THE DISTRIBUTION, ECOLOGY, AND CONSERVATION STATUS OF *RUBUS ACAULIS* MICHX. (DWARF OR ARCTIC RASPBERRY) IN MICHIGAN

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ABSTRACT

Rubus acaulis Michx. (dwarf or arctic raspberry) is a dwarf herbaceous perennial plant in the rose family (Rosaceae) characteristic of mesic to hydric open and forested habitats across boreal North America. The species ranges south locally to the conterminous United States, where it is designated a sensitive species by the United States Forest Service in Region 2 in Colorado and parts of Regions 6 and 9 in Washington and Michigan, respectively. *Rubus acaulis* was first discovered in Michigan in 1976, and several additional populations have been documented over the past decade from minerotrophic peatlands in eastern Upper Michigan, extending west to Marquette County. In these habitats, which are classified as patterned fen, northern fen, and poor fen, *R. acaulis* occurs with a consistent group of vascular plant associates, and is typically most frequent on the tops, sides, and margins of *Sphagnum*-dominated hummocks. Despite the recent documentation of several very large populations, the long-term prospects for the persistence of *R. acaulis* in Michigan remain uncertain due to the threat of climate change and associated disruption of ecosystem processes in its peatland habitats.

KEYWORDS: *Rubus acaulis*, Rosaceae, boreal flora, peatland, fen, conservation, climate change, Upper Michigan

INTRODUCTION

Rubus acaulis Michx. (Rosaceae) is a small herbaceous, rhizomatous raspberry (Figure 1), traditionally placed in the polyphyletic subgenus or section *Cylactis* (Raf.) Focke (Alice and Campbell 1999). The species is characterized by largely herbaceous, generally unarmed, short stems; ternate leaves with leaflets rounded at the apex; solitary, showy pink or rose flowers with glandless sepals and pedicels that are borne below (and often hidden within) the leaves; and edible, red, nearly globular fruits (Soper and Heimburger 1982; Gleason and Cronquist 1991; Ladyman 2006). The species is widespread across boreal North America, where it occurs primarily between 50° and 60° latitude (Soper and Heimburger 1982; USDA Forest Service, Eastern Region 2002; Kartesz, BONAP 2011). *Rubus acaulis* is sometimes taxonomically included within *R. arcticus* L.

FIGURE 1. *Rubus acaulis* (dwarf raspberry) in a Michigan patterned fen. Note the large flowers with rose-pink petals and rounded leaflets characteristic of the species. (Photograph by Bradford S. Slaughter, 18 June 2009.)

(as *R. arcticus* L. ssp. *acaulis* [Michx.] Focke), a circumpolar taxon that occurs at high latitudes primarily in Eurasia and Alaska (Hultén 1968; USDA Forest Service, Eastern Region 2002; USDA, NRCS 2012).

In the conterminous United States, *Rubus acaulis* is considered a boreal relict species with isolated populations in alpine regions of Washington, Montana, Wyoming, and Colorado and in peatland habitats in the northern Great Lakes region of Minnesota, Wisconsin, and Michigan (USDA Forest Service, Eastern Region 2002; Ladyman 2006; Kartesz, BONAP 2011; Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point 2012; MNFI 2013a). In the core of its boreal North American range, *R. acaulis* exhibits broad ecological amplitude, occurring in a variety of generally mesic to hydric habitats, including moist forests, meadows, bogs, muskegs, alpine slopes, tundra, and streambanks (Hultén 1968; Ladyman 2006). In the conterminous United States, it occurs in a restricted subset of habitats, including montane meadows, willow thickets, fens, riparian areas, and *Picea engelmannii* (Engelmann spruce) forests in western states and open to wooded peatlands, especially poor to rich fens, in the northern Great Lakes States (Wheeler and Glaser 1982; Glaser 1992c; USDA Forest Service, Eastern Region 2002; Washington Natural Heritage Program and U.S.D.I. Bureau of Land Management 2005; Ladyman 2006; Smith 2008; MNFI 2013a). Although *R. acaulis* is considered globally secure, the species is listed as imper-

TABLE 1. *Rubus acaulis* distribution, conservation status rank (S-rank; NatureServe 2013), state listing status, and USFS sensitive species status in the United States.

