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DECLINE OF *SIBBALDIA PROCUMBENS* (ROSACEAE) ON MOUNT WASHINGTON, WHITE MOUNTAINS, NH, USA

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ABSTRACT. *Sibbaldia procumbens* (Rosaceae) is globally widespread in alpine and subalpine habitats of the Northern Hemisphere, where it thrives in areas of late-lying snow that persist into summer. Despite its widespread circumboreal distribution and local abundance, *Sibbaldia* is one of the rarest plants in New England, USA, occurring only in a single ravine on Mount Washington, New Hampshire. The New Hampshire population has evidently been declining for several decades, possibly the result of a combination of interspecific competition, over-collection, and changes in environmental conditions. We assessed historical trends, current status, and potential causes of decline of the New Hampshire population through evaluation of herbarium and historical records, field surveys, and photographic comparisons. Our research at seven New England herbaria revealed 236 plants with roots, including many large adult plants, on 65 herbarium sheets. Most of these plants were collected between 1846 and 1908, representing trophy collection activity characteristic of some novel species during that period, and which may have had a lasting impact on the reproductive capacity of this long-lived perennial. Contemporary surveys (within the last 40 years) establish a continuous decline in abundance over time. During timed surveys at two previously documented stations within Tuckerman Ravine and adjacent appropriate habitat, we found no evidence of the species. We observed encroachment of the local snowbank habitat by mountain alder [*Alnus viridis* (Chaix) DC. subsp. *crispa* (Aiton) Turrill], and possibly other species. Our observations support the hypothesis that a combination of over-collection, competition from robust vegetation, and local disturbance may have contributed to its decline and possible extirpation. If extirpated, *Sibbaldia* would be the first documented alpine vascular plant to be extirpated from New

England. Because the decline of this species may have been anthropogenically facilitated, we recommend that the feasibility of re-establishment (from Mount Washington source material) be evaluated.

Key Words: William Oakes, Mount Washington, Presidential Range, snowbed, snowbank, alpine flora, extirpation

Sibbaldia procumbens L. (Rosaceae) is a widespread, caespitose, long-lived (to more than 25 years; Coker 1966), diminutive specialist of late-lying snowfields in arctic-alpine habitats. The global distribution of *S. procumbens* closely follows the major mountain regions of the Northern Hemisphere in the Canadian Arctic, Greenland, Iceland, Scandinavia, and southern Europe (including Corsica); the Caucasus; the Tibetan Himalaya and mountains of Sichuan, China; Taiwan; and the Bering region of Russia (Global Biodiversity Information Facility [GBIF]; gbif.org; 2017). In North America, *S. procumbens* is a common component of alpine snowbanks (or snowbeds) throughout Alaska and the western mountains, including the Olympic, Cascade, and Sierra Nevada ranges, isolated ranges of the Great Basin and Colorado Plateau, and the Rocky Mountains from Alberta to New Mexico (GBIF 2017). In eastern North America, *S. procumbens* is known primarily from the Hudson Bay region (Nunavik in northern Québec and Nunavut) and isolated stations in the mountains of Labrador (Mealy Mountains), Newfoundland (Highlands of St. John, Gros Morne, Lewis Hills), Québec (Monts Groulx; Gaspésie), and New England (a single ravine on Mount Washington; Aiken et al. 2007; GBIF 2017; Jones and Willey 2012; Willey and Jones 2012).

The New England population is of particular conservation interest in part because it is 620 km removed from the species' nearest known occurrence in the Monts Chic-Chocs of Québec's Gaspé Peninsula and approximately 1100 km from the next nearest occurrence in the Lewis Hills, Newfoundland (Jones and Willey 2012). The New England occurrence was historically confined to Tuckerman Ravine on Mount Washington, Coos County, New Hampshire, where it was discovered in 1846 by William Oakes (Pease 1917). The ravine headwall area here is a very large and diverse example of an alpine herbaceous snowbank/rill community (Sperduto and Nichols 2012). Contemporary observations since 1977 suggest that the population has declined [New Hampshire Natural Heritage Bureau (NH NHB), unpublished data]. *S. procumbens* is listed as "Endangered" by the state of New Hampshire (NH NHB 2013); as a Division 2 (Regionally Rare) priority species in the *Flora Conservanda* (Brumback et al. 1996; Brumback and Gerke 2013); and a Regional Forester's Sensitive Species by the USDA Forest

Service (USDA 2012). To investigate the species' historical and current status, and possible reasons for decline in the White Mountains, NH, USA, we examined collections at New England herbaria, undertook a series of field surveys at known locations, and compared historic and current photographs and descriptions of the sites.

