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Defining conservation priorities for plant taxa in southeastern New Brunswick, Canada using herbarium records

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Abstract

Biological databases are needed for the development of ecologically sensitive land management strategies. Quantitative information that would serve this purpose is typically unavailable or limited to a few species. An alternative is qualitative herbarium data. While often collected unsystematically, herbarium records are usually available for many taxa. We explored the use of herbarium records for defining conservation priorities for plant taxa found in southeastern New Brunswick, Canada. Our objectives were: (1) to identify rare plant taxa collected in the study area; and (2) to group these taxa by habitat affinity, and refine their conservation status based on the vulnerability of the habitats to current and anticipated land use. The temporal and geographical variations in the collection of the herbarium records are described. A total of 351 herbarium records were found, representing 161 different taxa from 46 families. Nine habitat types were identified. Two of these habitats, rich tolerant hardwood forest and wet *Thuja occidentalis* forest, were classified as endangered. Collections were concentrated near settlements, in areas with road access, or in known species-rich hotspots that were repeatedly revisited. The number of collections varied through time, depending on the presence of botanists working within the study area. Despite limitations, herbarium data served as a valuable first step in identifying species of conservation concern and highlighting information gaps requiring further investigation.

Keywords: Herbarium; Conservation; New Brunswick; Rare plant taxa; Ecosystem management

1. Introduction

Intensive land management has resulted in the loss of plant species diversity in many areas of North America (Duffy and Meier, 1992; Halpern and Spies, 1995; Meier et al., 1995). Concerns over the negative impact of intensive land use have led to calls for increased protection for species intolerant of human disturbance (e.g. Holsinger, 1992; Meier et al., 1995), and for the development of ecologically sensitive management practices to augment existing protected area networks (Falk, 1990; Matlack, 1994; Halpern and Spies, 1995). The need to implement both these initiatives is growing. Given the prevailing political and economic climates in many jurisdictions, opportunities for establishing new reserves have diminished and protection must be focused in locations where it is most needed (Pressey, 1992). Also, in landscapes where large percentages of the area are not protected from human use, there is no guarantee that established reserves will withstand the effects of isolation and invasion by exotics. As a result, provisions must be made to sustain populations of vulnerable species in the areas outside of reserves by conservation stewardship (e.g. Silver et al., 1995; MacDougall and Foley, 1996) or by management operations that reflect natural disturbance intensities and promote spatial and temporal habitat diversity (Freedman et al., 1994).

While the need for increased natural area protection and ecologically sensitive land management practices is recognized, mechanisms for creating and implementing

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such programmes efficiently are not always well developed. A fundamental limitation in many areas is the lack of species-level information on the composition and distribution of extant flora and their susceptibility to land use intervention. Of particular interest are the uncommon and rare species which make important contributions to local (Miller, 1986; Nilsson et al., 1988; Hill and Keddy, 1992; Johnson and Leopold, 1994) and regional (Gentry, 1986) species diversity, yet may be most at risk due to small population sizes and restricted distributions. Ideally, floristic databases would exist for all areas proposed for land management. Such databases would include information on the biology of member species, including the processes contributing to the limited abundance of rare species. Unfortunately, such information is often not available and may be obtained only through detailed demographic studies.

Conservation management planners thus face a dilemma. On the one hand, there is a need for programmes that promote the long-term viability of populations. On the other, the species- and assemblage-specific information required to effectively design such strategies is incomplete, with the number of species in need of study far outnumbering the number of scientists available to identify, study, and monitor them (Keddy, 1991).

Given this situation, and the fact that economy-driven land management will continue to take priority, alternative information sources are required to assist the design of conservation-oriented management procedures. This includes land use practices that minimize disturbance of sensitive habitats and the creation of protected area networks that maximize the capture of rare taxa in the limited area typically available for reserves in heavily managed landscapes (e.g. Pressey et al., 1994; Csuti et al., 1997). While detailed quantitative data are lacking, extensive qualitative data are often at hand on a region-by-region basis in herbaria. Herbarium data provide two types of information that are especially relevant for conservation planners: locations of species occurrence, indicating where species have been found and may persist, and descriptions of habitat affinities for each species. Habitat information describes the environmental conditions with which the taxon is associated, and can be used to direct Geographic Information Systems (GIS)-based searches for undiscovered locations where these conditions, and their associated species, may occur (Rhoads and Thompson, 1992; MacDougall and Loo, unpublished).

Herbarium data, and biological inventory information in general, do have limitations, leading some to question the value of such information for directing ecologically-based conservation work (e.g. Renner and Ricklefs, 1994). Collection efforts are often unsystematic (Shevock and Taylor, 1987; Stern and Eriksson, 1996); common species may be better represented than rare species (Rich and Woodruff, 1992), or the reverse; taxonomic nomenclature may be outdated (Robinson et al., 1990); and the information accompanying specimens, such as location and habitat descriptions, is sometimes imprecise, especially for older records. Despite these problems, herbarium data are generally available for most or all known plant species within a region, and given the increasing demand for baseline information by land managers and the cost of collecting such data in alternative ways, should be utilized as completely as possible.

In this study, we explored the use of herbarium data for defining conservation priorities for infrequently occurring vascular plant taxa within a 420 000-ha study area in southeastern New Brunswick, Canada (Fig. 1). Our objectives were: (1) to use herbarium records to identify provincially uncommon, rare, and very rare plant taxa recorded in the area; and (2) to further refine conservation priorities among the identified taxa based on habitat vulnerability. The temporal and geographical variations in the collection of the specimens, and the effect of these variations on the usefulness of the herbarium data, are described.

2. Study area

Much of the study area has been affected by human land use since the onset of European colonization some 200 years ago. At present, 17% of the land base is permanently cleared for settlement or agriculture. Most forested areas have at one time been logged or cleared for farming before being abandoned. The very few old growth forest patches that remain are largely restricted to inaccessible and commercially unimportant sites, such as black spruce bogs and steep coastal ravines. Approximately 6% of the land base is legally protected, either within Fundy National Park or three newly established conservation areas nearby (Fig. 1).

The study area has a diverse climate and physiography. The Bay of Fundy coast has a maritime climate with relatively cool summers, mild winters, and frequent fog. This coastal effect is limited in inland penetration to 5–10 km due to the presence of a highland plateau rising 100–300 m in elevation and running parallel to the coast (Power and Matson, 1995). Beyond the plateau, the study area is dominated by several large valleys associated with the St. John, Kennebecasis, and Petitcodiac Rivers, and extensive poorly drained lowlands in the north and east. The climate in these interior regions is warmer and drier in the summers compared with the coast, with colder average winter temperatures and greater snow fall accumulations (Power and Matson, 1995).

