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Bryophytes of Goochland County, Virginia

Mikayla Quinn
University of Richmond, mikayla.quinn@richmond.edu

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By Mikayla Quinn

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Advisor: Dr. W. John Hayden

Abstract

Bryophytes are non-vascular land plants that include mosses, liverworts, and hornworts. Although easier to overlook because of their smaller size, bryophytes are a fundamental part of the ecosystem. As such, maintaining record of their biodiversity is important. Yet, records of bryophyte species in Goochland County, VA were low compared to more thoroughly documented counties such as Prince Edward County. This study expands the documentation of bryophyte flora and presents a checklist of bryophyte species found Virginia's Goochland County from 2020-2023. Fieldwork conducted at public and privately-owned properties throughout the county between January 2020 and March 2023 yielded 702 specimens that were then identified during laboratory study. From 151 different identified species, a total of 134 records of first documented occurrence were noted for the county. New county record data was submitted to the Digital Atlas of the Virginia Flora (DAVF), and voucher specimens are maintained at the University of Richmond Herbarium (URV). All Goochland County bryophyte specimen records in digital format are in the process of being uploaded to the Consortium of Bryophyte Herbaria website as part of the University of Richmond Herbarium (URV) contribution towards documentation of the global biodiversity of these too-often neglected plants.

INTRODUCTION

Bryophytes *sensu lato* are a diverse group of terrestrial plants consisting of three divisions: Bryophyta, Marchantiophyta, and Anthocerotophyta. Bryophytes, usually under 5 cm tall, are smaller than most seed-producing plants. Because they lack vascular tissue, bryophytes grow low and compact against their substrate. Although moist habitats are ideal for growth, bryophytes can survive in drier environments for extended periods of time and have reasonable drought tolerance (Hu et al., 2016; and Stark et al., 2016). Both these qualities allow bryophytes

to populate rocks and exposed surfaces with minimal soil, habitats that few other plants can tolerate. The three divisions of Bryophyta *sensu lato* have similar life cycles with macroscopically visible, distinct gametophyte and sporophyte generations. Mosses in the division Bryophyta have leaves in more than three rows and differ in leaf and sporophyte structure from the liverworts, or hepatics, that make up the division Marchantiophyta (Breil, 2003). Division Anthocerotophyta refers to hornworts, which have sporophytes that grow from a persistent basal intercalary meristem instead of apical growth present in moss sporophytes (Frangedakis et al., 2020).

Human activity and land development have disrupted plant and animal life globally, decreasing and threatening the biodiversity on the planet (Bradshaw, 2020). More than 20% of the planet's original biodiversity has been lost due to decreasing the biomass of terrestrial vegetation (Bradshaw, 2020). Bryophytes remain ecologically important as a pioneer species after lichens. Their desiccant-tolerant nature and ability to colonize rock surfaces allows them to contribute to the formation of soil and nutrient cycling in the environment. Knowledge of bryophytes and their ecological roles must exist in order for protection and preservation success in maintaining functional ecosystems. This study's focus in collecting and recording more bryophyte specimens for herbarium collection and the enrichment of online databases improves the representation of the natural diversity of plant life. An inventory of naturally occurring bryophyte species contributes to informed future ecological studies.

This study focuses on Goochland County located in the Piedmont region of the Commonwealth of Virginia. The James River naturally forms its southern boundary. Neighboring counties include Fluvanna, Louisa, Hanover, Henrico, Powhatan, and Cumberland counties. Like its neighboring counties situated between the Coastal Plains and Blue Ridge Mountains,

Goochland County has rolling foothills and river valleys characteristic of the region with an elevation ranging from 120-525 feet above sea level (Draper Aden Associates, 1993).

Past studies about Virginia bryophyte flora occurred through the late nineteenth and mid-twentieth centuries but included collections mostly from mountainous regions of the western counties and the Coastal Plains region in the southeast. Bryophytes of the Virginia Piedmont became better represented through bryologist David A. Breil collections. Breil's survey of 16 central and southern Piedmont counties recorded 230 species for the region as a whole, 163 of which are mosses while the rest are liverwort and hornwort species (Breil, 1996; Breil 2003). The Digital Atlas of the Virginia Flora (DAVF) has over 170 recorded species for Prince Edward County because of Breil's bryophyte collections while based at Longwood University. Based on Breil's work, it can be reasonably expected that perhaps as many as 200 species may be present in any given Piedmont county of Virginia (Breil, 1996; Breil 2003). Up until 2020, only 16 species had been documented through the work of other researchers for Goochland County (Table 1). Aside from the 16 species documented on the DAVF, previous documentation of the bryophyte species in Goochland County is limited. This limited knowledge of bryophyte biodiversity in the county and the county's close proximity to the University of Richmond favored focusing research efforts on Goochland County. The objective of this research is to expand the documentation and thus provide a more thorough inventory of bryophyte species for Goochland County.

