COSEWIC
Assessment and Status Report

on the

Long's Bulrush
Scirpus longii

in Canada


SPECIAL CONCERN
2017

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – April 2017

Common name
Long's Bulrush

Scientific name
Scirpus longii

Status
Special Concern

Reason for designation
This globally vulnerable, long-lived wetland plant is restricted in Canada to a small region of Nova Scotia that supports nearly half of the world's population. The species is increasingly threatened by competition and shading from the invasive Glossy Buckthorn and native shrubs. Peat mining could be a future threat. Limited sexual reproduction and hybridization may also reduce survival of this sedge.

Occurrence
Nova Scotia

Status history
Designated Special Concern in April 1994. Status re-examined and confirmed in April 2017.

COSEWIC
Executive Summary

Long's Bulrush
Scirpus longii

Wildlife Species Description and Significance

Long's Bulrush is a robust, perennial sedge of peatlands. It forms circular clones of vegetative shoots from stout underground rhizomes. Flowering stems, infrequent in most occurrences, are 100-180 cm long and terminate in a much-branched cluster of up to 1,000 spikelets, each containing up to 60 tiny flowers that develop a woolly appearance at maturity. The flower cluster is subtended by three leaflike bracts, which are dark and sticky at the base. In addition to these bracts, thick rhizomes, large stature and red-brown fruits (seed-like achenes), distinguish the species from co-occurring relatives.

Long's Bulrush is a globally Vulnerable (G2G3) species with a restricted world distribution, for which Canada bears a high conservation responsibility. Canadian occurrences (46+% of the global total) are in a much less disturbed landscape than most in the United States, and may be especially significant because they are at the northern limit of the species' global distribution. Long's Bulrush is one of many disjunct, Atlantic Coastal Plain plants that are rare in Canada, and of public interest in southern Nova Scotia. It is a locally dominant species in peatlands and its impressive 400+ year clone longevity is often mentioned in Coastal Plain flora nature interpretation.

Distribution

Long's Bulrush has a restricted global range extending from southern New Jersey, U.S.A. to southern Nova Scotia, Canada. No records are more than 70 km from the coast. Historical occurrences of this plant in Connecticut and New York have been lost to human development resulting in an almost 300 km gap in the range between New Jersey and eastern New England in Rhode Island, southern New Hampshire and southern Maine. In Canada, Long's Bulrush is known from 37 subpopulations in a 94 km by 90 km area of southwestern Nova Scotia, where there is strong evidence that many undiscovered occurrences exist.

Habitat

Long's Bulrush is a species of wet, acidic, nutrient-poor, open peatlands with limited cover of shrubs or trees taller than the herbaceous shoots. Occurrences are especially frequent and subpopulations are generally larger in peatlands subject to annual flooding from adjacent streams, rivers and lakes, but the species is also found in peatlands away from watercourses, mostly within seasonally wet areas with low standing biomass.

Biology

Long's Bulrush is a clonal perennial. Vegetative reproduction via rhizomes is the primary mode of growth and clones can be extremely long-lived, with some large clones estimated to be several hundred years old. Flowering is infrequent in most subpopulations and is often induced by disturbance such as fire and Muskrat herbivory. Flowering occurs in late May and June. Pollen is dispersed by wind and possibly also by insects. The mating system and self-compatibility have not been investigated. Seed-like achenes mature in mid- to late summer and may germinate immediately. Germination and establishment are limited unless atypical ecological conditions, such as fire, reduce plant and litter cover. Seed dispersal via wind and water occurs primarily in late summer and autumn, continuing into winter if stalks remain standing. Internal or external dispersal by waterfowl may be important for longer distance movement. Time to maturity is likely at least several years, although flowering in the first year has been observed in New Jersey. Long-term seed banking could be significant given infrequency of flowering and increased seedling establishment associated with potentially infrequent disturbances. Rhizome fragmentation by ice or Muskrats appears to be important for dispersal along watercourses but is likely infrequent in peatlands away from water bodies.

Population Sizes and Trends

Population size is difficult to quantify because it is difficult to determine "mature individuals". The documented Canadian population is estimated at 2,700 clones containing 718,000 shoots, with the population of mature individuals probably best represented for status assessment by a number closer to 2,700. It is likely that undiscovered occurrences in southern Nova Scotia support additional clones and shoots at least equivalent in abundance to those currently documented.

The Canadian population appears to be relatively stable. All subpopulations documented in the last status report are extant, and with one possible exception there are no indications of significant declines. Glossy Buckthorn, natural succession, and potentially also localized all-terrain vehicle or development impacts, will likely cause low magnitude declines over the coming decades.

Threats and Limiting Factors

Threats to Long’s Bulrush are mostly slow-moving or spatially limited. Shading by the invasive exotic shrub Glossy Buckthorn is not yet significant but is the largest and most widespread short-term threat, with 20 of 37 subpopulations occurring within 15 km of known invaded sites. At least four of these 20 subpopulations have Glossy Buckthorn on their immediate margins and Glossy Buckthorn can be expected throughout the Canadian range of Long’s Bulrush (though not necessarily in all occupied habitat) within one to three times the presumed generation time of the bulrush.

Introgressive hybridization with the native and much more abundant Woolgrass Bulrush was detected at two of five subpopulations surveyed in a genetic analysis, and is believed to be an ongoing threat to genetic integrity of Long’s Bulrush. This threat is heightened by the increased occurrence of Woolgrass Bulrush in disturbed sites such as logging road ditches, but the longevity of clones and infrequency of flowering in Long’s Bulrush substantially limits the threat’s immediacy. Flooding by hydroelectric development undoubtedly eliminated subpopulations between 1900 and 1950 but is not expected to increase in the short-term. All-terrain vehicle use and natural succession are threats at some subpopulations. Peat mining is a potential future threat.

Infrequent flowering and resulting limited seed production, dispersal and establishment are significant limiting factors. The extent to which these are reduced in Canada from levels occurring prior to European settlement, because of human fire suppression or other factors, is not well understood.

Protection, Status and Ranks

Long’s Bulrush is listed as Special Concern under Schedule 3 of Canada’s *Species at Risk Act*, and Vulnerable under the *Nova Scotia Endangered Species Act*, with each status conferring limited protection. Long’s Bulrush is provided some legal protection under state endangered species acts in New Jersey, Rhode Island, New Hampshire, and Massachusetts. It is a Species of Special Concern in Connecticut, where it is presumed extirpated. NatureServe status ranks are G2G3 (Imperiled to Vulnerable) globally, Imperiled in United States (N2) and Imperilled to Vunerable in Canada (N2N3), SX (Presumed Extirpated) in New York, SH (Potentially Extirpated) in Connecticut, S1 (Critically Imperiled) in Rhode Island and New Hampshire, S2 (Imperiled) in New Jersey, Massachusetts and Maine, and S2S3 (Imperilled to Vulnerable) in Nova Scotia.

TECHNICAL SUMMARY

Scirpus longii

Long's Bulrush

Scirpe de Long

Range of occurrence in Canada (province/territory/ocean): Nova Scotia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	6-10 yrs Seedlings can mature to flowering within 6 months. New clonal individuals are estimated to be produced through rhizome division every 8 years and rhizome segment longevity of 15 years (Hill 1994)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, some declines projected Effects of exotic Glossy Buckthorn invasion, natural succession and possibly ATV damage and development are anticipated to cause slow and/or localized declines
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Probably less than 10%, potentially much less. Loss through shading by exotic Glossy Buckthorn or natural succession would be slow (very persistent rhizomes, slow tree growth in peatlands) and possibly a minor or non-factor at the most open, acidic peatland sites away from rivers and lakes
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	No declines documented
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Probably less than 10%, potentially much less. Loss through shading by exotic Glossy Buckthorn or natural succession would be slow (very persistent rhizomes, slow tree growth in peatlands) and possibly a minor or non-factor at the most open, acidic peatland sites away from rivers and lakes
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Future declines inferred. No significant declines known in past 3 generations. Small future declines inferred, probably less than 10%, potentially much less. See reasoning above.

Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	Glossy Buckthorn Invasion & Natural Succession a. Reversible at the site scale, but not practically so across full range b. Generally understood, but specifics incompletely understood c. Not ceased
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	4,862 km^2 High likelihood of undiscovered occurrences that would increase this value (see **Sampling Effort and Methods**)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	272 km^2 Based only on known occurrences. 95% certainty of 48 km^2 undiscovered, most likely at least ~136 km^2 undiscovered and potentially well over that such that actual value may exceed 500 km^2 (see **Extent of Occurrence and Area of Occupancy** and **Sampling Effort and Methods**)
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	37 Each subpopulation considered a separate location.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Probably not. Future loss possible but only limited losses of small subpopulations anticipated, which would likely not affect EOO, especially given potential for undiscovered subpopulations.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Possibly (projected). Some potential for future local losses leading to IAO decline based on very small size of 13 of 37 subpopulations and shading effects of Glossy Buckthorn or natural succession, or other impacts. Limited sexual reproduction suggests losses may not be counterbalanced by new establishment.

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Is there an [observed, inferred, or projected] decline in number of subpopulations?	Possibly (projected). Some potential for future subpopulation losses based on very small size of 13 of 37 subpopulations and shading effects of Glossy Buckthorn or induced natural succession, or other impacts. Limited sexual reproduction suggests losses may not be counterbalanced by new establishment.
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Possibly (projected). Some subpopulation (=location) losses could occur.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes (projected). Slow long-term decline projected due to exotic shrub invasion (Glossy Buckthorn) and natural habitat succession, with lack of compensatory recruitment.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations **(give plausible ranges)**	**N Mature Individuals** Number of mature individuals lies somewhere between number of clones and number of shoots, but should be closer to number of clones (see **Abundance**)
1) Smith Lake	3 clones; 355 shoots
2) Seven Mile Lake	~100? clones; prob. low 10,000s shoots
3) McGowan Lake	2 clones; ? shoots
4) Barren Meadow Brook	7 clones; 145 shoots
5) Shingle Lake	215 clones; low 10,000s shoots
6) Eel Weir Stillwater	198+ clones [count likely quite incomplete]; prob. 100,000s or more shoots
7) Molega Lake	21 clones; ? shoots
8) Wildcat River	100 clones; ~10,000 shoots
9) Hog Lake	13 clones; ? shoots
10) Echo Lodge	24 clones; ~360 shoots
11) Bull Moose Lake	7 clones; ? shoots
12) Little Rocky Lake	2 clones; ? shoots
13) First Christopher Lake	2 clones; ? shoots

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

14) Eighteen Mile Brook	sev 100 clones; prob. 100,000s shoots
15) Moosehorn Lake	7 clones; low 100s shoots
16) Ponhook Lake	Mid-100s? clones; prob. low to mid-10,000s shoots
17) Murray Meadows + Dean Brook	41 + sev 100 clones; 31,000 shoots
18) Wentworth Brook + Hemlock Run	~100 clones; 70,600 shoots [16% of observed total at Wentworth Brook subsite based on hybridization rates, MacKay *et al*. (2010)]
19) Kejimkujik National Park – Kejimkujik, George & Loon lakes	93-95 clones; low thousands of shoots
20) Dunraven Bog North	17 clones; ~500 shoots
21) Little Sixteen Mile Bay	1 clone; ? shoots
22) Upper Great Brook	10 to 20 clones; ? shoots
23) Ten Mile Lake	4 to 5 clones; 100s shoots
24) Six Mile Bog	1 clone; 1 shoot
25) Lower Great Brook	1 clone; 13 shoots
26) DeWolfe Brook	1 clone; 150-200 shoots
27) Hagen Meadow	~25 clones; 1000s shoots
28) Dunraven Bog South	107 clones; ~1500 shoots
29) Wilkins Lake	1 clone; ? shoots
30) Tidney River	many 100s to 1000+ clones; 120,000 shoots
31) Blue Hill Bog	100+ clones; ? shoots
32) Bloody Ck	~20 clones; 1000s shoots
33) Quinns Meadow	~100? clones; 1000s shoots
34) Gilfillan Lake	1 clone; ~400 shoots
35) Lac de l'École	~38 clones; ~1500 shoots [15% of observed total, based on ratio of pure *S. longii* to hybrids, MacKay (pers. comm. 2016)]
36) Quinan River	41 clones; 4500 shoots
37) Wilsons Lake	45 clones; ? shoots
Total	**Likely more than 10,000 individuals** (see **Abundance**) **~2,700 clones; ~718,000 shoots *in known sites***. Undiscovered sites likely ~double known population (see **Sampling Effort and Methods**). Likely no subpopulation exceeds 1,000 clones.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not applicable. No analysis completed.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes (see Appendix 3). Participants: Nick Hill, Ron MacKay, Sean Blaney, David Mazerolle, Bruce Bennett, Jim Pojar, Dan Brunton

i. Invasive non-native/alien species (IUCN# 8.1)
ii. Problematic native species: a) hybridization with increasing, disturbance-associated Woolgrass Bulrush; b) Competition related to succession (IUCN# 8.2)
iii. Fire Suppression, leading to succession, lack of flowering, and lack of establishment sites (IUCN# 7.1)

Minor, past, or potential future threats

iv. Dams and other water level alterations (IUCN# 7.2)
v. Roads and Railroads (IUCN# 4.1)
vi. Tourism & recreation areas (IUCN# 1.3)
vii. Mining & Quarrying (Peat Mining) (IUCN# 3.2)
viii. Recreation activities (IUCN# 6.1)

What additional limiting factors are relevant?