MATERIALS AND METHODS

To assess the historic abundance of the species on Mount Washington, as well as the extent of historic collections, we visited or consulted collections electronically (Consortium of Northeastern Herbaria, http://neherbaria.org/) at seven herbaria throughout New England: Harvard University Herbaria [New England Botanical Club (NEBC), Gray (GH), and Arnold Arboretum (A)]; Hodgdon (NHA) at University of New Hampshire; Torrey (CONN) at University of Connecticut; University of Massachusetts Amherst [includes MASS, and Amherst College (AC)]; Pringle (VT) at University of Vermont; and Yale University (YU). At each herbarium, we photographed or obtained images of all *Sibbaldia procumbens* that were clearly collected in the White Mountains, and recorded the number of individual specimens on each sheet, and whether the collection included roots/rhizomes, or if it was a snippet without roots. In addition, we recorded the name of the collector, date, and specific locality and descriptive information on the label, if provided. We also inspected records in the NH NHB Biotics database, and original observational references to evaluate the location or changes in abundance of the species over time.

To quantify the current status of the species, we conducted four intensive searches of historic locations on Mount Washington on 22 August 2014 (three people for 3.0 h), on 30 June 2015 (three people for 4.0 h), on 17 August 2015 (four people for 6.5 h), and on 22 September 2016 (two people for 3.0 h), totaling 53 search hours. During each trip, we searched extensively around the sites where the last individuals had been observed, as well as proximal areas both up and downslope, and in other potentially promising habitats within the ravine. These searches included the primary historically known location (Area 1) recorded in the NH NHB Biotics database, as well as a second distinct historical location (Area 2) described on two herbarium sheets by different collectors (Steele at NHA, and Zika at VT). This second locality was investigated on both 2015 visits, and in 2016.

Finally, to qualitatively evaluate potential change in habitat at the last two known localities, we compared photographs and vegetation descriptions from the 2014 to 2016 visits to those taken by the authors

Table 1. *Sibbaldia procumbens* collection activity by date range from seven herbaria in New England.

Date Range	Collectors	Plants with Roots	Snippets
1846	Oakes	37	3
1855	Boott	3	
1877-1886	Allen, E. and C.E. Faxon, Pringle, Dike, Blake, Farlow, Thaxter	124	3
1895-1908	Churchill, Williams, Grout, Egglston, Pease, Mackintosh, Floyd and Forbes	62	1
1925	Pease	1	
1946-1958	Steele	6	3
1977-1984	Storks, Zika		3
No Date	Unknown	3	
Total		236	13

or others during previous visits (2003 to 2011 for Area 1, and 1984 for Area 2). All photographs, field data, and herbaria research data compiled from this study are stored in permanent records at the NH NHB and with the USDA Forest Service, White Mountain National Forest.

RESULTS

At the seven herbaria visited, we catalogued a total of 236 *S. procumbens* plants with roots and 13 snippets on 65 herbaria sheets representing 68 collection events by 20 collectors (Table 1). Fifty-two percent of the plants with roots recorded were attributed to the most prolific collectors, C.E. and E. Faxon (85) and Oakes (37). The early collections ranged from one or two often large plants per sheet to those with typically many smaller plants (Figure 1). These collections likely represent only a fraction of the total number of *Sibbaldia* specimens in herbaria globally. Herbarium label data on specimens collected between the initial observation in 1846 and the early 1900s revealed few site-specific location clues or indicators of abundance (the most specific references mentioned only Tuckerman Ravine, the headwall, or proximity to the Snow Arch). Floyd and Forbes' (1907) label (NEBC-00768916) indicated that it was "very abundant," but this reference lacks necessary context. Steele (NHA-719976) consists of a single sheet with multiple small specimens collected between 1946 and 1958. Notes on the sheet make reference to two distinct areas, one of which we

Figure 1. *Sibbaldia procumbens* plants that were collected on Mount Washington by C. E. Faxon on July 4, 1878, and deposited as an herbarium specimen in the Arnold Arboretum Herbarium.

believe to be the well-known locality that most collectors apparently visited 100+ years ago on the lower headwall (Area 1) and also the one visited by contemporary botanists, from 1977 onwards. The second locality (Area 2) mentioned by Steele, and later by Zika (UVMVT-074530), refers to a location higher in the ravine in a nearby gully. Area 2 may have consisted of two or more proximal colonies, although uncertainty remains: in 1947 Steele describes two colonies within two feet of a stream in the gully; in 1984, Zika described (personal communication, field notes 2016) a colony in the gully as being less than 15 feet from a stream. Though Zika collected only one small snippet in 1984, the specimen label mentions "12 plants (four in flower), open alpine turf;" field notes refer to the site as a "fern and goldenrod glade." In total, there are only two plants with rhizomes and four snippets from Area 2 associated with the Steele and Zika collections.