METHODS

Collection

Collections were made from 16 locations across Goochland County between January 2020 and March 2023. Fieldwork occurred over a range of seasons from February-October, although most fieldwork was conducted during the summer months between June and August. Collection sites ranged from public parks, private properties, and University of Richmond-owned properties (Figure 1). In the southeast corner of the county, we had access to properties belonging to Historic Tuckahoe, the Collegiate School, West Creek Business Park, the University of Richmond Pagebrook Property, and Sabot Island. Centrally located sites in the county we visited include the Tucker Park, Hidden Rock Park, Leakes Mill Park, and the University of Richmond Ball Property. We conducted fieldwork in the western portion of the county at Matthews Park, Goochland Marsh State Wildlife Management Area, and outlying regions of the Rassawek Vineyard property. These locations, along with privately-owned properties, provided access to a wide range of habitats from which to collect. We collected bryophytes from clay soil banks, hardwood tree tunks, decaying logs, quartz rocks, and diabase boulders from surveying the forested areas, fields, and creeks of the properties we visited.

Bryophytes are small but resilient plants and therefore capable of growing across many substrates and in a variety of habitats. Bryophyte samples were gently scaped from soil, wood, and rock substrates varying between sunlight and moisture conditions. Sporophyte condition also influenced collections, with efforts made to obtain samples from bryophyte populations with mature sporophytes whenever possible. Collection numbers were assigned as samples were extracted and placed in temporary paper envelopes. GPS coordinates were recorded using Apple Maps and Polaris Navigation GPS (V.9.23) applications. Notes about the substrate the sample

was growing on and the habitat conditions at the time of collection were also recorded. Species identifications, even for apparently recognizable species, were not made in the field since bryophyte size makes leaf and sporophyte characteristics hard to observe with the naked eye. Collections were returned to the lab for dissection and microscopic examination prior to species identification.

Identification

Species identifications were determined by observing morphological characteristics. In the laboratory, samples from each collection were rehydrated and dissected. Wet mount slides with detached leaves were prepared. Branching and sporophyte characteristics for each sample were observed under a dissecting microscope. Compound light microscopy was used to view leaf shape and measure leaf size against a 2mm scalebar. Morphological characteristics were evaluated using dichotomous keys to arrive at a species identification. In addition to these characteristics, dichotomous keys further distinguished between coloration, cellular features, and habitat condition characters that were critical in arriving at a species identification.

Field guides by McKnight et al. (2013) and Pope (2016) provided dichotomous keys to the most common northeastern mosses. Volumes by Crum and Anderson (1981) were consulted as more definitive identification guides to taxa not included in the less comprehensive field books. Liverworts were identified using Conard and Redfearn (1984), Hicks (1982), and Pope (2016) field guides. We also used the Flora of North America online for obtaining additional keys to certain species. The Consortium of Bryophyte Herbaria and Digital Atlas of the Virginia Flora online databases provided photos that supplemented the drawings in the printed guides and county maps that displayed the present distribution of species in other counties.

Curation

After species identifications were recorded, specimens were prepared for storage in the University of Richmond Herbarium (URV) following standard curatorial procedures. Dried specimens were transferred into acid-free paper packets and mounted on sheets of herbarium paper for preservation. Labels containing each specimen's taxonomic information, georeferencing data, and habitat notes of the substrate at the time of collection were then applied. Specimens are deposited in the University of Richmond Herbarium (URV).

Digitization

Specimen data is shared with online databases, making them accessible beyond the University of Richmond Herbarium (URV). Taxonomic, location, and collection data for only the bryophyte specimens that proved to be county records were submitted to the Digital Atlas of the Virginia Flora (DAVF) which records county records of plant species. Upon submission to the DAVF, the existence of the species in Goochland County became officially documented.

All bryophyte specimens, county record or not, are digitally submitted to the Consortium of Bryophyte Herbaria (CBH). Labels of mounted herbarium specimens instead of the specimen itself were photographed since Bryophytes are much smaller than vascular plants and often look much different dried up than when wet. Brightness and contrast in photo batches were processed using Adobe Lightroom to make the text more legible and add metadata to each file so ownership and copyright status are attached to every image. Skeletal records including scientific name, location, and collection data were entered into the CBH online database to become a searchable record. Through attaching and entering barcodes, online records are paired to their respective physical herbarium specimens. Making this data accessible online now provides anyone who is

interested in researching a specific species with the opportunity to locate and work with the specimen stored in the herbarium.

RESULTS

Before we began documenting bryophyte species in Goochland County, 16 species were already recorded by others and listed in the Digital Atlas of the Virginia Flora (DAVF) prior to 2020. From our fieldwork across 16 sites, we collected a total of 702 specimens that encompass 149 species. We identified 114 species of moss, 34 liverwort species, and found one hornwort from Leakes Mill Park. Of the total 149 species listed here 134 are new first records of occurrence for Goochland County. We repeated observations for 15 of the 16 species previously documented in the county by others, reconfirming their presence in Goochland County. We have not yet encountered or made a collection of *Buxbaumia aphylla*.