- Lack of sexual reproduction in most subpopulations limits dispersal potential via seeds

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Maine (S2) – 320 km away New Hampshire (S1) – 415 km away Massachusetts (S2) – 400 km away
Is immigration known or possible?	Not known. Possible but presumably very infrequent.
Would immigrants be adapted to survive in Canada?	Probably. Climate and ecology are very similar.
Is there sufficient habitat for immigrants in Canada?	Yes. Extensive unoccupied but apparently suitable habitat.
Are conditions deteriorating in Canada?+	Not to the point that it would significantly limit rescue effect.
Are conditions for the source population deteriorating?+	Yes, to some extent.
Is the Canadian population considered to be a sink?+	No
Is rescue from outside populations likely?	No. Rare in all U.S. jurisdictions. All outside subpopulations have limited seed production and are across a large expanse of open ocean.

Data Sensitive Species

Is this a data sensitive species? No

+ See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status

COSEWIC: Designated Special Concern in April 1994. Status re-examined and confirmed in April 2017.

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** not applicable
Reasons for designation: This globally vulnerable, long-lived wetland plant is restricted in Canada to a small region of Nova Scotia that supports nearly half of the world's population. The species is increasingly threatened by competition and shading from the invasive Glossy Buckthorn and native shrubs. Peat mining could be a future threat. Limited sexual reproduction and hybridization may also reduce survival of this sedge.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met. Projected declines do not meet thresholds.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not met. Although the EOO and IAO are below thresholds for Endangered, and the species is undergoing slow habitat declines and potential declines in IAO, the species is not severely fragmented and does not undergo extreme fluctuations in any of the subcriteria and is believed to occur at more than 10 locations.
Criterion C (Small and Declining Number of Mature Individuals): Not met. Comes close to meeting Threatened. The number of mature individuals likely exceeds thresholds. Although the lowest possible number of individuals may be 2,700, the actual number would likely exceed the threshold of 10,000. Subpopulations are small and few, if any, have >1000 individuals.
Criterion D (Very Small or Restricted Population): Not met. The number of mature individuals and the IAO exceeds thresholds. No threats are known to be severe enough to drive the species to become critically endangered in a short period of time.
Criterion E (Quantitative Analysis): Not done.

PREFACE

Long’s Bulrush was last assessed by COSEWIC in 1994. Substantial new data have since been collected on the species in Canada and in the northeastern United States. The number of occurrences known in the United States has increased significantly, primarily through targeted surveys in Massachusetts (18 new occurrences) and southern Maine (11 new occurrences). Knowledge of the species in the United States, including an increased understanding of threats and conservation needs, has been well summarized in a species’ conservation plan for New England (Rawinski 2001).

In Canada, extensive field survey has shown Long’s Bulrush to be much more frequent than had been previously documented, increasing the number of known subpopulations from nine to 37. Fieldwork in 2015 randomly selected previously unsurveyed suitable habitat and found the species in four of eight 10 km x 10 km squares visited, indicating that there are probably substantially more undocumented sites within the known Nova Scotia range (95% probability of at least 12 undocumented occurrences representing roughly that number of new subpopulations, more likely 34+, as outlined under **Sampling Effort and Methods**). Additionally, an extensive subpopulation consisting of 18 sites over 15 km x 5 km is now known in Kejimkujik National Park, and one subpopulation is known on federal land of the Wildcat First Nation in Queens County. Numerous protected areas have been designated since 1994 in southern Nova Scotia. Protected areas (including Kejimkujik National Park) are now known to support seven Long’s Bulrush subpopulations in whole and portions of four more subpopulations. There are likely additional undocumented subpopulations in provincial protected areas. The total documented population in Canada has greatly increased but quantification of the increase is difficult because of incomplete counts in earlier work.

Two new threats facing Long’s Bulrush have been identified since 1994: hybridization with a disturbance-associated relative, and invasive plants affecting habitat quality. Ron MacKay of Mount St. Vincent University and his collaborators have documented genetic evidence from two Nova Scotia subpopulations (of five sampled) of introgressive hybridization with the more common, native Woolgrass Bulrush (*Scirpus cyperinus*). These data suggest introgression may be a significant long-term threat to Long’s Bulrush in Canada, though one mitigated by limited flowering in most subpopulations. MacKay and collaborators have found an association between the frequency of hybrid genotypes in a subpopulation and the frequency of flowering, further emphasizing lack of sexual reproduction (flowering, seed production, dispersal and seedling establishment) in genetically pure Long’s Bulrush as a limiting factor. The invasive exotic shrub Glossy Buckthorn (*Frangula alnus)* is now widespread within much of Long’s Bulrush range in Nova Scotia. It is not yet having major effects on Long’s Bulrush but is likely to become more significant in future. The significance of most other threats identified in the 1994 status report has been reduced because the Canadian population is known to be larger and involves many more subpopulations, and because 13 subpopulations are now wholly or partly within protected areas.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2017)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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2017

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

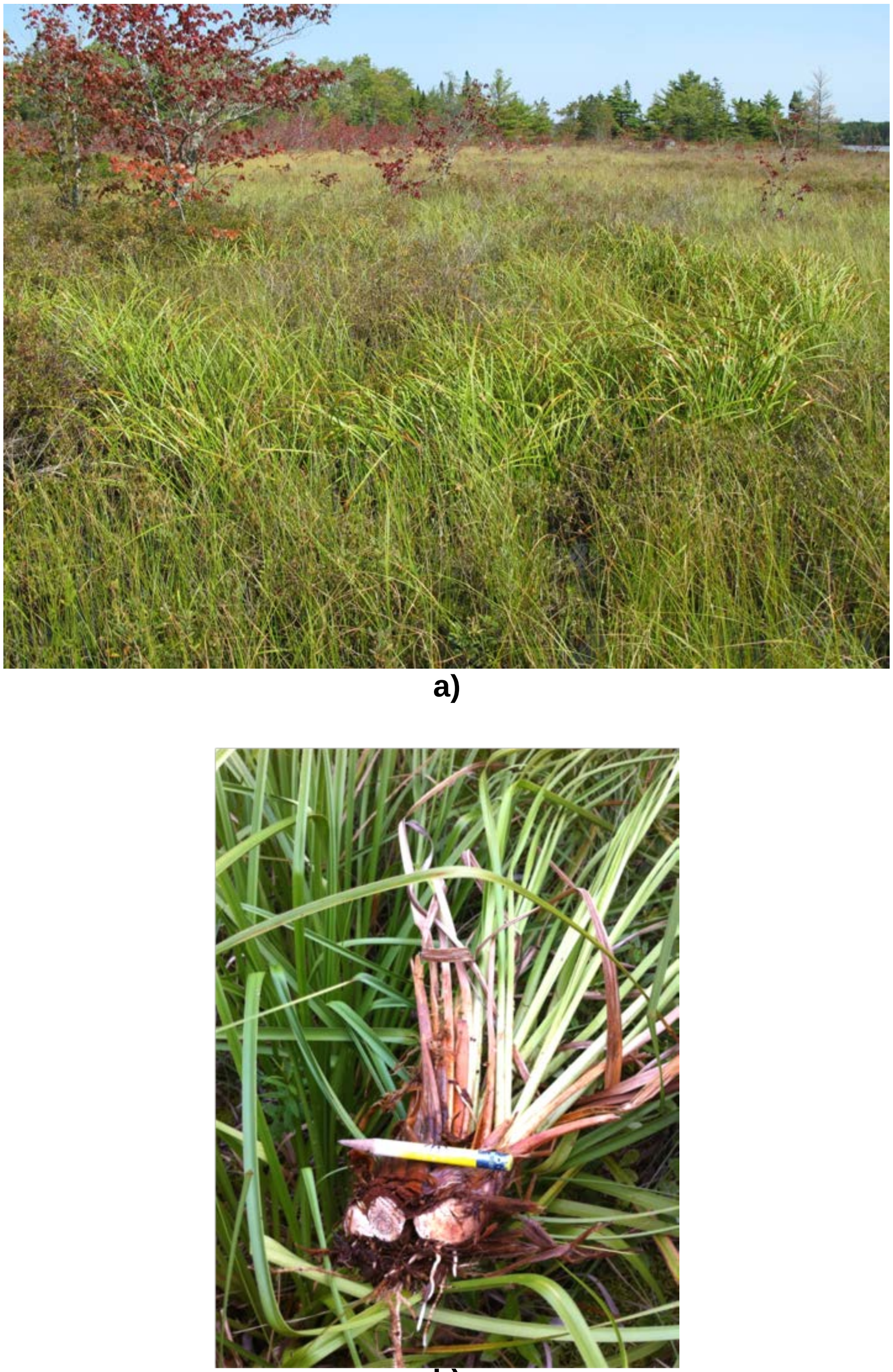
Scientific Name: *Scirpus longii* Fern.
Original Description: Fernald, M.L. (1911).
Synonym:: No published synonyms
English vernacular names: Long's Bulrush
French vernacular name: Scirpe de Long
Genus: *Scirpus*
Family: Cyperaceae
Order: Poales
Class: Commelinid clade (Angiosperm Phylogeny Group 2003)
Major plant group: Angiosperms, Monocots

The species level classification of Long's Bulrush is confirmed by comprehensive treatments of the species and its nearest relatives by Schuyler (1964) and of the narrowly defined genus *Scirpus* by Whittemore and Schuyler (2003). Long's Bulrush is most closely related to three other bulrushes within the section Trichophorum of Fernald (1950): Woolgrass Bulrush (*Scirpus cyperinus*, including the no longer recognized *S. rubricosus*), Black-girdled Bulrush (*Scirpus atrocinctus*), and Stalked Bulrush (*Scirpus pedicellatus*). Woolgrass Bulrush often hybridizes with these three relatives (Schuyler 1964; Whittemore and Schuyler 2003). Recent genetic work has found that about 80% of flowering plants sampled from New Hampshire, Massachusetts, Maine, USA and Nova Scotia, Canada have some level of genetic introgression (MacKay *et al*. 2010; MacKay pers. comm. 2016; Spalink pers. comm. 2016). The two Nova Scotia subpopulations of Long's Bulrush that exhibit frequent flowering have been shown to have extensive genetic introgression from Woolgrass Bulrush (MacKay *et al*. 2010; MacKay pers. comm. 2016). Hybridization is also known from New Jersey (Schuyler 1964), but genetic study suggests it is much less frequent (Spalink pers. comm. 2016). The two taxa are still considered valid species because F_1 hybrids are generally of low fitness (few or no viable seeds, abortive pollen and irregular chromosome pairing at meiosis; Schuyler 1964), and because genetic investigation has shown most non-flowering Long's Bulrush throughout the species' range to have no history of hybridization (MacKay *et al*. 2010; Spalink pers. comm. 2016).

Morphological Description

Long's Bulrush is a robust, perennial sedge that forms circular clones of rosette-like vegetative shoots (Figure 1) from tough, fibrous, underground rhizomes. The description below is based on Fernald (1911), Schuyler (1964), Hill (1994), and Blaney pers. obs. (2009-2015). Leaves are long (60-100 cm), narrow (not much more than 1 cm wide) and usually arching at two-thirds their length. Flowering is infrequent in most subpopulations. Flowering culms are 100-180 cm tall and are terminated by an elongate (up to about 30 cm), much-branched inflorescence made up of as many as 1,000 spikelets (Schuyler 1964) (Figure 2). The spikelets are small (<1 cm) but can contain more than 60 tiny bisexual flowers, each subtended by a blackish scale and consisting of 1-3 stamens, a single pistil with one ovule and six perianth bristles. The perianth bristles eventually become long and wrinkled, giving the inflorescence a woolly appearance at maturity. The mature achenes are reddish-brown rather than whitish to buff in related species.

Many occurrences are entirely non-flowering in any given year, a characteristic noted throughout the species' range (Fernald 1911; Schuyler 1963; Hill 1994; Rawinski 2001). Thus vegetative characteristics are crucial in identification. The large size and generally circular shape of mature clones is distinctive, caused by the uniform radial elongation of the rhizomes. Clones typically have their centres filled with shoots (i.e., leaves) when they are younger and smaller, with the central portions eventually dying back such that the larger clones (2-10+ m wide) form rings (Figure 1). Related species occur as small, dense tussocks singly or in loose patches and never form these large, circular clones. Clone shape is not always evident in sites with large numbers of Long's Bulrush. In these cases, clones can coalesce and become indistinct such that identification requires confirmation based on rhizome size and position. Long's Bulrush rhizomes are wider (usually 1.5 –3 cm diameter) than related species (usually 1-1.5 cm diameter; Hill 1994). Rhizome position (near the surface) is also useful in distinguishing Long's Bulrush from the similar Northern Beaked Sedge (*Carex utriculata*), which often occurs in the same habitats but has rhizomes well below the peat surface. Other characteristics distinguishing Long's Bulrush from Northern Beaked Sedge are small and indistinct "cells" formed by the visible venation at the base of the leaves (vs. large, distinct "cells"), leaves that spread outward from near the base rather than being erect near the base, and leaves that are more V-shaped than W-shaped in cross-section. There is overlap in size, but Long's Bulrush averages notably longer leaves, taller flowering culms and more elongate inflorescences than Woolgrass and Black-girdled bulrushes (Fernald 1911; estimated average roughly 50% larger, Blaney pers. obs. 2009-2015). Although rare in most Canadian subpopulations, flowering stems are also distinctive. Spikelets of Long's bulrush are individually pedicelled, distinguishing them from those of Woolgrass Bulrush (sessile spikelets occurring in glomerules) and the somewhat glutinous (sticky) involucre base is not seen in any related species. In pure genotypes, there is also a difference between species in length of flowering scales (2.0 – 3.1 mm in Long's Bulrush, 1.1 – 2.2 mm in Woolgrass Bulrush; Whittemore and Schuyler 2003).



a)

b)

Figure 1. a. Large Long's Bulrush (*Scirpus longii*) clone in typical lakeshore fen habitat at Ten Mile Lake, Queens County, Nova Scotia, and b. cut rhizome of Long's Bulrush, showing its thickness, from Seven Mile Lake, Lunenburg County, Nova Scotia. Photographs by Sean Blaney, AC CDC.

