The *Sphagnum* species of Massachusetts

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ABSTRACT

This study incorporates the knowledge gained from the many genetic studies completed in the past 25 years with traditional morphological- and ecological-based species concepts to arrive at an updated taxonomy for the *Sphagnum* species in Massachusetts and New England. In total, 43–44 *Sphagnum* species are documented for Massachusetts and 53 *Sphagnum* species are documented for all of New England. The study provides a county checklist as well as the determination that 21 species are potentially rare in Massachusetts. Four (or five) new state records are documented for Massachusetts: *S. divinum* and/or *S. diabolicum*, *S.* ×*mississippiense, S.* ×*missouricum*, and *S. tenellum*.

Key words: checklist, distribution records, New England, peat mosses, *Sphagnum* diversity

INTRODUCTION

"… mosses give stubborn resistance to tidy definition."
—H.A. Crum and L.E. Anderson, *Mosses of Eastern North America*

The lineage of class *Sphagnopsida* is an ancient one. The earliest vegetative remains of land plants to date are microfossils for plants having distinctive sphagnopsid vegetative features that occur in Ordovician rock dating at 454–455 Ma (Cardona-Correa et al. 2016). In addition, the genus *Sphagnum* L. is the most ecologically and economically important bryophyte genus. Indeed, it has been asserted that more carbon is likely sequestered in living *Sphagnum* and its peat than in any other plant genus (Clymo and Hayward 1982).

Largely following the taxonomic approach of Warnstorf (1903), the first published list of *Sphagnum* in Massachusetts was by Andrews (1906), hereafter referred to as "the 1906 list." This publication was for the entire state and based on collections that Andrews had identified and verified. The list had 35 taxa (23 species, 12 varieties). The list lacked information about the collections nor did it mention herbaria. The second list was published 54 years later by Hilferty (1960), hereafter referred to as the "1960 list." It followed Andrews (1913) for the *Sphagnum* taxonomy and had 26 taxa. It did not refer to Andrews's 1906 list, which had apparently been overlooked. The large drop in the number of taxa compared to the 1906 list is largely due to a notable reduction in the number of varieties that were recognized (22 species, 4 varieties). Hilferty (1960) included the respective distributions of each taxon in the state by county, herbaria where collections were held, and references to published local lists. Five taxa on the 1960 list were based solely on published reports (i.e., no herbarium collections were indicated).

RHODORA, Vol. 124, No. 1000, pp. 413–435, 2022

DOI: 10.3119/23-07

Since the publication of the 1960 list, additional *Sphagnum* species have been reported for Massachusetts (Anderson et al. 1997; McQueen and Andrus 2007; Miller and Robinson 2015; Robinson et al. 2023) and there have been several nomenclatural changes. Given the morphological plasticity associated with many *Sphagnum* species, coupled with the extensive interspecific morphological overlap that occurs among many species, genetic studies have greatly increased our knowledge of *Sphagnum* in the past 25 years and have led to many notable changes. This study has three major objectives: (1) to develop an updated list of *Sphagnum* species in Massachusetts that also incorporates the notable influence that genetic information has had on our understanding of the genus *Sphagnum* through 2023, (2) to provide the occurrence of each species by county based on herbarium records, and (3) to determine the potential state conservation status for each species whose respective number of records (including duplicates) is fewer than 30 in the Consortium of Bryophyte Herbaria (CBH) online database.

MATERIALS AND METHODS

Checklist Derived from McQueen and Andrus (2007). Starting in early 2023, a third listing of the *Sphagnum* species of Massachusetts based on the distribution data reported by McQueen and Andrus (2007), yielding 45 taxa (44 species and one subspecies), was developed by the author (Supplemental Table S1). This list, hereafter referred to as "the 2007 list," was then updated to create the list presented in this article ("the 2023 list"). As with Andrews's 1906 list, the 2007 list does not include data on collections and herbaria. I have a copy of a 1998 draft of the McQueen and Andrus document, which was written prior to McQueen's death in 1999 (Andrus died in 2020). The first completed version of the McQueen and Andrus document was submitted for publication in December 2003 (McQueen and Andrus 2003). This timeframe coincides with the period when genetic studies on bryophytes were just becoming common but, as was the case for the two prior species lists for *Sphagnum* in Massachusetts, species concepts for McQueen and Andrus (2007) were based on the parameters of morphology, ecology, and distribution. In contrast to the 1960 list, which followed a conservative species concept approach (taxonomic lumping), the 2007 list followed a taxonomic splitting approach.

The 2023 List. The online CBH database (CBH 2023) provided information from 39 herbaria on the occurrence, distribution, and collection dates for each species in Massachusetts on the 2007 list. *Sphagnum* species that were reported by McQueen and Andrus (2007) and by Ledlie and Allen (2019) for one or more of the neighboring states (Connecticut, Maine, New Hampshire, New Jersey, New York, Rhode Island, and Vermont) that they had not reported for Massachusetts were also included in the survey of the online CBH database (CBH 2023) for their possible occurrence and distribution in Massachusetts. This yielded herbarium records of four additional species for Massachusetts (*S. flexuosum* Dozy & Molk., *S. macrophyllum* Bernh. ex Brid., *S. tenellum* (Brid.) Bory, and *S. tenerum* Sull. & Lesq.); they are included on the 2023 list.

A review of the many genetic studies pertaining to the species on the draft 2023 list (as well as for the species occurring in neighboring states but not reported for Massachusetts) was undertaken. The incorporation of this information with the draft 2023 list resulted in the final version.

Adding a genetic dimension to species concepts has had both clarifying and confusing results. In some cases, genetic information has more clearly separated one species from another. In other cases, it has caused considerable confusion, particularly when associated with the use of infraspecific ranks (subspecies, variety, forma). The latter confusion arises in large part from the use of inconsistent approaches in the designation of infraspecific ranks (Ellison et al. 2014). This in turn can have legal consequences (e.g., delimitation and protection of taxa of special concern). Thus, the guidance of Ellison et al. (2014) is followed for the 2023 list and only one infraspecific ranking (subspecies, based on the clearly defined subspecies ranking definition in their article) is recognized and variety and form are not used.

County Distributions. Data files downloaded from the CBH database were sorted using Microsoft Excel Home and Student Version 2019 (Microsoft Corporation, Redmond, Washington) to obtain the total number of records (which includes duplicate collections), the range of collection dates, and the occurrence by county for each species. Although the L.H. Bailey Hortorium Herbarium (BH) is not yet fully databased (and thus not part of CBH), 304 collections covering the *Sphagnum* species from Massachusetts that are housed there were digitized and made available for this study. In addition, three vouchers of *S. warnstorfii* Russow and one of *S. contortum* Schultz that had been identified by Howard Crum (with Benito Tan also verifying the *S. contortum* voucher) and which had been collected for research by Motzkin et al. (1994) were lost (G. Motzkin, pers. comm.). As these two species have a limited presence in the state, these data were also included in the study.

The herbarium information is somewhat inconclusive because (1) not all records have been verified; (2) some collections are split into duplicates, with each duplicate being counted as a separate record; and (3) species are sometimes placed under the wrong and/or outdated name by CBH. For this article, the number of herbarium records includes duplicates and differs from the number of collections, which excludes duplicates. Given that a large percentage of the records have previously been identified and/or verified by competent sphagnologists (primarily Dick Andrus, but also Carl Warnstorf, Leroy Andrews, Cyrus McQueen, Lewis Anderson, and Jon Shaw), this information sheds light about the presence of a species in Massachusetts: how frequently it has been collected, where it has been collected, and when it was collected.