This annotated checklist presents the 150 species that are now known to exist in Goochland County. Nomenclature follows the DAVF. Their respective collection numbers are given as voucher specimens. Collection Numbers preceded by H were collected by Hayden while those preceded by Q were collected by Quinn. This checklist includes the 16 species recorded by others prior to the start of our work in 2020; these are indicated by a dagger in the margin (†) while those without are new county records.

ANNOTATED CHECKLIST

† = Documented independently of this study

Anthocerotophyta (Hornworts)

NOTOTHYLADACEAE

Phaeoceros laevis (L.) Prosk. *Q408*.

Marchantiophyta (Liverworts)

ANEURACEAE

Aneura pinguis (L.) Dumort. var. *pinguis* (L.) Dumort. *Q660*.

AYTONIACEAE

Asterella tenella (L.) P. Beauv. *Q162*.

Reboulia hemispherica (L.) Raddi. *H7358*.

CALYPOGEIACEAE

Calypogeia muelleriana (Schiffn.) K. Muell. *Q417*.

Calypogeia neesiana (C. Massal. & Carestia) Müll. Frib. *Q365*.

Calypogeia neogea (R.M. Schuster) Bakalin. *H6235*.

Calypogeia sullivantii Austin. *Q327*.

Plagiochila porelloides (Torr. ex Nees) Lindenb. *Q152*.

CEPHALOZIACEAE

Cephalozia bicuspidata (L.) Dumort. *H6491*.

Nowellia curvifolia (Dicks.) Mitt. *H6284*.

Odontoschisma denudatum (Nees) Dumort. *H6255*.

CEPHALOZIELLACEAE

Cephaloziella rubella (Nees) Warnst. *H6377*.

CONOCEPHALACEAE

Conocephalum salebrosum Szweyk., Buczk. & Odrzyk. *Q293*.

FOSSOMBRONIACEAE

Fossombronia foveolata Lindb. *Q165*.

FRULLANIACEAE

Frullania asagrayana Montagne. *Q651*.

Frullania brittoniae A. Evans. *Q252*.

Frullania eboracensis Gottsche ssp. *eboracensis*. *H6992*.

Frullania eboracensis Gottsche ssp. *virginica* (Lehm.) R.M. Schust. *Q181*.

Frullania inflata Gottsche var. *inflata*. *Q159*.

Frullania kunzei Lehmann & Lindberg. *Q423*.

GEOCALYACEAE

Chiloscyphus polyanthos (L.) Corda. *Q564*.

Geocalyx graveolens (Schrad.) Nees. *Q328*.

JAMESONIELLACEAE

Syzygiella autumnalis (DC.) K. Feldberg, Vána, Hentschel & Heinrichs. *Q330*.

JUNGERMANNIACEAE

Liochlaena lanceolata Nees. *Q999*.

LEJEUNEACEAE

Lejeunea laetevirens Nees & Mont. *Q339*.

LOPHOCOLEACEAE

Lophocolea coadunata (Sw.) Mont. *Q643*.

Lophocolea heterophylla (Schrad.) Dumort. *H6304*.

PALLAVICINIACEAE

Pallavicinia lyellii (Hook.) Carruth. *H6158*.

PELLIACEAE

Pellia epiphylla (L.) Corda. *H6873*

PORELLACEAE

†*Porella platyphylla* (L.) Pfeiffer. *Q232*.

RICCIACEAE

Riccia fluitans Linnaeus. *Q61*.

Riccia huebeneriana subsp. *sullivantii* (Austin) R.M. Schuster. *Q561*.

Riccia sorocarpa Bischoff. *H6872*.

SCAPANIACEAE

†*Scapania nemorea* (L.) Grolle. *Q658*.

Bryophyta (Mosses)

AMBLYSTEGIACEAE

Anacamptodon splachnoides (Froel. ex Brid.) Brid. *Q276*.

Hygroamblystegium varium (Hedwig) Mönkemeyer. *Q90*.

Leptodictyum riparium (Hedwig) Warnstorf. *Q88*.

Platydictya subtilis (Hedwig) H. A. Crum. *Q68*.

ANOMODONTACEAE

Anomodon attenuatus (Hedwig) Huebener. *H6261*.

Anomodon minor (Hedwig) Lindberg. *Q539*.

Anomodon rostratus (Hedwig) Schimper. *Q183*.

Anomodon tristis (Ces.) Sull. & Lesq. *H6232*.

AULACOMNIACEAE

†*Arrhenopterum heterostichum* Hedwig. *Q108*.

Aulacomnium palustre (Hedwig) Schwagrichen. *Q164*.

BARTRAMIACEAE

Bartramia pomiformis Hedwig. *H7355*.

Philonotis longiseta (Michaux) E. Britton. *Q87*.

