Weed Survey of Nova Scotia Lowbush Blueberry (*Vaccinium angustifolium* Ait.) Fields

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**ABSTRACT**

Weed surveys provide the basis for weed management research in lowbush blueberry, but have not been conducted in Nova Scotia since 2001. Documented declines in herbicide efficacy, loss and/or acquisition of herbicide active ingredients, confirmation of herbicide-resistant weed biotypes, and documented vectoring of weed seeds by machinery necessitate a new weed survey. A total of 165 bearing year lowbush blueberry fields were surveyed from 2017 to 2019, within which approximately 211 weed species were identified. Most weed species were herbaceous perennial forbs (89 species) and woody perennials (50 species), followed by annual broadleaf (24 species) and perennial grass weeds (20 species). The remaining flora consisted of a range of ferns, biennials, sedges and rushes, and orchids. The most common weed species were red sorrel (*Rumex acetosella* L.), poverty oatgrass (*Danthania spicata* L. Beauv.), haircap moss (*Polytrichum commune* Hedw.), hair fescue (*Festuca filiformis* Poir.), narrow-leaved goldenrod (*Euthamia graminifolia* (L.) Nutt.), tickle grass (*Agrostis hyemalis* (Walter) BSP.), woolly panicum (*Panicum lanugosum* Ell.), cow wheat (*Melampyrum lineare* Desr.), bunchberry (*Cornus canadensis* L.), and yellow hawkweed (*Hieracium caespitosum* Dumort). Increased occurrence of these weed species is likely the result of documented or observed reductions in hexazinone and terbacil efficacy, confirmation of triazine-resistant biotypes, and common occurrence of seeds of these weed species on machinery. Low crop prices have also caused reduced pronamide use, contributing to increased occurrence of hair fescue. Results are guiding future research priorities for weed management in lowbush blueberry.

**KEYWORDS**

Weed survey; vegetation survey; lowbush blueberry; wild blueberry; *vaccinium angustifolium* Ait

**Introduction**

Lowbush blueberry (*Vaccinium angustifolium* Ait.) is an economically important fruit crop in Canada and contributed 47.4 USD million CAN to farm gate value in 2017 (Anonymous, 2019). Lowbush blueberry is unique in that fields are developed from natural stands (Anonymous, 2019) that are managed under a 2-yr production cycle. Aboveground shoots are pruned to ground level in the first year (non-bearing year) and emerged shoots flower and produce berries in the second year (bearing year) (Wood, 2004). Weed management in this perennial monoculture is difficult and weeds contribute to significant variation in annual yields (Yarborough, 2011). Weeds also reduce berry quality (McCully et al., 1991) and interfere with the harvesting process (Jensen and Specht, 2002). Weed surveys have traditionally been used to assess the weed flora of lowbush blueberry fields and...
guide weed management research priorities (Jensen and Yarborough, 2004), but have not been conducted for over 15 years in Nova Scotia.

Weed surveys provide the quantitative information on weed community composition required for directing current research efforts and developing sustainable integrated weed management strategies (Frick and Thomas, 1992; Thomas et al., 1994; Webster and Coble, 1997). Data from consecutive surveys provide the basis for assessing ongoing changes in weed floras (Andreasen and Streibig, 2011), which is important for anticipating future problems and directing future research and extension efforts. The number of weed species in lowbush blueberry fields doubled to over 200 species between the early 1980’s (McCully et al., 1991) and early 2000’s (Jensen and Yarborough, 2004), but quantitative data on recent shifts in the weed flora of lowbush blueberry fields are lacking. Important changes in lowbush blueberry production in Nova Scotia since the early 2000’s that may affect the weed flora include evolution of herbicide-resistant weed species (Jensen et al., 2003; Jensen and Hainstock, 2000a, 2000b; Li et al., 2014), deregistration of the broad-spectrum herbicide atrazine (Anonymous, 2003), large-scale dispersal of weed seeds on equipment (Boyd and White, 2009), land leveling to facilitate mechanical rather than thermal field pruning (Eaton et al., 2004; Yarborough, 2004), increased growing season length (Drummond and Yarborough, 2014), and increased use of herbicides with narrow weed control spectrums (Boyd and White, 2010; Jensen and Specht, 2004; White and Kumar, 2017; White and Zhang, 2019). Therefore, it is important that a new weed survey must be conducted to document possible shifts in weed community composition and identify priority weed species for future research and grower awareness. The objective of this study was therefore to conduct a weed survey to assess the current weed community composition of lowbush blueberry fields in Nova Scotia.

Materials and Methods

A total of 165 lowbush blueberry fields were surveyed during July and August of the bearing year prior to field harvest between 2017 and 2019 (Figure 1; Table 1). Field size was determined after surveying using the Draft Logic Google Maps Area Calculator as outlined by Esau et al. (2019). Average field size was 6 ± 0.4 ha. Fields were surveyed in the same geographic areas as previous surveys, with the exception that we included fields in the South Shore counties of Nova Scotia (Table 1) which were
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Table 1. Number of bearing year lowbush blueberry fields surveyed in the major producing regions of Nova Scotia.

| County                        | Number of fields surveyed |
|-------------------------------|---------------------------|
| Cumberland                   | 66                        |
| Colchester                   | 39                        |
| Pictou                       | 21                        |
| Antigonish                   | 10                        |
| South Shore Counties (Queens, Shelburne, Yarmouth, Annapolis) | 10                        |
| Halifax                      | 9                         |
| Hants                        | 9                         |
| Guysborough                  | 1                         |

lacking in previous surveys. Bearing year fields were surveyed as they are rarely treated with herbicides and therefore tend to contain more weeds than non-bearing year fields. Fields were chosen by contacting growers and local field extension specialists in the major production areas to identify fields that were in production (e.g., not “resting”, or taken out of production) and in the bearing year at the time of the survey. Many fields were not being actively farmed during the survey due to low crop prices, and these were avoided to ensure survey results reflected the species that are surviving and occurring in actively farmed lowbush blueberry fields.

The methodology used in this weed survey was similar to McCully et al. (1991). Weed species density and identification, as well as crop density, were determined in twenty 1 m² quadrats in each field to be consistent with McCully et al. (1991) and other similar weed surveys (Thomas, 1985; Goodwin et al. 1986; Thomas and Ivany, 1990; Thomas et al., 1994; Abdullahi, 2004). Weeds were identified based on personal knowledge and use of Aiken and Darbyshire (1990), Bouchard et al. (1999), Cobb et al. (2005), D’Appollonio (2019), Dore and Roland (1942), Jensen et al. (2005), Munro et al. (2014), Néron et al. (2015), Newcomb and Morrison (1977), Pohl (1968), Sampson et al. (1990), Symonds and Merwin (1963), Symonds and Chelminski (1958), and Uva et al. (1997). Density was recorded as the number of individual plants for annual, biennial, simple herbaceous perennial (e.g., dicotyledonous species such as *Taraxacum* and *Centaurea*, cespitose grasses and sedges, and rushes), and tree species. Shoot (e.g., ramet) density of creeping herbaceous perennial and creeping woody perennial species was recorded due to inability to determine genet density. Quadrats were placed along a “W” in each field with five quadrats in each transect. Distance between quadrats in each transect was determined by the size and shape of the field, with more distance between quadrats in larger fields and less distance between quadrats in smaller fields (McCully et al., 1991). Weed species observed in fields, but outside of quadrats, were also recorded.