Rare Species. To provide a sharper focus on *Sphagnum* species that appear to be uncommon in Massachusetts, the CBH data were first parsed into the total number of records (including duplicates) for each species. Then species having fewer than 30 herbarium records were further parsed into (1) the total number of collections (records excluding duplicates), and (2) the total number of sites of occurrence. Combined with the collection dates, this information allows for a determination of their potential state conservation status.

RESULTS

The finalized 2023 list of *Sphagnum* in Massachusetts is shown in Table 1. It has 43–44 species and no infraspecific taxa, with nine of the species being allopolyploids. New state

Table 1. The 2023 list of *Sphagnum* L. species that have been collected in Massachusetts. The climate and latitude information indicate the general distribution range of each species. The oldest herbarium collection date is to the left of the forward slash and the most recent (MR) herbarium collection date is to the right of the slash. For *S. diabolicum* A.J. Shaw, Aguero, & Nieto-Lugilde, *S. divinum* Flatberg & K. Hassel, and *S. medium* Limpr., the oldest/MR herbarium collection dates are for all three species, treated collectively as a species complex. Allopolyploid species are denoted by an asterisk. In the Oldest/MR column, dates within parentheses accompanied by an exclamation mark indicate species identified by the author based on fieldwork in 2022 and 2023. Bold font means that a species is new for the state. Curly brackets indicate a species complex (not a single species). A question mark indicates that genetic analysis is required to determine if both *S. diabolicum* and *S. divinum* are present, or if just one is. In the Source column, A = McQueen and Andrus 2007; B = CBH 2023.

Species (publication date)	Climate	Latitude	Oldest/MR	Source
S. affine Renauld & Cardot, 1885 (Includes Massachusetts collections identified as *S. imbricatum* Hornsch. ex Russow. Isozymes support species ranking [Thingsgaard 2002].)	suboceanic	± southern	1881/(2023!)	A, B
S. angermanicum Melin, 1919	oceanic	northern	2001	A, B
S. angustifolium (Russow) C.E.O. Jensen, 1891 (RADseq analysis supports species ranking [Duffy et al. 2020].)	continental	northern	1978/(2023!)	A, B
S. austinii Sull., 1870 (Isozymes support species ranking [Thingsgaard 2002].)	oceanic	northern	1908	A, B
S. capillifolium (Ehrh.) Hedw., 1782 (Based on multilocus nucleotide sequences, Shaw [2005] concluded *S. capillifolium* (Ehrh.) Hedw. and *S. rubellum* Wilson to be separate species.)	continental	northern	1850/(2023!)	A, B
**S. ×carolinianum* R.E. Andrus, 1983 (Allopolyploidy shown by microsatellites [Ricca and Shaw 2010].)	oceanic	southern	1988	A, B
**S. ×centrale* C.E.O. Jensen, 1896 (Allopolyploidy shown by microsatellites [Karlin et al. 2010].)	continental	northern	1908/1988	A, B
S. compactum DC., 1805	widespread	widespread	1889/2007	A, B
S. contortum Schultz, 1819	continental	northern	1890/1991	A, B
S. cuspidatum Ehrh. ex Hoffm., 1795/1796 (Includes *S. viride* Flatberg, supported by isozymes [Hanssen et al. 2000] and RADseq analysis [Robinson et al. 2023].)	suboceanic	widespread	1850/(2023!)	A, B
S. diabolicum A.J. Shaw, Aguero, & Nieto-Lugilde, 2023 (RADseq data supports species ranking [Shaw et al. 2023].)	suboceanic	northern	(2023!)?	This article
S. divinum Flatberg & K. Hassel, 2018 (Microsatellites support species ranking [Hassel et al. 2018].)	suboceanic	northern	(2023!)?	This article

Table 1 continued

Species (publication date)	Climate	Latitude	Oldest/MR	Source
S. fallax (H. Klinggr.) H. Klinggr., 1880 (Includes *S. isoviitae* Flatberg; RADseq analysis does not support species ranking [Duffy et al. 2020].)	suboceanic	northern	1893/(2023!)	A, B
S. fimbriatum Wilson, 1847	widespread	northern	1881/(2023!)	A, B
S. flavicomans (Cardot) Warnst., 1911 (Includes plants identified as *S. plumulosum* Röll or as *S. subnitens* (Russow & Warnst.).)	oceanic	northern	1889/(2023!)	A, B
S. flexuosum Dozy & Molk., 1851 (RADseq analysis supports species ranking [Duffy et al. 2020].)	suboceanic	northern	1893/(2023!)	B
S. fuscum (Schimp.) H. Klinggr., 1872	widespread	northern	1889/(2023!)	A, B
S. girgensohnii Russow, 1865	widespread	northern	1877/(2023!)	A, B
S. lescurii Sull., 1856 (Based on microsatellites includes *S.* ×*missouricum* in part [Shaw et al. 2012].)	suboceanic	widespread	1881/2007	A, B
S. macrophyllum Bernh. ex Brid., 1826	oceanic	southern	1918/1970	B
{*S. magellanicum* Brid. 1798 (as s.l. complex)}	widespread	widespread	1888/(2023!)	A, B
**S.* ×*majus* (Russow) C.E.O. Jensen, 1890 (Includes *S.* ×*majus* subsp. *norvegicum* Flatberg based on RADseqanalysis [Nieto-Lugilde et al. 2022].Allopolyploidy shown by isozyme analysis [Såstad et al. 1999].)	widespread	northern	1978/(2023!)	A, B
S. medium Limpr., 1881 (Species ranking supported by plastid nucleotide sequences and microsatellites [Kyrkjeeide et al. 2016] and by RADseq analysis [Yusefi et al. 2017].)	suboceanic	northern	(2023!)	This article
S.* ×*mississippiense R.E. Andrus, (RADseq analysis supports species ranking and suggests allopolyploidy [Robinson et al. 2023].)	oceanic	southern	2005/2006	Robinson et al. 2023
S.* ×*missouricum Warnst. & Cardot, 1907 (Includes collections identified as *S. inundatum* Russow based onmicrosatellites [Shaw et al. 2012]. Allopolyploidy shown by microsatellites [Shaw et al. 2012].)	suboceanic	± northern	1908?/(2023!)	Shaw et al. 2012
**S.* ×*palustre* L., 1753 (Includes *S.* ×*henryense* Warnst. based on microsatellites [Karlin et al 2010b]. Allopolyploidy shown by microsatellites [Shaw et al. 2008b].)	suboceanic	± southern	1853/(2023!)	A, B
**S.* ×*papillosum* Lindb., 1872 (Allopolyploidy shown by microsatellites [Karlin et al. 2010a].)	suboceanic	northern	1889/(2023!)	A, B
S. platyphyllum (Lindb. ex Braithw.) Sull. ex Warnst., 1884	continental	northern	1889/1996	A, B