State	S-rank[1]	State Listing Status[2]	USFS Status	Notes	Sources
AK	SNR	None	None	Widespread	Hultén 1968
CO	S1	None	Sensitive, Region 2	Four extant sites and one historical site in the Pike and Arapaho National Forests	Spackman et al. 1997; Ladyman 2006
MI	S1	E	Sensitive, Region 9	See text	MNFI 2007; Voss and Reznicek 2012
MN	SNR	None	None	Core of conterminous U.S. range; documented from 18 counties	Glaser 1992c; MNDNR 2003; Ladyman 2006; Smith 2008
MT	SNR	None	None	Known from five observations in alpine peatlands	Montana Natural Heritage Program 2012
WA	S1	T	Sensitive, Region 6	One extant and one historic site	Washington Natural Heritage Program and U.S.D.I. Bureau of Land Management 2005; Ladyman 2006
WI	SNR	None	None	Newly documented in 2007 (*Horky #s.n.*, UWSP)	Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point 2012
WY	S2	None	Sensitive, Region 2	Four extant sites and one historical site in Bighorn National Forest, Yellowstone National Park, and possibly Medicine Bow National Forest. Rank recently downgraded from S1.	Fertig 2000a, 2000b; Ladyman 2006;l Heidel 2012

[1]SNR= Not Ranked; S1= Critically Imperiled; S2= Imperiled (NatureServe 2013)
[2]E= Endangered; T= Threatened

iled or critically imperiled in four of the eight states in which it occurs, including Michigan (Table 1). Reports of the species from Oregon and Maine have not been confirmed with specimens, and the taxon is not treated in recent floristic works encompassing those states (Ladyman 2006; Cook and Sundberg 2011; Haines 2011; C. S. Campbell, pers. comm., 7 February 2012).

Until recently, the status of *Rubus acaulis* in Michigan was poorly known. The species was first discovered in the state in 1976, and no new sites were documented until the mid-2000s (Voss 1985; MNFI 2013a). Recent discoveries and collections necessitate a review of our current understanding of the distribution, ecology, and conservation status of *R. acaulis* in Michigan. This paper aims to (1) provide updated collection data to inform the conservation and listing status of *R. acaulis* in Michigan; (2) clarify the distribution and ecology of *R. acaulis* in Michigan to aid survey and conservation efforts; (3) discuss the challenges as-

sociated with the conservation of a boreal relict species, particularly in the context of climatic warming; and (4) suggest avenues for monitoring and research.

COLLECTION HISTORY AND DISTRIBUTION

Rubus acaulis was first discovered in Michigan in 1976 by Charlotte Taylor while exploring a peatland in Schoolcraft County known colloquially as Shingleton Bog (C. M. Taylor, pers. comm., 11 March 2013). The first collections from this site date to May 1977 (*Henson #680, Henson #682*, MICH). Following its initial discovery, 26 years passed before a second location was documented, this one a partially forested peatland in western Luce County, north of Danaher Junction (*MacKinnon #03-283*, MICH). Since that time, the first author and colleagues have documented the species from six additional peatland sites in Chippewa, Luce, Schoolcraft, and Marquette counties between 46.1304° N and 46.3538° N latitude and 87.2521° W and 85.0236° W longitude (MNFI 2013a; Figure 2). Most Michigan occurrences are located in the Seney Sand Lake Plain ecoregion (Seney-Tahquamenon Sand Plain in Omernik and Bryce 2010) that