The first quantitative reference to the primary historical location (Area 1) on the lower headwall is from Irene Storks who visited the site in 1977 and 1978 (Storks NHA-719979; Storks and Crow 1979). They referred to "about 70 plants growing in scattered colonies in a small area." They also mentioned damage to the site between 1977 and 1978 from either natural disturbance or deliberate collection of a big chunk of turf, around which the plants observed in 1978 grew. They noted that a second such disturbance could eliminate the entire population. Other quantitative observations recorded in the NH NHB Biotics database or by Jones and Willey include the following: 30 individuals in 1991 (6 reproductive, 24 vegetative; Brumback); several unsuccessful searches in the 1990s, 2001 and 2002. Brumback and Weihrauch concluded in 2002 that the former location of some of the plants was now dominated by larger *Solidago macrophylla* Pursh, and that there was evidence of slumping and erosion. A remaining portion of the population was rediscovered in 2003 when three clumps were observed (Jones; Weihrauch); three were observed again in 2005 (Jones and Willey); and finally, two plants in 2006 (Mattrick; Jones and Willey), 2007 (Mattrick) and 2009 (Mattrick and Weise). A revisit in 2011 (Mattrick and Weise) revealed one dead *Sibbaldia*, apparently the last individual.

Our four visits, totaling 53 h of observer-time at the known historic localities between 2014 and 2016, revealed no evidence of *S. procumbens*. This included search time at the precise last confirmed localities within both Areas 1 and 2, as well as appropriate habitat elsewhere in the ravine.

When comparing images of the Area 1 in 2014 and 2015 to photographs from 2003 and 2007, 2009, and 2011, the mountain alder

cover near the *Sibbaldia* site had increased substantially. One of the alder stems from the large crown adjacent to the former *Sibbaldia* plants was sampled at its base, revealing 15 growth rings, indicating a 2001 date of origin, and validating its dramatic expansion in the immediate vicinity of the last observed plants. An expansion of *Calamagrostis canadensis* cover, where there was once *Solidago macrophylla* and *Geum peckii*, was apparent, potentially indicating other local shifts in vegetative composition. The associated species mentioned on Steele's herbarium label from his 1958 collection were still present at the site in recent surveys (hairy cap moss, *Deschampsia* and *Solidago macrophylla*), although he made no mention of *Alnus* and other abundant species noted in more contemporary surveys.

Area 2, described and photographed by Peter Zika in 1984 during his survey with Rose Paul, was re-located with certainty in 2016. The precise plant location was identifiable by rock features and the location of Paul in the process of photographing the plants. No *Sibbaldia* plants were observed at this specific location in 2016, or in the remainder of the gully in our surveys between 2014 and 2016. A detailed examination of photos taken during the two time periods revealed some variation in community structure and composition, with some areas appearing very stable and others more dynamic. A goldenrod and fern glade associated with the *Sibbaldia* described by Zika in 1984 (field notes, personal communication), was still apparent in 2016, but appeared to have diminished slightly in size due to a modest expansion of alder in the immediate vicinity of the former *Sibbaldia*. In addition, there was some apparent local expansion of peaty turf onto a formerly open outcrop at the historic *Sibbaldia* location. The floristic composition in 1984 and 2016 was similar: most of the species listed on the Zika specimen label were observed in 2016. A few species in each time period, however, were not observed in the other, including *Calamagrostis canadensis*, which was observed in 2016 (including a large patch a short distance upslope from the former *Sibbaldia* location).