Table 1 continued

Species (publication date)	Climate	Latitude	Oldest/MR	Source
S. pulchrum (Lindb.) Warnst., 1900	suboceanic	northern	1890/2022!)	A, B
S. pylaesii Brid., 1827	oceanic	northern	<1900/1976	A, B
S. quinquefarium (Lindb.) Warnst., 1886	suboceanic	northern	1978/2002	A, B
S. recurvum P. Beauv., 1805 (RADseq analysis supports species ranking [Duffy et al. 2020].)	suboceanic	southern	1839/(2023!)	A, B
S. riparium Ångstr., 1864	continental	northern	1986	A, B
S. rubellum Wilson, 1855 (Multilocus nucleotide sequences includes *S. andersonianum* R.E. Andrus and *S. bartlettianum* Warnst. [Shaw 2005].)	suboceanic	northern	1880/(2023!)	A, B
**S. ×russowii* Warnst., 1886 (Allopolyploidy shown by isozymes [Cronberg 1996].)	widespread	northern	1908/(2023!)	A, B
S. squarrosum Crome, 1803	widespread	northern	1908/(2023!)	A, B
S. subsecundum Nees, 1819 (Likely includes some collections identified as *S. inundatum* Russow based on microsatellites [Shaw et al. 2012].)	widespread	northern	1881/2009	A, B
S. subtile (Russow) Warnst. 1903. (Although multilocus nucleotide sequence data did not support separating *S. subtile* from *S. capillifolium* [Shaw et al. 2005], the status of *S. subtile* remains ambiguous.)	suboceanic	northern	1908/1998	A, B
S. tenellum (Brid.) Bory, 1804	oceanic	northern	1958/2007	B
S. tenerum Sull. & Lesq., 1856 (Multilocus nucleotide sequences support species ranking [Shaw 2005].)	oceanic	southern	1918/2007	B
S. teres (Schimp.) Ångstr. ex Hartm., 1861	continental	northern	1889/1998	A, B
**S. ×torreyanum* Sull., 1849 [1850] (Includes *S. ×atlanticum* R.E. Andrus based on microsatellites [Shaw et al. 2009], which also showed both taxa to be allopolyploids.)	oceanic	northern	1881/(2023!)	A, B
S. trinitense Müll. Hal., 1848 (Isozyme analysis [Hanssen 2000] and RADseq analysis [Robinson et al. 2023] both support species-level ranking.)	oceanic	southern	1908/2007	A, B
S. warnstorfii Russow, 1887	continental	northern	1890/(2023!)	A, B
S. wulfianum Girg., 1860	continental	northern	1889/(2023!)	A, B

records for Massachusetts are *S. diabolicum* A.J. Shaw, Aguero, & Nieto-Lugilde and/or *S. divinum* Flatberg & K. Hassel, *S.* ×*mississippiense* R.E. Andrus, *S.* ×*missouricum* Warnst. & Cardot, and *S. tenellum*. Although listed by McQueen and Andrus (2007) for Massachusetts, no herbarium records for either *S. andersonianum* R.E. Andrus or *S. majus* subsp. *norvegicum* Flatberg for the state were found in the CBH database.

Exclusion of Previously Reported Taxa

1. *Sphagnum cyclophyllum* Sull. & Lesq.: This species was not reported for Massachusetts by McQueen and Andrus (2007), and the two records for it in CBH are not that species.
2. *S. imbricatum* Hornsch. ex Russow: *Sphagnum imbricatum* s.s. is now associated with East Asian plants and excluded from almost all of North America (Andrus 1987; Thingsgaard 2002). McQueen and Andrus (2007) reported a recent collection from the Selawik National Wildlife Refuge in Northwest Arctic Borough, Alaska.
3. *S. inundatum* Russow: Recent genetic studies have excluded *S. inundatum* s.s. from North America (Shaw 2008a).
4. *S. magellanicum* Brid.: *Sphagnum magellanicum* s.s. is excluded from the Northern Hemisphere and is associated with plants on the southern tip of South America (Hassel et al. 2018).
5. *S. subnitens* Russow & Warnst. (synonym: *S. plumulosum* Röll): McQueen and Andrus (2007) excluded *S. subnitens* from northeastern North America but accepted it in coastal regions of northwestern North America. Genetic studies confirmed its presence in the latter region (Karlin et al. 2011).
6. *S. portoricense* Hampe: Although not reported for Massachusetts by McQueen and Andrus (2007), CBH includes one collection of this species. However, this collection was incorrectly identified; it is *S. affine* Renauld & Cardot.

Species Complex Notes

The *Sphagnum capillifolium* (Ehrh.) Hedw. Species Complex. This study recognizes four species of this complex in Massachusetts (Table 2), all gametophytically haploid. Genetic studies placed two species recognized by McQueen and Andrus (2007) (*S. andersonianum* and *S. bartlettianum* Warnst.) in *S. rubellum* Wilson (Shaw et al. 2005). Although multilocus nucleotide sequence data also did not support separating *S. subtile* (Russow) Warnst. from *S. capillifolium* (Shaw et al. 2005), the standing of *S. subtile* remains ambiguous. Morphological studies (including common garden experiments) clearly show that the gametophyte (McQueen 1989) and spore (McQueen 1985) morphologies of *S. subtile* differ notably from those of *S. capillifolium*. McQueen and Andrus (2007) recognized *S. subtile* and noted that "this species is conspicuously distinct [from *S. capillifolium*] in gametophyte and spore morphology as well as niche." Noting that the two species can often be separated morphologically, Anderson et al. (2009) treated *S. subtile* as being separate from *S. capillifolium* pending further molecular study. This conclusion is followed here.

Although multilocus nucleotide sequence data clearly separated *Sphagnum capillifolium* from *S. rubellum* (Shaw 2005), interspecific gene flow between the two species was indicated by isozyme electrophoresis (Cronberg 1998). Although well-developed plants

Table 2. A comparison of the 2023 listing for *Sphagnum* L. in Massachusetts with the 2007, 1960, and 1906 lists, with the latter three lists having their nomenclature updated to that used by the 2023 list. Species on the 2023 list that are new reports for Massachusetts are indicated by arrows. Allopolyploid species are denoted by an asterisk. Occurrences based solely on published records are indicated by ≈. Species verified by Andrews without citation of herbarium records are indicated by √. Subgenera and sections are in bold. Curly brackets indicate species complexes, and taxa within a complex are indented beneath the complex name. A question mark indicates that genetic analysis is required to determine if both *S. diabolicum* and *S. divinum* are present, or just one is.

Species	2023	2007	1960	1906
Total taxa on original list	43−44 spp.	44 spp. & 1 subsp.	22 spp. & 4 vars.	23 spp. & 12 vars.
Total taxa on updated list	43–44 spp.	38 spp.	24 spp.	23 spp.
Taxa not on prior lists	4–5	11	5	−
Cumulative total	43–44	39	28	23
Subgenus *Sphagnum* L.				
**S. ×papillosum* Lindb.	+	+	+	−
{*S. imbricatum* Hornsch. ex Russow complex}	+	+	+	√
S. affine Renauld & Cardot	+	+	+	√
S. austinii Sull.	+	+	−	−
{*S. magellanicum* Brid. s.l. complex}	+	+	+	√
→ *S. diabolicum* A.J. Shaw, Aguero, & Nieto-Lugilde	+?	−	−	−
→ *S. divinum* Flatberg & K. Hassel	+?	−	−	−
S. medium Limpr. s.s.	+	−	−	√
{*S. ×palustre* L. s.l. complex}	+	+	+	√
**S. ×centrale* C.E.O. Jensen	+	+	−	−
**S. palustre*	+	+	+	√
Subgenus *Rigida* (Lindb.) A. Eddy				
S. compactum DC.	+	+	+	√
Subgenus *Cuspidata* Lindb.				
**S. ×majus* (Russow) C.E.O. Jensen	+	+	−	−
S. pulchrum (Lindb.) Warnst.	+	+	−	−
S. riparium Ångstr.	+	+	−	−
→ *S. tenellum* (Brid.) Bory	+	−	−	−
{*S. cuspidatum* Ehrh. ex Hoffm. s.l. complex}	+	+	+	√
S. cuspidatum s.s.	+	+	+	√
**S. ×torreyanum* Sull.	+	+	+	√
S. trinitense Müll. Hal.	+	+	−	−
→ **S. ×mississipiense* R.E. Andrus	+	−	−	−
{*S. recurvum* P. Beauv. s.l. complex}	+	+	+	√
S. angustifolium (Russow) C.E.O. Jensen	+	+	≈	√
S. fallax (H. Klinggr.) H. Klinggr.	+	+	−	−
S. flexuosum Dozy & Molk.	+	−	−	√
S. recurvum s.s.	+	+	+	√
Subgenus *Subsecunda* (Lindb.) A.J. Shaw				
S. contortum Schultz	+	+	−	√
S. macrophyllum Bernh. ex Brid.	+	−	+	−
S. platyphyllum (Lindb. ex Braith.) Sull. ex Warnst.	+	+	−	√
S. pylaesii Brid.	+	+	−	−