Figure 2. Mature Long's Bulrush (*Scirpus longii*) inflorescence, Lac de l'École, Yarmouth County, Nova Scotia. Photograph by Sean Blaney, AC CDC.

Population Spatial Structure and Variability

At the global scale, Long's Bulrush occurs in three disjunct regions (southern New Jersey, eastern New England, and southern Nova Scotia), each isolated by 300 km or more. Within regions, known subpopulations are generally somewhat isolated from each other by natural absence of suitable habitat, and in the United States, by anthropogenic habitat change. The disjunction between the two American regions of the species' range has been significantly increased by the extirpation of the species in New York and Connecticut (see **Global Range**; DeBarros pers. comm. 2016; New York Department of Environmental Conservation 2016). The Canadian population is widely spread in southern Nova Scotia, with the largest disjunction between subpopulations[1] being 32 km between the Quinan River and Bloody Creek subpopulations. As discussed under **Sampling Effort and Methods**, a substantial number of undiscovered subpopulations likely exist in between currently known occurrences, meaning that disjunction between sites is likely less than is currently documented.

There is variation in prevalence of flowering across the Nova Scotia range of Long's Bulrush, but no other morphological variation is known within plants classified as Long's Bulrush (as opposed to presumed or proven hybrids). Flowering has not been observed in most small subpopulations, although most have only been visited once and flowering in other years may have been missed. Among subpopulations with multiple visits (10 of 37 subpopulations), Lac de l'École and the Wentworth Brook northern subsite [called "Riverside" by Hill (1994) and MacKay *et al*. (2010)] are unique in consistently having widespread flowering (Figure 2). Consistent with findings across the northern part of the species' range (Spalink pers. comm. 2016), regular flowering in these subpopulations appears to be correlated with level of hybridization with Woolgrass Bulrush. These are the only two sites out of six sampled by MacKay *et al.* (2010) in which extensive introgressive hybridization was found, although a few hybrid individuals were found at two other sites (the southern "Hemlock Run" subsite of the Wentworth Brook subpopulation, and the Eel Weir Stillwater subpopulation; MacKay *et al*. 2010; see **Threats – Hybridization**). Morphologically intermediate suspected Woolgrass x Long's Bulrush hybrids have not been noted outside the Medway and Mersey river systems and Lac de l'École on the Tusket River (Atlantic Canada Conservation Data Centre [AC CDC] 2016), and the two hybrid sites were sampled by MacKay *et al*. (2010) specifically because of their frequent flowering and/or suspected hybridization. Along with documentation of limited or no hybridization at non-flowering subpopulations in Nova Scotia and elsewhere (MacKay *et al*. 2010; MacKay pers. comm. 2016; Spalink pers. comm. 2016), these data suggest that extensive hybridization may be exceptional. It is worth noting, however, that hybridization is noticeable primarily in inflorescence characteristics and is thus hard to detect by morphology in the typically vegetative subpopulations. MacKay *et al*. (2010) also document minor movement of Long's Bulrush genes into putative Woolgrass Bulrush collected near their Long's Bulrush sites (hybrid indices no greater than 0.11, where 1.0 indicates pure Long's Bulrush).

[1] Subpopulations are defined in this report as occurrences separated from others by at least 2 km if connected by water flow along a river or lake shore, or by at least 1 km of suspected unoccupied habitat if not connected by water flow along a river or lake shore.

MacKay *et al*. (2010) and subsequent investigations by Ron MacKay (Mount St. Vincent University) and Daniel Spalink (University of Wisconsin, Madison) have increased our understanding of genetic variation in Long's Bulrush. MacKay *et al*. (2010) examined variation in Long's Bulrush (three sites) and Woolgrass Bulrush (six sites) from the Medway River - Pleasant River system using 35 random amplified polymorphic DNA (RAPD) markers. They documented eight markers specific to Long's Bulrush, eight specific to Woolgrass Bulrush and 19 occurring in some individuals of both species. There was strong correlation of marker frequency among the three Long's Bulrush sites, indicating close relationships between them despite the gaps between sites of 17 km to 29 km. Nei's coefficient of genetic differentiation (F_{ST}; Nei 1977) for the three Long's Bulrush sites was 0.29, which is considered a moderate to high level of genetic variability among sampled populations.

Unpublished genetic data suggests the Nova Scotia subpopulations sampled by MacKay (Medway system and Lac de l'École) have been derived from a single colonization event originating with the Massachusetts population (Spalink pers. comm. 2016), with the Nova Scotia occurrences sufficiently isolated from the Massachusetts population to have developed a limited degree of population-level genetic differentiation (MacKay pers. comm. 2016; Spalink pers. comm. 2016). Local and range-wide genetic diversity of Long's Bulrush is significantly less than that found in adjacent Woolgrass Bulrush in all sites investigated in Nova Scotia (MacKay *et al*. 2010) and in the United States (Spalink pers. comm. 2016), as would be expected from a population that experienced a significant genetic bottleneck during glaciation (MacKay pers. comm. 2016).

Designatable Units

In Canada, Long's Bulrush is restricted to a small portion of the COSEWIC Atlantic Ecological Area in southwestern Nova Scotia, thus Canadian subpopulations should be considered a single designatable unit (DU).

Special Significance

Long's Bulrush is a globally Vulnerable (G3) species (NatureServe 2016) with a restricted global distribution. The total Canadian population includes 46% of the species' subpopulations and Canada supports a high proportion of the global population and range. The Canadian portion of the species' range also occurs within a much less disturbed landscape, with 13 subpopulations falling fully or partly within protected areas, compared to the remainder of the species' range in the United States. Canada thus has an especially high conservation responsibility for the species, which may become even more significant as development and possibly climate change further constrain its occurrence further south.

Long's Bulrush is one of a large suite of species of the United States' Atlantic Coastal Plain that are disjunct in southern Nova Scotia. Many of these species are not otherwise known in Canada or are nationally rare (Environment Canada and Parks Canada Agency 2010). Ongoing stewardship and outreach programs have raised the profile of these rare species, which are now known and appreciated by many cottagers, residents and visitors in southern Nova Scotia. Due in part to its long lifespan, Long's Bulrush is often highlighted in nature interpretation related to Atlantic Coastal Plain flora. Long's Bulrush is a locally significant, community-dominant species in some peatlands both in Nova Scotia and in its American range, where it can be the largest species present and can form a large portion of the vascular plant biomass (Hill 1994; Rawinski 2001).

Canadian subpopulations of Long's Bulrush are isolated from the nearest neighbouring occurrence in Bideford, Maine by 366 km and are at the northeastern range limit for the species. Canadian subpopulations could thus have a disproportionate significance to the species' rangewide genetic diversity (Lesica and Allendorf 1995; Garcia-Ramos and Kirkpatrick 1997; Eckert *et al.* 2008). An unpublished analysis by Daniel Spalink compared projected future climate against current climate tolerance inferred from the species' present geographic range and found that New Jersey and southern Massachusetts could be unsuitable for Long's Bulrush by 2080, but that the Canadian range will remain climatically suitable (Spalink pers. comm. 2016).

The leaves of the related Woolgrass Bulrush were used by Indigenous peoples for weaving mats and storage bags (Smith 1932). It seems likely that the longer and tougher leaves of Long's Bulrush would have also been used where available.

DISTRIBUTION

Global Range

Long's Bulrush has a very restricted global range (Figure 3), extending from southern New Jersey to southern Maine, USA with a disjunct population in southern Nova Scotia. No records are more than 70 km from the coast in any part of the species' range. Single historical occurrences known from Connecticut and New York have been lost to human development, and the species is considered possibly extirpated in Connecticut (last seen 1917, DeBarros pers. comm. 2016) and extirpated in New York (last seen 1905, New York Department of Environmental Conservation 2016). The United States range thus consists of two portions disjunct by almost 300 km: a) southern New Jersey, and b) eastern New England in Rhode Island, Massachusetts, southern New Hampshire and southern Maine. A report of Long's Bulrush from North Carolina (Fernald 1943) was based on a misidentified specimen (Whittemore and Schuyler 2003).

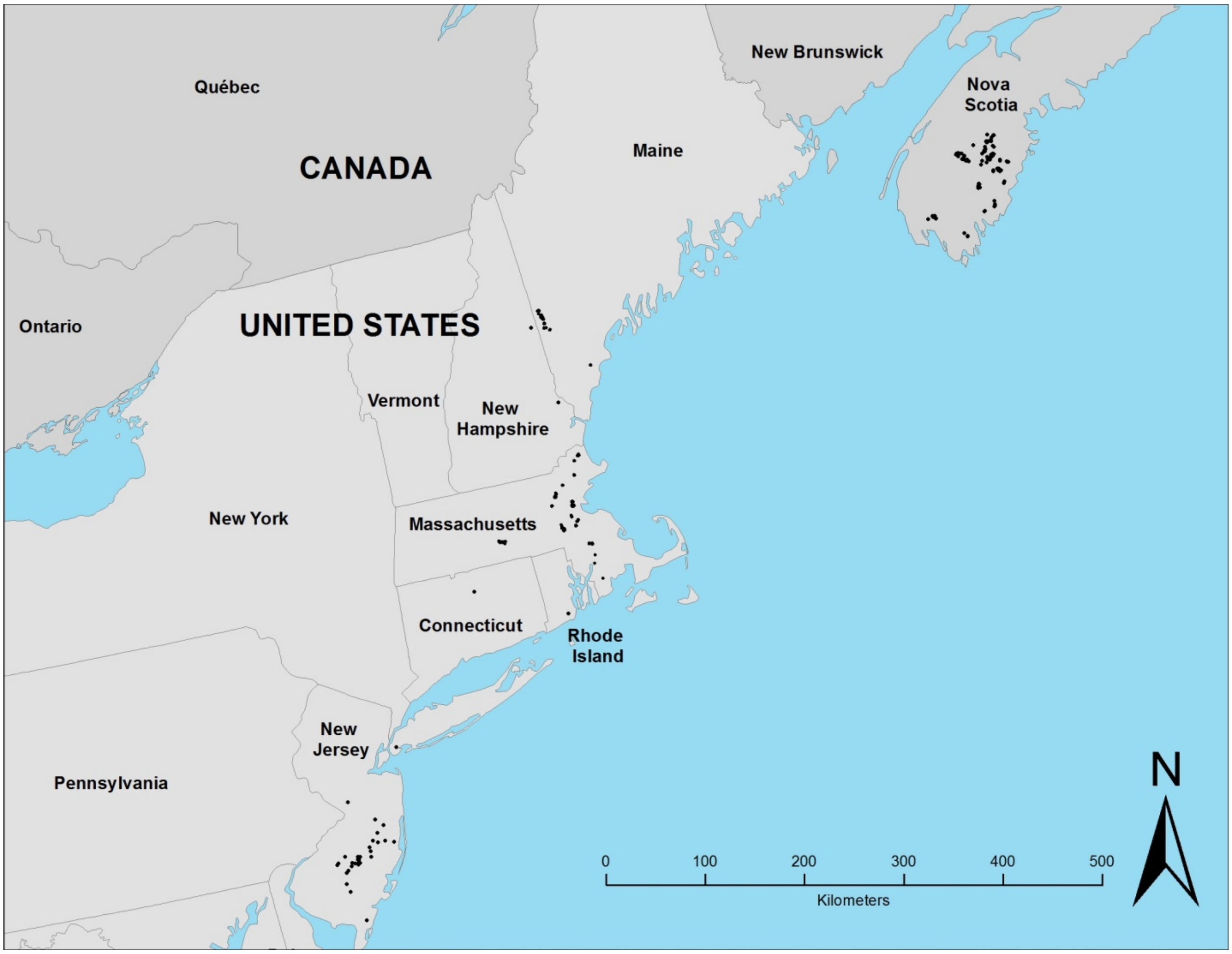
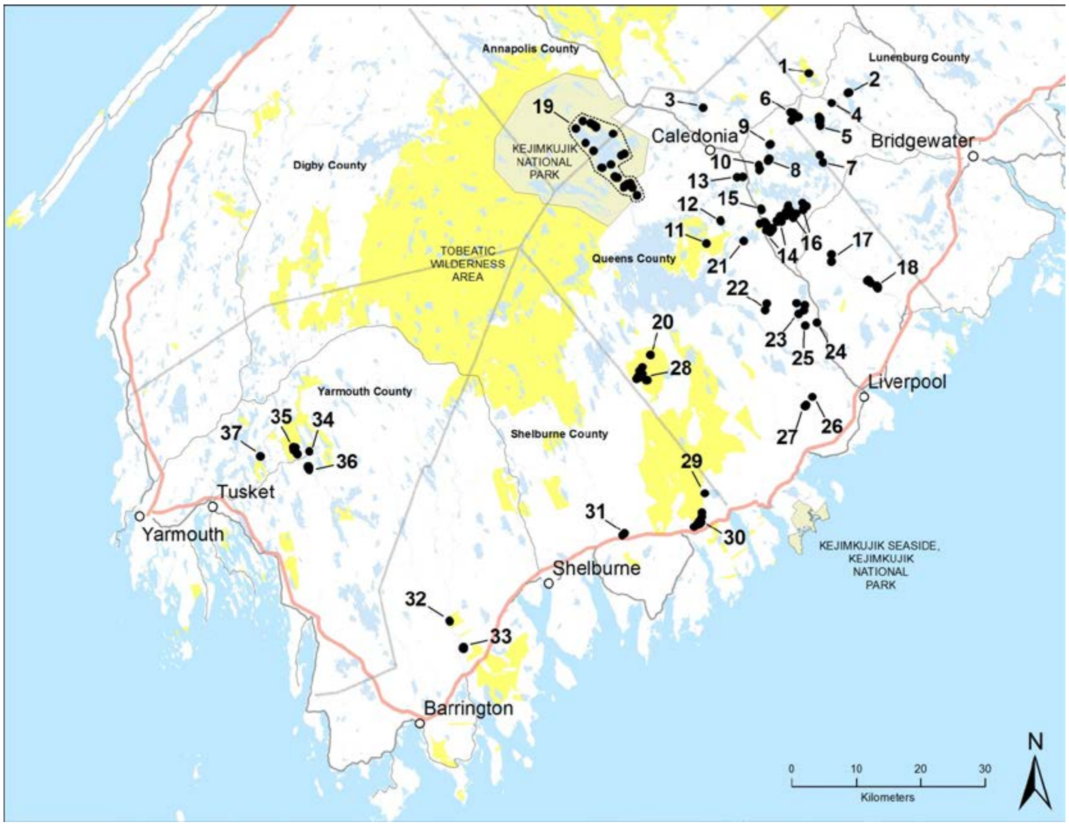


Figure 3. Global distribution of Long's Bulrush (*Scirpus longii*; black dots). Distribution in New Jersey is shown only at the county level (one square per county). Other New Jersey records are known but were not available for this report. New York and Connecticut records are historical.