Philonotis fontana (Hedwig) Brid. *var. fontana Q163*.

BRACHYTHECIACEAE

Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen var. *velutinum*. *Q488*.

Brachythecium acuminatum (Brid.) Schimp. *H6317*.

Brachythecium rivulare Schimper. *Q237*.

Brachythecium rutabulum (Hedwig) Schimper. *Q296*.

Brachythecium salebrosum (Hoffm. ex F. Weber & D. Mohr) Schimp. *Q218*.

Bryhnia graminicolor (Bridel) Grout. *Q518*.

Bryhnia novae-angliae (Sull. & Lesq.) Grout. *Q433*.

†*Bryoandersonia illecebra* (Hedwig) H. Robinson. *Q105*.

Eurhynchiastrum pulchellum (Hedw.) Ignatov & Huttunen var. *pulchellum*. *Q262*.

Oxyrrhynchium hians (Hedwig) Loeske. *Q67B*.

Rhynchostegium serrulatum (Hedwig) A. Jaeger. *Q83*.

Sciuro-hypnum plumosum (Hedwig) Ignatov & Huttunen. *Q89A*.

Sciuro-hypnum reflexum (Starke) Ignatov & Huttunen. *Q440A*.

BRYACEAE

Bryum argenteum Hedwig var. *argenteum*. *H6980*.

Gemmabryum dichotomum (Hedw.) J.R. Spence & H.P. Ramsay. *H6264*.

Ptychostomum creberimum (Taylor) J.R. Spence & H.P. Ramsay. *H6670*.

Ptychostomum pseudotriquetrum (Hedwig) J. R. Spence & H. P. Ramsay ex Holyoak & N. Pedersen. *Q86*.

Rhodobryum ontariense (Kindb.) Kindb. *Q1017*.

Rosulabryum capillare (Hedw.) J.R. Spence. *H6289*.

BUXBAUMIACEAE

†*Buxbaumia aphylla* Hedwig.

CLIMACIACEAE

†*Climacium americanum* Bridel. *Q357*.

CRYPHAEACEAE

Cryphaea glomerata Schimper ex Sullivant. *Q73*.

DICRANACEAE

Dicranella heteromalla (Hedwig) Schimper. *H6292*.

Dicranum condensatum Hedwig. *H7345*.

Dicranum flagellare Hedwig. *H6249*.

Dicranum montanum Hedwig. *Q225*.

†*Dicranum scoparium* Hedwig. *Q178*.

DIPHYSCIACEAE

Diphyscium foliosum (Hedwig) D. Mohr. *H6262*.

DITRICHACEAE

Ceratodon purpureus (Hedwig) Bridel. *Q715*.

Ditrichum pallidum (Hedwig) Hampe. *Q364*.

ENTODONTACEAE

Entodon challengeri (Paris) Cardot. *Q227*.

Entodon cladorrhizans (Hedwig) Müller Hal. *H6147*.

Entodon seductrix (Hedwig) Müller Hal. *H6253*.

FISSIDENTACEAE

Fissidens bryoides Hedwig. *Q527*.

Fissidens obtusifolius Wilson. *Q142*.

Fissidens osmundoides Hedwig. *Q258*.

Fissidens taxifolius Hedwig. *Q541*.

FONTINALACEAE

Fontinalis dalecarlica Schimper. *Q714*.

FUNARIACEAE

Funaria hygrometrica Hedwig var. *hygrometrica*. *Q269*.

Physcomitrium pyriforme (Hedwig) Hampe. *Q504*.

GRIMMIACEAE

Grimmia pilifera Palisot de Beauvois. *Q419A*.

Schistidium dupretii (Thér.) W. A. Weber. *H6265*.

HEDWIGIACEAE

Hedwigia ciliata (Hedw.) P. Beauv. *H6862*.

HYPNACEAE

Callicladium haldanianum (Grev.) H.A. Crum. *Q346*.

Ctenidium molluscum (Hedwig) Mitten. *Q221*.

Herzogiella striatella (Bridel) Z. Iwatsuki. *Q89B*.

Herzogiella turfacea (Lindberg) Z. Iwatsuki. *Q335*.

Hypnum cupressiforme Hedwig var. *cupressiforme*. *Q308*.

Hypnum fauriei Cardot. *H6247*.

Hypnum imponens Hedwig. *Q96*.

Hypnum lindbergii Mitten. *Q97*.

Hypnum pallescens (Hedwig) P. Beauvois. *Q224*.

Platygyrium repens (Bridel) Schimper. *H6151*.

Pylaisia condensata Kindberg. *Q67A*.

†*Pylaisia intricata* (Hedwig) Schimper. *Q69*.

Pylaisia polyantha (Hedwig) Schimper. *Q259*.

LEPTODONTACEAE

Forsstroemia producta (Hornsch.) Paris. *H6488*.

Forsstroemia trichomitria (Hedwig) Lindberg. *Q112*.