Data were summarized into the quantitative measures of frequency (unadjusted and adjusted), field uniformity (all fields and occurrence fields), density (all fields and occurrence fields), and relative abundance (McCully et al., 1991; Thomas et al., 1994). Unadjusted frequency indicates the percentage of the total number of fields surveyed that contained a weed within at least one quadrat, whereas adjusted frequency includes fields in which the weed was also observed outside the quadrats. Field uniformity (all fields) indicates the percentage of the total number of quadrats sampled that contained a weed, whereas field uniformity (occurrence fields) is expressed as the percentage of quadrats that contained a weed, but only when considering the fields in which the weed occurred. Density is the mean density of a weed species, with the expression of the density (all fields) and density (occurrence fields) similar to that as indicated for field uniformity.

Relative abundance was used as a measurement to compare the individual weed species relative to each other. This measurement was calculated from the frequency (unadjusted), field uniformity (all fields), and mean density (all fields) using the formula provided by McCully et al. (1991). The calculation was as follows:

\[
Relative\text{ frequency for species } A (RF_A) = \frac{frequency\text{ value of species } A}{frequency\text{ value for all species}} \times 100
\]
Relative field uniformity for species $A$  
\[ \text{RelativefielduniformityforspeciesA}(RU_A) = \frac{\text{fielduniformityvalueof species A}}{\text{fielduniformityvaluesforallspecies}} \times 100 \]

Relative mean density for species $A$  
\[ \text{RelativemeandensityforspeciesA}(RD_A) = \frac{\text{meanfielddensityvalueof species A}}{\text{meanfielddensityvaluesforallspecies}} \times 100 \]

Relative abundance for species $A$  
\[ \text{RelativeabundanceforspeciesA}(RA_A) = RF_A + RU_A + RD_A. \]

Relative abundance was used as the primary factor for ranking importance of weed species identified in the survey (Thomas and Ivany, 1990; McCully et al., 1991; Thomas et al., 1994), with frequency, field uniformity, and density considered on an individual weed basis.

**Results and Discussion**

**General Weed Flora**

A total of 211 weed species were found in this weed survey, with 183 weed species identified within the quadrats and an additional 28 species observed outside the quadrats (Table 2). A total of 141 and 191 weed species were found in 1984–1985 and 2000–2001, respectively (McCully et al., 1991; Jensen and Sampson, unpublished data). Our results, therefore, indicate an increase in the number of weed species in lowbush blueberry fields, though we identified more genera to species (e.g., *Solidago* and *Hieracium*) than previous surveys and included fields from the South Shore counties (Table 1) that were not included in the previous surveys. Similar to previous weed surveys, herbaceous and woody perennials dominated the weed flora, followed by annual broadleaf and perennial grass weeds (Table 2). Sedges and rushes continue to be common and are likely more numerous than indicated in these surveys due to difficulty in identifying all samples to species due to lack of flowers. A small range of biennial weeds, ferns, orchids, and annual grasses comprised the remainder of the weed flora (Table 2).

**Common Weeds Found within Quadrats**

The most common weed species in lowbush blueberry fields were red sorrel (*Rumex acetosella* L.), poverty oat grass (*Danthonia spicata* L. Beauv.), haircap moss (*Polytrichum commune* Hedw.), hair fescue (*Festuca filiformis* Pourr.), narrow-leaved goldenrod (*Euthamia graminifolia* (L) Nutt.), rough hair grass (*Agrostis hyemalis* (Walter) BSP.), woolly panicum (*Panicum lanigus* Ell.), cow wheat (*Melampyrum lineare* Desr.), bunchberry (*Cornus canadensis* L.), and yellow hawkweed (*Hieracium caespitosum* Dumort) (Table 3).

Red sorrel had the highest frequency, field uniformity, density, and relative abundance (Table 3). The unadjusted frequency of red sorrel increased from 73% in 1984–1985 to 80.5% in 2000–2001 to 97.6% in 2017–2019 (Table 3), potentially due to presence of red sorrel seed as a common contaminant

**Table 2. Number of weed species in dominant weed classes found inside and outside the quadrats in 2017–2019.**

| Weed Classification     | Inside the quadrats | Outside the quadrats |
|-------------------------|---------------------|----------------------|
| Herbaceous perennial    | 75                  | 14                   |
| Woody perennial         | 42                  | 8                    |
| Annual broadleaf        | 22                  | 2                    |
| Perennial grass         | 18                  | 2                    |
| Sedge/rush              | 8                   | 0                    |
| Biennial                | 5                   | 1                    |
| Fern                    | 4                   | 1                    |
| Annual grass            | 5                   | 0                    |
| Orchid                  | 4                   | 0                    |
| Total species           | 183                 | 28                   |
| Scientific name                  | Common name                      | Frequency | Field uniformity | Density |
|---------------------------------|----------------------------------|-----------|------------------|---------|
|                                 |                                  | Unadjusted| Adjusted | All fields | Occurrence fields | All fields | Occurrence fields | Relative abundance |
| Vaccinium spp.*                 | Lowbush blueberry                | 100.00    | 100.00     | 95.24      | 95.24             | 262.35     | 262.35             | 94.03               |
| Rumex acetosella L.             | Red sorrel                       | 97.58     | 97.58      | 62.88      | 64.44             | 72.05      | 73.84             | 39.80               |
| Danthonia spicata L.            | Poverty oat grass                | 92.73     | 93.33      | 43.36      | 46.76             | 5.70       | 6.14              | 18.56               |
| Polytrichum commune Hedw.       | Haircap moss                     | 53.94     | 53.33      | 10.94      | 20.56             | 43.82      | 20.56             | 16.99               |
| Festuca filiformis Poir.        | Hair fescue                      | 67.88     | 74.55      | 25.36      | 37.37             | 3.00       | 4.41              | 11.70               |
| Euthamia graminifolia (L.) Nutt.| Narrow-leaved goldenrod         | 78.79     | 86.06      | 17.00      | 21.58             | 2.66       | 3.38              | 10.27               |
| Agrostis hyemalis (Walter) B.S. | Rough hair grass                 | 67.88     | 69.09      | 16.97      | 25.00             | 1.81       | 2.66              | 9.31                |
| Panicum lanugosum Ell.          | Woolly panicum                  | 49.09     | 50.91      | 10.73      | 21.85             | 4.10       | 8.36              | 7.02                |
| Melampyrum lineare Desr.        | Cow wheat                        | 43.03     | 44.24      | 10.42      | 24.23             | 1.84       | 4.27              | 5.98                |
| Coms canadenis L.               | Bunchberry                       | 41.82     | 43.64      | 7.48       | 17.90             | 3.12       | 7.47              | 5.48                |
| Hieracium caespitum Dumort.     | Yellow hawkweed                  | 34.55     | 40.00      | 8.15       | 23.60             | 2.23       | 6.45              | 4.93                |
| Hypericum perforatum L.         | Common St. John’s wort           | 43.64     | 58.18      | 5.97       | 13.68             | 0.33       | 0.75              | 4.54                |
| Hypericum canadense L.          | Canada St. John’s wort           | 40.00     | 47.27      | 5.12       | 12.80             | 1.30       | 3.24              | 4.32                |
| Scirpus atrovirens Willd.       | Black bulrush                    | 30.91     | 38.18      | 4.67       | 15.00             | 0.23       | 0.76              | 3.33                |
| Juncus bufonius L.              | Toad rush                        | 27.88     | 33.94      | 4.55       | 16.30             | 0.59       | 2.13              | 3.18                |
| Vicia cracca L.                 | Tufted vetch                     | 30.91     | 41.82      | 3.91       | 12.65             | 0.24       | 0.76              | 3.14                |
| Poa compressa L.                | Canada bluegrass                 | 23.64     | 29.70      | 4.67       | 19.74             | 1.07       | 4.53              | 3.04                |
| Luzula multiflora (Retz.) Lejuene| Wood rush                        | 21.82     | 21.82      | 4.18       | 19.17             | 0.15       | 0.71              | 2.57                |
| Viola spp.                      | Violets                          | 19.39     | 20.61      | 3.12       | 16.09             | 0.56       | 2.88              | 2.24                |
| Maianthemum canadense Desf.     | Lily valley                      | 20.61     | 20.61      | 2.24       | 10.88             | 0.78       | 3.76              | 2.15                |
| Viola obliqua Hill.             | Marsh violet                     | 17.58     | 20.61      | 2.47       | 12.76             | 0.31       | 1.74              | 1.89                |
| Galeopsis tetrahit L.           | Hemp nettle                      | 19.39     | 24.24      | 1.55       | 7.97              | 0.08       | 0.40              | 0.73                |
| Festuca rubra L.                | Red fescue                       | 7.88      | 9.09       | 3.39       | 43.08             | 1.25       | 15.85             | 1.69                |
| Apocynum androsaemifolium L.    | Spreading dogbane                | 16.36     | 18.79      | 1.73       | 10.56             | 0.14       | 0.87              | 1.58                |
| Panicum capillare L.            | Witch grass                      | 13.94     | 15.76      | 2.09       | 15.00             | 0.44       | 3.12              | 1.58                |
| Solidago pubera L.              | Downey goldenrod                 | 12.73     | 14.55      | 2.42       | 19.05             | 0.35       | 2.74              | 1.56                |
| Pteridium aquilinum (L.) Kuhn.  | Bracken fern                     | 15.15     | 17.58      | 1.61       | 10.60             | 0.11       | 0.74              | 1.46                |
| Potentilla simplex Michx.       | Five finger cinquefoil           | 13.94     | 20.61      | 1.79       | 12.83             | 0.18       | 1.28              | 1.44                |
| Carex spp.                      | Sedge                            | 10.91     | 12.12      | 1.70       | 15.56             | 0.12       | 1.11              | 1.20                |
| Lobelia inflata L.              | Indian tobacco                   | 12.73     | 18.79      | 1.27       | 10.00             | 0.04       | 0.31              | 1.19                |
| Oxalis stricta L.               | Wood sorrel                      | 12.12     | 15.76      | 0.82       | 6.75              | 0.11       | 0.88              | 1.06                |
| Galtheria procumbens L.         | Teaberry                         | 9.09      | 9.70       | 1.24       | 13.67             | 0.51       | 5.62              | 1.05                |
| Betula populifolia Marshall     | Wire birch                       | 10.30     | 20.00      | 1.15       | 11.18             | 0.03       | 0.31              | 1.00                |
| Aster spp.                      | Asters                           | 9.09      | 11.52      | 1.12       | 12.33             | 0.06       | 0.68              | 0.91                |
| Kalmia angustifolia L.          | Lambkill                         | 7.27      | 8.48       | 1.39       | 21.67             | 0.23       | 3.22              | 0.90                |
| Plantanthera hyperborea (L.) Lindl. | Green orchid               | 10.30     | 12.12      | 0.76       | 7.35              | 0.01       | 0.11              | 0.89                |
| Elytrigia repens (L.) Desv ex B.D. Jacks | Quack grass          | 8.48      | 10.91      | 0.67       | 7.86              | 0.13       | 1.58              | 0.78                |
| Rosa spp.                       | Wild rose                        | 8.48      | 15.76      | 0.67       | 7.86              | 0.03       | 0.31              | 0.75                |
| Tragopogon pratensis L.          | Meadow                           | 8.48      | 10.84      | 0.67       | 7.86              | 0.03       | 0.31              | 0.75                |
| Solidago flexicaulis L.         | Broadleaf goldenrod             | 6.06      | 8.48       | 0.97       | 16.00             | 0.05       | 0.76              | 0.67                |