Canadian Range

Long's Bulrush is known in Canada only from southern Nova Scotia, where 37 subpopulations occur in an area extending 91 km north to south, and 95 km east to west (AC CDC 2016; Figure 4). Documented occurrences are concentrated in Queens County and adjacent areas of Shelburne, Lunenburg, and Annapolis counties, with scattered occurrences known southward through Shelburne County and into Yarmouth County. As discussed under **Search Effort**, there is strong evidence that Canadian occurrences are not fully documented. The apparent concentration in the northern part of the species' Nova Scotia range may be at least in part an artefact of more intensive and directed fieldwork in that region. There has also been very little targeted fieldwork that would have been likely to detect the species north of its currently documented northern limit in Nova Scotia, so its actual range could extend northward. The currently documented northern range limit is, however, similar to that of several other plants with Atlantic Coastal Plain affinities that are widely distributed in southern Nova Scotia such as Virginia Meadow-Beauty (*Rhexia* *virginica*), Round-leaved Greenbriar (*Smilax rotundifolia*), Brookside Alder (*Alnus serrulata*), Buttonbush (*Cephalanthus occidentalis*), Goldencrest (*Lophiola aurea*), and Redtop Panic Grass (*Panicum rigidulum* var. *pubescens*; AC CDC 2016).



Mapped Subpopulations:
1) Smith Lk; 2) 7 Mile Lk; 3) McGowan Lk; 4) Barren Meadow Bk; 5) Shingle Lk; 6) Eel Weir Stillwater; 7) Molega Lk; 8) Wildcat R; 9) Hog Lk; 10) Echo Lodge; 11) Bull Moose Lk; 12) Little Rocky Lk; 13) First Christopher Lk; 14) 18 Mile Bk; 15) Moosehorn Lk; 16) Ponhook Lk; 17) Murray Meadows; 18) Wentworth Bk; 19) Kejimkujik Nat. Pk.; 20) Dunraven Bog N; 21) Little 16 Mile Bay; 22) Upper Great Bk; 23) Ten Mile Lake; 24) Six Mile Bog; 25) Lower Great Bk; 26) DeWolfe Bk; 27) Hagen Meadow; 28) Dunraven Bog S; 29) Wilkins Lk; 30) Tidney River; 31) Blue Hill Bog; 32) Bloody Ck; 33) Quinns Meadow; 34) Gilfillan Lk; 35) Lac de l'Ecole; 36) Quinan River; 37) Wilsons Lk

Figure 4. Canadian occurrences of Long's Bulrush in southern Nova Scotia. Protected areas are shaded yellow.

Extent of Occurrence and Area of Occupancy

Extent of occurrence (EOO) based on a minimum area convex polygon around documented occurrences of Long's Bulrush in Nova Scotia is 4,862 km^2. It is very likely that undocumented occurrences could boost the actual extent of occurrence over 5,000 km^2 (see **Search Effort**). However, it is much less likely that undocumented occurrences would put extent of occurrence above 20,000 km^2. For Long's Bulrush to occupy an area that large in Canada would require occurrence well outside the region of southern Nova Scotia within which species of strong Atlantic Coastal Plain affinity such as Long's Bulrush are largely restricted (Roland and Smith 1969; AC CDC 2016).

Index of area of occupancy (IAO) is 272 km^2 based on documented occurrence in 68 2 km x 2 km squares (AC CDC 2016) aligned with the Universal Transverse Mercator (UTM) 10 km x 10 km grid (Natural Resources Canada 1976, 1996). As described under **Sampling Effort and Methods**, the lower boundary of the 95% confidence interval for number of undocumented occurrences is 12 additional occurrences (48 km^2) and a conservative median value for the confidence interval around the number of additional undocumented occurrences is 34 (136 km^2), with the number of undocumented occurrences potentially higher than that to the point that the actual IAO may exceed 500 km^2.

Search Effort

Long's Bulrush is a relatively cryptic species unless one has experience identifying it (Hill 1994; Rawinski 2001; AC CDC field observations 2009-2015). Most subpopulations are entirely vegetative in any given year and are thus easily mistaken for other more common species of the sedge family. Detection often requires significant effort to access the species' wet, peaty habitats.

Early field botanists in Nova Scotia, up to Roland and Smith (1969) and their collaborators, were not sufficiently familiar with Long's Bulrush to have detected it. The only early Nova Scotia records were from Ponhook Lake and adjacent Moosehorn Lake in Queens County in 1941 by Harvard University botanist Charles Weatherby (Weatherby 1942), who knew the species from the United States. Similarly, Long's Bulrush was not found in surveys of Atlantic Coastal Plain flora on 47 southern Nova Scotia lakes (some of which are now known to support the species) by Nicholas Hill and Paul Keddy in 1988 (Hill and Johannson 1992), and in extensive AC CDC fieldwork in southern Nova Scotia between 1999 and 2009 (AC CDC 2016).

Almost all that was known of Long's Bulrush in Canada up to 1994 was a result of fieldwork by Nicholas Hill, who estimates he spent two or three weeks on targeted surveys for the species in the early 1990s, along with extensive coincidental survey with other Atlantic Coastal Plain flora fieldwork (Hill and Johannson 1992; Hill 1994, pers. comm. 2016). A few field days of survey by Duncan Bayne of Nova Scotia Nature Trust discovered two new subpopulations in the Medway River system in 2006. Subsequently, significant search effort on a variety of projects related to Atlantic Coastal Plain flora in southern Nova Scotia documented 30 new subpopulations between 2009 and 2015. These projects varied in the extent to which they covered Long's Bulrush habitat but collectively amounted to around 200 person-days. The most significant of these projects were: a) the Mersey Tobeatic Research Institute Atlantic Coastal Plain Flora Atlas project from 2011 to 2014, in which extensive Long's Bulrush data were compiled during comprehensive shoreline surveys by expert botanists on all lakes known to support COSEWIC-listed Atlantic Coastal Plain flora; b) 2011 to 2013 fieldwork by AC CDC in Kejimkujik National Park that documented three new subpopulations; c) 2010 AC CDC fieldwork for the COSEWIC Goldencrest status report (COSEWIC 2012a) in which new Long's Bulrush occurrences were documented at three of 14 lakes visited; d) 2011 AC CDC fieldwork for Environment

Canada addressing the Atlantic Coastal Plain Flora Recovery Plan Critical Habitat Schedule of Studies that documented extensive new data in and near the previously known Dunraven Bog and Eighteen Mile Brook occurrences; e) 2011 AC CDC fieldwork in the Shingle Lake Barrens that documented two new occurrences; and f) 2016 AC CDC fieldwork completing shoreline rare plant surveys on Kejimkujik Lake in Kejimkujik National Park, in which four new occurrences and some suspected hybrids plants were found. Data for all the above projects are in AC CDC (2016). Long's Bulrush was likely missed in some sites visited between 2009 and 2015, especially earlier in the period when AC CDC botanists' understanding of the species' niche was limited (Blaney pers. obs. 2009-2015).

Potential peatland habitats for Long's Bulrush are very common in southern Nova Scotia. The number of sites that have been well-searched for the species is likely in the low hundreds, while the number of sites with at least moderate potential for the species would be in the high hundreds or low thousands. It thus seems reasonable to assume that additional fieldwork will discover additional occurrences. Rationale and results of 2015 fieldwork conducted for this status report are detailed below in *Sampling Effort and Methods*.

HABITAT

Habitat Requirements

Hill and Johannson (1992) and Hill (1994) provide detailed descriptions of Long's Bulrush habitat in Nova Scotia noting that all occurrences were on peat in acidic (measured pH values of five sites 4.3 to 4.5) and nutrient-poor conditions. Despite the many new occurrences documented since 1994, the habitat breadth described by Hill has not been significantly expanded. He listed habitats in the following somewhat intergrading categories: 1) *Stillwater meadows* – peatlands bordering slow-moving, tannic (tea-coloured) streams; 2) *Fens* – small or more often large peatlands not necessarily associated with lakes or rivers, with Long's Bulrush generally in wetter, lower biomass portions with dwarfed shrubs and higher dominance of graminoids; 3) *Bay bogs* – generally smaller peatlands formed by the filling in of bays on lakes or rivers; 4) *Barrier bogs* – smaller peatlands separated from lakeshores by a ridge of gravel and boulders formed by ice movement, with the ridge causing the wetlands to retain water after lake levels drop in the summer; 5) *Lake shores* – occurrence directly on the lakeshore on thin layers of peaty muck or tightly compressed peat held together by roots, over top of gravel on broad, low-gradient shores. Lake shores are the least frequent type of occurrence (AC CDC 2016), and use of this habitat is only known in Nova Scotia from Ponhook, Little Ponhook, and Kejimkujik lakes, and Lac de l'École, all lakes downstream of large watersheds that create large fluctuations in water level. Hill (1994) suggested that lakeshore occurrences were in areas with somewhat below-average exposure to ice scour but with sufficient disturbance from ice or other factors to reduce shrub growth.

Although low shrubs (especially Sweet Gale [*Myrica gale*], and Leatherleaf [*Chamaedaphne calyculata*]; generally dwarfed by site conditions) are present in almost all Long’s Bulrush sites in Nova Scotia, limited cover of taller shrubs along with high cover of other graminoid species are common themes across all the above habitat types. A few occurrences are now known in habitats fairly densely occupied by shrubs in the range of 1 m tall and a few are in fen margins shaded by encroaching Red Maple (*Acer rubrum*), but these are exceptions and may represent individuals likely to disappear over time. Hill and Johannson (1992) note that Long’s Bulrush, like many Atlantic Coastal Plain plants in Nova Scotia, is a stress-tolerant species that is limited by competition, especially competition with shrubs. They suggest it is likely that the anaerobic conditions of saturated, seasonally flooded sites dwarf the shrubs present and limit the total shrub cover. Winter flooding may also be important in preventing freezing damage to rhizomes, as is the case in other rare Atlantic Coastal Plain species in Nova Scotia (i.e., Pink Coreopsis [*Coreopsis rosea*] and Plymouth Gentian [*Sabatia kennedyana*], Hazel 2004, Lusk and Reekie 2007).

AC CDC (2016) has 167 records from 32 (of 37) subpopulations of Long’s Bulrush with information on associated plant species. Bryophyte information is lacking, though *Sphagnum* mosses are generally dominant (Blaney pers. obs. 2009-2015). The most frequently recorded associate species, in order, are: Sweet Gale, Leatherleaf, Few-Seeded Sedge (*Carex oligosperma*), Pickering's Reed Grass (*Calamagrostis pickeringii*), Northern Pitcher Plant (*Sarracenia purpurea*), Bog Aster (*Oclemena nemoralis*), Coastal Sedge (*Carex exilis*), Bog Goldenrod (*Solidago uliginosa*), White Beakrush (*Rhynchospora alba*), Tussock Sedge (*Carex stricta*), Smooth Twig-rush (*Cladium mariscoides*), Button Sedge (*Carex bullata*), Bog Rosemary (*Andromeda polifolia* var. *glaucophylla*), Bluejoint Reed Grass (*Calamagrostis canadensis*), Dwarf Huckleberry (*Gaylussacia bigeloviana*), Sheep Laurel (*Kalmia angustifolia*), Large Cranberry (*Vaccinium macrocarpon*), Three-Way Sedge (*Dulichium arundinaceum*), Common Juniper (*Juniperus communis* var*. depressa*), Bog Laurel (*Kalmia polifolia*), Tufted Clubrush (*Trichophorum caespitosum*), and Small Cranberry (*Vaccinium oxycoccos*). There is some variation in heterospecific species composition and stature across habitat types occupied by Long’s Bulrush. Lakeshore sites include numerous species not found in other habitats (see associate species listed in COSEWIC 2009, 2012a) and are often dominated by Tall Cordgrass (*Spartina pectinata*), Switch Grass (*Panicum virgatum* var. *spissum*), Smooth Twig-Rush and Royal Fern (*Osmunda regalis* var. *spectabilis*). Meadow sites experiencing flooding from adjacent waterbodies, especially rivers, tend to be more nutrient-rich and have a higher standing biomass. Such sites have denser, taller cover of shrubs (especially Sweet Gale, also often White Meadowsweet [*Spiraea latifolia*]) and often a high cover of Canada Bluejoint and/or Tall Cordgrass, which are rare or absent in nutrient-poor peatlands (AC CDC 2016).