LESKEACEAE

Leskea australis Sharp. *Q284*.

Leskea gracilescens Hedwig. *H6149*.

Leskea obscura Hedwig. *Q469*.

Leskea polycarpa Hedwig. *Q440B*.

LEUCOBRYACEAE

†*Leucobryum albidum* (P. Beauvois) Lindberg. *Q95*.

†*Leucobryum glaucum* (Hedwig) Angstr. *Q222*.

LEUCODONTACEAE

Leucodon brachypus Bridel. *Q288*.

†*Leucodon julaceus* (Hedwig) Sullivant. *Q71*.

MIELICHHOFERIACEAE

Pohlia annotina (Hedwig) Lindberg. *Q242*.

MNIACEAE

Mnium hornum Hedwig. *Q312*.

Plagiomnium ciliare (Müller Hal.) T. J. Koponen. *Q109*.

Plagiomnium cuspidatum (Hedwig) T.J. Koponen. *H6156*.

Rhizomnium punctatum (Hedw.) T.J. Kop. *Q458*.

MYRINIACEAE

Schwetschkeopsis fabronia (Schwagrichen) Brotherus. *Q66*.

ORTHOTRICHACEAE

Drummondia prorepens (Hedwig) E. Britton. *Q256*.

Orthotrichum anomalum Hedwig. *Q338*.

Orthotrichum ohioense Sullivant & Lesquereux. *H6150*.

Orthotrichum stellatum Bridel. *H167A*.

Ulota crispa (Hedwig) Bridel. *Q418*.

PLAGIOTHECIACEAE

Plagiothecium cavifolium (Brid.) Z. Iwats. *Q347*.

Plagiothecium laetum Schimper. *Q496*.

POLYTRICHACEAE

Atrichum altecristatum (Renauld & Cardot) B. B. Smyth & L. C. D. Smyth. *Q415*.

†*Atrichum angustatum* (Bridel) Bruch & Schimper. *Q101*.

Atrichum crispulum Schimp. ex Besch. *Q425*.

Atrichum crispum (James) Sull. *Q526*.

Atrichum undulatum (Hedwig) P. Beauvois. *Q110*.

Pogonatum pensilvanicum (Hedw.) P. Beauv. *H6463*.

†*Polytrichastrum ohioense* (Renauld & Cardot) G. L. Smith. *Q404*.

POTTIACEAE

Barbula unguiculata Hedwig. *H6229*.

Syntrichia fragilis (Taylor) Ochyra. *Q286*.

Tortella humilis (Hedw.) Jenn. *H6157*.

Weissia controversa Hedwig. *H6291*.

SEMATOPHYLLACEAE

Brotherella recurvans (Michx) M. Fleisch. *H6144*.

Pylaisiadelpha tenuirostris (Bruch & Schimper ex Sullivant) W. R. Buck. *Q80*.

Sematophyllum demissum (Wilson) Mitt. *Q304*.

SPHAGNACEAE

Sphagnum affine Renauld & Cardot. *Q774*.

Sphagnum compactum Lam. & DC. *H6786*.

Sphagnum henryense Warnstorf. *Q1021*.

Sphagnum palustre Linnaeus. *Q175*.

Sphagnum recurvum Palisot de Beauvois. *Q663*.

Sphagnum subsecundum Nees. *Q1004*.

THELIACEAE

†*Thelia asprella* (Schimper) Sullivant. *Q93*.

Thelia hirtella (Hedwig) Sullivant. *H6155*.

THUIDIACEAE

†*Thuidium delicatulum* (Hedwig) Schimper. *Q79*.

Discussion

Bryophytes support the larger ecosystems of vascular flora making the documentation of their biodiversity essential as the environment changes. Goochland County bryophyte species records before this study was conducted did not accurately reflect the level of biodiversity that could be found in the county. Investigating sites across Goochland County has expanded the list of documented species. The species identification process exemplifies breadth of bryophyte biodiversity. For mosses, we first assessed growth form, leaf costa, and leaf shape features leading to more specific keys to species (Figure 2). Observing upright growth without branching versus horizontal and branching growth patterns led to a moss collection's characterization as an acrocarp or pleurocarp respectively. A collection was determined to be costate or ecostate based on the presence or absence of a vein in the middle of their leaves. Leaf shape varied along a

spectrum from narrow and linear lanceolate leaves to rounded and ovate shapes. Tongue-shaped leaves and sickle-shaped leaves were also frequently observed. Working through these characters first led to subkeys to species that were determined based on additional characteristics often required to make a species identification (Figure 2). Marginal teeth, acumination at the leaf tips, and lamellae width were distinct when present. Cell shape, size, and surface texture were observed. Sporophyte capsule shape, upright or drooping orientation, and setae height were also useful towards keying a collection out to a particular species. Substrate conditions were also frequently included in the keys. Liverworts were similarly assessed by growth form between leafy and thalloid. Leaf arrangements, lobe shape, and underleaf characters were observed to distinguish between species.