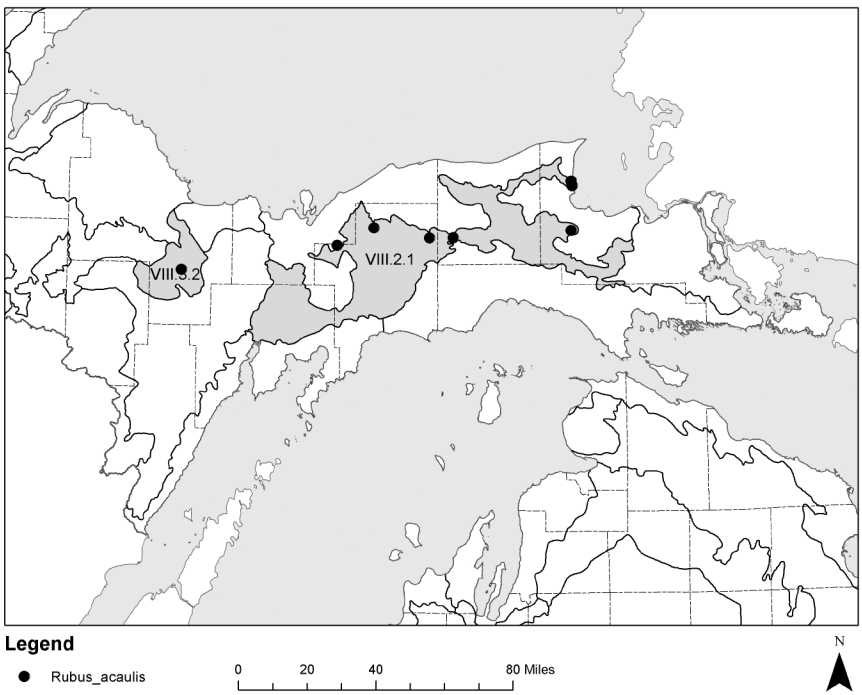

FIGURE 2. Known occurrences of *Rubus acaulis* in Michigan. VIII.2.1 = Seney Sand Lake Plain Ecoregion; VIII.3.2 = Gwinn Ecoregion (Albert 1995).

encompasses much of the central eastern Upper Peninsula, including portions of Chippewa, Mackinac, Luce, Schoolcraft, Alger, and Delta counties (Albert 1995; Figure 2). This ecoregion is characterized by expansive peatlands developed over poorly drained outwash and lacustrine sands associated with former embayments of Glacial Lake Algonquin (Albert 1995; Jerome 2006). Although Glacial Lake Algonquin last covered this area between 11,000 and 10,000 Y.B.P., the peatlands apparently established more recently (beginning approximately 5,000 to 3,000 Y.B.P.) following a climatic shift to cooler, wetter conditions (Futyma 1982; Futyma and Miller 1986; Madsen 1987; Brugam and Johnson 1997).

At the time of the General Land Office (GLO) surveys in the mid-1800s, the Seney Sand Lake Plain supported approximately 190,000 ha (470,000 ac) of swamp forest dominated by *Thuja occidentalis* (northern white-cedar) and other conifers, and 83,000 ha (200,000 ac) of open peatland (Comer et al. 1995). Although logging and attempts at drainage have altered wetlands in the ecoregion, the peat deposits currently support extensive mixed conifer swamps dominated by *T. occidentalis*, *Larix laricina* (tamarack), and *Picea mariana* (black spruce) (Albert 1995). Open peatlands, including groundwater-fed fens and weakly minerotrophic to ombrotrophic bogs and muskegs, also remain common, particularly on the broadest peat deposits southwest of Seney and northeast of Newberry (Comer et al. 1995). *Rubus acaulis* has been documented from seven such open peatland sites in the Seney Sand Lake Plain, at elevations ranging from 190 m (620 ft) near the mouth of the Tahquamenon River in Chippewa County to 254 m (830 ft) in the north-central portion of the ecoregion (Figure 2).

In 2010, the first author collected *Rubus acaulis* from an open peatland known as the Cyr Swamp in south-central Marquette County that occupies much of the poorly drained outwash plain in the Gwinn Ecoregion (included within the Menominee Drumlins and Ground Moraine Level IV ecoregion of Omernik and Bryce 2010). This is the first documented site for the species outside of the Seney Sand Lake Plain, and also the westernmost (87.2521° W), southernmost (46.1304° N), and highest elevation (approximately 330 m, or 1080 ft) documented site for *R. acaulis* in Michigan. West of the Gwinn Ecoregion, higher-relief landforms developed over ancient metamorphic and igneous bedrock restrict the development and scale of minerotrophic peatlands, limiting potential habitat for *R. acaulis*. However, *R. acaulis* has been documented from forested peatlands in Douglas County, Wisconsin and St. Louis County, Minnesota, suggesting the possibility that the species may occur in similar habitats in western Upper Michigan (Smith 2008; Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point 2012).

ECOLOGY

In Michigan, *Rubus acaulis* occurs in minerotrophic shrub- and sedge-dominated peatlands, corresponding to several vegetative associations described and classified in the United States National Vegetation Classification (USNVC) (NatureServe 2013) (Table 2). The Michigan Natural Features Inventory (MNFI)

TABLE 2. United States National Vegetation Classification (USNVC) Ecological Associations associated with *Rubus acaulis* populations in Upper Michigan (NatureServe 2013).