DISCUSSION

Our results from 2009–2016 indicate that *Sibbaldia* has likely been extirpated from historically known sites on Mount Washington, and the last confirmed living individual was observed in 2009. It is certainly possible that the species remains undetected at its primary historic occurrence or in similar habitats elsewhere on the Mount Washington massif, but we suggest that even if present, it may be functionally extinct, or in steady decline. The extent of herbaria collections

examined by the authors indicate that *Sibbaldia* was robustly established within the ravine in the late 1800s prior to its decline by the late 1900s. Collection was extensive throughout the late 19th and early 20th century, possibly contributing to the decline of this species. In fact, there are more than three times as many plants with roots at the seven herbaria examined than the maximum number of plants counted in the field within the last 100 years (~70 plants in 1977). Since the plants are so long-lived, this level of collection may have had a substantial impact on the long-term reproductive capacity and resiliency of the population. *Potentilla robbinsiana* Oakes ex Rydb. was nearly extirpated on Mount Washington, in large part due to over-collection by some of the same 19th century botanists who collected *Sibbaldia*, as evidenced by large numbers of herbaria specimens (Cogbill 1993). A diminished contemporary population of *Sibbaldia* may have been more vulnerable to other forces, including catastrophic local disturbance (avalanche, soil sloughing, burial), competition from other plants, or both.

A comparison of photographs and vegetation descriptions from the early 2000s (Area 1) and 1984 (Area 2) to the current condition on Mount Washington also suggests that the areas have undergone local compositional changes. Alder (*Alnus viridis* ssp. *crispa*) has overtaken the immediate location of *S. procumbens* (Area 1 and portions of Area 2), and other composition shifts were apparent as well. Research elsewhere in the species' range indicated that *S. procumbens* is disturbance-dependent (Dale and Weaver 1974; Virtanen et al. 1997), occupies sites with relatively short vegetation (rarely >10 cm in height; Coker 1966), is shade-intolerant, and susceptible to competition from taller plant species. This suggests that competition from alder and robust herbaceous vegetation in Tuckerman Ravine may have contributed to *Sibbaldia*'s decline. Capers and Stone (2011) observed an increase in the frequency of trees and the abundance of shrubs in alpine areas of the Bigelow Range in Maine (USA) over a 33-year study period. We recommend additional research on the drivers and extent of potential compositional change that may be underway in alpine ravines and snowbank communities, including integration of recent advances in understanding of avalanche and other geomorphic disturbance dynamics in Tuckerman and other alpine ravines (Martin and Germain 2016). Capers and Slack (2016) established a baseline study of alpine snowbeds on Mt. Washington, which will be useful to tracking change over time in examples of these communities, although the study does not include ravine sites.

A third potential factor contributing to decline may be direct local disturbances to plants noted by several contemporary observers. Storks and Crow (1979) noted large missing chunks of turf within the population in the 1970s, and evidence of slumping was noted by several observers in the 1990s and 2000s. The last two living plants were noted by Mattrick and Weise as growing on a slab of turf that had slid two years before their demise. Extremely small populations are vulnerable to fine-scale disturbance regardless of whether drivers of disturbance frequency and plant competition are changing.

In conclusion, we found evidence consistent with all three potential reasons for decline of *Sibbaldia* (over-collection, competition from other plants, and local environmental disturbance). The magnitude and scale of change in species competition and disturbance regimes within the ravine, and potential links to climate change, are unknown and deserve further study. Factors that may have affected *Sibbaldia* also have implications for other rare snowbed species, such as *Omalotheca supina* or *Salix herbacea*. If *Sibbaldia* has, in fact, disappeared from New England, it joins two other species that were extirpated from Tuckerman Ravine by human recreational impacts in the late 1970s: *Barbarea orthoceras* Ledeb. and *Omalotheca supina* L. (DC); (Storks and Crow 1979; Zika 1991). These extirpations were related to effects of trail construction and maintenance before there was deliberate consideration of rare plant locations. Because the glacial ravines of Mount Washington harbor some of the rarest plant species on the mountain and in New England (Jones and Willey 2012), and because alpine herbaceous snowbank/rill communities in ravines support a great diversity of alpine and montane species (>90 vascular plants alone and more than half of all rare alpine species; Sperduto and Kimball 2011; Sperduto and Nichols 2012), we suggest that long-term, standardized sampling be undertaken in order to assess the potential effects of climate change and changing disturbance processes on this unique system. In addition, given that anthropogenic processes may have contributed to the decline of *S. procumbens* on Mount Washington (i.e., over-collection, and possibly climate change mitigated shifts in composition and disturbance dynamics), the feasibility of reintroduction should be assessed. An assessment of the genetic distinctiveness of the New England specimens, as compared the population on Monts Chic-Chocs of Québec's Gaspé Peninsula, would complement this analysis. These activities could be facilitated by the existence *Sibbaldia* seeds that were collected by the NH Task Force as part of the New England Plant Conservation Program (Brumback and

Gerke 2013) and stored at the seed bank facility at the New England Wildflower Society.

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