Habitats occupied in New England are very similar to those in Canada, with 15 of 17 fen associate species given in Rawinski (2001) either listed above or otherwise common in Nova Scotia peatlands. Rawinski (2001) also notes Long’s Bulrush occurrence in somewhat more nutrient-rich river meadow sites analagous to river sites in Nova Scotia but supporting species that in Nova Scotia tend to be restricted to richer habitats than those occuped by Long’s Bulrush such as Marsh Cinquefoil (*Comarum palustre*), Meadow Willow (*Salix petiolaris*), Sweet Flag (*Acorus americanus*), Hybrid Cattail (*Typha* x *glauca*), Broadleaved Cattail (*Typha latifolia*), and the exotic Purple Loosestrife (*Lythrum salicaria*), which Rawinski notes as a threat. The nutrient status and species composition of these sites are likely more affected by human activity than is the case in Nova Scotia, as human population densities are higher, development may be in close proximity to subpopulations, drainage patterns are often altered, and cattle grazing sometimes extends directly into Long's Bulrush habitat (Rawinski 2001).

Habitats in the New Jersey Pine Barrens share the acidic, nutrient-poor character of more northern sites and share some associate species (e.g., Button Sedge, Leatherleaf, Coast Sedge, Goldencrest; Schuyler and Stasz 1985) but are in a significantly more fire-influenced landscape that supports numerous southern species not present in Canada. In New Jersey, Long's Bulrush tends to occur on sites with shallower peat that are more susceptible to drought and intense fires burning the peat layer. Schuyler and Stasz (1985) and Snyder (pers. comm. 2016) report the rapid development and subsequent decline of a very large subpopulation on a site in Atsion, New Jersey, where an especially intense fire eliminated most of the peat layer so that plants were growing on seasonally wet sand. Long's Bulrush is also occasionally seen in artificially disturbed sites such as ditches and along trails in New Jersey (Snyder pers. comm. 2016).

Habitat Trends

Habitat availability for Long's Bulrush in Nova Scotia is relatively stable, with potential for future widespread but slow declines in habitat quality due to shading from the invasive shrub Glossy Buckthorn. All-terrain vehicle use and cottage development cause minor, local impacts on habitats. These factors are all described in greater detail under **Threats**. The peatlands and floodplain wetlands occupied by the species have relatively low development potential. There has been little recent conversion of these habitats to other uses in southern Nova Scotia, and little indication of development interest, although peat mining is a possibility, as is local drainage ditching (legal or illegal) at sites near human development.

The most significant losses of Long's Bulrush habitat in Nova Scotia have been the large areas flooded by damming for hydroelectric power generation. All relevant dams were constructed prior to 1950, outside the period relevant for this status assessment, and no plans for new hydroelectric dams are known, but if heights of existing dams were increased, additional Long's Bulrush habitat may be lost. The Mersey River system (nine known extant subpopulations) and adjacent areas have been especially affected by damming. The massive Lake Rossignol reservoir (130 km^2) on the upper Mersey River flooded eleven interconnected lakes, drowning a land area of 67 km^2 that included extensive peatland. The downstream series of five hydroelectric dams and a spillway flood all 24 km of the Mersey River between Lake Rossignol and the head of tide. Ideal peaty floodplain meadow was likely frequent in this zone historically. The upper parts of the adjacent Shelburne and Jordan River systems are also affected by this development, with several large lakes dammed at higher than natural water levels and diverted into the Mersey system to increase water availability for power generation. A large peatland system adjacent to one of these, Jordan Lake, was searched for Long's Bulrush in 2015 without success and much of what otherwise might have been good habitat appeared too wet to be ideal for the species (Blaney pers. obs. 2015). Other major flooding of potential habitat has occurred in the Tusket River system through the hydroelectric dam at Lake Vaughn and reservoir dams that have flooded Kings and Gavels lakes (just downstream of the Wilsons Lake occurrence) and Great Barren Lake (immediately upstream of the large, Quinan River occurrence discovered in 2015).

Habitat protection has significantly increased with the designation of extensive protected areas in the southwestern Nova Scotia range of Long's Bulrush. The proportion of protected area within the Long's Bulrush extent of occurrence (4,847 km^2) has risen from 4.2% in 1994 (Kejimkujik National Park only) to 26.2% today, mostly through the designation of provincial Wilderness Areas and Nature Reserves, but also through the efforts of Nature Conservancy of Canada and Nova Scotia Nature Trust (NS DOE 2016). Seven of 37 known subpopulations are now fully within protected areas and four more are partially within protected areas (see **Habitat Protection and Ownership**).

BIOLOGY

The paragraphs below draw heavily on the following references: Schuyler (1963); Schuyler and Stasz (1985); Hill and Johannson (1992); Hill (1994); Rawinski (2001); MacKay *et al*. (2010), with information supplemented from a few other published sources and from unpublished fieldwork (Blaney pers. obs. 2009-2015) by the AC CDC.

Life Cycle and Reproduction

Long's Bulrush is a clonal perennial species. Flowering is infrequent in most subpopulations and is often induced by disturbance events such as fire. Rawinski (2001) notes, "Fertile culm formation in Long's bulrush is apparently most often stimulated by stress to the plant, be it from fire, herbivory, other forms of physical damage, or prolonged flooding. If vegetative clumps of Long's bulrush are dug up in the early spring and transplanted, they usually produce fertile culms that same year (personal observation)". Flowering occurs in May and June (starting late May in Nova Scotia), earlier than in the related Woolgrass Bulrush and Black-girdled Bulrush, which flower primarily in July and into August (Fernald 1911; Hill and Johannson 1992; Rawinski 2001). Sexual reproduction occurs via wind pollination (Hill and Johannson 1992; Rawinski 2001) and possibly also by insect movement of pollen (Hill and Johannson 1992; see **Interspecific Interactions**). The bisexual flowers always have a single ovary, and have 1-3 stamens. Rawinski (2001, unreferenced) suggests that Long's Bulrush is "probably self-compatible", although the limited available information on the broadly defined genus *Scirpus* has shown significant self-incompatibility (Charpentier *et al*. 2000; Yang *et al*. 2013). Long's Bulrush seeds are mature in late July or August and can germinate in the same year (Schuyler and Stasz 1985; Rawinski 2001). Observations suggest that germination and establishment are limited unless plant and litter cover are reduced such as through grazing and fire (Schuyler and Stasz 1985; Rawinksi 2001). Passive seed dispersal from the parent plant via wind and water is mostly in late summer and autumn, but might continue into the winter if stalks remain standing. Internal or external dispersal by waterfowl (i.e., endo- and epizoochory) may be important for longer distance movement (see **Dispersal and Migration**). The Canadian population has been reported to produce fertile seed, as Hill (1994) germinated fresh, wild collected seed from Ponhook Lake in a misting chamber. In New Jersey, a small proportion of seedlings flowered within about six months after germination on an intensely burned site (Schuyler and Stasz 1985) but this would likely be very rare if it occurred at all in the shorter growing season of southern Nova Scotia. Most seeds do not germinate immediately and some likely remain in the soil seed bank. Seed banking and seed longevity have not been directly investigated but long-term seed banking could be significant for Long's Bulrush given its infrequency of flowering and the association of seedling establishment with potentially infrequent disturbances (especially fire; Schuyler and Stasz 1985). Very long term seed banking may have contributed to the rapid development of large numbers of plants after intense fire in Atsion, New Jersey (Snyder pers. comm. 2016); however, the documentation of this phenomenon in Schuyler and Stasz (1985) does not discuss seed banking, and Schuyler (pers. comm. to John Lortie, cited in Lortie 1996) believed the extensive seedling establishment was via new seed production from pre-existing occurrences (legacy clones that survived the fire) and not from the soil seed bank.

Flowering plants with proliferating spikelets, in which small plantlets develop from seed on erect flowering stems, have been observed at the Wentworth Brook subpopulation on the Medway River. Establishment of these plantlets when stems fall over is likely contributing to the site's unusual density of small clones (Blaney pers. obs. 2009-2015). Most of the apparent Long's Bulrush individuals at this site are genetic hybrids with varying degrees of introgression with Woolgrass Bulrush (MacKay 2010). Vivipary has been seen in New Jersey (Snyder pers. comm. 2016), but is not documented in the literature nor is it characteristic of other related species (Whittemore and Schuyler 2003) and it may relate to hybridization.

Typical vegetative reproduction in Long's Bulrush is via rhizome growth (0.8 cm to 2.2 cm / year; Hill 1994) and initiation of new shoots (10-13 leaves / year; Hill 1994), or by rhizome fragmentation. Leaves die back to the shoot base at the rhizome in winter. The very tough rhizomes, found at or just below the soil surface, are not easily fragmented and considerable effort is required to break them by hand (Blaney pers. obs. 2009-2015). Observed natural sources of fragmentation include ice scour on shoreline subpopulations and herbivory by Muskrat (*Ondatra zibethicus*; Hill and Johannson 1992; Rawinski 2001). Muskrats can be common in annually flooded lakeshore and river subpopulations and will feed preferentially on Long's Bulrush (Rawinski 2001). Neither Muskrats nor ice scour would be frequent in peatlands away from water bodies, where vegetative increase in the number of clones might only occur where partial rhizome mortality isolates previously connected clonal sections. Clones of Long's Bulrush can be extremely long-lived. Hill (1994) calculated the age of 5 m to 6 m diameter clones at 114 years, based on observed growth rates of 1.45 to 2.4 cm/year, suggesting that the largest circular clones (10 m diameter) were likely about 400 years old. Larger patches could be older still, if they involve single clones.

Generation time is the average age of reproductive individuals in the population. Rhizome segments capable of producing daughter shoots and capable of survival if severed from the parent plant are thus mature individuals (see **Population**). Hill (1994) carefully examined annual constrictions in rhizomes and noted that rhizomes produced intravaginal daughter shoots every 8 years (+/- 6.1 years standard deviation), and that rhizomes remain viable for up to 15 years. Generation time is thus estimated at six to ten years but could be much longer if the seed bank is taken into account.

Physiology and Adaptability

Nicholas Hill of Mount St. Vincent University and Edward Reekie of Acadia University experimentally manipulated soil nutrient levels of cultivated plants in the early 1990s and found that fertilization stimulated flowering and rhizome branching via the formation of intravaginal tillers. Fertilization did not stimulate shoot production on mature rhizomes, where dormant buds were only activated by physical damage (Hill pers. comm. 2016), an adaptive response to herbivory. Hill also experimented with removal of portions of dense ring clones in natural subpopulations and found increased shrub presence within the clones after four years (Hill pers. comm. 2016). Long's Bulrush is known to flower in response to stress from fire (Schuyler 1963), flooding (Rawinski 2001), Muskrat herbivory (Hill 1994), and transplantation (Hill 1994; Rawinski 2001). The species is classed as a pyrophyte (able to withstand or achieve a competitive advantage from fire), based primarily on greatly increased flowering and seedling establishment after fire reduced cover of competitors in the highly fire-influenced New Jersey Pine Barrens (Schuyler 1963; Schuyler and Stasz 1985).

Long's Bulrush can cope with anaerobic conditions of saturated soil and with varying water levels, including annual flooding from November to April (Hill 1994). Based on known occurrences, and the plant's absence from peatland with unnaturally high water levels upstream from dams (AC CDC 2016), it appears that it is unable to tolerate persistent flooding. Nova Scotia habitats do not dry as thoroughly in summer as some New Jersey sand plain sites (Snyder pers. comm. 2016), but can become dry to 15 cm peat depth (Hill 1994). Long's Bulrush is a species that is well-adapted to and almost exclusively restricted to low nutrient, acidic soils throughout its range (pH at five sites 4.3 to 4.5, Hill 1994; and supported by Hill and Johannson 1992; Rawinski 2001; AC CDC 2016). In the few Nova Scotia occurrences on non-peatland lakeshores, Long's Bulrush copes with heavy ice scour and wave action. As with other Atlantic Coastal Plain flora in Nova Scotia, all these stresses are likely important for the persistence of Long's Bulrush because they reduce competition from other more common plant species, especially shrubs and trees (Keddy and Wisheu 1989; Hill and Johannson 1992; Hill and Keddy 1992; Hill *et al*. 1998), in addition to stimulating flowering.

The limited global range of Long's Bulrush suggests that its climate envelope may be fairly small (although other explanations for limited range are possible). Nova Scotia occurrences are at the species' global northern limit and are restricted to the warmest region of Nova Scotia, suggesting that Canadian occurrences may be limited by cold climatic conditions. Canadian occurrences could thus be especially significant in a warmer future climate if areas supporting more southern populations were to become climatically unsuitable. Spalink (pers. comm. 2016) has modelled future climate suitability and suggested that New Jersey and southern Massachusetts will be outside the species' tolerances, as inferred by its current range, by 2080. In contrast, however, climate change was not rated as a significant threat in New Jersey, with the species scored as "Not Vulnerable – Presumed Stable" in a Climate Change Vulnerability Index analysis (Ring *et al*. 2013).

Dispersal and Migration

Long's Bulrush can accomplish small-scale movement through elongation of rhizomes. Hill and Johannson (1992) note a maximum clone size of 50 m across and they measured growth rates of 1.45 to 2.4 cm/year. Undispersed seeds can germinate from within the spikelets where mature stalks fall to the ground (Rawinski 2001) and potential for similar dispersal of plantlets in proliferating spikelets was noted in a single Nova Scotia subpopulation (Blaney pers. obs. 2009-2015; see **Life Cycle and Reproduction**). Either of these phenomena would allow dispersal of up to about 1.5 m per generation. Vegetative dispersal can also occur via rhizome fragmentation caused by either Muskrat feeding or ice action (Hill and Johannson 1992; Hill 1994; Rawinski 2001), and by subsequent movement in water. This would have the potential for dispersal on the scale of metres to kilometres, and would likely be most significant in river sites subject to strong currents during flooding.