USNVC Ecological Association Unique Identifier	USNVC Ecological Association Common Name
CEGL002494	Bog Birch – Leatherleaf Rich Fen
CEGL002495	Bog Birch – Shrubby-cinquefoil Rich Boreal Fen
CEGL002500	Boreal Sedge Rich Fen
CEGL005226	Tamarack Scrub Poor Fen
CEGL005227	Bog Birch – Willow Shore Fen

classifies all eight *R. acaulis* sites as one of three fen types: patterned fen, northern fen, and poor fen (Kost et al. 2007; MNFI 2013a). Patterned fens appear to be particularly important habitat for *R. acaulis*, supporting five of the eight documented populations in Michigan. These peatlands are named for their so-called "ribbed" appearance associated with the presence of alternating peat ridges (strings) and hollows (flarks) oriented along the contours of the peatland slope, perpendicular to the flow of groundwater (Kost et al. 2007; Slaughter and Cohen 2010) (Figure 3). Patterned fens develop in "water tracks," which are concave- or flat-surfaced zones of drainage that channel sheet flow across peatland surfaces (Glaser 1992a; Price and Maloney 1994). Water tracks begin as narrow channels in swamp forest or other wetland communities at the upslope margins of the open peatlands and coalesce and widen downslope (Glaser 1992a). Strings and flarks are thought to develop due to the repeated inundation of depressions on the surface of the peatland, which causes their eventual expansion and coalescence across the contours of the peatland slope (Foster et al. 1983; Foster and King 1984; Glaser 1992b; Price and Maloney 1994; Quinton and Roulet 1998). Although patterned fen is known from only 20 sites in Michigan and the community is considered imperiled in the state (Kost et al. 2007), many occurrences are expansive, and the statewide acreage currently occupied by high-quality patterned fen is approximately 15,600 ha (38,500 ac, or 60 square miles) (MNFI 2013a).

Within patterned fens, *Rubus acaulis* occurs primarily in hummocky areas that support *Sphagnum*, ericaceous shrubs, and wetland conifers. This habitat occurs in the ecotone between swamp forest and open fen meadow and in "tails" of woody vegetation that occur either as extensions of the swamp forest within the fen meadow or immediately downslope of isolated dune ridges, where woody vegetation develops in response to impeded water flow and increased nutrient inputs from the adjacent mineral soils (Heinselman 1963, 1965, 1970; Glaser et al. 1981; Crum 1988; Glaser 1992a, 1992b, 1992c; Cohen et al. 2009; MNFI 2013a). Within the patterned water tracks that support fen meadow, *R. acaulis* is concentrated on the strings, where it is typically rooted in *Sphagnum* spp (Figure 3). These mosses create a thin, highly acidic (pH= 4.5–5.5), fibric substrate over peats that are otherwise less acidic (pH= 6.0-7.0), derived from sedges, and more decomposed. *R. acaulis* also occurs occasionally in mucky depressions and in flarks that lack *Sphagnum* mosses, but the species appears to be less widely distributed and less abundant in these habitats (MNFI 2013a). The relative impor-

FIGURE 3. Poor fen in Marquette County, Michigan. This extensive poor fen supports a very limited area of shrub-dominated strings (foreground) and sedge-dominated flarks (middle) where sheet flow is impeded by scattered dune ridges covered in pine forest (background). *Rubus acaulis* occurs primarily on *Sphagnum* hummocks within this fen. (Photograph by Bradford S. Slaughter, 12 September 2010.)

tance of *Sphagnum* hummocks and strings for *R. acaulis* may be associated with the water-holding capacity of hummock-forming *Sphagnum* species (Hájek and Beckett 2008), which may buffer this microhabitat from the impacts of drought.

The other three *Rubus acaulis* sites are classified as either northern fen (two sites) or poor fen (one site). Northern fens and poor fens lack strings and flarks, but are otherwise characterized by vegetation structure and plant species composition similar to that expressed in patterned fen (MNFI 2013a). The northern fen sites are dominated by fine-leaved sedges and minerotrophic shrubs with limited importance of *Sphagnum* and ericaceous shrubs and occur on slightly acid to mildly alkaline (pH 6.5–7.5) sedge- or shrub-derived peats (Kost et al. 2007; Cohen and Kost 2008a; MNFI 2013a). The single *R. acaulis* site characterized as a poor fen supports extensive areas of *Sphagnum* and ericaceous shrubs with lower importance of fine-leaved sedges and minerotrophic shrubs and occurs on medium acid to slightly acid (pH 5.5–6.5) sedge- and shrub-derived peats (Kost et al. 2007; Cohen and Kost 2008b; MNFI 2013a). Although northern fen and poor fen differ in vegetation dominance and soil properties, *R. acaulis* tends to occupy the same *Sphagnum* hummock microhabitat in both communities (MNFI 2013a). The species occurs with lower frequency and at lower density in sedge-