The bedrock geology of the study area is extremely variable in age and composition, and is dominated by

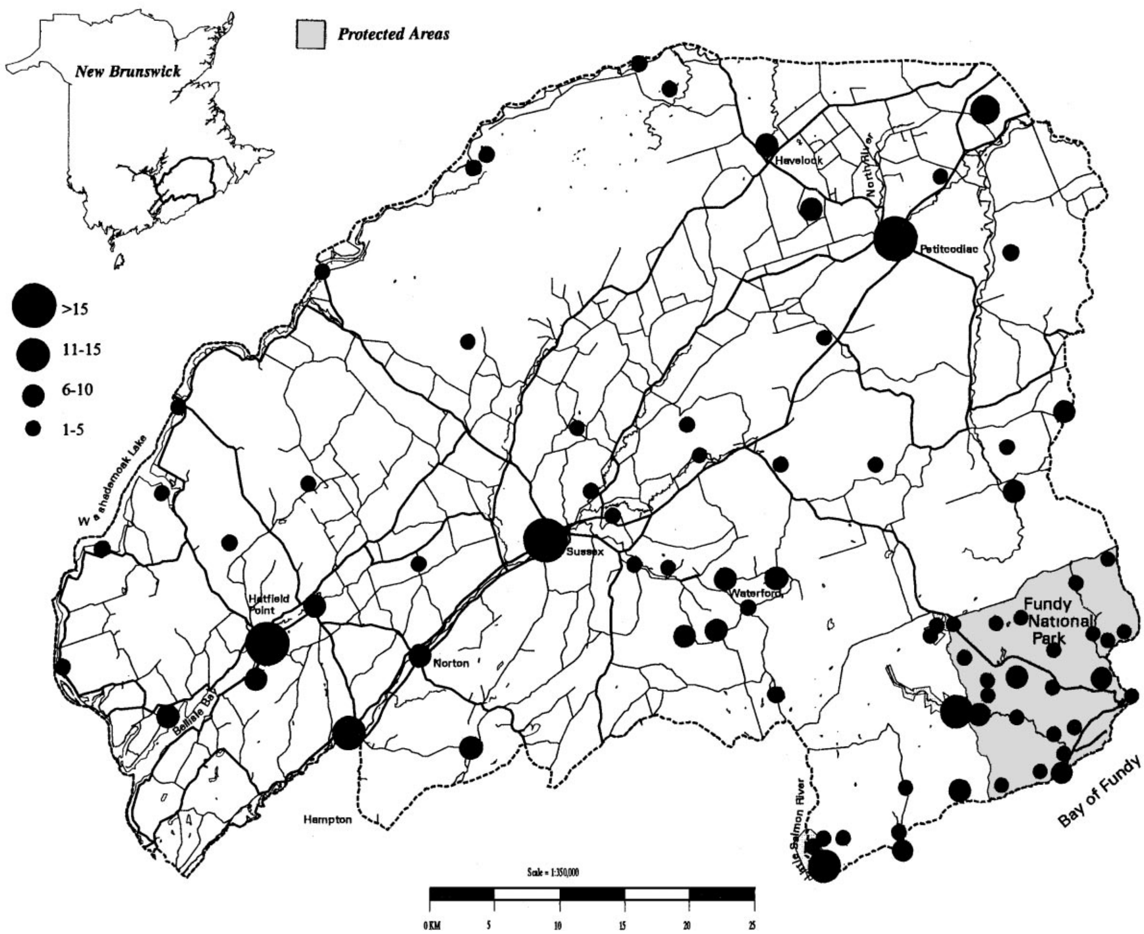

Fig. 1. Study map, indicating location within New Brunswick, major roads and water bodies, and the distribution and abundance of recorded taxa.

metasedimentary rock consisting of weathered red mudstones or red and grey mudstones with feldsparic to lithic sandstones, by polymictic conglomerates that often contain calcium carbonate in the cementing material, or by relatively infertile felsic or mixed igneous volcanics and mafic volcanics. Pockets of argillaceous limestones and shales are scattered throughout the central and northern sections of the study area (Colpitts et al., 1995). Surficial deposits range greatly in depth, texture, percentage of coarse fragments, fertility, and mode of deposition. The types of surface material in the study area include glaciofluvial, and post-glacial alluvial deposits, compact and non-compact glacial till, pre-glacial residual deposits, and peat in poorly drained areas (Colpitts et al., 1995).

The dominant forest types in the study area include *Picea rubens–Abies balsamea* assemblages on the inland valley slopes, *Picea mariana* on the poorly drained lowlands, upland *Acer saccharum–Fagus grandifolia–Betula alleghaniensis* forest, and coastal stands of *Picea rubens* (New Brunswick Department of Natural Resources and Energy, 1996). A total of 645 plant taxa have been recorded in the area since collections began in the 1870s (MacDougall, unpublished). This represents close to 60% of the provincial flora in only 5.8% of the land base, a function of the area's physical diversity.

3. Methods

The list of rare flora used for this study was obtained by overlaying the study area boundaries on the range maps of provincially classified uncommon, rare, and very rare species, subspecies, varieties, and fertile hybrids as presented in The Rare Vascular Plants of New Brunswick (Hinds, 1983) and Flora of New Brunswick (Hinds, 1986). The source material for these two publications (herbarium records) was revisited to confirm the presence of each identified species within the study area boundaries. Three local herbaria were used—the Connell Memorial herbarium at the University of New Brunswick, the New Brunswick Museum herbarium, and the Fundy National Park herbarium. Any doubt regarding the location where the specimen was collected or species identification resulted in its exclusion.

The classification of flora as uncommon, rare, or very rare followed the system used by Hinds (1986). This system was based primarily on the number of herbarium records existing for each species on a province-wide basis, with the distribution of collection locations, the degree of conspicuousness of the species, the age of the records, and habitat availability also being considered. 'Very rare' species were those represented by fewer than five records since collections began in New Brunswick in the mid-1800s. 'Rare' species were those collected five to 10 times in total and often were associated with habitat conditions of limited occurrence within the province. 'Uncommon' species were those typically represented by >10 records, and were either locally common, but found in very few regions of the province, or locally scarce, but scattered over several regions (Hinds, personal communication).