(Continued)
| Scientific name                        | Common name | Frequency | Field uniformity | Density |
|----------------------------------------|-------------|-----------|------------------|---------|
|                                        |             | Unadjusted| Adjusted         | All fields | Occurrence | All fields | Occurrence | Relative abundance |
|                                        |             | %         | %                | %        | plants m⁻²  | %          | plants m⁻²  |                  |
| *Muhlenbergia mexicana* (L.) Trin.     | Muhly grass | 5.45      | 6.67             | 0.82     | 15.00       | 0.16       | 3.02       | 0.62             |
| *Betula* spp.                          | Birch       | 6.06      | 6.06             | 0.73     | 12.00       | 0.02       | 0.39       | 0.60             |
| *Viola sagittata* Aiton                | Arrow-leaved violet | 4.51     | 4.51             | 1.12     | 31.43       | 0.05       | 1.83       | 0.60             |
| *Lysimachia terrestris* (L.) BSP. Fern. | Yellow Loosestrife | 6.06     | 10.91            | 0.45     | 6.00        | 0.05       | 0.76       | 0.54             |
| *Equisetum arvense* L.                | Field horsetail | 6.06     | 6.67             | 0.42     | 7.00        | 0.03       | 0.54       | 0.53             |
| *Acer rubrum* (L.)                    | Red maple   | 6.06      | 12.73            | 0.36     | 0.00        | 0.01       | 0.21       | 0.51             |
| *Abies balsamea* (L.) Mill.           | Balsam Fir  | 5.45      | 6.06             | 0.45     | 8.33        | 0.03       | 0.63       | 0.49             |
| *Picea* spp.                          | Spruce      | 4.85      | 6.67             | 0.61     | 12.50       | 0.01       | 0.14       | 0.48             |
| *Daucus carota* L.                    | Wild carrot | 4.85      | 6.06             | 0.55     | 11.25       | 0.06       | 1.21       | 0.48             |
| *Prenanthes trifoliolata* (Cass.) Fern. | Lions paw   | 5.45      | 8.27             | 0.42     | 7.50        | 0.01       | 0.16       | 0.48             |
| *Potentilla tridentata* Ait.           | Three-finger cinquefoil | 5.45     | 6.06             | 0.33     | 6.11        | 0.09       | 1.63       | 0.48             |
| *Symphyotrichum lateriflorum* (L.) Å. Löve & D. Löve | Calico aster | 4.85     | 6.06             | 0.48     | 10.00       | 0.02       | 0.50       | 0.46             |
| *Spiraea* spp.                        | Spirea      | 4.85      | 13.33            | 0.45     | 9.38        | 0.01       | 0.30       | 0.45             |
| *Stellaria graminea* L.               | Grass-leaved stitchwort | 4.85     | 7.88             | 0.42     | 8.75        | 0.03       | 0.59       | 0.44             |
| *Erechtites hieracifolius* (L.) Raf. Ex DC. | American burnweed | 4.24     | 4.24             | 0.52     | 12.14       | 0.02       | 0.39       | 0.42             |
| *Hypericum ellipticum* Hook.          | Creeping St John wort | 4.24     | 4.24             | 0.42     | 10.00       | 0.07       | 1.60       | 0.41             |
| *Veronica officinalis* L.             | Common speedwell | 4.24     | 4.24             | 0.42     | 10.00       | 0.03       | 0.79       | 0.40             |
| *Cerastium vulgatum* L.               | Mouse-eared chickweed | 4.85     | 5.45             | 0.27     | 5.63        | 0.02       | 0.34       | 0.40             |
| *Rubus hispidus* L.                   | Trailing blackberry | 4.24     | 12.73            | 0.36     | 8.57        | 0.02       | 0.49       | 0.38             |
| *Centarea nigra* L.                   | Black knapweed | 3.64     | 6.67             | 0.36     | 10.00       | 0.03       | 0.84       | 0.35             |
| *Aronia arbutifolia* (L.) Pers. Elliott | Red chokeberry | 3.64     | 4.85             | 0.24     | 6.67        | 0.06       | 1.63       | 0.32             |
| *Berberis canadensis* Mill.           | Barberry    | 3.03      | 4.24             | 0.39     | 13.00       | 0.05       | 1.56       | 0.32             |
| *Agrastis gigantea* Roth              | Red top     | 3.64      | 3.64             | 0.18     | 5.00        | 0.02       | 0.42       | 0.30             |
| *Gaylussacia baccata* (Wangenh.) K. Koch | Black huckleberry | 3.03    | 6.67             | 0.30     | 10.00       | 0.03       | 1.15       | 0.29             |
| *Nuttallanthus canadensis* (L.) D. A. Sutton | Canada toadflax | 3.03    | 6.06             | 0.21     | 7.00        | 0.03       | 1.10       | 0.27             |
| *Aronia melanocarpa* (Michx.) Elliott | Black chokeberry | 3.03     | 3.64             | 0.21     | 7.00        | 0.01       | 0.21       | 0.26             |
| *Spirea tomentosa* L.                 | Hardhack    | 2.42      | 3.64             | 0.36     | 15.00       | 0.01       | 0.40       | 0.26             |
| *Juncus effusus* L.                   | Soft rush   | 2.42      | 3.64             | 0.30     | 12.50       | 0.05       | 2.18       | 0.25             |
| *Amelanchier* spp.                    | Serviceberry | 3.03     | 5.45             | 0.15     | 5.00        | 0.00       | 0.14       | 0.25             |
| *Spergula arvensis* L.                | Corn spurry | 2.42      | 2.42             | 0.27     | 11.25       | 0.04       | 1.64       | 0.24             |
| *Sisyrinchium montanum* Greene        | Common blue-eyed grass | 2.42     | 2.42             | 0.24     | 10.00       | 0.01       | 0.53       | 0.23             |
| *Eurybia spectabilis* (Aiton) G.L. Nesom | Showy aster  | 2.42     | 3.03             | 0.21     | 8.75        | 0.02       | 0.95       | 0.22             |
| *Coptis trifolia* (L.) Salisb.        | Goldthread  | 2.42      | 2.42             | 0.18     | 7.50        | 0.05       | 2.24       | 0.22             |
| *Prunella vulgaris* L.                | Heal all    | 2.42      | 2.42             | 0.18     | 7.50        | 0.02       | 0.71       | 0.21             |
| *Hieracium praealtum* Vill. Ex Gochnat | Tall hawkweed | 1.82     | 3.64             | 0.30     | 16.67       | 0.04       | 2.17       | 0.21             |
| *Epilobium ciliatum* Raf.             | Northern willow herb | 2.42     | 4.24             | 0.15     | 6.25        | 0.01       | 0.45       | 0.21             |
| *Rosa virginiana* Mill.               | Virginia rose | 2.42     | 2.42             | 0.15     | 6.25        | 0.01       | 0.43       | 0.21             |