TABLE 3. Vascular plant taxa that occur at seven or eight of eight documented Michigan *Rubus acaulis* sites. Taxa that occur at all eight sites indicated in **bold**. Data sources: MNFI (unpublished data); Schultz (1987); MacKinnon (2005).

Tree	Shrub	Herb
Larix laricina	*Alnus incana*	*Anemone quinquefolia*
Picea mariana	***Andromeda glaucophylla***	*Calamagrostis canadensis*
Pinus strobus	***Aronia prunifolia***	*Carex exilis*
Thuja occidentalis	***Betula pumila***	***Carex lasiocarpa***
	Chamaedaphne calyculata	*Carex livida*
	Dasiphora fruticosa	***Cladium mariscoides***
	Lonicera villosa	*Comarum palustre*
	Myrica gale	*Coptis trifolia*
	Rhamnus alnifolia	***Doellingeria umbellata***
	Rhododendron groenlandicum	*Drosera rotundifolia*
	Vaccinium oxycoccos	***Equisetum fluviatile***
		Iris versicolor
		Linnaea borealis
		Maianthemum trifolium
		Muhlenbergia glomerata
		Oclemena nemoralis
		Osmunda regalis
		Pogonia ophioglossoides
		Pyrola americana
		Rhynchospora alba
		Sarracenia purpurea
		Solidago rugosa
		Solidago uliginosa
		Trichophorum alpinum
		Trichophorum cespitosum

dominated areas within these fen systems. Of note, *R. acaulis* has not been documented from poor fens weakly influenced by groundwater (pH< 5.5), nor has it been observed in the moderately to strongly alkaline (pH 8.0–8.5), marly northern fens that are especially characteristic of the Niagara Escarpment region of the eastern Upper Peninsula (Albert 1995; MNFI 2013a).

Vegetative associates of *Rubus acaulis* in Michigan are consistent across its three peatland habitats. A total of 22 taxa occur at all *R. acaulis* sites, and 40 taxa occur in at least seven of the eight documented sites (Table 3). Stunted individuals of *Larix laricina*, *Picea mariana*, *Thuja occidentalis*, and *Pinus strobus* (white pine) are characteristic of all *R. acaulis* sites. Fen hummocks are typically dominated by ericaceous shrubs such as *Andromeda glaucophylla* (bog rosemary), *Chamaedaphne calyculata* (leatherleaf), *Rhododendron groenlandicum* (Labrador-tea), and *Vaccinium oxycoccos* (small cranberry), as well as shrubs indicative of more minerotrophic conditions, such as *Betula pumila* (bog birch), *Dasiphora fruticosa* (shrubby cinquefoil), *Myrica gale* (sweet gale), and *Rhamnus alnifolia* (alder-leaved buckthorn). Characteristic ground layer associates on hummocks include *Anemone quinquefolia* (wood anemone), *Carex lasiocarpa* (wiregrass sedge), *Doellingeria umbellata* (tall flat-topped white aster), *Equisetum fluviatile* (water horsetail), *Maianthemum trifolium* (false mayflower), *Muhlenbergia glomerata* (marsh wild-timothy), *Oclemena nemoralis* (bog aster), *Os-*

munda regalis (royal fern), *Pyrola americana* (round-leaved pyrola), *Sarracenia purpurea* (pitcher-plant), *Solidago uliginosa* (bog goldenrod), *Trichophorum alpinum* (Alpine bulrush), and *T. cespitosum* (tufted bulrush). In depressions and flarks, *R. acaulis* occurs with several additional herbaceous associates, including *Carex livida* (livid sedge), *Cladium mariscoides* (twig-rush), *Iris versicolor* (wild blue flag), and *Rhynchospora alba* (white beak-rush). One other notable associate is *Rubus pubescens* (dwarf raspberry), a widespread species that differs from *R. acaulis* in its smaller, white flowers, pedicels that bear at least a few glands, and sharply acute to acuminate leaflets (Voss and Reznicek 2012). This species occasionally hybridizes with *R. acaulis*, producing *R.* x*paracaulis*, which has been collected from Michigan (Henson 682; MICH; determination E. G. Voss). In total, approximately 220 vascular plant taxa have been documented from Michigan peatlands that support populations of *R. acaulis* (MNFI 2013b).