Table 2. continued

	2023	2007	1960	1906
{*S. subsecundum* Nees s.l. complex}	+	+	+	√
**S.* ×*carolinianum* R.E. Andrus	+	+	−	−
S. lescurii Sull.	+	+	−	√
→ **S.* ×*missouricum* Warnst. & Cardot	+	+	−	√
S. subsecundum	+	+	+	√
Subgenus *Acutifolia* (Russow) A.J. Shaw				
Section *Acutifolia* (Russow) Schimp.				
S. angermanicum Melin	+	+	−	−
S. fimbriatum Wilson	+	+	+	√
S. flavicomans (Cardot) Warnst.	+	+	+	√
S. fuscum (Schimp.) H. Klinggr.	+	+	≈	√
S. girgensohnii Russow	+	+	+	√
**S.* ×*russowii* Warnst.	+	+	≈	−
S. warnstorfii Russow	+	+	≈	−
{*S. capillifolium* (Ehrh.) Hedw. s.l. complex}	+	+	+	√
S. capillifolium	+	+	+	√
S. rubellum Wilson	+	+	+	√
S. subtile (Russow) Warnst.	+	+	−	−
S. tenerum Sull. & Lesq.	+	−	+	−
{*S. subnitens* Russow & Warnst. s.l. complex}	+	+	+	√
S. flavicomans (Cardot) Warnst.	+	+	+	√
Section *Squarrosa* (Russow) Schimp.				
S. squarrosum Crome	+	+	+	√
S. teres (Schimp.) Ångstr. ex Hartm.	+	+	+	√
Section *Polyclada* (C.E.O. Jensen) Warnst.				
S. wulfianum Girg.	+	+	−	−

of *S. capillifolium* can be readily distinguished from those of *S. rubellum*, McQueen (1989) found that gametophytic morphological overlap between these two species was so excessive that they were not always distinguishable from one another. He did find, however, that they could be distinguished based on spore morphology (McQueen 1985).

The *Sphagnum cuspidatum* Ehrh. ex Hoffm. Species Complex. This study recognizes four species in this complex as occurring in Massachusetts, with *S.* ×*torreyanum* Sull. an allopolyploid and *S.* ×*mississippiense* R.E. Andrus a putative allopolyploid (Table 2). Although previously treated as a species by McQueen and Andrus (2007), genetic study supports *S.* ×*atlanticum* R.E. Andrus being placed in *S.* ×*torreyanum* (Shaw et al. 2009) and *S. viride* Flatberg being merged with *S. cuspidatum* (Hanssen et al. 2000; Robinson et al. 2023). The recent report of *S.* ×*mississippiense* for Massachusetts by Robinson et al. (2023) represents a notable northern range extension for this allopolyploid species, with the nearest known population being in southern New Jersey. The close morphological relationship among members of this complex is exemplified by the treatment by Anderson et al. (2009), who placed *S. viride* and *S.* ×*mississippiense* in *S. cuspidatum* and were skeptical about recognizing *S. trinitense* Müll. Hal. as being a distinct species from *S. cuspidatum*.

The allopolyploid *Sphagnum* ×*majus* (Russow) C.E.O. Jensen is not considered to be a member of the *S. cuspidatum* species complex, but isozyme analysis (Såstad et al. 1999) and RADseq analysis (Nieto-Lugilde et al. 2022) both show *S. cuspidatum* to be one likely progenitor of this species. Although *S.* ×*majus* subsp. *norvegicum* Flatberg is recognized by McQueen and Andrus (2007), RADseq analysis did not show any genetic differentiation between *S.* ×*majus* subsp. *majus* and *S.* ×*majus* subsp. *norvegicum* and thus does not support the recognition of the subspecies (Nieto-Lugilde et al. 2022).

The *Sphagnum imbricatum* Hornsch. ex Russow Species Complex. Morphological, ecological, and geographic distribution studies led to the splitting of the discontinuously circumboreal *S. imbricatum* into four species (Andrus 1987). This was subsequently supported by isozyme-based studies (Thingsgaard 2002). *S. imbricatum* s.s. is now associated with East Asian plants and occurs in Alaska (McQueen and Andrus 2007). Two segregates of this complex occur in Massachusetts: *S. affine* and *S. austinii* Sull. Given that only two herbarium collections of *S. austinii* are present for the state, both from the same site, it is likely that all, or almost all, of the other Massachusetts records of *S. imbricatum* s.l. are referable to *S. affine*.

The *Sphagnum magellanicum* Brid. Species Complex. Two or three species in this recently discovered species complex occur in Massachusetts (Table 2); all are gametophytically haploid. Based on plastid nucleotide sequences and microsatellites (simple sequence repeats), Kyrkjeeide et al. (2016) discovered the widespread *S. magellanicum* to be a complex of several genetically differentiated segregates. Subsequently, a RADseq-based study focused on two of the segregates found that they were notably divergent from each other (Yusefi et al. 2017). These two segregates were subsequently defined as *S. divinum* (a new species distributed in Eurasia and northern North America) and the resurrected *S. medium* Limpr. (Europe and northeastern North America), which had long been considered a synonym of *S. magellanicum*. Hassel et al. (2018) also associated *S. magellanicum* s.s. with plants on the southern tip of South America. More recent studies based on RADseq data have shown a third segregate of the *S. magellanicum* species complex to be present in northeastern North America: *S. diabolicum* (Shaw et al. 2023). Shaw et al. (2023) found that there is a notable lack of reliable species-specific diagnostic morphological characters among *S. medium*, *S. diabolicum*, and *S. divinum*, with *S. medium* having the most distinct morphology and ecology of these three species. At present, genetic analysis is required to distinguish *S. diabolicum* from *S. divinum* (Shaw et al. 2023). All three are reported for New England, but genetically confirmed collections have not been reported for Massachusetts (Shaw et al. 2023). Based on morphology, I have identified *S. medium* as being present in Massachusetts and have found that *S. diabolicum* and/or *S. divinum* occur in the state. Pictures of these species are provided in the Supplemental Appendix. Given the above, I include all three species in the state listing, but use *S. magellanicum* s.l. complex for the information about the overall status of these species collectively in the state.

The *Sphagnum subsecundum* Nees Species Complex. This species complex has four species in Massachusetts, with two being allopolyploid (Table 2). Three species in this complex share an intertwined evolutionary history and until recently were known as

S. subsecundum s.s., *S. inundatum* (referable to *S.* ×*missouricum*), and *S. lescurii* Sull. Morphological overlap among these three species is considerable, with *S. inundatum* being morphologically intermediate between the other two species. Given the complexity, many older collections were simply identified as *S. subsecundum* s.l.