Species were added to or deleted from the species list based on new information obtained since the publications of Hinds (1983, 1986). Some species have been found to be more widely distributed and abundant than originally believed. Other species have been found to be less abundant, either due to habitat loss or misidentification of the species when originally collected. Several species have been newly discovered in New Brunswick within the past decade and are known to occur in the study area.

Once the list of uncommon, rare, and very rare taxa was finalized, habitat affinities were established for each species using information presented in Hinds (1986), habitat descriptions included by the original collector with the herbarium specimen, and information obtained from other botanical sources (e.g. Fernald, 1950; Roland and Smith, 1969; Lellinger, 1985).

Taxa with similar or identical affinities were grouped together, forming a list of habitat types of conservation significance within the study area. All identified habitat types were assessed for vulnerability based on existing and anticipated land use, with five vulnerability ratings (1–5) being employed. 'Endangered' (1) referred to habitats that had experienced, or were experiencing, widespread conversion to alternate land uses, or were being intensively managed for timber, and had little remaining area where original habitat conditions persisted. 'Threatened' (2) referred to habitats in the study area that were being intensively managed or had been converted over parts, but not all, of their distribution, and would become endangered if such activity continued. 'At risk' (3) referred to habitats altered by land use (e.g. microclimatic changes in forest understory, lake eutrophication), but not fully destroyed, with the alterations potentially threatening the ability of the habitat to support its associated rare vascular flora. 'Secure' (4) referred to habitats with no existing or anticipated threats. 'Uncertain' (5) referred to habitats where threats could not be determined.

The identified habitat types were further separated into three categories: taxa found in spatially restricted habitats, such as cliff faces or peatlands; taxa found in widely occurring and more continuously distributed habitats that cover thousands of hectares, such as boreal conifer forest or upland deciduous forest; and taxa which occur in a wide range of habitats. The purpose of this second separation was to highlight taxa tightly associated with habitat types detectable using GIS-based modelling procedures or high-resolution remote sensing, thus facilitating searches for undiscovered sites.

Temporal and spatial variations in the collection of the targeted species were determined by recording the date and location of all specimens. All locations were marked on a study area map that depicted roads, settled areas, and river valleys. The date of each collection was grouped by decade and plotted to show how the number of collected specimens fluctuated over time. Locally extirpated taxa were considered to be those for which there had been no herbarium entry in the last 35 years, the time when collection intensity began to greatly increase in southeastern New Brunswick (Fig. 2).

4. Results

A total of 351 local herbaria records of provincially classified uncommon, rare, and very rare plant taxa were found for the study area, representing 161 different taxa from 46 families (mean = 2.2 records per taxon, range 1–8) (Table 1).

Plants recorded in the herbaria were scattered throughout much of the study area (Fig. 1). The largest region for which there were no records was in the north–central part of the study area. This region has no all-season roads and consists primarily of poorly

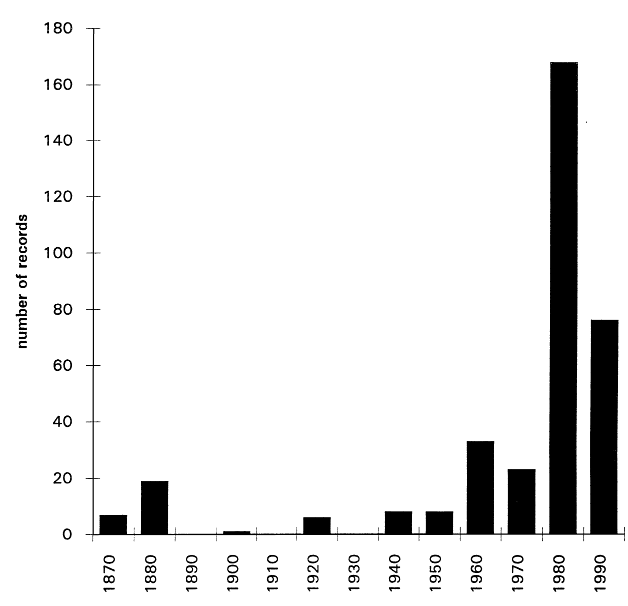

Fig. 2. The number of herbarium records per decade from 1870–1879 to 1990–1995.

Table 1
List of uncommon, rare, or very rare vascular plant taxa within the study area based on herbarium records

Taxa	Status	Habitat	Records	Last
Lycopodiaceae				
Diphasiastrum×sabinifolium Willd.[a]	uncommon	C	1	1960
Huperzia selago L. [ab]	uncommon	A7	6	1995
Selaginellaceae				
Selaginella rupestris (L.) Spring	very rare	A7	2	1982
Selaginella selaginoides (L.) Link [a]	very rare	A7	1	1982
Isoetaceae				
Isoetes×harveyi A. A. Eaton	uncommon	A5	1	1978
Isoetes tuckermanii A. Br.	uncommon	A5	1	1981
Ophioglossaceae				
Ophioglossum pusillum Raf.	rare	A4	1	1962
Pteridaceae				
Adiantum pedatum L.	uncommon	A1	1	**1927**
Aspleniaceae				
Asplenium trichomanes L.	very rare	A7	1	**1945**
Asplenium trichomanes-ramosum L. [a]	very rare	A7	1	1982
Dryopteridaceae				
Cystopteris laurentiana (Weath.) Blasdell	very rare	A7	1	1982
Dryopteris fragrans (L.) Schott [a]	rare	A7	6	1982
Dryopteris×triploidea Wherry	uncommon	B1	3	1992
Polystichum braunii (Spenner) Fee [a]	rare	B1	6	1994
Woodsia alpina (Bolton) S.F. Gray [a]	very rare	A7	1	1994
Woodsia glabella R. Br. [a]	rare	A7	7	1994
Schizaeaceae				
Schizaea pusilla Pursh [a]	very rare	A4	1	1992
Sparganiaceae				
Sparganium fluctuans (Morong) Robins [a]	uncommon	A5	1	1992
Potamogetonaceae				
Potamogeton oakesianus Robbins	rare	A5	1	1994
Potamogeton richardsonii (Ar. Benn.) Rydb.	rare	A5	1	1985
Potamogeton robbinsii Oakes	uncommon	A5	1	1985
Potamogeton zosteriformis Fern.	uncommon	A5	1	**1955**
Zannichelliaceae				
Zannichellia palustris L.	uncommon	A6	[c]	[c]
Juncaginaceae				
Triglochin gaspense Lieth and D. Love	rare	A6	1	1985
Poaceae				
Agrostis perennans (Walt.) Tuckerm.	uncommon	C	2	1982
Calamagrostis pickeringii Gray	very rare	C	2	1984
Distichlis spicata (L.) Greene	rare	A6	1	**1923**
Eragrostis pectinacea (Michx.) Nees	uncommon	B2	1	1984
Milium effusum L. [a]	uncommon	A1	7	1988
Oryzopsis canadensis (Poir.) Torr.	uncommon	B2	2	1984
Oryzopsis pungens (Torr.) Hitchc. [a]	rare	A7	1	1982
Poa alsodes Gray	uncommon	A1	4	1991
Poa glaucantha Gaudin. [a]	rare	A7	2	1982
Trisetum triflorum var. *triflorum* (Bigel.) Love and Love [a]	very rare	A7	3	1982
Cyperaceae				
Bolboschoenus fluviatilis (Torr.) Sojak	rare	A5	1	1983
Carex adusta Boott	uncommon	C	2	1980
Carex arcta Boott	uncommon	C	1	**1884**
Carex atlantica Bailey	rare	A4	4	1982
Carex backii Boott	very rare	A7	1	1994
Carex brunnescens var. *brunnescens* (Pers.)Poir. [a]	uncommon	A7	2	1990
Carex capillaris L. [a]	uncommon	C	3	1991