The only quantitative data on vegetative associates of *Rubus acaulis* in Michigan was collected by Schultz (1987) at Shingleton Bog, the first documented site for dwarf raspberry in Michigan. In all three fen openings studied by Schultz, *Trichophorum cespitosum* was the most or secondmost important vascular plant associate (Table 4). Other important species included *Anemone quinquefolia*, *Andromeda glaucophylla*, *Solidago uliginosa*, *Vaccinium oxycoccos*, *Muhlenbergia glomerata*, *Oclemena nemoralis*, *Rhododendron groenlandicum*, *Dasiphora fruticosa*, and *Maianthemum trifolium* (Table 4). *Sphagnum* spp. provided at least 20% average cover in all three study sites; only *Sphagnum* mosses and *Trichophorum cespitosum* averaged greater than 10% cover in all three fen openings (Table 5). Although most of the aforementioned taxa are broadly distributed in Upper Michigan wetland communities, their co-occurrence indicates potential habitat for *R. acaulis* in the Seney Sand Lake Plain Ecoregion.

Specimen labels and MNFI field survey data do not identify bryophyte associates of *Rubus acaulis* to the species level. In general, strings (in patterned fens) and hummocks within minerotrophic fen systems support several *Sphagnum* species, including *S. angustifolium*, *S. capillifolium*, *S. magellanicum*, *S. re-*

TABLE 4. Ten most important vascular and non-vascular plant associates in *Rubus acaulis* quadrats, Shingleton Bog, ranked by Importance Value (IV = relative frequency + relative dominance). Adapted from Schultz (1987).

Big Bog		**South Bog**		**Section 12 Bog**	
Species	**IV**	**Species**	**IV**	**Species**	**IV**
Trichophorum cespitosum	121	*Sphagnum* spp.	132	*Trichophorum cespitosum*	144
Rubus acaulis	102	*Trichophorum cespitosum*	103	*Sphagnum* spp.	125
Rhamnus alnifolia	88	*Rubus acaulis*	102	*Solidago uliginosa*	103
Picea mariana	72	*Anemone quinquefolia*	101	*Rubus acaulis*	102
Sphagnum spp.	71	*Vaccinium oxycoccos*	84	*Andromeda glaucophylla*	102
Dasiphora fruticosa	70	*Alnus incana*	71	*Anemone quinquefolia*	101
Andromeda glaucophylla	69	*Rhododendron groenlandicum*	69	*Vaccinium oxycoccos*	100
Maianthemum trifolium	69	*Andromeda glaucophylla*	67	*Lonicera villosa*	87
Oclemena nemoralis	67	*Oclemena nemoralis*	67	*Muhlenbergia glomerata*	84
Solidago uliginosa	67	*Viola* spp.	67	*Drosera rotundifolia*	83
Muhlenbergia glomerata	67				

TABLE 5. Ten vascular and non-vascular plants with the highest percent cover in *Rubus acaulis* quadrats, Shingleton Bog. Adapted from Schultz (1987).

Big Bog		**South Bog**		**Section 12 Bog**	
Species	**IV**	**Species**	**IV**	**Species**	**IV**
Trichophorum cespitosum	38	*Sphagnum* spp.	32	*Trichophorum cespitosum*	44
Sphagnum spp.	21	*Trichophorum cespitosum*	19	*Sphagnum* spp.	25
Gaultheria hispidula	6	*Dasiphora fruticosa*	5	*Picea mariana*	5
Picea mariana	6	*Alnus incana*	5	*Thuja occidentalis*	5
Thuja occidentalis	6	*Picea mariana*	4	*Solidago uliginosa*	3
Rhamnus alnifolia	4	*Ilex verticillata*	5	*Lonicera villosa*	3
Dasiphora fruticosa	4	*Viburnum cassinoides*	3	*Carex exilis*	2
Trichophorum alpinum	3	*Rubus acaulis*	2	*Rubus acaulis*	2
Maianthemum trifolium	2	*Carex exilis*	2	*Andromeda glaucophylla*	2
Rubus acaulis	2	*Prunella vulgaris*	2	*Larix laricina*	2
Andromeda glaucophylla	2	*Rhododendron groenlandicum*	2	*Menyanthes trifoliata*	2
Carex stricta	2	*Sarracenia purpurea*	2		
		Thuja occidentalis	2		
		Carex stricta	2		
		Cirsium spp.	2		