Dispersal at the scale of 10 km or more would be most likely to occur at the seed stage, and seed production is limited in most Canadian subpopulations. Long's Bulrush achenes are very small (<1 mm), and could be moved by wind. The elongate bristles would likely tend to increase movement by wind, though they are not as clearly adapted to do so as is the case in the related cottongrasses (*Eriophorum* spp.) or clubrushes (*Trichophorum* spp.). The elongate bristles form a woolly, somewhat tangled mass within a spikelet and probably tend to disperse in small groups (Blaney pers. obs. 2009-2015). The bristles may aid in water dispersal by increasing flotation time, as is the case in some beakrushes (*Rhynchospora* spp.; Moore 1997). The relative lack of genetic differentiation between subpopulations over 17 km of the Medway River (MacKay *et al*. 2010) could indicate that movement of seeds or rhizome fragments in water are significant modes of dispersal.

Although they are not barbed as in some beakrushes (Moore 1997), the bristles may also contribute to animal-mediated dispersal by catching on fur or feathers. Waterfowl and other birds provide the most likely means of very long-distance dispersal. Woolgrass Bulrush seeds, very similar to those of Long's Bulrush, are noted as a duck food in a variety of references (e.g., Silberhorn 1995; Illinois Wildflowers 2016), but this may be a transfer of a characteristic actually related to larger seeded species, formerly in *Scirpus* but now in the genera *Schoenoplectus* and *Bolboschoenus*, which are specifically referenced in relation to internal dispersal by ducks (Mueller and van der Valk 2002; Brochet *et al*. 2010, 2012). Martin and Uhler (1939) state that Woolgrass Bulrush is "worthless as a duck food". The tiny seeds of Long's Bulrush would be readily transportable via external transport in mud on the feet or feathers of ducks (Vivian-Smith and Stiles 1994; Figuerola and Green 2002). Potential dispersal distances for bulrush seed movement by ducks has been estimated at up to 1,400 km but more typically 20 km to 30 km (based on internal movement of seeds of Hardstem and Softstem bulrush, *Schoenoplectus acutus* and *S. tabernaemontani*; Mueller and van der Valk 2002).

The traditional view on colonization of Atlantic Coastal Plain plant species into Nova Scotia (Roland and Smith 1969) is that these plants reached the province after having colonized (or having persisted throughout the period of glaciation on) land exposed by lower sea levels between present-day southern Nova Scotia and Massachusetts. This suggests a slow migration to Nova Scotia via shorter-distance, stepwise dispersal events over thousands of years. A recent evaluation (Clayden *et al.* 2009) suggests this scenario may be unlikely for southern species like Long's Bulrush because offshore land is now known to have had high boreal or arctic climate, and to have been more limited in time and space than previously believed. Thus long distance dispersal (on the scale of 350+ km between occupied areas of southern Nova Scotia and New England) may be possible for Long's Beakrush over geological time.

Interspecific Interactions

Muskrat is an important herbivore of Long's Bulrush. In lakeshore and river shore occurrences, Muskrats may feed extensively on Long's Bulrush rhizomes (Hill and Johannson 1992; Hill 1994; Rawinski 2001), primarily outside the growing season when the habitat is flooded. In the large and dense occurrence on Grassy Point on Ponhook Lake, Muskrats cut 20% of the estimated 9,000 vegetative shoots in the winter of 1990-1991 (Hill 1994; from his unpublished data). Hill (1994) notes, "Although damage may be extensive, recovery of above-ground shoot production from remaining *S. longii* rhizomes is rapid". Muskrat herbivory appears to stimulate flowering the following season. Hill (1994) noted only 24 flowering culms at Grassy Point and found that 11 of 12 examined were produced directly from the Muskrat-grazed end of a rhizome. This interaction may be significant given the limited flowering in most subpopulations and the general absence of fire, the other major stimulus of flowering, in present-day Long's Bulrush habitats. Muskrat herbivory is also significant to vegetative reproduction and dispersal because many small clones in some lake and river shore subpopulations subject to winter flooding appear to have been established via water-borne movement of rhizome fragments that are likely a product of Muskrat feeding (Hill 1994).

Insect herbivores of Long's Bulrush have not been well documented. Seed bugs (family Cymidae) in the genus *Cymus* have been recorded in Massachusetts feeding on inflorescences (Rawinski 2001). *C. luridus*, *C. angustatus*, and *C. discors* have been documented on the closely related Woolgrass Bulrush and might be expected on Long's Bulrush inflorescences. All three species are known in Nova Scotia (Maw *et al*. 2000). Other insects documented using Woolgrass Bulrush as a food source that might be expected to also use Long's Bulrush are: the weevil (family Curculionidae) *Dirabius rectirostris*, which is known in the Maritimes from the stems of Woolgrass Bulrush (Majka *et al*. 2007), the Dion Skipper (*Euphyes dion*) butterfly, the Buttonbush Owlet moth (*Ledaea perditalis*, family Erebidae; Illinois Wildflowers 2016) and the chinch bug (family Blissidae) *Ischnodemus rufipes* (Wheeler 2013). The latter three species are not known from Nova Scotia but occur within the range of Long's Bulrush in the United States. The Southern Corn Billbug (a weevil, *Sphenophorus callosus*) has been recorded from inside stems of Woolgrass Bulrush in the southern United States but is not known from Canada and does not appear to occur in states within Long's Bulrush's range (North Carolina State University 1982). However, many other congeneric species are ecologically similar economic pests of grass crops (Satterthwait 1931, cited in Wright *et al*. 1982) and some of the 21 congeneric species occurring in Canada (Bousquet *et al*. 2013) might be found in Long's Bulrush stems. Other leaf or root feeders are listed in association with Woolgrass Bulrush based on citations that only specify "*Scirpus* species". These include the leaf beetles (family Chrysomelidae) *Donacia fulgens* and *Donacia subtilis* (Marx 1957 in Harms and Grodowitz 2009), *Poecilocera harrisii* (known north at least to Massachusetts, BugGuide 2016) and *Stenispa metallica* (Riley *et al*. 2002 in Harms and Grodowitz 2009; known north to southern Maine, BugGuide 2016; neither yet known in Canada, Bousquet *et al*. 2013), the owlet moths Multicolored Sedgeminer (*Meropleon [=Oligia] diversicolor*; common in Nova Scotia, AC CDC 2016), and the Subflava and Oblong Sedge Borers (*Capsula* [=*Archanara*] *subflava* and *C. oblonga*; both known from Nova Scotia, AC CDC 2016) (McCafferty and Minno 1979 in Harms and Grodowitz 2009), and the shore fly (family Ephydridae) *Hydrellia griseola* (Lange *et al*. 1953 in Harms and Grodowitz 2009; known from Nova Scotia, Deonier 1971).

Insect pollinators are not known to be significant for Long's Bulrush and the species and its relatives are generally considered strictly wind pollinated. Nonetheless, syrphid flies have been observed on Long's Bulrush flowers in Nova Scotia (Hill 1994) and there is evidence that syrphid flies may contribute to pollination of other bulrush species (Leereveld *et al*. 1981). In addition, there is some evidence that the role of insects, particularly flies, in contributing to pollination of apparently wind-pollinated plants may be underestimated (see Pojar 1973; Larson *et al*. 2001).

Waterfowl and other birds are the most likely means of longer distance dispersal of Long's Bulrush, via the movement of seeds externally or internally. This is outlined in more detail under **Dispersal and Migration**.

Woolgrass Bulrush forms arbuscules (Cooke and Lefor 1998; Bauer *et al*. 2003), and Long's Bulrush may do so as well. Arbuscules are specialized nutrient-transfer structures on the roots, resulting from invasion of arbuscular mycorrhizal fungi into the root's cortical cells. Arbuscular mycorrhizal relationships are mutualistic interactions in which the fungi receive photosynthates via carbon-rich root exudates and plants improve their uptake of soil nutrients, particularly phosphorus, resulting in increased growth (Bauer *et al*. 2003, and references therein). Arbuscular mycorrhizal fungi require oxygen, which may be a factor in the absence of arbuscules on various species of peatland sedges in Alberta (Thormann *et al*. 1999), although some Long's Bulrush habitats may have sufficiently aerated groundwater to allow growth of mycorrhizae, as was documented in sedges of prairie fens (Turner *et al*. 2000).

Competitive interactions with other vascular plants, especially shrubs, appear to influence Long's Bulrush distribution at the local scale, with Long's Bulrush most frequent and vigorous in areas with limited cover of shrubs or herbs of the same stature as bulrush shoots (Hill and Johannson 1992; Hill 1994; Rawinski 2001; AC CDC 2016). Hill and Johannson (1992) also document exclusion and suppression of shrubs and of other herbs by Long's Bulrush clones, recording significantly reduced shrub height, shrub cover and vascular plant species diversity inside circular clones in comparison with areas immediately outside the clones. The differences were more pronounced in larger and presumably older clones. They suggest that the dense ring of shoots may prevent vegetative incursion and the network of old rhizomes and cover of Long's Bulrush leaf litter may reduce establishment of other species within the clone.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

As noted in **Search Effort**, most Long's Bulrush occurrences known prior to 2015 were documented within the previous six years and are believed to be relatively stable. The good state of knowledge of known sites and the extensive unsurveyed potential habitat in southern Nova Scotia suggested that new fieldwork should emphasize investigation of the distribution and number of undocumented occurrences rather than revisiting known sites. Fieldwork for this status report thus involved stratified random sampling of potential habitat, in addition to targeted visits to a few areas with older records.

Randomized selection of survey sites was as follows:

1) Potential Long's Bulrush range was divided into 10 km x 10 km grid squares using the UTM grid. Potential range was considered to be the area south and west of the LaHave River (the northeasternmost watershed known to support the species) in Lunenburg County, south of the northernmost occurrence (Smith Lake, Lunenburg Co.) and east of the westernmost occurrences (northwest Kejimkujik Lake, Queens Co., and Wilson Lake, Yarmouth Co.). Grid squares containing mostly ocean were excluded (some of these had suitable peatland habitat; they were excluded because limited field time

meant a limited number of squares could be surveyed, and if several coastal squares with limited land happened to be selected they might bias results), as were remote grid squares with very limited road access in Kejimkujik National Park and the Tobeatic Wilderness area. This produced a search region of 63 10 km x 10 km grid squares (Appendix 1).

2) To ensure randomly selected survey sites were spread over the whole region, this potential range was divided into eight zones of six to nine grid squares based on a 30 km x 30 km division of the survey region, and one grid square in each zone was randomly selected for survey.

3) Aerial photography of the selected grid squares was carefully examined in Google Earth for suitable open peatland habitat, and the accessible sites judged as having the highest potential for Long's Bulrush (larger peatlands, especially those near watercourses, with paler regions evident in aerial photographs indicative of graminoid dominance and limited shrubs) were searched on foot. Search effort ranged from one person-day to three person-days per square (11 days total), depending on botanist availability.

New occurrences of Long's Bulrush were found in four out of eight 10 x 10 km grid squares (Appendix 1). One of the new occurrences is part of the previously known Eighteen Mile Brook subpopulation, while the others represented four new subpopulations (one square had two separate new subpopulations). Two of the new subpopulations (Quinans River and Tom Tigney River) were among the largest known for the species. The randomized site selection allows an estimation of the number of undiscovered Long's Bulrush "occurrences". Although most of these new occurrences would represent new subpopulations, the term "occurrences" is used in this section instead of subpopulations because some new sites might be close to and thus included within already known subpopulations. If the hit rate of five new occurrences per eight grid squares were applied to the whole study area of 63 squares, there would be 39 occurrences not known prior to 2015 (34 undiscovered occurrences plus the five found in 2015 randomized fieldwork).

There are three reasons that 34 additional undiscovered occurrences should be considered a low estimate of the actual number of undiscovered subpopulations. First, not all suitable habitat in a square was searched. In all squares but one, there was substantial additional high potential habitat that could not be searched because of limited time and/or road access. Intensive effort in all surveyed squares might well produce records in up to three additional squares (so that 7 of 8 squares would have had new occurrences) and additional records in occupied squares. In other words, the rate of 5 occurrences in 8 grid squares (0.625 occurrence rate) is an underestimate. Second, the study area represented only a portion of potential Long's Bulrush range. Eleven full squares within Long's Bulrush range were excluded from the study area because of access issues and twelve squares with suitable habitat were excluded because they were primarily saltwater. Long's Bulrush is very likely to occur at least once in many of these 23 squares excluded from the 63 survey area squares. Finally, there may also be occurrences outside the known range to the northeast or northwest.

A 95% confidence interval on the number of 10 km squares in the 63 square study area that support undiscovered subpopulations can be derived following methods outlined in NIST (2012). Based on the 50% discovery rate of new Long's Bulrush occurrences per 10 km square and assuming a binomial distribution, there is a 95% probability that the actual number of 10-km squares in the 63 square study area supporting new occurrences area is between 16 and 53 (this includes the four squares in which new occurrences were discovered, thus between 12 and 49 additional squares with undiscovered new occurrences). Extrapolating the conservative observed rate of 1.25 new occurrences per occupied square would translate to 20 to 66 new occurrences (including the five new occurrences discovered in 2015, thus between 15 and 61 undiscovered new occurrences).

An additional three person-days in 2015 were spent on non-random searching of sites at or near previous records that did not have data from the past decade in AC CDC (2016). Two days were spent on the Medway River, where the Echo Lodge, Wentworth Brook and Hemlock Run occurrences were relocated, their known extent was significantly expanded and two large, new occurrences 980 m apart were discovered at Murray Meadows and Dean Brook. One day was spent on the Lower Great Brook system (near the Upper Great Brook occurrence), where two very small new occurrences were found.