Genetic studies have excluded *Sphagnum inundatum* s.s. from North America (Shaw 2008a). North American plants formerly identified as *S. inundatum* are referable to *S.* ×*missouricum*, an allopolyploid derived from *S. subsecundum* and *S. lescurii* (Shaw et al. 2012). *Sphagnum* ×*missouricum* has a variable morphology, often with plants being morphologically intermediate between the two ancestral species. However, many plants of *S.* ×*missouricum* are morphologically indistinguishable from *S. lescurii*, and some plants can be difficult to distinguish from *S. subsecundum*. Genetic study confirms that all three species occur in Massachusetts (Ricca and Shaw 2010). For this article, the collections previously identified as *S. inundatum* are treated as being *S.* ×*missouricum*. Thus, (1) herbarium records for *S. lescurii* include collections of *S.* ×*missouricum* that are morphologically indistinguishable from *S. lescurii*, (2) herbarium records for collections of *S. subsecundum* s.s. include collections of *S.* ×*missouricum* that are morphologically very close to that species, and (3) herbarium records for *S. subsecundum* s.l. include all three species. Thus, the overall distribution and status of each of these species in Massachusetts are ambiguous. However, all three species appear to occur across the state. Although the number of herbarium records for *S.* ×*missouricum* is much lower than that of the other two members of the *S. subsecundum* s.l. complex (Table 3), many collections of this species are likely to have been identified as being *S. lescurii* and/or *S. subsecundum*. Taking this into consideration, *S.* ×*missouricum* is more common in the state than its herbarium records suggest.

The fourth species in the *Sphagnum subsecundum* species complex is the allopolyploid *Sphagnum* ×*carolinianum* R.E. Andrus. It is a distinctive aquatic species when well developed, but some plants can be confused in the field with both *S. lescurii* (Anderson et al. 2009) and plants of *S.* ×*missouricum* that are morphologically close to *S. lescurii* (Shaw et al. 2010). Genetic analysis shows that *S. lescurii* appears to be one ancestral species of *S.* ×*carolinianum* (Ricca and Shaw 2010). Although McQueen and Andrus (2007) report *S.* ×*carolinianum* to range as far north as Newfoundland and Labrador, a genetic study by Shaw et al. (2012) found that specimens originally identified as *S.* ×*carolinianum* that occurred further north than New Jersey were either *S. lescurii* or *S.* ×*missouricum*. Subsequently, Duffy et al. (2022) postulated that the northern limit of *S.* ×*carolinianum* might be in New Jersey. The two findings are surprising because the majority of the collections of *S.* ×*carolinianum* from north of New Jersey included in their respective studies were gathered and initially identified by two experts (Dick Andrus and Jon Shaw). This strongly suggests that morphological overlap between *S.* ×*carolinianum* and both *S. lescurii* and *S.* ×*missouricum* is more extensive than was once thought. However, neither Shaw et al. (2012) nor Duffy et al. (2022) included the single Massachusetts collection of *S.* ×*carolinianum*, which had been identified by its author (Dick Andrus). Further, the habitat that the Massachusetts collection occurred in is atypical for that species. Thus, the status of *S.* ×*carolinianum* in Massachusetts is ambiguous. In light of the extensive morphological overlap that appears to occur among

Table 3. The total number of herbarium records (including duplicates) in the CBH database as well as the counties of occurrence for each *Sphagnum* species in Massachusetts at the time of this study. Bold font indicates that genetic study by Ricca and Shaw (2010) has confirmed the identification of that county record. Counties are grouped into three regions: western, central, and eastern Massachusetts. Allopolyploid species are denoted by an asterisk. For this table, *S. diabolicum* A.J. Shaw, Aguero, & Nieto-Lugilde, *S. divinum* Flatberg & K. Hassel, and *S. medium* Limpr. are listed as one taxon (*S. magellanicum* s.l.) for the county distribution data. Curly brackets indicate a species complex. The following abbreviations are used to denote the counties of Massachusetts: Bar = Barnstable; Ber = Berkshire; Bri = Bristol; Duk = Duke; Ess = Essex; Fra = Franklin; Hdn = Hampden; Hsr = Hampshire; Mid = Middlesex, Nan = Nantucket; Nor = Norfolk; Ply = Plymouth; Suf = Suffolk; Wor = Worcester.

		Counties		
Species	**Records**	**Western**	**Central**	**Eastern**
≤ 30 total records (21)				
S. angermanicum Melin	2	–	–	Duk, Mid
S. austinii Sull.	3	–	–	Bar
**S. ×carolinianum* R.E. Andrus	1	–	Fra	–
**S. ×centrale* C.E.O. Jensen	26	Ber	Fra, Hdn, Hsr	Bar, Mid, Nor
S. contortum Schultz	14	–	Hdn, **Hsr***	Ess, Mid
S. fuscum (Schimp.) H. Klinggr.	22	Ber	Fra, Wor	Ess, Nan, Nor
S. macrophyllum Bernh ex Brid.	4	–	–	Bar
**S. ×majus* (Russow) C.E.O. Jensen	7	–	Wor	–
**S. ×mississippiense* R.E. Andrus	2	–	–	Duk
S. platyphyllum (Lindb. ex Braithw.) Sull. ex Warnst.	27	–	**Fra**	Ess, Suf
S. pulchrum (Lindb.) Warnst.	19	–	Wor	Bri, Mid, Nor, Suf
S. pylaesii Brid.	3	–	–	Bar, Bri
S. quinquefarium (Lindb.) Warnst.	2	Ber	Wor	–
S. riparium Ångstr.	2	Ber	–	–
**S. ×russowii* Warnst.	24	Ber	Fra, Wor	Duk, Ess, Mid, Nan, Nor
S. subtile (Russow) Warnst.	23	–	Fra, Hsr, Wor	Bar, Bri, Ess, Mid
S. tenellum (Brid.) Bory	2	–	–	Bar, Nan
S. tenerum Sull. & Lesq.	8	–	–	Bar, Ess, Nan
S. trinitense Müll. Hal.	21	–	–	Bar, Duk, Nan
S. warnstorfii Russow	9	Ber	Fra	Ess
S. wulfianum Girg.	3	Ber	Fra	Nor
≥ 30 total records (22)				
S. affine Renauld & Cardot	250	Ber	Fra, Hdn, Hsr, Wor	Bar, Bri, Duk, Ess, Mid, Nan, Nor, Suf
S. angustifolium (Russow) C.E.O. Jensen	45	Ber	Fra, Hdn, Hsr, Wor	Bri, Nan, Ply
S. capillifolium (Ehrh.) Hedw.	104	Ber	Fra, Hdn, Wor	Bar, Bri, Duk, Ess, Mid, Nan, Ply
S. compactum DC.	41	Ber	Wor	Bar, Mid, Nan
S. cuspidatum Ehrh. ex Hoffm.	171	–	Fra, Wor	Bar, Bri, Duk, Ess, Mid, Nan, Nor, Ply, Suf
S. fallax (H. Klinggr.) H. Klinggr.	127	Ber	Fra, Hdn, Hsr, Wor	Duk, Ess, Mid, Nan, Ply