curvum, and occasionally *S. warnstorfii* (Slaughter and Cohen 2010). The upper portions of strings and hummocks, which can be highly acidic due to isolation from groundwater, may support *S. fuscum* and *Polytrichum juniperinum* (juniper polytrichum moss) (Wheeler et al. 1983; Crum 1988). Bryophytes are typically of low importance in flarks and depressions, but are represented by several species, including *Aulacomnium palustre*, *Calliergon trifarium*, *Campylium polygamum*, *C. stellatum*, *Dicranum undulatum*, *Drepanocladus* spp., *Polytrichum strictum*, *Scorpidium scorpioides*, several sphagnum mosses (e.g., *Sphagnum angustifolium*, *S. cuspidatum*, *S. majus*, *S. magellanicum*, *S. papillosum*, *S. recurvum*, *S. subsecundum*, and *S. teres*), and several liverworts (including *Calypogeia* spp., *Cephalozia* spp., *Kurzia setacea*, and *Mylia anomala*) (Wheeler et al. 1983; Madsen 1987; Crum 1988; Janssens 1992). Further surveys are needed to document microhabitat-specific bryophyte associates of *R. acaulis* in Michigan.

CONSERVATION STATUS

Following its discovery in Michigan in 1976, *Rubus acaulis* was assigned threatened status in the 1980 listing of state endangered and threatened plant species. Subsequent to its discovery, *R. acaulis* was listed as a sensitive species in the Hiawatha National Forest within USFS Region 9 (USDA Forest Service, Eastern Region 2002). Over 20 years passed without any new sites being discovered, and the species was upgraded to endangered status in 1999. Since that time, several additional populations of *R. acaulis* have been documented in Upper Michigan, and a total of eight occurrences are currently tracked by MNFI (MNFI 2013a). All of these populations appear to have good to excellent viabil-

ity based on area of occupancy, population density, occurrence in relatively undisturbed habitats, and other factors (MNFI 2013a). The first documented population in Schoolcraft County occurs within the Shingleton Bog Candidate Research Natural Area (cRNA) within the Hiawatha National Forest. Establishment of this area as a RNA would provide formal protection for this *R. acaulis* population and its fen habitat. A second population of *R. acaulis* occurs in the eastern unit of the Hiawatha National Forest. A third population is partly protected within Tahquamenon Falls State Park, and extends into the adjacent Lake Superior State Forest (LSSF). Four other populations occur within LSSF and adjacent commercial forest lands, and one population has been documented from the Escanaba River State Forest (ERSF) (MNFI 2013a). Although the largest and presumably most viable *R. acaulis* populations occur within LSSF and ERSF, only one of these sites (Creighton Marsh) has received a special conservation designation as an Ecological Reference Area (Cohen et al. 2009), and efforts to provide additional measures of protection to the other sites have proven controversial (Casperson 2013; Garmon 2013).

One of the potential challenges to long-term conservation of *Rubus acaulis* in Michigan is poor fruit set and, presumably, low levels of outcrossing (Ladyman 2006). Over a three year span, the second author monitored *R. acaulis* populations in Shingleton Bog out of concern for the potential of a newly constructed logging road to disrupt water flow within the fen and negatively impact the habitat (Schultz 1987, 1988, 1990). Over that three year-span, the number of stems, average number of leaves per stem, percent cover, and number of fruits or dried flowers showed little variability in 18 permanent 1 m^2 quadrats (Schultz 1990). Few fruits were observed in any year, consistent with the documentation of scarce fruit production at the other Michigan sites (MNFI 2013a). Flower and especially fruit production also appears to be poor in the western United States, suggesting that *R. acaulis* reproduces primarily through cloning at the edges of its range (Spackman et al. 1997; Fertig 2000b; Ladyman 2006). Clonal reproduction is a life history strategy that has been demonstrated for several other edge-of-range plant species, and appears to be associated with a variety of genetic and environmental factors (Dorken and Eckert 2001; Beatty et al. 2008). Inferences from studies on *R. arcticus* ssp. *arcticus* suggest the lack of fruiting may be due to the presence of triploid populations, a preponderance of self-incompatible clones, or a lack of pollination (presumably by honeybees and/or bumblebees) (Tammisola and Ryynänen 1970; Ladyman 2006).