During identification, morphological characteristics and habitat distinctions outlined in the keys are not always rigid or obvious. Leaf shape in mosses may have straddled ovate and lanceolate shape categories while distinctions between cell size ratios can be ambiguous. Analyzing morphologies along a continuum required some collections to be re-keyed multiple times to arrive at a species identification most consistent with its structure. Some collections without mature sporophytes or gemmae present needed to make a species determination remained unidentifiable and are not included in final tallies of species records or total specimens processed.

Only 16 bryophyte species were recorded for Goochland County prior to our research in 2020. We identified 149 species from our fieldwork between then and 2023 and found that 134 of those were not previously recorded. We found 73 of these species the first year of this study. The second and third years of the study yielded 36 and 25 new records respectively (Figure 3). As more species are documented, it became more of a challenge to find unrecorded species,

resulting in lower counts of new records the following two years. Combining the 16 previously known species with 134 additional species from our work increases the cumulative total number of species now documented for Goochland County to 150 (Figure 3).

At the county level, this increased number of species for Goochland County better reflects bryophyte diversity one might expect to find. The difference in species lists between Goochland and Prince Edward counties (Figure 3) suggests that there still remains other species that have yet to be documented for Goochland. The 230 species documented for the Piedmont of Virginia region as a whole further support the continued likelihood for finding additional species.

Statistics evaluating biodiversity levels, determining whether certain species are invasive, or monitoring population changes due to climate change were not conducted. Future fieldwork may revisit the sites of specimens that were unidentified during a different season. Our research substantially improved documentation of the county's bryophytes, but there is always the possibility of visiting additional sites and collecting more. Continued collection from sites along the northern border of the county, central and eastern side, would broaden the coverage of surveyed sites. Small liverworts easily overlooked during fieldwork may also be investigated in future research. We recorded only one hornwort species for Goochland County, but four other species are also known to occur in Virginia (Virginia Botanica Associates, 2023). Focused collection of more hornwort species for Goochland County remains open for future study.

The recorded bryophyte flora consisted of only 16 species before this study. This research documents 134 additional bryophyte species. Our annotated checklist documents the presence of the 150 species listed within it for Goochland County. However, more comprehensive species lists for Prince Edward County and the Piedmont region as a whole support the possibility of additional species that have yet to be documented. The numbers of specimens and county records

presented in this report may increase through continued fieldwork to sites we did not visit. While county record data has been submitted to the DAVF, data for more than 500 specimens has been uploaded to the CBH as skeletal records (Consortium of Bryophyte Herbaria, 2023). Digitization efforts for the remaining specimens will continue as part of the University of Richmond's ongoing efforts to document Goochland County's bryophyte biodiversity. Overall, this research has improved Goochland County bryophytes documentation and supported the University of Richmond Herbarium (URV) cryptogamic collections. This focus on the bryophytes contributes towards a better understanding and representation of the natural diversity of the understudied plant life that plays major roles in the function of ecosystems that support more familiar plant, animal, and human life.

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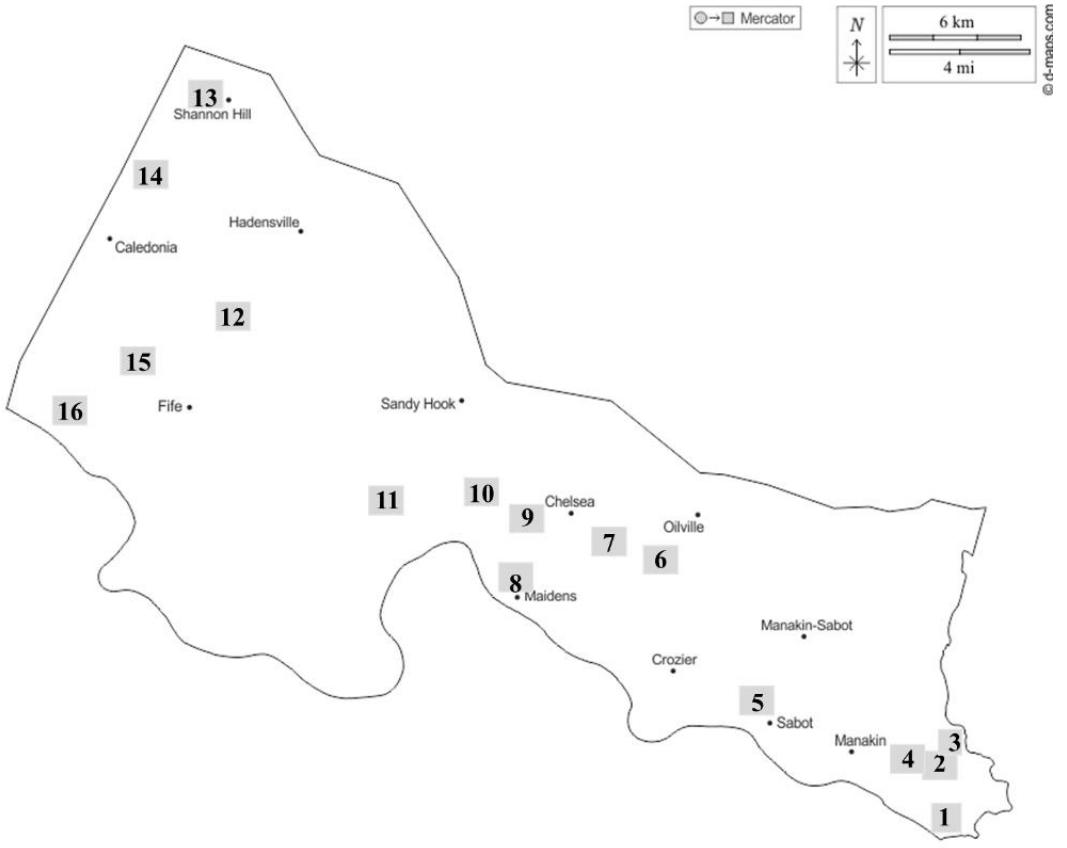
Appendix