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Table 1—*(continued)*

Taxa	Status	Habitat	Records	Last
Carex castanea Wahl.	uncommon	B2	1	1987
Carex conoidea Schkuhr	uncommon	A3	4	1994
Carex eburnea Boott	rare	A7	1	1982
Carex exilis Dew [a]	rare	A4	3	1994
Carex flaccidula Steudel.	uncommon	B1	8	1983
Carex folliculata L.	uncommon	A4	3	1994
Carex gracillima Schw.	uncommon	B1	5	1994
Carex granularis var. *haleana* (Olney) Porter	uncommon	B2	1	**1885**
Carex grisea Wahl.	very rare	B1	2	1980
Carex hirtifolia Mackenz.	rare	A1	2	1981
Carex lacustris Willd.	uncommon	A4	5	1989
Carex limosa L.	uncommon	A4	1	1995
Carex lucorum Link	uncommon	C	2	1980
Carex lupulina Muhl.	uncommon	C	1	**1878**
Carex michauxiana Boeckl. [a]	uncommon	A4	3	1994
Carex ormostachya Wieg.	uncommon	A1	2	1994
Carex peckii Howe	uncommon	C	3	1988
Carex recta Boott [a]	uncommon	A6	2	1982
Carex saxatilis L.	very rare	A3	1	**1878**
Carex sprengelii Dewey	rare	A1	1	1981
Carex tenera Dew.	uncommon	B2	4	1980
Carex tenuiflora Wahl.	rare	A4	1	**1945**
Carex tuckermanii Dewey	uncommon	B1	1	**1889**
Carex wiegandii Mackenz.	rare	A4	3	1991
Cyperus aristatus Rottb.	rare	A3	1	1983
Eleocharis intermedia (Muhl.) Schultes	very rare	B2	1	1990
Rhynchospora capitellata (Michx.) Vahl	uncommon	A3	1	1983
Schoenoplectus torreyi (Olney) Palla	uncommon	B2	[c]	[c]
Scirpus pendulus Muhl.	very rare	A4	1	1980
Trichophorum alpinum (L) Pers.	uncommon	B2	2	1994
Trichophorum clintonii (Gray) S. G. Smith [a]	uncommon	B2	1	1982
Xyridaceae				
Xyris montana Ries. [a]	uncommon	A4	2	1964
Lemnaceae				
Lemna trisulca L.	uncommon	A5	4	1985
Juncaceae				
Juncus alpinoarticulatus Vill.	uncommon	B2	1	1964
Juncus nodosus L. [a]	uncommon	B2	2	1985
Juncus vaseyi Engelm.[a]	uncommon	B2	3	1983
Liliaceae				
Allium canadense L.	rare	B2	1	1980
Allium tricoccum L.	rare	A1	4	1988
Maianthemuum racemosum (L.) Link [a]	uncommon	B1	4	1994
Orchidaceae				
Arethusa bulbosa L. [a]	uncommon	A4	1	**1878**
Calopogon tuberosus (L.) BSP [a]	uncommon	A4	2	1994
Calypso bulbosa (L.) Oakes	uncommon	A2	1	**1882**
Coeloglossum viride (L.) Hartman	uncommon	C	1	1994
Corallorhiza maculata f. *flavida* (Peck) Farw.	uncommon	B1	1	1994
Cypripedium pubescens Willd.	uncommon	B1	2	1994
Cypripedium reginae Walt.	rare	A2	1	1994
Goodyera pubescens (Willd.) R. Br.	very rare	B1	1	**1882**
Goodyera tesselata Lodd.	uncommon	B1	1	1994
Liparis loeselii (L.) Richard	rare	B2	1	1987
Platanthera×andrewsii (M. White) Luer.	rare	C	2	1994
Platanthera grandiflora (Bigel.) Lindl.	uncommon	C	3	1994
Platanthera hookeri (Torr.) Lindl.	uncommon	A2	4	1994
Plantanthera macrophylla (Goldie) Luer.	rare	B1	1	1994
Plantanthera orbiculata (Pursh) Lindl. [a]	uncommon	B1	3	1994
Spiranthes lucida (Eat.) Ames	uncommon	B2	1	**1881**