(Continued)
| Scientific name                        | Common name                           | Field uniformity | Density |          | Relative abundance |
|---------------------------------------|---------------------------------------|------------------|---------|----------|---------------------|
|                                       | Frequency | Occurrence fields | All fields |          | plants m⁻²        |
|                                       | %        | %                | %        |          |                     |
| **Solidago rugosa Mill.**             |           |                  |          |          |                     |
| Trifolium                           |           |                  |          |          |                     |
| Platanthera                         |           |                  |          |          |                     |
| Plantago                              |           |                  |          |          |                     |
| Frangula                              |           |                  |          |          |                     |
| Viola                                |           |                  |          |          |                     |
| Oenothera                            |           |                  |          |          |                     |
| Aralia                               |           |                  |          |          |                     |
| Oenothera biennis L.                 |           |                  |          |          |                     |
| Alnus spp.                           |           |                  |          |          |                     |
| Hybanthus concolor (T.F. Forst.)     |           |                  |          |          |                     |
| Spreng.                              |           |                  |          |          |                     |
| Mitchellia repens L.                 |           |                  |          |          |                     |
| RHINANTHUS MINOR L. SPP. MINOR       |           |                  |          |          |                     |
| Solidago canadensis L.               |           |                  |          |          |                     |
| Potentilla canadensis L.             |           |                  |          |          |                     |
| Epilobium coloratum Biehler          |           |                  |          |          |                     |
| Viola primulifolia L. (pro sp.)      |           |                  |          |          |                     |
| [lanceolata X macloskeyi]            |           |                  |          |          |                     |
| Dichanthelium boreale (Nash)         |           |                  |          |          |                     |
| Freckmann                            |           |                  |          |          |                     |
| Frangula alnus Mill.                 |           |                  |          |          |                     |
| Gnaphalium                           |           |                  |          |          |                     |
| Uliginosum L.                       |           |                  |          |          |                     |
| Plantago major L.                    |           |                  |          |          |                     |
| Plantanthera leucophaea (Nutt.)      |           |                  |          |          |                     |
| Lindl.                               |           |                  |          |          |                     |
| Scorzoneraoides autumnalis (L.)      |           |                  |          |          |                     |
| Moench                              |           |                  |          |          |                     |
| Trifolium repens L.                  |           |                  |          |          |                     |

