawa, Ontario, Canada.

Courtin, J., K.R. Stoof-Leichsenring, S. Lisovski, Y. Liu, I.G. Alsos, B.K. Biskaborn, B. Diekmann, M. Melles, B. Wagner, L. Pestryakova, J. Russell, Y. Huang, and U. Herzschuh. 2025. Potential plant extinctions with the loss of the Pleistocene mammoth steppe. Nature Communications 16: 645. https://doi.org/10.1038/s41467-024-55542-x

Hounsell, R.W., and E.C. Smith. 1966. Contributions to the flora of Nova Scotia VIII. Distribution of Arctic-alpine and boreal disjuncts. Rhodora 68: 409–419. Accessed 6 August 2025. https://www.biodiversitylibrary.org/page/632489.

Landry, M., and L.C. Cwynar. 2005. History of the endangered Thread-leaved Sundew (*Drosera filiformis*) in southern Nova Scotia. Canadian Journal of Botany 83: 14–21. https://doi.org/10.1139/b04-137

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

SARA (*Species at Risk Act*) Public Registry. 2025. Species summary: Eastern Mountain Avens (Geum peckii). Government of Canada, Ottawa, Ontario, Canada. Accessed 6 August 2025. https://species-registry.canada.ca/index-en.html#/species/184-143.

PAUL M. CATLING
Ottawa, ON, Canada