Goochland County Bryophytes before 2020

Arrhenopterum heterostichum
Atrichum angustatum
Bryoandersonia illecebra
Buxbaumia aphylla
Climacium americanum
Dicranum scoparium
Leucobryum albidum
Leucobryum glaucum
Leucodon julaceus
Polytrichastrum ohioense
Porella platyphylla
Pylaisia intricata
Scapania nemorea
Sphagnum palustre
Thelia asprella
Thuidium delicatulum

Table 1. Goochland County Bryophytes documented before 2020. Bryophyte species (16) were recorded by others for Goochland County on the Digital Atlas of the Virginia Flora as of January 2020.



Collection Locations in Goochland County

Site Number	Property
1	Historic Tuckahoe
2	Robins Campus, Collegiate School
3	West Creek Business Park
4	Pagebrook Road Property, University of Richmond
5	James River Mitigation Wetlands
6	Shepherd Property
7	Ball Property, University of Richmond
8	Tucker Park
9	Hidden Rock Park
10	Clements Property
11	Leakes Mill Park
12	Matthews Park
13	Moss Property
14	Robinson Property
15	Rassawek Vineyard
16	Goochland Marsh State Wildlife Management Area

Figure 1. Collection Locations in Goochland County. Fieldwork was conducted across the county between January 2020 and March 2023. Bryophyte collections were made from both public and private properties. Properties marked with an asterisk (*) are privately owned.