(Continued)
| Scientific name | Common name | Frequency | Field uniformity | Density |
|-----------------|-------------|-----------|------------------|---------|
| *Poa saltuensis* (Fern. & Wieg.) | Forest meadow grass | 1.21 | 1.21 | 0.06 | 5.00 | 0.00 | 0.25 | 0.10 |
| *Populus grandidentata* Michx. | Large-toothed aspen | 1.21 | 1.82 | 0.06 | 5.00 | 0.00 | 0.20 | 0.10 |
| *Populus spp.* | Aspen | 1.21 | 3.64 | 0.06 | 5.00 | 0.00 | 0.18 | 0.10 |
| *Centaurea jacea* L. | Brown knapweed | 1.21 | 4.85 | 0.06 | 5.00 | 0.00 | 0.13 | 0.10 |
| *Spiranthes lacera* Raf. | Slender lady's tresses | 1.21 | 1.82 | 0.06 | 5.00 | 0.00 | 0.10 | 0.10 |
| *Picea glauca* (Moench) Voss | White spruce | 1.21 | 6.06 | 0.06 | 5.00 | 0.00 | 0.10 | 0.10 |
| *Prunus pensylvanica* L. f. | Pincherry | 1.21 | 3.03 | 0.06 | 5.00 | 0.00 | 0.05 | 0.10 |
| *Platanthera blephariglottis* (Willd.) Lindl. | White fringed bog orchid | 1.21 | 1.21 | 0.06 | 5.00 | 0.00 | 0.05 | 0.10 |
| *Solidago speciosa* Nutt. | Showy goldenrod | 1.21 | 1.21 | 0.06 | 5.00 | 0.00 | 0.05 | 0.10 |
| *Doellingeria umbellata* (P.Mill.) Nees | Tall white aster | 1.21 | 4.85 | 0.06 | 5.00 | 0.00 | 0.05 | 0.10 |
| *Lactuca canadensis* L. | Canada lettuce | 1.21 | 3.03 | 0.06 | 2.50 | 0.00 | 0.05 | 0.10 |
| *Hieracium pilosella* L. | Mouse-ear hawkweed | 0.03 | 1.21 | 0.15 | 25.00 | 0.18 | 30.00 | 0.08 |
| *Phleum pratense* L. | Timothy grass | 0.61 | 2.42 | 0.15 | 25.00 | 0.00 | 0.45 | 0.08 |
| *Piptatheropsis pungens* (Torr.) Romasch., P.M. Peterson & R. J. Soreng | Mountain rice grass | 0.61 | 0.61 | 0.12 | 20.00 | 0.00 | 0.50 | 0.07 |
| * Panicum dichotomiflorum* (L.) Michx. | Fall panicum grass | 0.61 | 0.61 | 0.09 | 15.00 | 0.03 | 5.30 | 0.07 |
| *Plantago lanceolata* L. | Narrow leaf plantain | 0.61 | 0.61 | 0.09 | 15.00 | 0.01 | 1.90 | 0.07 |
| *Pinus strobus* L. | White pine | 0.61 | 0.61 | 0.09 | 15.00 | 0.00 | 0.20 | 0.06 |
| *Acer spp.* | Maple | 0.61 | 1.82 | 0.09 | 15.00 | 0.00 | 0.15 | 0.06 |
| *Piptatheropsis canadensis* (Poir.) Romasch., P.M. Peterson & R.J. Soreng | Canada rice grass | 0.61 | 0.61 | 0.09 | 15.00 | 0.00 | 0.15 | 0.06 |
| *Oxalis corniculata* L. | Creeping wood sorrel | 0.61 | 0.61 | 0.06 | 10.00 | 0.03 | 4.20 | 0.06 |
| *Lindernia dubia* (L.) Pennell | False pimpernel | 0.61 | 1.21 | 0.06 | 10.00 | 0.01 | 2.20 | 0.06 |
| *Stellaria media* (L.) Vill. | Common starwort | 0.61 | 0.61 | 0.06 | 10.00 | 0.01 | 0.90 | 0.06 |
| *Polygonum sagittatum* L. | Arrow-leaved tearthumb | 0.61 | 0.61 | 0.06 | 10.00 | 0.00 | 0.80 | 0.06 |
| *Stenaria nigricans* (Lam.) Terrell var. nigricans | Baby's breath | 0.61 | 0.61 | 0.06 | 10.00 | 0.00 | 0.60 | 0.06 |
| *Artemisia campestris* L. | Tall wormwood | 0.61 | 0.61 | 0.06 | 10.00 | 0.00 | 0.55 | 0.06 |
| *Lycopus americanus* Muhl. ex W.P.C. Barton | Water horehound | 0.61 | 0.61 | 0.06 | 10.00 | 0.00 | 0.50 | 0.06 |
| *Viola sagittata* Aiton | Ovate-leaved violate | 0.61 | 0.61 | 0.06 | 10.00 | 0.00 | 0.10 | 0.06 |
| *Polygonum lindheimeri* A. Gray | Purple milkwort | 0.61 | 0.61 | 0.03 | 5.00 | 0.01 | 1.20 | 0.05 |
| *Setaria glauca* (L.) Beauv. | Yellow foxtail | 0.61 | 0.61 | 0.03 | 5.00 | 0.01 | 0.95 | 0.05 |
| *Salix spp.* | Willow | 0.61 | 2.42 | 0.03 | 5.00 | 0.00 | 0.55 | 0.05 |
| *Raphanus raphanistrum* L. | Wild radish | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.55 | 0.05 |
| *Lactuca serriola* L. | Prickly lettuce | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.40 | 0.05 |
| *Amelanchier canadensis* (L.) Med. | Shadbush | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.40 | 0.05 |

(Continued)
| Scientific name | Common name | Frequency Unadjusted | Field uniformity | Density % plants m⁻² |
|-----------------|-------------|----------------------|------------------|---------------------|
| *Solidago hispida* Muhl. ex Willd. | Hairy goldenrod | 0.61 | 2.42 | 0.03 | 5.00 | 0.00 | 0.35 | 0.05 |
| *Chenopodium album* L. | Lambsquarters | 0.61 | 1.82 | 0.03 | 5.00 | 0.00 | 0.30 | 0.05 |
| *Epilobium angustifolium* L. | Fireweed | 0.61 | 2.42 | 0.03 | 5.00 | 0.00 | 0.30 | 0.05 |
| *Hypericum boreale* (Britton) E.P. Bicknell | Northern St. John’s wort | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.30 | 0.05 |
| *Solidago nemoralis* Aiton | Gray goldenrod | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.30 | 0.05 |
| *Arctostaphylos uva-ursi* (L.) Spreng | Bear berry | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.30 | 0.05 |
| *Carex crawfordii* Fernald | Crawford’s sedge | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.30 | 0.05 |
| *Comptonia peregrina* (L.) J.M. Coult. | Sweet fern | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.25 | 0.05 |
| *Solidago stricta* Aiton | Wand-like goldenrod | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.20 | 0.05 |
| *Rumex crispus* L. | Curly dock | 0.61 | 2.42 | 0.03 | 5.00 | 0.00 | 0.20 | 0.05 |
| *Hieracium longipilum* Torr. | Hairy hawkweed | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.20 | 0.05 |
| *Ilex mucronata* (L.) Powell, Savolainen & Andrews | Mountain holly | 0.61 | 1.82 | 0.03 | 5.00 | 0.00 | 0.20 | 0.05 |
| *Polygonum convolvulus* (L.) A. Löve | Wild buckwheat | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.15 | 0.05 |
| *Thelypteris noveboracensis* (L.) Nieuwl. | New York fern | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.15 | 0.05 |
| *Hieracium aurantiacum* (L.) F.W. Schultz & Sch.Bip. | Orange hawkweed | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.15 | 0.05 |
| *Tridentis borealis* Raf. | Star flower | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.15 | 0.05 |
| *Doellingeria umbellata* (Mill.) Nees | Flat topped aster | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.10 | 0.05 |
| *Agrostis stolonifera* L. | Creeping bent grass | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.10 | 0.05 |
| *Taraxacum officinale* F.H. Wigg. | Dandelion | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.10 | 0.05 |
| *Sambucus racemosa* L. var. melanocarpa (A. Gray) McMinn | Black elderberry | 0.61 | 1.82 | 0.03 | 5.00 | 0.00 | 0.10 | 0.05 |
| *Carex tribuloides* Wahlemb. var. tribuloides | Broom sedge | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.10 | 0.05 |
| *Anthoxanthum odoratum* L. | Sweet vernal grass | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Ranunculus acris* L. | Tall buttercup | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Poa annua* L. | Annual bluegrass | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Lotus corniculatus* L. | Common bird’s-foot trefoil | 0.61 | 1.82 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Ajuga reptans* L. | Bugleweed | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Sambucus racemosa* L. | White berried elder | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Bellis perennis* L. | Common daisy | 0.61 | 3.03 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Cuphea viscosissima* Jacq. | Clammy cuphea | 0.61 | 1.21 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Fragaria virginiana* Duchesne | Wild strawberry | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Thelypteris palustris* Rich. | Marsh fern | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
| *Quercus spp.* | Oak | 0.61 | 0.61 | 0.03 | 5.00 | 0.00 | 0.05 | 0.05 |
Table 3. (Continued).

| Scientific name                | Common name | Frequency Unadjusted % | Field uniformity | Density plants m⁻² | Relative abundance |
|-------------------------------|-------------|------------------------|------------------|--------------------|--------------------|
| *Erigeron annuus* (L.) Pers.  | Annual fleabane | 0.61                  | 0.61              | 5.00               | 0.45               | 0.05               |
| *Pinus spp.*                  | Pine        | 0.61                  | 0.61              | 5.00               | 0.00               | 0.05               |
| *Verbascum thapsus* L.        | Common mullein | 0.61                  | 0.61              | 5.00               | 0.00               | 0.05               |
| *Dichanthelium* depauperatum (Muhl.) Gould | Starved panic grass | 0.61                  | 0.61              | 5.00               | 0.00               | 0.05               |
| *Hypochaeris radicata* L.     | Cat's ear   | 0.61                  | 0.61              | 5.00               | 0.00               | 0.05               |
| *Carex arctata* Boot ex Hook.| Dropping woodland sedge | 0.61                  | 0.61              | 5.00               | 0.00               | 0.05               |
| *Veronica serpyllifolia* L.   | Thymeleaf speedwell | 0.61                  | 0.61              | 5.00               | 0.00               | 0.05               |