Table 1—*(continued)*

Taxa	Status	Habitat	Records	Last
Salicaceae				
Salix pedicellaris Pursh	uncommon	A4	2	1983
Polygonaceae				
Polygonum arifolium L.	rare	A4	1	1991
Polygonum ramosissimum Michx.	uncommon	A6	1	**1950**
Chenopodiaceae				
Chenopodium simplex Aellen	rare	B1	3	1983
Caryophyllaceae				
Stellaria alsine Grimm	uncommon	B2	1	1979
Stellaria humifusa Rottb. [a]	uncommon	A6	2	1982
Ranunculaceae				
Hepatica nobilis P. Mill.	rare	B1	1	**1927**
Ranunculus gmelinii var. *hookeri* (Don) Benson	rare	A5	3	1994
Berberidaceae				
Caulophyllum thalictroides (L.) Michx.	uncommon	A1	2	1981
Brassicaceae				
Arabis drummondii Gray	uncommon	A7	4	1994
Arabis hirsuta (L.) Scop.	uncommon	A7	5	1994
Barbarea orthoceras Ledeb	uncommon	A3	1	1980
Draba arabisans Michx.	rare	A7	3	1988
Saxifragaceae				
Penthorum sedoides L.	uncommon	A3	2	1988
Saxifraga paniculata P. Mill. [a]	rare	A7	3	1982
Rosaceae				
Agrimonia gryposepala Wallr.	uncommon	A1	1	**1927**
*Amelanchier sanguinea (*Pursh) DC	uncommon	C	5	1987
Rosa palustris Marsh.	uncommon	A4	2	1994
Rubus occidentalis L.	rare	A1	1	1980
Sanguisorba canadensis L. [a]	rare	B2	1	1994
Geraniaceae				
Geranium bicknellii Britt.	uncommon	B2	3	1974
Geranium robertianum L. [a]	uncommon	C	7	1987
Polygalaceae				
Polygala paucifolia Willd.	rare	B1	2	1995
Polygala sanguinea L.	rare	B2	1	1995
Callitricaceae				
Callitriche hermaphroditica L.	uncommon	A6	1	1965
Hypericaceae				
Hypericum majus (Gray) Britt.	uncommon	B2	2	1983
Hypericum mutilum L.	uncommon	B2	2	1985
Violaceae				
Viola adunca Sm.	uncommon	B2	4	1983
Viola labradorica Schrank [a]	uncommon	A7	5	1983
Viola nephrophylla Greene	uncommon	A3	2	1991
Viola selkirkii Pursh	uncommon	B1	2	1994
Onagraceae				
Epilobium hornemannii Reichenb. [a]	uncommon	C	1	1982
Haloragaceae				
Myriophyllum heterophyllum Michx.	very rare	A5	2	1985
Araliaceae				
Panax trifolius L. [a]	uncommon	A1	4	1974
Apiaceae				
Cryptotaenia canadensis (L.) DC	extirpated	A1	1	**1885**
Sanicula trifoliata Bickn.	very rare	A1	1	**1882**

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Table 1—*(continued)*

Taxa	Status	Habitat	Records	Last
Pyrolaceae				
Monotropa hypopithys L.	uncommon	B1	7	1995
Pyrola chlorantha Sw.	uncommon	B1	1	1980
Pyrola minor L.	rare	B1	4	1994
Ericaceae				
Arctostaphylos uva-ursi (L.) Spreng.	uncommon	A7	2	1982
Gaylussacia dumosa (Andr.) T. and G. [a]	uncommon	A4	2	1994
Vaccinium caespitosum Michx. [a]	uncommon	B2	3	1983
Primulaceae				
Lysimachia quadrifolia L.	rare	C	1	1981
Lysimachia thyrsiflora L.	uncommon	A4	2	1983
Primula laurentiana Fern. [a]	very rare	A7	1	1977
Gentianaceae				
Bartonia paniculata subsp. *iodandra* (Robins.) Gillett. [a]	very rare	A4	3	1994
Lamiaceae				
Hedeoma pulegiodes (L.) Pers.	rare	B2	2	1983
Pycnanthemum virginianum (L.) Durand and Jackson	very rare	A3	1	1980
Scrophulariaceae				
Euphrasia randii Rob.	very rare	A7	1	1994
Scrophularia lanceolata Pursh	uncommon	C	3	1995
Lentibulariaceae				
Utricularia geminiscapa Benj.	rare	A5	3	1994
Rubiaceae				
Galium boreale L.	uncommon	B2	3	1987
Galium obtusum Bigel.	uncommon	B2	1	1981
Asteraceae				
Ageratina altissima (L.) King and H.E. Robins [a]	uncommon	C	7	1994
Antennaria neglecta var. *randii* (Fern.) Cronq [a]	uncommon	A7	4	1969
Antennaria plantaginifolia (L.) Richards	very rare	C	3	1988
Aster borealis (T. and G.) Prov.	very rare	A4	1	1994
Aster vimineus Lam.	rare	C	1	1978
Bidens connata Muhl.	uncommon	A3	1	**1881**
Bidens discoidea (T. and G.) Britt.	very rare	A3	1	1995
Erigeron hyssopifolius Michx. [a]	uncommon	A3	3	1994
Hieracium paniculatum L.	very rare	C	1	1985
Hieracium robinsonii (Zahn) Fern. [a]	very rare	A7	2	1982
Prenanthes racemosa Michx.	uncommon	C	2	1988
Tanacetum bipinnatum subsp. *huronense* (Nutt.) Breutung.	uncommon	A3	1	1981

'Status' refers to abundance within the province of New Brunswick, for the most part as classified by Hinds (1986). 'Habitat' refers to the habitat types classified in Table 2. 'Records' refer to the number of herbarium records existing for each species. 'Last' is the date of the most recent herbarium record for each species. Dates in bold indicate taxa not recorded before 1960, the time when collection intensity greatly increased in southeastern New Brunswick.

[a] Taxa recorded at least once in Fundy National Park or the adjacent reserves.

[b] New evidence (Beitel and Mickel, 1992) suggests that *Huperzia selago* is divisible into two species: *H. selago* and *H. appalachiana*, and that both, as well as their hybrid, may occur along the coastal areas of New Brunswick. We have not attempted to resolve these taxonomically difficult entities in this study.

[c] Appeared to occur within the study area based on Hinds (1986), but herbaria records could not be relocated.

drained *Picea mariana* forests, bogs, and sedge meadows. Most records were collected at locations near settlements, accessible by all-weather roads, or had, for some other reason, been heavily searched by local botanists. Fundy National Park had 39 taxa of interest and contained 16% of all study area records, reflecting almost continuous collection since park inception in 1950. All but two of the records before 1960 were clustered around the four major settlements of the study area—Sussex, Petitcodiac, Hampton, and Norton. The large concentration of records near Hatfield Point was the result of the area being a summer residence of the fifth author at one time, as well as being a site where numerous habitat types (shoreline, marsh, rich hardwood forest) converge over a small geographic area. The Little Salmon River gorge, North River *Thuja occidentalis* forest, and Havelock are known botanical 'hotspots' and, thus, have been revisited on numerous occasions by botanists. Many of the single records found at other locations were chance collections, or reflect surveyed habitats where uncommon or rare taxa infrequently occur, or are especially difficult to detect.