Rubus acaulis is a relict species that occupies peatland habitats that are expected to be sensitive to climatic warming and associated changes in water balance and nutrient cycling (Galatowitsch et al. 2009; Kost and Lee 2011). A warmer climate is expected to cause an increase in vascular plant cover, particularly that of ericaceous shrubs, as a result of lowered water tables and altered nutrient cycling (Weltzin et al. 2003; Galatowitsch et al. 2009; Essl et al. 2012; van Dijk et al. 2012; Bragazza et al. 2013; Jassey et al. 2013). *Sphagnum* cover, on the other hand, is expected to decline. Because Michigan populations of *R. acaulis* occur in close association with *Sphagnum*, a reduction of cover and vigor of these mosses will likely have detrimental impacts to the species. In addition, warmer, drier conditions will likely lead to more frequent and severe peatland

wildfires that threaten to reduce moss cover and organic soils and alter peatland ecology and vegetation (Galatowitsch et al. 2009). Galatowitsch et al. (2009) suggest several climate change adaptation strategies to reduce the potential negative impacts of climatic warming on peatland habitats, including the prohibition of drainage projects in the vicinity of peatlands, the prohibition of groundwater withdrawals in recharge areas of fens, and the control of peat fires. Regardless of actions taken to mitigate the effects of climate change on peatland ecology, the long-term persistence of *R. acaulis* in Michigan appears to be at risk. Canadian climate change models for *R. acaulis* put Upper Michigan out of the climatic range of the taxon under 19 of 20 climate projection scenarios by 2040 and in all 20 scenarios by 2070 (Natural Resources Canada, Canadian Forest Service 2011).

Based on the range of the species, area of occupancy, number of occurrences, population sizes, condition of habitat, and threats, including climate change (NatureServe 2013), the Endangered Species Technical Committee for Plants should consider downgrading the conservation status of *R. acaulis* in Michigan from S1 (critically imperiled) to S2 (imperiled).

SUGGESTIONS FOR FUTURE WORK

Additional surveys for *Rubus acaulis* should be conducted throughout Upper Michigan. Three particular areas are likely to yield additional populations: (1) the vicinity of Seney National Wildlife Refuge, encompassing much of northern and eastern Schoolcraft County; (2) the peatlands of northwestern Chippewa County and northern and eastern Luce County, in the vicinity of Trout Lake, Eckerman Corner, Hulbert, Newberry, McMillan, and Paradise; and (3) the vicinity of Cyr Swamp in Marquette County, south of Gwinn and primarily east of the Escanaba River, with a smaller area of shrub-dominated fen west of the river. Potential habitat in all three areas is extensive. High resolution aerial imagery of this entire region is widely available and can be used to target likely fens within these areas. The preponderance of boreal relict species in the Keweenaw Peninsula and especially Isle Royale (Given and Soper 1981; Marr et al. 2009) and presence of fen habitats (Slavick and Janke 1987; Cohen 2009) suggests at least a fair probability that *R. acaulis* may occur in one or both of these locales, as well. Although *R. acaulis* may occur elsewhere in western Upper Michigan, its typical fen habitat is less widely distributed and much less extensive in this region. At each newly documented *R. acaulis* site, detailed lists of vascular plant associates and especially non-vascular plant associates (hornworts, liverworts, and mosses) should be recorded to improve our understanding of *R. acaulis* habitat in Michigan.

Monitoring of *R. acaulis* and its habitat should be implemented to track changes in population size, plant vigor, and fecundity and to document changes in organic soils, hydrology, and species composition and vegetative structure of the peatlands it occupies. Because *R. acaulis* in Michigan is a relict, edge-of-range species, it is likely to be especially sensitive to climate change and associ-

ated changes in its peatland habitats. Therefore, its population dynamics may serve as a good indicator of the health of several of the largest peatland ecosystems in Upper Michigan. Although *R. acaulis* is considered secure globally, these peripheral populations may possess genetic distinctiveness that may prove important to the overall conservation of the taxon, particularly with regard to adaptive potential in the face of climatic warming (Beatty et al. 2008). With this in mind, population and genetic studies that address the viability and genotypic richness of *R. acaulis* populations in Michigan are suggested in order to better determine the long-term viability of this species in the state.

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