*Vaccinium angustifolium* (Ait.) was most common in the fields surveyed, though *V. myrtillus* (Michx.) occurred at some sites. These species were not distinguished from each other during density counts.

on harvesting equipment (Boyd and White, 2009). Field uniformity (all fields) was below 30% in the early 1980’s (15.7%) and 2000’s (25.7%) but increased to 62.9% in our survey (Table 3). Similarly, density (all fields) increased from 6 to 1 plants m⁻² in 1984–1985 and 2000–2001, respectively, to 72.1 plants m⁻² in our survey (Table 3), indicating prolific growth of red sorrel in lowbush blueberry fields. Red sorrel was traditionally controlled with PRE hexazinone applications (Jensen, 1985a; Jensen and Specht, 2002), though the activity of this herbicide is now variable (Kennedy et al., 2010, 2011) and hexazinone-resistant populations have been identified in Nova Scotia (Li et al., 2014). Red sorrel can be suppressed with fall pronamide applications (Hughes et al., 2016), though cost of this herbicide precludes its use by most growers. In addition, the basic biology of red sorrel has likely contributed to the increased occurrence of this weed species. Red sorrel spreads by seeds and a shallow creeping root system (Kennedy, 2009; White, 2014). Seedlings emerge throughout the growing season (White et al., 2014), but vegetative reproduction of ramets from the creeping root system is the primary means of population growth (Kennedy, 2009; White et al., 2014). Ramets emerge throughout the growing season in Nova Scotia (White et al., 2014, 2015a) and emerged ramets remain as vegetative rosettes below the blueberry canopy due to a vernalization requirement for flowering (White et al., 2014, 2015b). This growth pattern facilitates prolonged periods of indeterminate vegetative growth in this weed species which, when coupled with lack of adequate control from herbicides, seed spread on machinery, documented increases in lowbush blueberry growing season length (Drummond and Yarborough, 2014), and increased vegetative growth of red sorrel following fertilization (Kennedy et al., 2011), likely accounts for the large increase in field uniformity and density that have occurred since 2000–2001. Red sorrel can contribute to several crop management issues in lowbush blueberry (Hughes, 2012; Hughes et al., 2016; Jensen and Specht, 2002) and development of control strategies for this weed species should be a major component of future research activities.

Poverty oat grass was the second most abundant weed (Table 3) and is a common tuft-forming perennial grass in lowbush blueberry fields (Hall, 1959; Hall et al., 1979; Jensen and Yarborough, 2004; Yarborough and Bhowmik, 1989). The frequency of fields containing this weed species increased from 64.3% in 1984–1985 to 92.7% in 2017–2019, and density and field uniformity increased from 0.7 plants m⁻² and 20.7 to 5.7 plants m⁻² and 43.4, respectively (Table 3). Although traditionally controlled by hexazinone (Jensen, 1985a; Jensen and Specht, 2002; Yarborough and Bhowmik, 1989; Yarborough et al., 1986) and terbacil (Smagula and Ismail, 1981), poverty oat grass biotypes tolerant to hexazinone have been identified (Burgess, 2002; Jensen et al., 2003; Jensen and Hainstock, 2000a) that now limit efficacy of this herbicide. Poverty oat grass is, however, a good living mulch in lowbush
blueberry fields if suppressed with herbicides (Burgess, 2002), and <15 plants m\(^{-2}\) are not competitive for nitrogen with lowbush blueberry (Marty et al., 2019). Current density is below this threshold (Table 3) and the grass is easily suppressed with currently registered ACCCase-inhibiting herbicides such as fluazifop-p-butyl and sethoxydim (White and Zhang, 2019). This grass may therefore be beneficial in many fields where it occurs. Lack of alternative POST herbicides for this weed, however, should be addressed (White and Zhang, 2019) as dense populations of flowering poverty oat grass plants impede harvesting (Jensen and Hainstock, 2000a; Jensen and Specht, 2002) and prolonged use of ACCCase-inhibiting herbicides will lead to resistance development (Beckie et al., 2013; Valverde, 2007). Non-chemical control methods are generally lacking for poverty oat grass, though burning and use of sulfur applications to reduce soil pH in lowbush blueberry fields reduces grass cover (Smagula et al., 2009) and may contribute to management of this species.

Haircap moss was the third most common weed species in our survey but was not included in previous weed surveys, making it difficult to assess trends over time. We included this weed species as dense patches of haircap moss reduce lowbush blueberry stem density and yield (Percival and Garbary, 2012). This weed species was found in 53.9% of fields surveyed (Table 3), but field uniformity was low (Table 3) and indicates patchy distribution of this weed species in lowbush blueberry fields. Flumioxazin is currently registered for control of haircap moss (Percival and Garbary, 2012) and recent advances in precision agriculture technology provide an opportunity to improve management of this weed (Esau et al., 2014, 2018). Flumioxazin is, however, limited to fall applications (Anonymous, 2017) and identification of a spring treatment for haircap moss would be beneficial.

Hair fescue was the fourth most common weed species (Table 3) and is a tuft-forming perennial grass of great concern as tufts form dense sods that reduce lowbush blueberry yield by >50% (White, 2019; Zhang, 2017; Zhang et al., 2018). Frequency, field uniformity, and density of this weed decreased between 1984 – 1985 (26.1%, 6.4, and 2.3 plants m\(^{-2}\), respectively) and 2000–2001 (7%, 1.4, and 0.1 plants m\(^{-2}\), respectively) (McCully et al., 1991; Jensen and Sampson, unpublished data), likely due to control of this species by hexazinone and terbacil (Jensen, 1985a, 1985b; Sampson et al., 1990; Smagula and Ismail, 1981). Hexazinone resistance, however, is now suspected in hair fescue (Jensen and Yarborough, 2004) and hexazinone failed to control hair fescue in recent research trials (White, 2019; Zhang, 2017). Terbacil efficacy is also variable (Zhang, 2017; Zhang et al., 2018) and generally limited to single-season suppression (White, 2019). Hair fescue frequency, field uniformity, and density have all increased since 2000–2001 (Table 3), and declining hexazinone and terbacil efficacy have likely contributed to this. Hair fescue seed is also common on harvesters (Boyd and White, 2009), likely contributing to increased occurrence as hair fescue seeds lack primary dormancy and readily germinate after dispersal (White, 2018). Burn pruning did not eliminate established tufts (Penney et al., 2008), but hair fescue seeds are killed by short-term exposure to 200 and 300 C (White and Boyd, 2016). Adoption of flail mowing for pruning (Eaton et al., 2004; Yarborough, 2004) may therefore be contributing to prevalence of this weed species as well. Hair fescue is controlled by pronamide (White, 2019; Zhang et al., 2018) but cost of this product limits grower use. Precision agriculture technologies reduce pronamide costs (Esau et al., 2014), though growers have been slow to adopt this technology despite short payback periods (Esau et al., 2016). The ALS/AHAS-inhibiting herbicide foramsulfuron provides non-bearing year suppression of hair fescue (White and Kumar, 2017; Zhang, 2017), though efficacy is variable (Zhang et al., 2018) and hair fescue recovers in the bearing year unless fall non-bearing pronamide applications are used (White, 2019). Promising new herbicides for management of this weed species are largely limited to additional ALS/AHAS-inhibitors (Yarborough and Cote, 2014; Zhang et al., 2018), leading to concerns about the long-term sustainability of new herbicide products for management of this weed species.