Table 3. continued

Species	Records	Counties		
		Western	**Central**	**Eastern**
S. fimbriatum Wilson	218	Ber	Fra, Hdn, Hsr, Wor	Bar, Duk, Ess, Mid, Nan, Nor, Ply, Suf
S. flavicomans (Cardot) Warnst.	74	–	Wor	Bar, Ess, Mid, Nan, Nor, Ply, Suf
S. flexuosum Dozy & Molk.	69	–	Fra, Hdn, Hsr, Wor	Bar, Ess, Mid, Nor
S. girgensohnii Russow	58	Ber	Fra, Hdn, Hsr, Wor	Bar, Bri, Mid, Nor
S. lescurii Sull.	148	Ber	**Fra**, Hdn, Hsr	Bar, Duk, Ess, Mid, **Nan**, Nor, Ply, Suf
{*S. magellanicum* Brid. s.l.}	109	Ber	Fra, Hdn, Wor	Bar, Duk, Ess, Mid, Nan, Nor, Ply, Suf
**S.* ×*missouricum* Warnst. & Cardot	43	Ber	**Fra**, **Hdn**, **Hsr**, Wor	Bar, Duk, Ess, Mid
**S.* ×*palustre* L.	375	Ber	Fra, Hdn, Hsr, Wor	Bar, Bri, Duk, Ess, Mid, Nan, Nor, Ply, Suf
**S.* ×*papillosum* Lindb.	102	–	Fra, Wor	Bar, Duk, Mid, Nor
S. recurvum P. Beauv.	187	Ber	Fra, Hdn, Wor	Bar, Bri, Duk, Ess, Mid, Nan, Nor
S. rubellum Wilson	101	–	Fra, Hdn, Wor	Bar, Bri, Duk, Ess, Mid, Nan, Nor, Suf
S. subsecundum Nees	149	**Ber**	**Fra**, Hdn, Hsr	Bar, Duk, Ess, Mid, Nan, Nor, Suf
S. squarrosum Crome	48	Ber	Fra, Hsr	Bar, Duk, Ess, Mid, Nor
S. teres (Schimp.) Ångstr. ex Hartm.	75	Ber	Fra, Hdn, Hsr, Wor	Mid, Nor
**S.* ×*torreyanum* Sull.	147	–	Fra, Hdn, Wor	Bar, Duk, Ess, Mid, Nan, Nor, Ply, Suf

S. ×*carolinianum*, *S. lescurii*, and *S.* ×*missouricum*, genetic analysis may be required to confirm if *S.* ×*carolinianum* is present in Massachusetts.

The *Sphagnum* ×*palustre* L. Species Complex. Genetic studies support the presence of two species in this complex in Massachusetts (Table 2). Although *S.* ×*henryense* Warnst. has been considered to be distinct from *S.* ×*palustre* by many (Andrus 1980; Crum 1984; Karlin and Andrus 1988; Karlin et al. 1991; Anderson 1990; McQueen and Andrus 2007; Michaelis 2019), Anderson et al. (2009) merged *S.* ×*henryense* with *S.* ×*palustre* solely based on morphological characters. A subsequent study based on microsatellite analysis found *S.* ×*henryense* to be an allopolyploid and also concluded that it was conspecific with *S.* ×*palustre* (Karlin et al. 2010b). Microsatellites provide preliminary evidence that *S.* ×*centrale* C.E.O. Jensen and *S. palustre* have one parental species in common and differ in the second (Karlin et al. 2010b).

The *Sphagnum recurvum* P. Beauv. Species Complex. This study recognizes the presence of four species in this complex in Massachusetts (Table 2), all gametophytically haploid. Genetic studies showed that *S. isoviitae* Flatberg, which was recognized by McQueen and Andrus (2007), belonged in *S. fallax* (H. Klinggr.) H. Klinggr. (Stenøien and S. Såstad 1999; Duffy et al. 2020). The latter study also placed *S. brevifolium* (Lindb. ex Braithw.) Röll, which is reported by McQueen and Andrus (2007) for Maine, New Hampshire, and Vermont but not Massachusetts, in *S. fallax*.

Comparison with Prior State Listings. The three prior state listings were updated to follow the nomenclature of the 2023 list, as shown in supplemental tables S1, S2, and S3. A comparison with the 2023 list and the updated versions of the three prior lists is shown in Table 2. Based on the updated lists, the total number of species reported for the state has increased with each listing, ranging from 23 for the 1906 list to 43–44 for the 2023 list. The largest increase in new reports for the state is associated with the 2007 list. The infraspecific rankings decrease from the older to the newer listings, with no infraspecific rankings included on the 2023 list. Three of the four species that had been overlooked by McQueen and Andrus (2007) had been included on the 1906 list (*S. flexuosum*) and the 1960 list (*S. macrophyllum* and *S. tenerum*).

Influence of Genetic Studies on Species Recognition. The effects of genetic studies on species recognition had a notable influence on taxa within the species complexes, where a history of confusion about the formal taxonomic status of the component species has been a long-term issue. Six species (*Sphagnum andersonianum*, *S. atlanticum*, *S. bartlettianum*, *S.* ×*henryense*, *S. isoviitae*, and *S. viride*) recognized by McQueen and Andrus (2007) for Massachusetts have been merged with another member of their respective species complexes, in large part based on genetic analyses (see previous discussion and Supplemental Table S3). In addition, genetic data does not support the formal taxonomic recognition of *S.* ×*majus* subsp. *norvegicum* Flatberg (Nieto-Lugilde et al. 2022).

In the case of the putative allopolyploid *Sphagnum* ×*mississippiense,* which had been merged with *S. cuspidatum* by Anderson et al. (2009), RADseq and plastid sequence data unequivocally supported its ranking at the species level (Robinson et al. 2023). In contrast, genetic analyses were primarily responsible for splitting up what had long been considered a single widespread and morphologically distinct species (*S. magellanicum*) (Kyrkjeeide

et al. 2016; Yousefi et al. 2017). Consequently, the breakup of *S. magellanicum* s.l. has resulted in two or three species (Hassel et al. 2018; Shaw et al. 2023) replacing *S. magellanicum* in Massachusetts (*S. medium* along with *S. diabolicum* and/or *S. divinum*).

Influence of Genetic Studies on Infrageneric Structure. Eight of the nine sections in *Sphagnum* recognized by McQueen and Andrus (2007) are represented in Massachusetts. These sections were delimited using morphology. In contrast, based on 11 loci across the nuclear, plastid, and mitochondrial genomes, Shaw et al. (2010) divided the genus into six subgenera, with five subgenera (subg. *Cuspidata* Lindb., subg. *Rigida* (Lindb.) A. Eddy, subg. *Sphagnum* L., subg. *Squarrosa* (Russow) A.J. Shaw, and subg. *Subsecunda* (Lindb.) A.J. Shaw) corresponding to previously recognized sections. The sixth, subgenus *Acutifolia* (Russow) A.J. Shaw, differs in that it included three former sections that share close phylogenetic relationships: the core section *Acutifolia* (Russow) Schimp., section *Insulosa* Isov. (which is not present in Massachusetts), and section *Polyclada* Warnst. A subsequent study based on the entire genomes of both mitochondria and plastids led Shaw et al. (2016) to recognize five subgenera within *Sphagnum*, with subg. *Squarrosa* placed as a fourth section within subgenus *Acutifolia*. This study follows Shaw et al. (2016), with all five subgenera being represented in Massachusetts (Table 2).