The decade-by-decade distribution of records since collections began in the latter half of the 19th century (Fig. 2) indicate concentrations of collecting in the 1870s, and again in the 1960s and extending to the present. These temporal variations in record abundance reflect the presence, capability, and enthusiasm of local botanists working within the study area. Two botanists, G. V. Hay and J. Brittain, collected extensively in the Sussex and Petitcodiac areas in the late 1800s. The increased number of records in recent decades coincides with the employment of resident botanists at the University of New Brunswick and the New Brunswick Museum, and increased collection effort by amateur naturalists.

Nineteen species were collected prior to 1960 and have not been recorded since (Table 1). Sixty-three per cent of these species occurred in habitat that has been intensively utilized for agriculture, logging, or settlement since the collections were made. The remaining species were found in commercially less-important habitat, such as boggy meadows, salt marshes, ponds, and rock faces, that has been less affected by human disturbance.

Nine habitat types were identified and eight were assigned a vulnerability rating (Table 2). The 'open areas' habitat type (B2) could not be assessed for habitat vulnerability and was, therefore, classified as 'uncertain'.

Seven of the nine identified habitat types were classified as 'spatially restricted' because of their small total area resulting from natural or human-caused scarcity of suitable environmental conditions. In total, 57% of the uncommon, rare, or very rare taxa were found in these seven habitats. Rich tolerant hardwood forest habitat (A1) occurred on bottomland alluvial deposits, or on enriched upland soils overlying limestone parent material. Dominant canopy trees were *Acer saccharum*, *Fagus grandifolia* and *Fraxinus americana*, with *Juglans cinerea* and *Ulmus americana* occasionally present. Wet cedar forest (A2) occurred on enriched peatlands and was dominated by *Thuja occidentalis,* with *Picea mariana* and *Acer rubrum* sometimes being present. Freshwater shoreline habitat type (A3) was characterized as areas with rock, gravel, mud, or silt substrates experiencing intense annual disturbance from flooding or ice scour. Freshwater wetland habitat class (A4) included bogs, fens, marshes, sedge meadows, and alder thickets. Open water habitat (A5) included ponds and pond margins, lakes, slow moving rivers and streams. Saltwater wetlands (A6) consisted of coastal salt marshes and inland salt springs found in association with potash deposits near Sussex. Rock face habitat (A7) included cliffs, ledges, escarpments, and coastal headlands.

Two habitat types, 'forested area' and 'open area', were broad, non-specific, often spatially contiguous, and occurred over large portions of the

Table 2
Vulnerability ratings of identified habitats within the study area

Habitat type		Threats	Rare taxa	Extirpated	Rating
A1	Rich tolerant hardwood forest	Clearance for agriculture Harvest for firewood/cabinet wood Cattlegrazing in understorey Genetic impoverishment by fragmentation	13	4	1
A2	Wet cedar forest	Drainage for agriculture Logging	3	1	1
A3	Freshwater shoreline	Flooding by hydroelectric dams Trampling by cattle	12	2	2
A4	Freshwater wetlands	Drainage for agriculture Peat mining Clearcutting of adjacent forest Causeway construction Exotic invasion (e.g. *Lythrum salicaria*)	21	2	2
A5	Open water	Eutrophication near settled areas Exotic invasion (e.g. *Lythrum salicaria*)	12	1	3
A6	Saltwater wetlands	Destruction of inland salt springs Recreational activity in coastal areas	7	2	3
B1	Forested areas	Logging Permanent land clearance	20	3	3
A7	Rock faces	Clearance of adjacent forest canopy surrounding small outcrops Disruption of groundwater flow feeding rockface seepage zones	25	1	4
B2	Open areas	Habitat conversion	26	2	5

Ratings are: 1, endangered; 2, threatened; 3, at risk; 4, secure; 5, uncertain. 'A' habitat types have spatially restricted distributions; 'B' habitats are wide-ranging. 'Rare taxa' indicate the number of provincially uncommon, rare, and very rare taxa found in each identified habitat type. 'Extirpated' indicates the number of extirpated taxa within the study area.

study area. 'Forested' habitat (B1) included the extensive stands of coniferous, deciduous, and mixed forest found on wet, mesic, and dry substrates. 'Open area' habitat (B2) included meadows, ditches, roadsides, fields, and treeless floodplains. In total, these two habitat types captured 29% of the listed taxa.

A group of taxa were not associated with any specific habitat type (C), occurring in both forested and open locations. This group contained 22 taxa, or 14% of the total list.

5. Discussion

5.1. Usefulness of herbarium records

Herbarium records provided a good first step for defining species-level conservation priorities for vascular plant species within our study area. By combining herbarium data with a provincial-level classification system for uncommon, rare, and very rare flora, we were able to identify 161 species, subspecies, varieties, and fertile hybrids that may be of conservation concern due to their limited abundance or distribution. With the addition of information on habitat affinities of these species, we were able to further prioritize our list of species based on anticipated habitat vulnerability to human land use activities.

The taxa list used for this analysis had both strengths and inconsistencies that needed qualification when interpreting the results. Unlike some herbaria, where many of the collection records are old and possibly outdated, most of the herbarium specimens used in this study were collected within the past 15 years. This increased the likelihood that these populations persist today, and allowed comparison between the earlier and recent collections to identify species that may be locally extirpated.

The number of records were distributed relatively evenly among taxonomic families. Two of the most taxonomically difficult groups, sedges and grasses, were well represented both in terms of the number of species and the number of collection records per species, compared with more charismatic and typically well-collected groups, such as Orchidaceae and Liliaceae.

An examination of geographical and temporal trends of specimen collection revealed discrepancies. Spatially, there were biases toward major settlements, especially among the older records, areas accessible by well-constructed and maintained all-weather roads, and areas frequented by botanists, especially Fundy National Park and the Hatfield Point area. The two periods of heaviest collection, the 1880s and the most recent decades beginning in the 1960s, reflect the presence of capable and enthusiastic botanists working in the study area. The total collection effort was not assessed, due to the volume of records and because many collectors do not sample well-known taxa on a consistent basis. As a result, it could not be determined if areas lacking collection records were unsurveyed or if they actually lacked rare taxa. However, we are aware of no systematic survey in the region other than our own, and, thus, we assume that areas without records are mostly unvisited by botanists.

The biases present in the herbarium data hamper interpretation of the results. The unsystematic nature of record collection meant that certain habitats which were inaccessible or unappealing for some collectors (e.g. bogs and swamps) were likely under-represented, especially in the north–central region of the study area. The identification of hotspots for rare flora using the number of records per site was biased by the tendency for botanists to revisit rich sites several times, especially as new botanists arrived in the province. This resampling inflated species tallies relative to other less-surveyed locations, and it cannot be assumed that these sites are the only species-rich sites if poorly surveyed areas exist nearby.