Narrow-leaved goldenrod was the fifth most common weed species in our survey and has become the dominant goldenrod species in lowbush blueberry fields in Nova Scotia (Table 3). Goldenrods are common weeds in lowbush blueberry fields (Hall, 1959; Jensen, 1985a, 1985b; Lapointe and Rochefort, 2001; Yarborough et al., 1986) and occurred in 69% of fields surveyed in 1984–1985 (McCully et al., 1991). Narrow-leaved goldenrod occurred in 31.3% of fields surveyed in 2000–2001 and had a field
uniformity and density of 13.9 and 0.2 plants m$^{-2}$, respectively. Our data, therefore, indicate an increase in the occurrence of this particular goldenrod species (Table 3), likely due to reduced hexazinone efficacy on narrow-leaved goldenrod (White et al., 2016) and incomplete control from POST mesotrione applications (Boyd et al. 2010; Farooq et al., 2019). Control is improved when mesotrione is applied in conjunction with PRE hexazinone applications (Boyd and White, 2010) or when sequential mesotrione applications are used (Farooq et al., 2019). Hexazinone use, however, has declined due to low crop prices and mesotrione applications are limited to one application per year in lowbush blueberry in Canada (Anonymous, 2017). Pursuit of a sequential mesotrione registration for lowbush blueberry in Canada should continue as nonchemical management techniques such as cutting above blueberry stems only provide short-term suppression of this weed species (Farooq, 2018).

The next two most common weed species were the tuft-forming perennial grasses rough hair grass and woolly panicum (Table 3). Rough hair grass was not documented in 1984–1985 but was found in 2000–2001 (McCully et al., 1991; Jensen and Sampson, unpublished data). Frequency, field uniformity, and density of this weed in 2000–2001 were 25%, 4.4, and 0.2 plants m$^{-2}$, respectively, indicating an increase in prevalence of this weed in our survey (Table 3). This is likely due to the occurrence of dense stands of presumably hexazinone-tolerant biotypes of this grass species and deregistration of atrazine (Jensen and Hainstock, 2000b; Jensen and Yarborough, 2004). Rough hair grass is, however, susceptible to terbacil (Jensen and Hainstock, 2000b), currently registered ACCase-inhibiting herbicides (Boyd et al., 2014; White and Zhang, 2019), and foramsulfuron (White and Zhang, 2019) and is therefore quite easily managed in lowbush blueberry fields. Woolly panicum has been a consistently common grass across all weed surveys in lowbush blueberry fields in Nova Scotia, but is generally of little concern due to the low field uniformity of this grass species (Table 3). Frequency of this grass increased from 35% to 49% between 2000–2001 and 2017–2019, however, and field uniformity and density were higher in our survey (Table 3) than in 1984–1985 (8.5% and 1.5 plants m$^{-2}$, respectively) and 2000–2001 (5.2% and 0.2 plants m$^{-2}$, respectively). Implications of this increased prevalence, however, are unclear as limited research has been conducted to date on this grass species. Panicum spp. in general are quite susceptible to ACCase and ALS/AHAS-inhibiting herbicides that have activity on grasses (Jensen and Yarborough, 2004; Zandstra et al., 2004) and this species is likely also easily managed with these herbicides in lowbush blueberry fields.

Cow wheat was the eighth most common weed species in lowbush blueberry fields (Table 3), and frequency, field uniformity, and density of this weed have increased steadily since 1984–1985 (15.7%, 2.3, and 0.1 plants m$^{-2}$, respectively) and 2000–2001 (30.5%, 7.3, and 0.3 plants m$^{-2}$, respectively). Cow wheat is a facultative root hemiparasitic annual plant that occurs widely in North America (Cantlon et al., 1963; Nave et al., 2018). Increased occurrence of this weed species is, therefore, a concern as hemiparasitic species generally withdraw resources from host plants via haustoria connections (Cantlon et al., 1963; Těšitel et al., 2010), potentially reducing growth of the host plant. Parasitism of lowbush blueberry has not been documented in commercial fields, but has been observed in jack pine (Pinus banksiana) stands (Cantlon et al., 1963). Common cow wheat (Melampyrum pratense) also parasitizes Vaccinium spp. such as bilberry (V. myrtillus L.) and lingonberry (V. vitis-idaea L.) (Masselink, 1980). Cow wheat can be managed with mesotrione (Anonymous, 2015b) and foramsulfuron (Gavin Graham, personal communication; Scott White, personal observation), but future research should be conducted to determine potential parasitic interactions between cow wheat and lowbush blueberry as this may be contributing to yield losses in lowbush blueberry fields.

Bunchberry was the most common weed species found in 1984–1985 (McCully et al., 1991) but frequency, field uniformity, and density have generally declined between 1984 and 1985 (74.8%, 21.1, and 41.3 plants m$^{-2}$, respectively), 2000–2001 (57%, 14.5, and 0.6 plants m$^{-2}$, respectively) and 2017–2019 (Table 3), likely due to registration of the ALS/AHAS-inhibiting herbicide tribenuron methyl in 1994 for management of this weed species (Anonymous, 2015a; Jensen and Specht, 2004). Although still effective, alternatives to tribenuron methyl should be identified to diversify control
options for this weed species as it competes for space with lowbush blueberry (Yarborough and Bhowmik, 1993) if it is not managed.

Surveyed collectively under the Hieracium genus in the past, hawkweeds were found in 48% of fields surveyed in 1984–1985 but declined to 3.9% of fields surveyed in 2000–2001, presumably due to susceptibility of these weeds to hexazinone and atrazine (Jensen, 1985a, 1985b; Penney and McRae, 2000) and possibly terbacil (Anonymous, 2017). The increased frequency, field uniformity, and density of yellow hawkweed in our survey is, therefore, a concern as it suggests development of hexazinone-resistant biotypes of this weed species. Eriavbe (2014) reported short-term suppression of Hieracium spp. with hexazinone, indicating a decline in hexazinone efficacy on this genus. Synthetic auxin herbicides, however, gave good control (Eriavbe, 2014) and clopyralid is now recommended to manage hawkweeds (Anonymous, 2017). Future research should combine additional herbicide screening activities with focus on evaluating various clopyralid application timings, rates, and tank mixture partners for improved control of this increasingly common weed genera.

**Less Common but Potentially Problematic Weeds Found Within Quadrats**

Although less common than the weed species discussed above, many other weed species identified in the quadrats during the survey should be of concern due to trends in survey responses, lack of adequate control measures, or potential for future problems.

Other herbaceous perennial weeds identified in the survey that should be of concern are common St. John’s wort (Hypericum perforatum L.) and spreading dogbane (Apocynum androsaemifolium L.). Although field uniformity indicates common St. John’s wort is patchy in fields where it occurs (Table 3), frequency of this weed increased from 11.3% in 1984–1985 to 43.6% in 2017–2019. Common St. John’s wort produces an abundance of highly viable seeds (Crompton et al., 1988) and rhizomes (Crompton et al., 1988; Sampson et al., 1990). Stems can reach 90 cm in height (Crompton et al., 1988), providing an opportunity to shade lowbush blueberry plants and interfere with harvesting. The plant is not controlled by s-triazine herbicides, such as hexazinone (Crompton et al., 1988) and glyphosate is considered the most effective herbicide for this weed species (Campbell et al., 1979, 1975). Growers will therefore likely need to rely on careful spot applications or wiper applications of glyphosate (Jensen and Yarborough, 2004) until an alternative treatment can be developed.