Species Distribution by County. Table 3 shows the number of herbarium records (including duplicates) for each species listed in the CBH database, as well as their respective distributions across counties. The five species having more than 170 herbarium records each (including duplicates) are as follows (listed in order of decreasing number of total records): *Sphagnum ×palustre*, *S. affine*, *S. fimbriatum* Wilson, *S. recurvum*, and *S. cuspidatum*. Collectively, the members of the *S. subsecundum* species complex also have a high combined number of herbarium records (295 records). At the other end of the spectrum are 12 species having fewer than 10 herbarium records each.

Two species (*Sphagnum affine* and *S. ×palustre*) have been collected in every county of the state, followed by *S. fimbriatum*, which has been collected in all but Bristol County (Table 3). In stark contrast are the six species whose collections have been limited to just one county each (*S. austinii*, *S. ×carolinianum*, *S. macrophyllum*, *S. ×majus*, *S. mississippiense*, and *S. quinquefarium* (Lindb.) Warnst.). A distinct distributional pattern within the state is associated with species having an oceanic geographic distribution. Eight of these have only been collected east of Worcester County (*S. angermanicum* Melin, *S. austinii*, *S. macrophyllum*, *S. mississippiense*, *S. pylaesii* Brid., *S. tenellum*, *S. tenerum*, and *S. trinitense*) with an eighth (*S. flavicomans* (Cardot) Warnst.) reaching into Worcester County.

Collection Notes. The oldest herbarium collection of *Sphagnum* from Massachusetts that is listed in the CBH database dates from 1839 (Table 1). Made by J.W. Grosvenor in the Town of Barre, Worcester County, the collection was of *S. recurvum* s.l. Numerous collections of *Sphagnum* were made in Massachusetts in the late 1800s and early 1900s. The collectors included LeRoy Andrews, Harley Bartlett, Daniel Eaton, Edwin Faxon, Merritt Fernald, Chester Kingman, and Bayard Long, with Clara Cummings contributing to a much lesser extent. Andrews's collections are largely housed at BH. Andrews (1902a, 1902b, 1957) reported having made collections of 11 *Sphagnum* species from the Mount

Greylock region between 1901 and 1911, including two species which were not on his 1906 list (both collected after that list had been published). Background information about early New England bryologists is provided by Reid (1987). There was a renaissance of *Sphagnum* collection in the state in the late 1900s, including collections made by Dick Andrus, Antoni Damman, Walter Judd, William Town, Anna Reid, and Norton Miller. Collecting activity dropped notably after 2000, with Norton Miller (who died in 2011) being the most prolific collector during this timeframe. A paper based on the many bryophyte collections from Martha's Vineyard and Nomans Land that Miller made between 2005 and 2007 was posthumously published (Miller and Robinson 2015).

Two Massachusetts locations with a notably high species diversity of *Sphagnum* are the Ponkapoag mire complex (Norfolk County), for which Judd (1980) reported 15 species (16 species when updated to the 2023 list), and the Tom Swamp mire complex in Harvard Forest (Worcester County), with 18 species based on CBH data (16 species when updated to the 2023 list). Tom Swamp was explored by the Third A. LeRoy Andrews Bryological Foray in 1978 (Mishler and Miller 1983).

Corrections on Reports of New State Records. Five *Sphagnum* species reported as being new state records for Massachusetts by Hilferty (1959), Andersen et al. (1997), and Miller and Robinson (2015) had been previously reported for Massachusetts by Andrews (1906). They include three species (*S. affine* [listed as *S. imbricatum* var. *affine* (Russow & Cardot) Warnst.], *S. flavicomans* [listed as *S. plumulosum* var. *flavicomans* (Cardot) A.L. Andrews], and *S. teres* (Schimp.) Ångstr. ex Hartm.) reported by Hilferty (1959), *S. contortum* reported by Anderson et al. (1997), and *S. lescurii* (listed as *S. subsecundum* var. *rufescens* (Nees & Hornsch.) Huebener) reported by Miller and Robinson (2015). Further, the latter taxon is a synonym of *S. lescurii*, which Miller and Robinson (2015) had correctly listed as not being a new record.

The inclusion of *Sphagnum tenellum* Pers. ex Nees & Hornsch. (as *S. tenellum* Pers.) on the 1960 list reflects confusion based on three homonyms: the aforementioned species (published in 1823; it is a synonym of *S. teres*), *S. tenellum* (Brid.) Bory (published in 1804, in subgenus *Cuspidata*), and *S. tenellum* (Schimp.) H. Klinggr. (published in 1872; it is a synonym of *S. rubellum*). *Sphagnum tenellum* (Brid.) Bory has priority because it was published first, which makes the other two illegitimate; they are based on material of different species. Andrews (1913, 1919) thought that *S. tenellum* Pers. ex Nees & Hornsch. (as *S. tenellum* Pers.) was the correct name for *S. tenellum* (Brid.) Bory. Following Andrews, Hilferty (1959, 1960) thus used *S. tenellum* Pers. ex Nees & Hornsch. (as *S. tenellum* Pers.) in his two publications. However, there are just two collections of *S. tenellum* (Brid.) Bory present in the CBH database for Massachusetts, and both would have been unavailable to Hilferty at the time he did his research. One of the two collections, although collected in 1958, was not identified until 1984. The second collection was made in May 2007. It thus appears that Hilferty's reporting of *S. tenellum* Pers. for Massachusetts was based on collections identified with the homonym *S. tenellum* (Schimp.) H. Klinggr., for which there are several records in CBH that were made prior to 1900. As McQueen and Andrus (2007) did not report *S. tenellum* (Brid.) Bory for Massachusetts, the older of the two *S. tenellum* (Brid.) Bory collections listed in CBH appears to have been overlooked by them, and the more recent collection was made too

close to the publication date of McQueen and Andrus (2007) to have been included. Thus the 2023 listing is the first report of *S. tenellum* (Brid.) Bory for the state. Finally, confusion about the authorship and application of *S. tenellum* still persists, with Global Biodiversity Information Facility (2022) listing *S. tenellum* Bridel as the accepted name and *S. tenellum* (Brid.) Bory as doubtful, not recognizing that Bridel is the author of the basionym. Further, Hodgetts et al. (2020) lists the correct name as being *S. tenellum* (Brid.) Pers. ex Brid., which is a slightly different authorship for the same species that is allowable under the rules of nomenclature.

Species Reported for New England. A survey of McQueen and Andrus (2007), CBH (2023), and Ledlie and Allen (2019) yielded nine species that are documented in other New England states but are not documented for Massachusetts by the present study (Table 4). There were no nomenclatural updates for any of these nine species, although a study combining genetic data, morphology, and ecological data supported species ranking for the recently described *Sphagnum beothuk* R.E. Andrus (Kyrkjeeide et al. 2015). In addition, genetic confirmation of the occurrence of both *S. diabolicum* and *S. divinum* for some New England states, but not for Massachusetts, has been provided by Shaw et al. (2023) and Kassel et al. (2018), respectively. Although at least one of the latter two species occurs in Massachusetts based on morphology, genetic study is needed to confirm if just one or both of them are present. Four other New England *Sphagnum* species not reported for Massachusetts are likely to occur there based on their distributions (Table 4). As noted previously, although reported for some New England states by McQueen and Andrus (2007) but not for Massachusetts, RADseq analysis placed *S. brevifolium* in *S. fallax* (Duffy et al. 2020), which is present in Massachusetts. Taking all of this into account, 53 *Sphagnum* species are documented to occur in all of New England.