Abundance

For the purposes of COSEWIC assessment the counted unit is the "mature individual", a unit capable of either vegetative or sexual reproduction, capable of survival if severed from the parental plant, and having some potential to be separated from the parent plant by natural processes (COSEWIC 2015). Under that definition, any severed rhizome segment could be a mature individual. The rhizome is not readily observable in the field, but the number of shoots[2] is a good metric for the number of segments per rhizome. Counting shoots overestimates effective population size relative to extinction risk because for any one clone the very tough rhizomes would never be fragmented segment by segment. Fragmentation may in fact be virtually absent in peatlands well away from watercourses, where Muskrat feeding and ice damage are probably absent. The number of mature individuals in a Long's Bulrush subpopulation is thus somewhere between a minimum value of the number of clones (a collection of genetically identical shoots connected by rhizomes, i.e., a genet) and a maximum value of the number of shoots, with a lower value in that range more appropriate given limited frequency of fragmentation in many sites.

[2] Shoots, or ramets, are also called rosettes by fieldworkers, because leaves on vegetative shoots all originate from the same area below the peat surface and spread outward at the base

The total number of clones in the Canadian population is roughly estimated at 2,700, with considerable uncertainty around clone numbers in the large Ponhook Lake and Eel Weir Stillwater subpopulations. The number of shoots in the Canadian population is very roughly estimated at about 718,000. As described in **Sampling Effort and Methods**, there could be undiscovered subpopulations amounting to a population equal to or larger than that currently documented. The number of mature individuals in the Canadian population is thus between 2,700 and 1,436,000, with a value toward the low end of that large range most appropriate because fragmentation is limited. If clones were strictly considered as individuals, the Canadian population (including undiscovered sites) might be less than 10,000. However, because of the potential for reproduction by fragmentation in many subpopulations, the ratio of clones to individuals should be considered somewhat less than 1:1 and the Canadian population very likely exceeds 10,000.

Hybridization is a complicating factor in assessing Long's Bulrush populations. Hybridization has been documented via species-specific RAPD markers (MacKay *et al*. 2010; MacKay pers. comm. 2016; see **Population Spatial Structure and Variability** and **Threats** – **Hybridization**). COSEWIC (2010) guidelines on inclusion of hybrid individuals are not firm, but suggest that "Where human-mediated hybridization occurs, F1 hybrids and their introgressed progeny should generally be considered a loss to the wildlife species and a threat to its persistence" (thus not included in population counts). Hybridization could be considered "human-mediated" if it occurred as a result of "...destruction or modification of suitable habitat and the removal of reproductive barriers (including geographical, physical or behavioural) that previously existed between the two genetically distinct native populations" (COSEWIC 2016). This is a marginal case because Woolgrass Bulrush would have been fairly common prior to European settlement and some hybridization has likely always occurred, but human disturbance has increased Woolgrass Bulrush abundance and may have made its average flowering time earlier thereby increasing chances of hybridization (see **Threats – Problematic Native Species**). For this report, the population values for introgressed subpopulations have been adjusted downward to reflect the fact that they are mostly composed of hybrids but do contain some genetically pure individuals (Table 1). Subpopulations with very limited hybridization or no investigation of hybridization are treated as genetically pure.

Table 1. Subpopulations of Long's Bulrush (*Scirpus longii*) in Canada, with numbers, descriptions and ownership. Many estimates of clone and shoot numbers are very imprecise. See Appendix 2 for details on their derivation. The "# Clones" and "# Shoots" values are field-based estimates expressing uncertainty where it exists. The "Rounded # Clones" and "Rounded # Shoots" values are derived from these to allow overall population estimation. The numbers of separate GPS coordinates in the AC CDC database are given in "# data points". Shaded entries (subpopulations 18 and 37) have had numbers adjusted as noted to reflect known levels of hybridization. Undiscovered subpopulations could be about as large as those documented below (see Sampling Effort and Methods).

Subpopulation	Watershed	# Clones	Rounded # Clones	# Shoots	Rounded # Shoots	# data points	Description	Ownership
1) Smith Lake	LaHave	3	3	355	355	3	3 clones over 25 m	100% Smith Lake Nature Reserve (provincial)

Subpopulation	Watershed	# Clones	Rounded # Clones	# Shoots	Rounded # Shoots	# data points	Description	Ownership
2) Seven Mile Lake	LaHave	~100?	100	prob. low 10,000s	15,000	2	1 large (130m x 5m to 20m), 1 small occurrence (10m x 1-2m), 200m apart on opposite sides of Demones Run	100% private
3) McGowan Lake	Medway	2	2	?	200	1	2 clones at single point	100% Provincial Crown
4) Barren Meadow Brook	Medway	7	7	145	145	4	7 clones over 10m	100% private
5) Shingle Lake	Medway	215	215	low 10,000s	15,000	10	4 quite isolated occurrences over 1.4 km; 1 small, 1 fairly large near lake; 2 small occurrences in fens well N of lake	almost 100% Provincial Crown
6) Eel Weir Stillwater	Medway	198+ (prob. incompletely counted)	198	prob. 100,000s or more	200,000	41	extensive occurrence over ~3.4 km of peatland and floodplain meadow fronting on Pleasant River and Shingle Lake	100% private
7) Molega Lake	Medway	21	21	?	2,100	2	2 occurrences 1.3 km apart; 1 with 5 clones, 1 with single clone	100% private
8) Wildcat River	Medway	100	100	~10,000	10,000	41	exactly 100 clones counted over 200m, plus single clone 100m downstream	100% federal
9) Hog Lake	Medway	13	13	?	1,300	2	13 clones in 2 small occurrences 100m apart	100% private
10) Echo Lodge	Medway	24	24	~360	360	20	24 clones noted in 4 separate rivershore fens over 1.2 km; probably also present in additional similar habitats upstream & downstream	100% private
11) Bull Moose Lake	Medway	7	7	?	700	1	7 clones over 57m	100% Lake Rossignol Wilderness Area

Subpopulation	Watershed	# Clones	Rounded # Clones	# Shoots	Rounded # Shoots	# data points	Description	Ownership
12) Little Rocky Lake	Medway	2	2	?	200	2	2 small clones 100m apart	100% Provincial Crown
13) First Christopher Lake	Medway	2	2	?	200	2	2 large clones (each 8m diameter) 900m apart	100% Private
14) Eighteen Mile Brook	Medway	sev 100	250	prob. 100,000s	180,000	87	extensive occurrence within 3.5km x 2.2km area	~58% Provincial Crown, 42% private
15) Moosehorn Lake	Medway	7	7	low 100s	700	2	5 clones & 2 clones at sites 140m apart	100% Provincial Crown
16) Ponhook Lake	Medway	mid-100s?	350	prob. low to mid-10,000s	25,000	74	19+ different fens or lakeshore sites occupied within an area 3.7km x 2.0km on Ponhook Lk & Little Ponhook Lk + one fen 450m up a small stream from Ponhook Lk	almost 100% private
17) Murray Meadows	Medway	41 + sev 100	300	31,000	2,100 + 29,000	27	very dense subpopulations over 90m x 70m on E side of river; 41 clones over 130m x 40m just up Murray Bk 960m south	Murray Meadows subsite 100% Provincial Crown; much larger Dean Brook subsite 100% private
18) Wentworth Brook	Medway	[16% pure out of 100s] + 78+	65	[est. 16%? out of 1000s of hybrids] + 69,000+	70,600	83	in 4 separate fens on opposite sides of the river; common to abundant over 550m x ~40m; abundant over 90m x 50m in another (extensive known hybridization here); no numbers for other sites	mostly private; three sites on Medway River Conservation Lands (NSNT)
19) Kejimkujik NP - Kejimkujik, George & Loon lakes	Mersey	93 to 95	93 to 95	low 1000s	4,500	32	16 lake & river fens + 2 lakeshore occurrences; none with very large numbers	100% Kejimkujik NP (federal)
22) Dunraven Bog North	Mersey	17	17	~500	500	11	small subpopulations in two areas separated by 600m	100% Dunraven Bog Nature Reserve (provincial)

Subpopulation	Watershed	# Clones	Rounded # Clones	# Shoots	Rounded # Shoots	# data points	Description	Ownership
23) Little Sixteen Mile Bay	Mersey	1	1	?	100	1	1 clone	100% Private
24) Upper Great Brook	Mersey	10 to 20	15	?	1,500	1	10 to 20 clones at two wetlands ~900m apart	100% Private
25) Ten Mile Lake	Mersey	4 to 5	4	100s	500	4	4 small lakeshore fen occurrences, each a single (or 2) large clone(s); well separated from one another by 0.7 km to 1.3 km	100% Provincial Crown
26) Six Mile Bog	Mersey	1	1	1	1	1	1 very small clone	100% private
27) Lower Great Brook	Mersey	1	1	13	13	1	1 clone	100% private
28) DeWolfe Brook	Five Rivers	1	1	150-200	175	1	1 clone, 6m diameter	100% Provincial Crown
29) Hagen Meadow	Five Rivers	~25	25	1000s	3,000	3	3 sites over 260m; dense occurrence over 73m, plus two smaller clones	100% Provincial Crown
30) Dunraven Bog South	Sable	107	107	~1500	1,500	14	107 clones noted in 8 areas widely spread over 2 km x 1.6 km area	100% Dunraven Bog Nature Reserve (provincial)
31) Wilkins Lake	Tidney	1	1	?	100	2	1 clone	100% private
32) Tidney River	Tidney	many 100s to 1000+	400	120,000	120,000	110	locally abundant over 2.6 km of river floodplain peatland	mostly private; some on Tidney River Wilderness Area
33) Blue Hill Bog	Ogdens Creek	100+	100	?	10,000	3	100+ clones over 700m	100% Provincial Crown
34) Bloody Ck	Clyde	~20	20	1000s	2,000	3	large clones forming patch of 0.3 ha	100% Quinns Meadow/Clyde River Conservation Lands (NCC)
35) Quinns Meadow	Clyde	~100?	100	1000s	10,000	37	fairly dense occurrence over 300m x 75m	100% private
36) Gilfillan Lake	Tusket	1	1	~400	400	1	Dense patch (1 clone?) of 2m x 2m	100% private

Subpopulation	Watershed	# Clones	Rounded # Clones	# Shoots	Rounded # Shoots	# data points	Description	Ownership
37) Lac de l'École	Tusket	est. 15% of 100s	38	est. 15% of 6,500	1,500	16	common within 300m x 375m fen; 3 other isolated small shoreline occurrences within 600m. ~85% hybrids fide MacKay (pers. comm. 2016)	75% private; 25% Lac de l'École Conservation Lands (NCC)
38) Quinan River	Tusket	41	41	4,500	4,500	38	common on both sides of river over 600m x 210m	100% private
39) Wilsons Lake	Tusket	45	86	?	4,500	5	Small subpopulation in one lakeshore fen	100% Wilsons Lake Conservation Lands (NSNT)
TOTALS			**2716**		**717,949**			

Methods used to census Long's Bulrush subpopulations in Nova Scotia have not been consistent over time. Smaller subpopulations have mostly been counted by number of clones (which are easily distinguished as distinct, isolated circular patches in most subpopulations), and sometimes with number of shoots counted as well. Larger subpopulations, especially those where clones are coalesced and indistinct, have sometimes been quantified only by area occupied. Table 1 lists Canadian subpopulations with the best available quantifications, and Appendix 2 describes population estimation methods. A large majority of the Canadian population, especially when considering number of shoots, occurs within the nine largest of the 37 subpopulations, each estimated at over 10,000 shoots, with three subpopulations estimated at 100,000+ shoots (Eel Weir Stillwater, Eighteen Mile Brook, and Tidney River). Many subpopulations are very small, with 15 having fewer than 10 clones, including 12 subpopulations with only one to three clones. It is believed most likely that no subpopulation exceeds 1,000 clones, although Tidney River could approach or potentially exceed that number.

Fluctuations and Trends

Long's Bulrush is a long-lived and slow-growing species and there is no evidence of fluctuations over the short term relevant to the application of the "extreme fluctuation" criterion for COSEWIC assessment. There is evidence of longer-term fluctuations associated with synchronous establishment after fire (Schuyler and Stasz 1985). Hill and Johannson (1992) found charcoal fragments in peat at the Eighteen Mile Brook subpopulation and suggested the site's many clones in the 5 m to 6 m size class may have established after a fire around 1890 that was mentioned by the landowner. The observed rhizome growth rate recorded at the site supported this hypothesis, producing an estimated establishment date close to the 1890s (1870s) for clones of that size (Hill and Johannson 1992).

There is little evidence of decline in the Canadian population of Long’s Bulrush in the 22 years since the previous status report (Hill 1994). All occurrences mentioned in Hill (1994) are extant, including the two occurrences (Moosehorn Lake and Ponhook Lake) first discovered in 1941 (Weatherby 1942). At most of the Hill (1994) sites (Shingle Lake, Eel Weir Stillwater, Medway River - Echo Lodge, Eighteen Mile Brook, Dunraven Bog, Quinns Meadow, and Wilsons Lake), subsequent surveys have increased known subpopulations and extended the area known to be occupied by the subpopulation, sometimes substantially as at Quinns Meadow (one site with 100 shoots in one clone in 1994 compared to 35 sites with many clones over 300 m x 85 m in 2013; AC CDC 2016) and Dunraven Bog (one site with 19 small clones in 1994; 22 sites with 124 clones over 4.3 km x 1.7 km in 2012; AC CDC 2016). The species’ documented slow rate of clonal expansion (Hill 1994) indicates that the well-established clones at these sites were likely present but missed in earlier surveys. Thus differences probably reflect increased search effort more than population increases. One subpopulation, Ponhook Lake, has some suggestion of decline since 1990. In August 2012, Nicholas Hill noted 10 sites (out of 61 total data points now known for the Ponhook Lake subpopulation from various sources; AC CDC 2016) around Grassy Point, where area occupied by Long’s Bulrush had been reduced since his 1990 work, based on his memory and/or presence of dead rhizomes (AC CDC 2016). The species is still relatively common and locally abundant within that portion of Ponhook Lake shoreline and the extent to which total numbers in the subpopulation might have been reduced is unclear.