Frequency of fields containing spreading dogbane increased from 1.7% in 1984–1985 to 16.4% in 2017–2019 (Table 3), though field uniformity values continue to indicate patchy occurrence of this weed in fields where it occurs (Table 3). The plant reproduces by seeds and creeping roots (Bergweiler and Manning, 1999; Sampson et al., 1990), making control difficult. Stems can also exceed 75 cm in height and shading from this weed species can reduce lowbush blueberry yield by >80% (Yarborough and Marra, 1997). Broadcast herbicide applications provide variable levels of control (Wu and Boyd, 2012) and the weed is most reliably controlled with spot applications of dicamba (Wu and Boyd, 2012). Spreading dogbane is, however, difficult to spot treat with herbicides without contacting blueberry plants. Therefore, research into herbicides with improved safety on lowbush blueberry is required as herbicides are more effective than non-chemical alternatives such as clipping or hand pulling (Wu and Boyd, 2012).

Woody perennials of concern identified include red and black chokeberry (Aronia arbutifolia (L.) Pers. and Aronia melanocarpa (Michx.) Elliott), black huckleberry (Gaylussacia baccata (Wangen.) K. Koch), glossy buckthorn (Frangula alnus Mill.), and spireas (Spiraea tomentosa L., Spiraea alba var. latifolia, and Spiraea spp.). All of these weeds are of concern due to lack of hexazinone efficacy (Jensen, 1985a; Yarborough and Bhowmik, 1989) and limited selective control options (Jensen and Specht, 2004; Jensen and Yarborough, 2004). Chokeberries, black huckleberry, and glossy buckthorn, however, are of particular concern due to contribution of fruit contaminants to harvested blueberries (Jensen and Yarborough, 2004; Yarborough and Ismail, 1979, 1980). Glossy buckthorn in particular should be of high priority due to potential dispersal of seeds by birds (Craves, 2015) and increasing prevalence of this invasive species throughout Nova Scotia (Belliveau, 2012).
The other major perennial grass weed identified in the survey was red fescue (*Festuca rubra* L.), a rhizomatous perennial grass presumably introduced into lowbush blueberry fields as a contaminant in straw used for burning. This grass was first recorded in 2000–2001 when it occurred in 0.8% of fields surveyed. It occurred in about 8% of fields we surveyed and has a very high field uniformity and density in fields where it occurs (Table 3). This grass forms dense sods that reduce lowbush blueberry growth and yield (Sikoriya, 2014) and is only known to be adequately controlled by pronamide, dichlobenil, or glyphosate (Sikoriya, 2014). Costs associated with pronamide and dichlobenil, however, limit grower use of these herbicides, and glyphosate poses a significant crop injury risk. Future perennial grass management research must consider red fescue as well before this weed species becomes more prevalent.

Of the sedges and rushes identified, black bulrush continues to be common in lowbush blueberry fields and frequency increased from 3.5% in 1984–1985 to 30.9% in our survey (Table 3), despite registration of spot applications of nicosulfuron + rimsulfuron to control this weed species (Jensen and Hainstock, 2003; Jensen and Specht, 2004). Field uniformity in occurrence fields, however, is high enough that spot applications may be impractical for many growers (Table 3), potentially forcing growers to rely on less effective broadcast applications of herbicides, such as mesotrione or terbacil (Boyd and White, 2010). Growers should therefore be more aggressive with nicosulfuron + rimsulfuron spot applications in fields where this weed occurs, and a safe and effective broadcast treatment for this weed species is needed.

Other annual weeds that should be emphasized include hemp nettle (*Galeopsis tetrahit* L.), horseweed (*Conyza canadensis* (L.) Cronquist), and American burnweed (*Erechtites hieracifolius* (L.) Raf. Ex DC.). Hemp nettle is a common weed of arable crops, such as cereals (Thomas et al., 1994) where it can reduce yield by up to 50% at densities of 28–248 plants m⁻² (Légère and Deschênes, 1991). Average density in lowbush blueberry fields is lower (Table 3), and effect of this weed on lowbush blueberry growth and development is unclear. Plants can reach 75 cm in height (O’Donovan and Sharma, 1987) and therefore pose a risk of shading lowbush blueberry plants or hindering harvest operations at high densities. Currently, there is no registered treatment for this weed species. Horseweed is a facultative winter or summer annual (Tozzi and Van Acker, 2014) that occurred in 1.8% of fields surveyed (Table 3). This weed is nonetheless a concern as it is a common weed in no-till farming systems (Brown and Whitwell, 1988) and is a prolific producer of wind-borne seeds that can be dispersed up to 500 km (Bhowmik and Bekech, 1993; Shields et al., 2006). This weed has also developed resistance to several herbicides in other cropping systems (Koger et al., 2004; Lehoczki et al., 1984), indicating potential for similar problems in lowbush blueberry. American burnweed was not previously documented in Nova Scotia and occurred in 4.2% of fields surveyed (Table 3). The plant was first reported as a weed in lowbush blueberry fields in Maine, USA where it formed very dense stands that reduced yield and hindered harvest in some fields (David Yarborough, personal communication). The plant is susceptible to many currently registered herbicides in lowbush blueberry (White and Webb, 2018) but can produce up to 32,000 wind-borne seeds (Csiszár, 2006) that exhibit typical summer annual dormancy characteristics (White et al., 2017) and form persistent seed banks (Baskin and Baskin, 1996). Growers should therefore begin monitoring for this weed species and implementing control measures before plants go to seed. In addition to herbicides, non-chemical strategies such as mechanical weed pullers (Simard et al., 2019) could be investigated for management of these annual weeds in lowbush blueberry fields.

**Weeds Present Outside the Quadrats**

There were 28 additional weeds found in at least one field but never within the quadrats, though most were herbaceous and woody perennials (Table 2) that occurred in 0.6% to 3% of fields surveyed (Table 4). Some problematic species were identified, though potential for them to become widespread seems unlikely. Many of the woody perennials found are common tree and shrub species in Nova Scotia,
most of which are controlled with hexazinone or spot applications of other registered herbicides (Jensen, 1985a; Sampson et al., 1990). Although herbaceous perennials, such as Canada thistle cause significant problems in arable crops and pastures, this weed has been of low frequency in lowbush blueberry (McCully et al., 1991; Jensen and Sampson, unpublished data) and therefore seems incapable of becoming prolific in this cropping system. The identification of sheep fescue in one field indicates that this grass species is still present in some areas, though low occurrence of this grass suggests continued susceptibility to herbicides, such as hexazinone and terbacil.

**Conclusion**

In conclusion, this study represents the most comprehensive weed survey in lowbush blueberry fields in Nova Scotia and is the first to include lowbush blueberry fields from southern Nova Scotia. A total of 211 non-blueberry plants were identified and the weed flora was dominated by herbaceous and woody perennial, annual broadleaf, and perennial grass weeds. Priority species that should be the focus of future weed management research due to increased occurrence since previous surveys include red sorrel, hair fescue, narrow-leaved goldenrod, cow wheat, and hawkweeds. A range of other less frequent, but potentially problematic species were also identified, including red fescue, common St. John’s wort, and spreading dogbane. These weeds have also increased in occurrence relative to previous surveys, and there is an opportunity to develop control measures for these weeds before they become widespread. We also report the first occurrence of potentially serious weeds such as American burnweed and glossy buckthorn, both of which have the potential to become widespread problems in lowbush blueberry fields if effective management strategies are not developed. Results of this weed survey are being used by the Wild Blueberry Producer’s Association of Nova Scotia to develop new weed management research priorities.
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Statement of conflicting interests

The authors state that there is no conflict of interest.

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