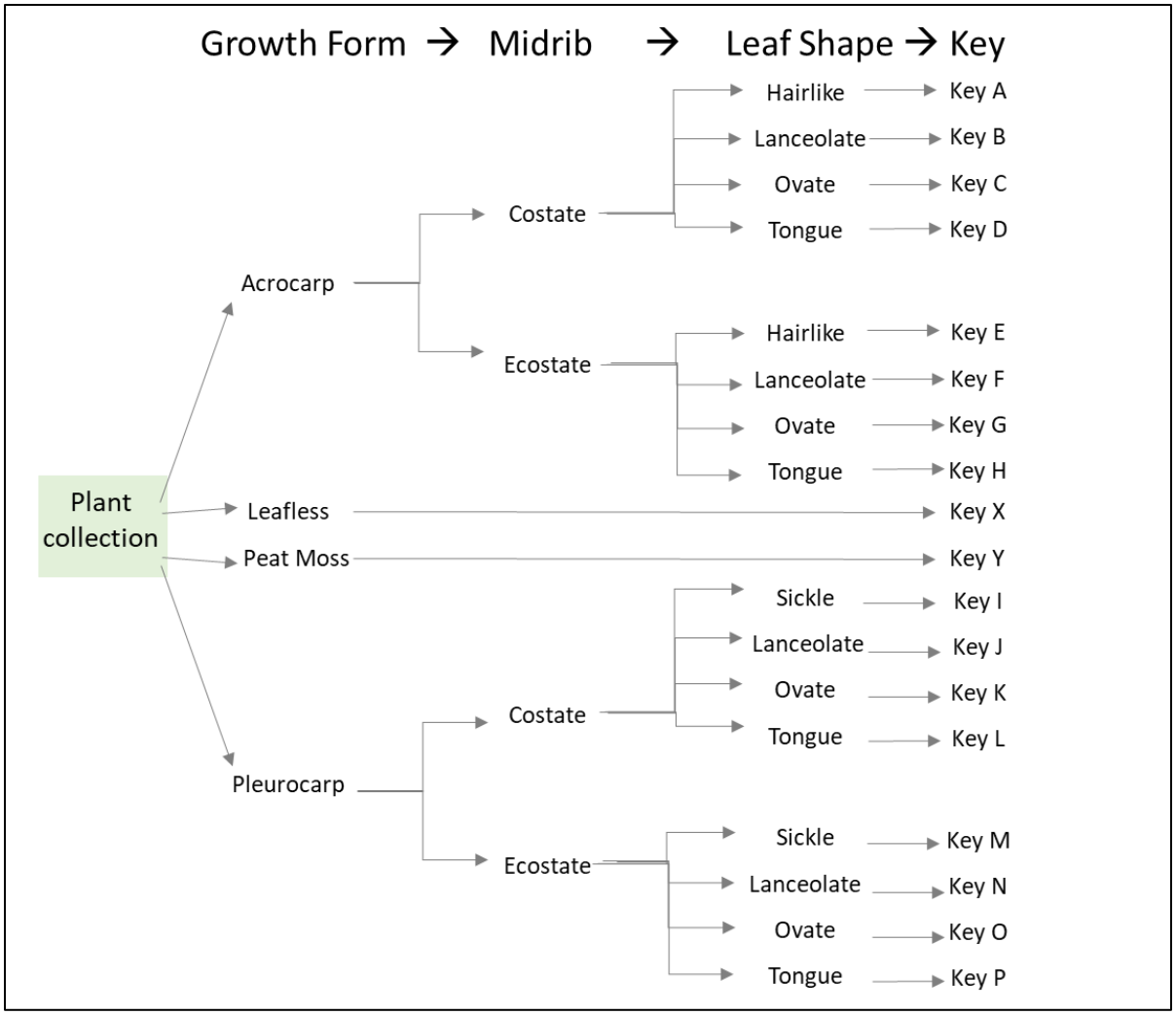


Figure 2. Overview of dichotomous key for moss species identifications. Broad assessments of growth form, leaf costa, and leaf shape characteristics lead to more specific keys to species identification. Adaptation of the McKnight et al. (2013) "Key Features Path to the Keys" (pp. 16-17).

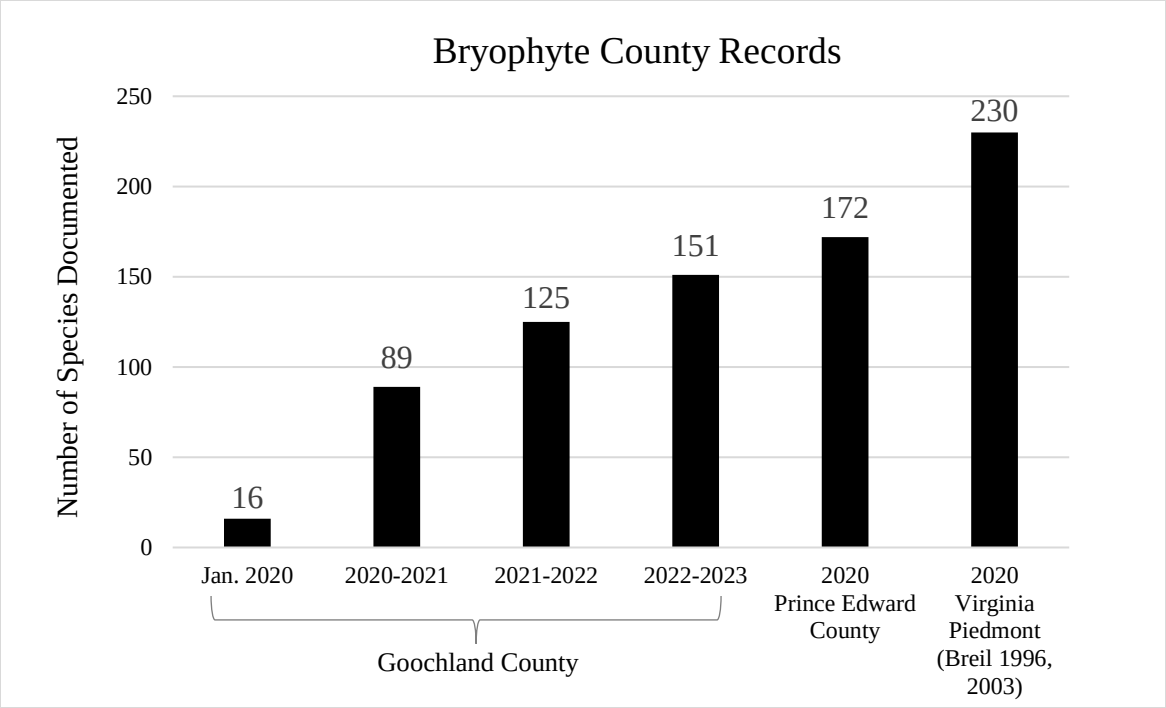


Figure 3. Bryophyte County Records. Collections between January 2020 and March 2023 increased the number of documented species in Goochland County. These records are compared to Prince Edward County and the Virginia Piedmont region for larger geographic context.