Finally, the list of potentially extirpated taxa generated using herbarium data (Table 1) must be viewed with caution. For the few listed taxa occurring on remote, inaccessible, or inhospitable terrain, such as rock faces and bogs, the absence of recent records likely reflects collection effort rather than extirpation. For those listed taxa occurring in habitats subject to intensive human disturbance (e.g. rich tolerant hardwood forest, wet cedar forest), the probability of local extirpation is high. However, this listing, and others like it that have been generated in New Brunswick (e.g. New Brunswick Committee on Endangered Species, 1995), is largely restricted to taxa that were recorded at an early date in and around settled areas. It does not provide any information on possibly extirpated taxa in the majority of the study area, the forested regions of the coastal plateau and interior, where very little collection was done before 1970, and which are now being subjected to intensive forest management. The absence of known extirpated taxa in such habitats has been interpreted by some to imply that forest practices have had no impact on floral diversity. However, it more likely reflects a lack of information. Given the reduction in the percentage of mature forest in these areas, the shift in the composition of dominant canopy species (Lutz, 1997), conversion to plantations (5% of the entire study area) that include non-native tree species, and fragmentation by roads, it seems likely that some taxa have been, or will be, adversely affected by forestry operations.

5.2. Habitat

Habitat descriptions that accompanied herbarium records helped to further prioritize species already identified as provincially uncommon, rare, or very rare. For example, among the taxa classified as 'very rare', some taxa were more threatened than others because they occurred in habitat vulnerable to current land use. The provincial classifications developed by Hinds (1986) were of limited use, because they relied heavily on numbers of herbarium records per taxon. However, record abundance does not necessarily reflect the processes that lead to species becoming rare or threatened. Rarity can result from a number of causes, and less-abundant species appear in a variety of distributional configurations (Rabinowitz et al., 1986; Fielder and Ahouse, 1990). While it is impossible to identify the processes that limit a species' frequency without detailed demographic work, habitat abundance, and knowledge of the vulnerability of the habitat to human intervention, can provide insight into important determinants of rarity and threatened status. Generally, limited availability of suitable habitat is most responsible for restricting the distribution or abundance of species. Less-abundant species associated with commercially valued habitat, such as fertile bottomlands, wet cedar forest, peat-rich bogs, or mature forest patches, can be considered at greater risk than less-abundant species occurring in unproductive or inaccessible habitats. Therefore, while the small population sizes of uncommon, rare, and very rare taxa make them all vulnerable to intensive human disturbance, those dependent on threatened habitat demand more immediate conservation attention.

Habitat information can also be useful for directing landscape-level searches for rare taxa using high-resolution remote sensing techniques or GIS-based modelling procedures (MacDougall and Loo, unpublished). In extensive unsurveyed areas, these methods provide an efficient means for detecting sites with a high probability of hosting rarities. Such searches are most suitable for taxa that are tightly associated with small and spatially discrete habitats. In our study area, we determined that 57% of the taxa met this criterion, occurring in open water, edaphically-rich tolerant hardwood forest, exposed rock faces, freshwater wetlands, saltwater wetlands, or disturbance-intensive shorelines. All of these habitat types have a limited distribution and are either visually distinguishable from the air or can be spatially referenced using one or a combination of the land resource data variables available in New Brunswick. While the predictive success of using remote sensed or GIS-based habitat searches is often low, typically 10–20% (MacDougall and Loo, unpublished), they provide a systematic means to direct field surveys for taxa restricted to small and highly localized habitat types within large geographic areas. These surveys could, thus, be used to offset geographical biases present in existing herbaria data.

The remaining 43% of the taxa occurred in multiple habitats or in habitats occurring over large sections of the study area. These habitat types can also be detected using remote sensing or GIS-based procedures. However, the abundance of sites with these features, and the large areas over which they occur, limit the suitability for directing botanical searches. For example, *Platanthera orbiculata* is known to occur in "dryish or swampy coniferous, deciduous, or mixed woods" (Hinds, 1986), a habitat type that describes ca. 50% of the entire 420 000-ha study area. This level of information does not help botanists narrow the search for this or other similarly described species, because the size of the potential areas of occurrence are large. As a result, supplemental means are required for locating widely distributed or multiple-habitat species. To this end, it may be possible to combine such herbarium data with digitized land resource databases and field reconnaissance to search for undiscovered populations of rare taxa occurring over wide geographic regions (e.g. Sperduto, 1995).

The vulnerability of wide-ranging or multiple-habitat taxa is difficult to assess, because human disturbance over large areas varies in frequency, intensity, and extent. By chance alone, populations of these taxa may be largely unaffected by land use, or completely extirpated. There is a particular need to locate and protect populations of wide-ranging or habitat-nonspecific taxa. Genetically, levels of inter-population differentiation for these taxa can be high compared with taxa found in specific, more predictable habitats (Schlichting, 1986; Hamrick and Godt, 1989; Hamrick et al., 1992), and they should, thus, be protected across their distributional range. However, because of their unpredictable pattern of distribution, taxon-specific searches may be the only means to locate populations (Nilsson et al., 1988), using past records of occurrence from herbaria as starting points for search effort. Such searches would be time-intensive, especially for taxa found in broadly distributed habitats, such as *Picea–Abies* bottomland forest which can extend for tens of thousands of hectares, and would only be appropriate for taxa believed to be most threatened. An alternative is to hope that protected areas designed to represent samples of broadly distributed habitat types would capture many of the rare taxa associated with those habitats. It has been suggested that such representative areas may be able to capture as much as 90% of resident species (Jenkins, 1985; Noss, 1987). Without searches, it is impossible to test this assumption, and it is likely that the 10% missed will be the most rare.

5.3. Conservation implications in our study area

All 161 identified taxa require special consideration by conservation planners, because their small population sizes or limited distributions make them potentially vulnerable to habitat alteration by land use activities. The degree of this vulnerability cannot be determined directly using the location data and the number of records, although taxa listed as very rare, based on these records, are probably good candidates, especially if their limited abundance is consistent in other adjacent regions or on a provincial, national, or continental basis. Alternatively, some taxa are undoubtedly more abundant or widely dispersed than existing records indicate, and are either inconspicuous or occur in habitats that are not regularly surveyed by botanists.