Potential State Conservation Status Rankings. Twenty-one *Sphagnum* species are represented by fewer than 30 herbarium records (including duplicates), a strong indicator that they are likely rare in the state (Table 5), especially since herbarium records (including duplicates) often reflect redundancy. This redundancy arises from the following: (1) a given collection may be split into duplicates, with each duplicate counting as a separate record, and (2) a given site may be represented by multiple collections of a given species. Members of the *S. magellanicum* species complex are excluded from Table 5 because more research is needed to determine their respective standings in Massachusetts. As the state plant conservation status is based in part on the number of sites where a species occurs, the herbarium records for each of these 21 species were further parsed into the number of collections (records excluding duplicates) and the number of sites where collections had been made (Table 5). Based only on the number of sites, 13 of these 21 species, particularly those known from just one or two sites each, would have a potential state plant conservation status of S1 (critically imperiled—because of extreme rarity, generally 1–5 occurrences in the state; MassWildlife's Natural Heritage & Endangered Species Program 2023). Pictures of three of the potential S1 species are provided in the Supplemental Appendix. The remaining eight species would have a potential state plant conservation status ranking of S2 (imperiled—due to very few populations in the state, generally 6–20 occurrences; MassWildlife's Natural Heritage

Table 4. *Sphagnum* L. species documented to occur in other New England states, New York, and New Jersey but not for Massachusetts. Arrows indicate species that are not currently documented for Massachusetts but are likely to be present there based on their known geographic distributions. Species not documented for New England but that occur in Long Island, New York and/or southern New Jersey are in bold. Sources are enclosed within parentheses. A: McQueen and Andrus 2007; B: CBH 2023; C: Ledlie & Allen 2019. D: Shaw et al. 2023; E: Hassel et al. 2018.

S. annulatum H. Lindberg ex Warnst. (B, C)
S. balticum (Russow) C.E.O. Jensen (B, C)
S. beothuk R.E. Andrus (B, C)
***S. cribrosum* Lindb.** (A, B)
***S. cyclophyllum* Sull. & Lesq.** (A, B)
S. diabolicum A.J. Shaw, Aguero & Nieto-Lugilde ← (D)
S. divinum Flatberg & K. Hassel ← (E)
S. lindbergii Schimp. (A, B, C)
S. mcqueenii R.E. Andrus ← (A, B, C)
S. molle Sull. ← (A, B, C)
***S. perichaetiale* Hampe** (A, B)
***S. portoricense* Hampe** (A, B)
S. rubiginosum Flatberg (B, C)
S. strictum Sull. ← (A, B, C)
S. subfulvum Sjörs ← (A, B, C)

Table 5. *Sphagnum* L. species having fewer than 30 herbarium records (including duplicates) from Massachusetts based on this study. The total number of collections (records excluding duplicates) and the number of sites associated with the herbarium records as well as the Tentative State Conservation Rank are provided for each species based on the data on hand. An exclamation mark indicates species that have been identified by the author in Massachusetts based on recent fieldwork. The number of sites listed within square brackets includes new sites that were discovered by the recent fieldwork. Asterisks indicate allopolyploid species.

Species	Collections	Sites	Tentative state conservation rank
S. angermanicum Melin	2	2	S1
S. austinii Sull.	2	1	SH
**S. ×carolinianum* R.E. Andrus	1	1	SH
**S. ×centrale* C.E.O. Jensen	20	18	SH
S. contortum Schultz	8	5	SH
S. fuscum (Schimp.) H. Klinggr.	17	[10]	S2!
S. macrophyllum Bernh. ex Brid.	2	2	SH
**S. ×majus* (Russow) C.E.O. Jensen	2	[2]	S1!
**S. mississippiense* R.E. Andrus	2	2	S1
S. platyphyllum (Lindb. ex Braithw.) Sull. ex Warnst.	7	5	SH
S. pulchrum (Lindb.) Warnst.	12	[7]	S2!
S. pylaesii Brid.	2	2	SH
S. quinquefarium (Lindb.) Warnst.	2	2	S1
S. riparium Ångstr.	1	1	SH
**S. ×russowii* Warnst.	21	[19]	S2!
S. subtile (Russow) Warnst.	16	14	SH
S. tenellum (Brid.) Bory	2	2	S1
S. tenerum Sull. & Lesq.	6	6	S1
S. trinitense Müll. Hal.	21	10	S2
S. warnstorfii Russow	8	7	S2!
S. wulfianum Girg.	3	[4]	S1!

& Endangered Species Program 2023). However, the state conservation ranking for species also considers how recently an occurrence has been documented, with species whose most recent record of occurrence is more than 25 years before the present being ranked as SH (historic—native species that have occurred historically but are not currently known to be extant in the state; MassWildlife's Natural Heritage & Endangered Species Program 2023). Consequently, unless more recent records are made, nine of these 21 species would be ranked as SH (Table 5). In contrast, the most recent record of occurrence, based on herbarium records, for each of the 22–23 *Sphagnum* species having more than 30 herbarium records (including duplicates) in the state is fewer than or equal to 25 years ago (i.e., they are all considered to be extant in the state). As the delineation of the Priority Habitat for a given rare species is based only on its records of occurrence in Massachusetts that have been made within the past 25 years (Division of Fisheries and Wildlife 2020), the species having a SH ranking would be excluded from this determination. Clearly, these 21 species should be a major focus for future studies on the state's *Sphagnum* flora.

ACKNOWLEDGMENTS

I thank Robert Wernerehl, Glenn Motzkin, Paul Somers, and Sue Williams for their assistance with getting my feet wet in the bogs and rich fens of Massachusetts. I also thank Anna Stalter for arranging for the digitization of the Massachusetts collections of *Sphagnum* housed at BH and making them available to me. I thank the two anonymous reviewers for their insightful comments as well as those provided by the editor. Herbarium data on the *Sphagnum* species collected in Massachusetts were provided to the Consortium of Bryophyte Herbaria by: BING, BRIT, CAS-BOT-BC, CHRB, CINC, COLO-B, CSCN, DUKE, F:Botany, FH, FLAS, ILL, ISC, MCTC, MICH, MO-Bryophytes, MSC, MT, MU, NCU-Bryophytes, NEB, NEBC, NHA, NYS-NYSi, PH, SUCO, TENN, TRH-B, UBC, UConn-CONN, UNM-Bryophytes, US, VSC, VT, WCUH-Bryophytes, WIS, WTU-Bryophytes, and YPM-YU. In addition, digitized data for its collections of *Sphagnum* from Massachusetts were provided by BH.

SUPPLEMENTAL ONLINE APPENDIX AND TABLES

Supplemental Appendix. The appendix shows pictures of the *Sphagnum magellanicum* species complex (*Sphagnum diabolicum* and/or *S. divinum,* and *S. medium*)*, S. ×majus, S. riparium,* and *S. wulfianum*.

Supplemental Online Tables S1, S2, and S3 (combined into one pdf)

Table S1. Updating the *Sphagnum* species of Massachusetts listed in the following article to the 2023 listing: Andrews, A.L.R. 1906. Preliminary lists of New England plants, XVIII. Sphagnaceae. Rhodora 8:62–65.

Table S2. Updating the *Sphagnum* species of Massachusetts listed in the following article to the 2023 listing. Hilferty, F.J. 1960. The mosses of Massachusetts. Rhodora 62:145–173.

Table S3. Updating the *Sphagnum* species of Massachusetts listed in the following publication to the 2023 listing. McQueen, C.B. and R.E. Andrus. 2007. Sphagnaceae Dumortier, pp.45–101. *In:* Flora of North America Editorial Committee, eds. Flora of North America North of Mexico. Vol. 27. Oxford University Press, New York, NY.

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