In terms of habitat vulnerability, tolerant hardwood forest found on enriched alluvial bottomland soils or on upland sites overlaying limestone parent material, and wet *Thuja occidentalis* forest occurring in calcareous lowlands, appear to be the most threatened habitat types in our study area (Table 2). A comparison of the distribution of environmental conditions that support these forest assemblages with the current distribution of the forest types themselves suggest that significant reductions have occurred since the onset of European colonization in the late 18th century (Lutz, 1997). At present, both of these habitat types are unprotected in the study area, and inadequately protected in New Brunswick in general.

The rich soils and moderate climate of the tolerant hardwood forest found in association with the area's river valleys meant that this assemblage type was often the first to be cleared for agriculture and associated settlements, and today remains largely unforested. Similar trends have been reported for edaphically-rich hardwood forest in the USA (Curtis, 1956; Bratton et al., 1993; Rudis, 1995; Dunnwiddie et al., 1996; Lynch, 1996) and Canada (Simard and Bouchard, 1996). In our study area, many of the ground flora taxa found associated with rich tolerant hardwood forest are 'Alleghanian' species (e.g. *Adiantum pedatum*, *Allium tricoccum*, *Caulophyllum thalictroides* (Roland and Smith, 1969)), with centres of distribution in the northeastern and central-eastern regions of the USA. New Brunswick is at or near the northern limit of their distributions and, as a result, these species may never have been abundant. Given the probable inherent rarity of these taxa within New Brunswick, there would be few source populations to initiate recolonization following local extirpation, a problem exacerbated by the clearance and extensive fragmentation of river valley forest that once served as migration corridors. Four of the candidate extirpated species in our study area occurred in this habitat. While extirpation cannot be confirmed without intensive ground searches, many of the records came from areas now heavily settled or cleared, and the original populations, identified by the herbarium records, are gone. Even the mature *Acer saccharum–Fraxinus americana–Ulmus americana* bottomland forests that hosted these species are exceedingly rare (MacDougall and Loo, 1996), further suggesting that the species in question are no longer present.

Wet *Thuja occidentalis* forest was likely never widely abundant within our southeastern New Brunswick study area, due to the limited distribution of suitable environmental conditions. Despite this, past records in the study area and surveys from wet cedar forest in other nearby regions of New Brunswick suggest that these habitats hosted a rich assemblage of ground flora, including many uncommon, rare, and very rare taxa. In particular, the calcareous substrate, combined with the heavily shaded and sphagnum-dominated understorey of mature cedar stands, supported many orchids and sedges that were most commonly found in this habitat. During the settlement of southeastern New Brunswick, much wet *T. occidentalis* forest was cleared and drained for farming, and an analysis of old survey records in our study area suggests a 50% reduction in the occurrence of *T. occidentalis* (Lutz, 1997). Recent increases in the price of *T. occidentalis* timber has led to intensive harvest, further reducing the distribution of this forest type. The result of the elimination of wet *T. occidentalis* has been the likely extirpation of *Calypso bulbosa* from our study area. *Cypripedium reginae* is known from only one location and is endangered within New Brunswick, the result of habitat loss, as well as picking and collecting (Hinds, 1986).

Habitats occurring in infertile or inaccessible areas, and their member taxa, are not considered endangered at present. However, some are threatened or at risk (Table 2). Freshwater wetlands are threatened by a variety of land use activities. Intensive forest harvest around peat bogs, combined with the construction of permanent causeways, threaten existing hydrological patterns. Interference with the timing and intensity of water level fluctuations in wetlands can have serious impact on the composition and diversity of vegetation (Keddy, 1990). The threat to both shoreline habitat and open water habitat depends on the size of the water body and its accessibility. Large and easily accessed bodies of water, such as Washademoak Lake and Belleisle Bay, have become heavily developed for cottages. Much of the shoreline has been cleared, and groundwater pollution has created eutrophic conditions in some areas, affecting aquatic flora. Invasion by the non-native purple loosestrife *Lythrum salicaria* is also increasing in both shoreline and shallow aquatic habitats. Many of the smaller water bodies have experienced little or no development, and some of the more species-rich river shorelines are found in steep and inaccessible ravines and gorges, both along the coast and in the interior.

There are only two coastal salt marshes in the study area, and one occurs in Fundy National Park. Several inland salt springs associated with subterranean potash deposits exist near Sussex and host numerous halophytic species. Much of this area has been intensively disturbed, although at present all but one of the originally recorded species (Ganong, 1898) can still be found in good number. The one habitat grouping that appears to be secure is rock faces. Many of the cliffs, ledges, headlands, and escarpments in our study area occur in areas with steep and inaccessible terrain, and, thus, experience limited human disturbance.

It is difficult to use habitat vulnerability to evaluate the conservation status of uncommon, rare, or very rare taxa which are not associated with a specific habitat, or occur in habitat extensively distributed over the study area. All that is known is that the taxa are not abundant, that they have been found in the area at one time, and, based on these past observations, they may also persist at other locations. However, without surveys directed specifically to locate these taxa, it is impossible to determine the levels of abundance or the degree of threat. At least, this study has identified these taxa as having conservation significance, and indicated that they should not be ignored if observed by collectors or amateur naturalists. If these taxa are brought to the attention of forest workers and others who regularly travel in the forest, further populations could be located. The important first step is to determine which taxa are in this category, and this was achieved using herbarium data.

6. Conclusion

Land managers need spatially explicit information on the location of sites of conservation interest. Our study shows that herbarium records can be used to identify habitats having a high potential of hosting uncommon, rare, or very rare flora. While these data have obvious limitations, they do not diminish the importance of herbarium data for ecological and conservation work. If combined with rigorous and systematic ground searches, quantitative demographic studies, and monitoring programmes, herbarium records provide an invaluable first step for identifying taxa of potential conservation interest in the area, for providing spatially explicit data on locations where these taxa once occurred, defining the habitat types with which they are associated, and identifying information gaps on the location, distribution, and habitat affinities for which further investigation is required. In New Brunswick, there are ca. 1200 identified native vascular plant species, subspecies, varieties, and fertile hybrids, with ca. 35% classified as uncommon or rare. At present, only eight of these taxa have any formal legislative protection. However, at least 13 additional taxa are believed to have been extirpated from the province (New Brunswick Committee on Endangered Species, 1995), and our data suggest that there may be other candidates that at least have experienced local extirpation. It is impossible for ecologists or land managers to identify the scope of the conservation problem of these taxa without some means to further separate out which are priorities for research or active intervention. Using the herbarium data as suggested in this study provides a means to begin doing just this.

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