One occurrence, Eighteen Mile Brook, has some inconclusive evidence of long-term increase. This site is an open fen bisected by provincial Highway 8, with Long’s Bulrush abundant in some areas up to the roadside. Weatherby (1942) reported the first Nova Scotia record of the provincially rare Bog Willow (*Salix pedicellaris*) from this site but did not find Long’s Bulrush. Given his discovery of the species nearby at Moosehorn Lake, it seems likely that he would have noticed the species were it as common at the site as it is presently; however, the possibility that he simply overlooked the plants cannot be discounted.

The population trend for Long’s Bulrush in the next 30 years (three times generation time) seems likely to be one of relative stability because of the long-lived nature of larger Long’s Bulrush clones and the slow-moving nature of the major threats. However, there is potential for slow decline due to shading from invasion of the exotic shrub Glossy Buckthorn or from natural succession. The widespread limitation of seed production and seedling establishment increases the significance of these threats because it limits dispersal to more suitable open localities. Hybridization seems likely to have an even more slow-moving negative effect on population size because of infrequent flowering, seed production and seedling establishment in most populations.

Rescue Effect

Although long distance dispersal was likely significant in establishing Long's Bulrush in Nova Scotia (see **Dispersal and Migration**), rescue is likely limited for the species because the Nova Scotia population is separated from the nearest documented American occurrence in York County, Maine by at least 366 km. Minimum distances to the nearest potential habitat in southernmost Nova Scotia are about 340 km from southern Maine and 415 km from northern Massachusetts. In all cases the majority of the distance is across the open ocean of the Gulf of Maine. Rescue from subpopulations in New England is further limited because of the species' rarity there, and the infrequency of flowering and seed production. Establishment in Nova Scotia from United States populations is thus likely to be extremely rare.

THREATS AND LIMITING FACTORS

Threats

Although thirteen of the 37 subpopulations of Long's Bulrush are within protected areas, they still face several widespread threats. These include invasive Glossy Buckthorn, *Frangula alnus,* which is now apparent within 15 km of 20 of the 37 subpopulations. Hybridization from introgression with the more widespread and common native Woolgrass Bulrush also poses a problem, although this may be more acute in unprotected landscapes. Due to the longevity of clones of Long's Bulrush, current threats are not expected to measurably impact population size or subpopulation occurrence for over 50 years, which exceeds the estimated timespan of three generations, and thus overall threats were calculated as Low (See Threats Calculator, Appendix 3).

<u>Invasive exotic species (8.1)</u>

The exotic shrub Glossy Buckthorn, *Frangula alnus,* is one of the most problematic invasive plant species in Canada and the northeast U.S. (Catling and Porebski 1994; Frappier *et al.* 2003a, 2003b; Catling and Mitrow 2012; IPANE 2012), and is noted as a threat to Long's Bulrush in Massachusetts (Rawinski 2001). Peaty wetlands have a well-documented susceptibility to Glossy Buckthorn invasions that create a canopy where little or no canopy cover was originally present (references below). Establishment of canopy cover would significantly impact Long's Bulrush, which is mostly known from completely open sites and which appears competitively disadvantaged in sites where canopy cover is beginning to develop (Blaney pers. obs. 2009-2015). Peaty wetland invasion by Glossy Buckthorn is known to have occurred in Wisconsin (Reinartz and Kline 1998, where it was noted as having "over-run the 1,000 ha Cedarburg Bog in 20 years"), Illinois (Taft and Solecki 1990), Michigan (Fiedler and Landis 2012), Ontario (Catling and Mitrow 2012), and Nova Scotia (Hill and Blaney 2009). Glossy Buckthorn is unusual among invasive species in Nova Scotia because although it thrives in disturbed sites, it also readily colonizes completely undisturbed sites well away from human settlement (AC CDC 2016). In the acidic wetlands in which it occurs in southern Nova Scotia, it is generally the only non-native species present (Hill and Blaney 2009; Blaney pers. obs. 2009-2015). Moreover, in the Maritimes, including along the Medway, Mersey, and Pleasant rivers where many Long's Bulrush sites occur, riparian floodplain habitats are especially susceptible to Glossy Buckthorn invasion (Blaney pers. obs. 2009-2015; AC CDC 2016).

Glossy Buckthorn is locally abundant in northern Queens County, Nova Scotia with the epicentre of the invasion around the village of Caledonia just east of Kejimkujik and with dense stands locally present and spreading within 20 km of the village (i.e., Kejimkujik National Park near entrance and at Cannon Brook, Wildcat River, Eel Weir Stillwater on the Pleasant River, Carrigan Lake, and Molega Lake; Blaney pers. obs. 2009-2015; AC CDC 2016). Eighteen of the 37 Canadian subpopulations of Long's Bulrush are in this region, and two other occurrences are just downstream on the Mersey River. Based on frequency of observation of single individuals or small groups of Glossy Buckthorn in this region (Blaney pers. obs. 2009-2015), few if any of the 18 Long's Bulrush subpopulations above would be more than a few km from Glossy Buckthorn at present. Additionally, an early stage invasion is known at Barrington in Shelburne County in southernmost Nova Scotia within 12 km to 15 km of the Quinns Meadow and Bloody Creek subpopulations (AC CDC 2016).

Based on similarity to Queens County habitats in which dense invasion of Glossy Buckthorn has been observed, the Long's Bulrush habitats most susceptible to invasion are river shore and lakeshore peatlands, and fen margins where some Red Maple cover is already present (Blaney pers. obs. 2009-2015). Subpopulations within large bogs not associated with waterbodies seem less susceptible to invasion (Blaney pers. obs. 2009-2015). Estimated susceptibility of each Long's Bulrush subpopulation to invasion is noted under **Number of Locations**.

Athough no direct impacts of Glossy Buckthorn have yet been observed in Canadian subpopulations of Long's Bulrush, well-established, dense Glossy Buckthorn occurrences are known in the immediate vicinity (<500 m) of the large Eel Weir Stillwater subpopulation and incipient invasions are known at similar distances from the Wildcat River, Echo Lodge, and Loon Lake subpopulations. Impacts may also be already occurring at undiscovered occurrences around Caledonia. There are currently no potential biological control agents for Glossy Buckthorn (Gassman *et al*. 2011) and because of lack of resources and remoteness of many areas, manual control is unlikely to check its spread in southern Nova Scotia, except perhaps in Kejimkujik National Park (Smith and Crossland pers. comm. 2016). Given the capability of Glossy Buckthorn to establish in wild habitats, its ability to jump distances on the scale of 10+ km via bird dispersal (Catling and Mitrow 2012), and its observed rate of spread in southern Nova Scotia, the entire Nova Scotia range of Long's Bulrush is likely to have Glossy Buckthorn at least locally present within about 50 years (Blaney pers. obs. 2009-2015), and the subpopulations in the most susceptible habitats closest to established buckthorn occurrences may become shaded. The extent that this will impact subpopulations is hard to determine, but once shading occurs decline may take a decade or more based on persistence of clones (in a possibly weakened state with shorter than average leaves) under partial cover of Red Maple estimated at 20+ years old at Eighteen Mile Brook (Blaney pers. obs. 2009-2015).

Rawinski (2001) identifies Purple Loosestrife and Common Reed (undoubtedly the European variety *Phragmites australis* var. *australis*) as additional invasive exotic competitors in Long's Bulrush habitat in New England, but these are very rare within the Nova Scotia range of Long's Bulrush and are not threats at present (Blaney pers. obs. 2009-2015).

Problematic Native Species (8.2) – Hybridization with Woolgrass Bulrush

Prior to 2010, hybridization of Long's Bulrush with the closely related Woolgrass Bulrush was described based on morphological characters in Massachusetts and New Jersey (Schuyler 1964), and in Nova Scotia (Hill 1994), but was suspected of being fairly uncommon. Woolgrass Bulrush is a common native species throughout the Nova Scotia range of Long's Bulrush. In undisturbed conditions it will occur on lake and river shores in proximity to Long's Bulrush, and in slightly more productive, nutrient-rich wetlands, but it tends to be absent or quite rare in the low biomass open peatlands occupied by Long's Bulrush (Hill 1994; Blaney pers. obs. 2009-2015). In addition to some spatial separation, hybridization is reduced because Long's Bulrush flowers about one month earlier than Woolgrass Bulrush (Fernald 1911; Schuyler 1963; Hill 1994).

Hybridization is an anthropogenically influenced threat (see also discussion of hybridization under **Abundance**) because Woolgrass Bulrush capitalizes on human disturbance, readily colonizing roadside ditches (including the many logging roads present throughout southern Nova Scotia outside protected areas), gravel pits and wet old fields; thus its population and its wind-borne pollen are undoubtedly more abundant at present than in pre-settlement conditions. Hybridization may be further enhanced by human disturbance if Woolgrass Bulrush in disturbed sites tends to flower earlier such that its flowering time overlaps with that of Long's Bulrush. This is likely the case because wetland plants in ditches and other exposed soil habitats are often phenologically advanced over the same species in natural shoreline and wetland habitats where early season growth is limited by inundation or cold, saturated soils (Blaney pers. obs. 2009-2015).

MacKay *et al*. (2010 and pers. comm. 2016; see **Population Spatial Structure and Variability**) found extensive hybridization using species-specific RAPD markers in two of six sites examined in Nova Scotia, and limited hybridization in two others. Sampled plants at Wentworth Brook (northern subsite) and Lac de l'École had few genetically pure Long's Bulrush among the sampled plants. At Wentworth Brook, only seven of 39 sampled plants were genetically pure Long's Bulrush and hybrid indices ($F_{ST;}$ Nei 1977) for individual plants ranged from 0.09 to 0.92, mean = 0.497 (a value of 0 indicates pure Woolgrass Bulrush and 1 indicates pure Long's Bulrush). At Eel Weir Stillwater and the southern Hemlock Run subsite of the Wentworth Brook subpopulation hybrid, genotypes were detected in three of 32 sampled individuals (hybrid indices 0.38, 0.58, 0.85). In contrast, no hybrid genotypes were detected at Eighteen Mile Brook (eight plants sampled) and Quinns Meadow (26 plants sampled). In a separate and as yet unpublished study using similar methods, some history of hybridization was demonstrated in 80% of flowering Long's Bulrush examined between Massachusetts and Maine (Spalink pers. comm. 2016).

Hybridization has been suspected at only two other Nova Scotia sites, on Molega Lake and Kejimkujik Lake in Kejimkujik National Park, where a lakeside fen has an unusual abundance and density of very large plants exhibiting characteristics more similar to Woolgrass Bulrush than to Long's Bulrush (Blaney pers. obs. 2009-2015). These plants are not listed in Table 1 because they are less morphologically similar to Long's Bulrush than plants in sites with genetically confirmed hybrids and because no genetic evidence of their hybrid origin is available. Hybridization has likely occurred at other Nova Scotia sites, but as detailed in **Population Spatial Structure and Variability**, the two significantly introgressed sites were selected for genetic study specifically because of their unusual morphology and flowering frequency, suggesting that levels of introgression documented in those sites may be exceptional for Nova Scotia. The threat caused by anthropogenically enhanced hybridization would vary by site, with occurrences in large protected areas such as Kejimkujik National Park and the Tobeatic Wilderness Area presumably having lower numbers of sites where the two species grow sympatrically. Given the longevity of Long's Bulrush clones and the infrequency of flowering events that would allow hybridization, this threat is unlikely to have substantial effects in the next one to two decades.

Fire Suppression (7.1) leading to Natural Succession (Problematic Native Species, 8.2)

As discussed under **Limiting Factors**, the naturally infrequent flowering of Long's Bulrush and resultant limitations on dispersal and establishment could be exacerbated by human-mediated fire suppression. A lack of fire seems the most likely explanation for the lack of flowering in many subpopulations across the species' range. However, although Long's Bulrush is strongly fire-associated in New Jersey (Schuyler and Stasz 1985) and would very likely benefit from increased fire in peatlands in Nova Scotia, there is inconclusive evidence that current fire frequency in Nova Scotian peatlands is greatly reduced from historical levels (i.e., that low fire frequency is a threat rather than a natural limiting factor). Even if current fire frequency in peatlands is reduced from historical levels, it is likely that impacts are only beginning to show. The relatively slow succession in peatlands and the very long-lived nature of Long's Bulrush clones mean that its current distribution and abundance could remain at least somewhat reflective of the extreme (up to 615%; see **Limiting Factors**) increases in fire frequency over natural levels associated with non-Aboriginal human settlement in eastern North America from 1760 to 1960 (Wein and Moore 1979). Thus if fire suppression is a threat, it is one that will be mostly impacting Long's Bulrush over decades into the future via natural habitat succession and increased incursion of the exotic Glossy Buckthorn.

Long's Bulrush is a species of completely or almost completely open habitats where shrub cover is reduced. Thus natural succession, involving increasing density and cover of bog shrubs (especially Sweet Gale, Leatherleaf, Sheep Laurel, Bog Laurel, and Black Huckleberry), and increasing tree cover of Red Maple, Tamarack (*Larix laricina*), Black Spruce (*Picea mariana*) and sometimes White Pine (*Pinus strobus*) is likely to result in declines in Long's Bulrush over time. Occurrence of Long's Bulrush in sites partly shaded by Red Maple is fairly frequent (e.g., portions of the Eel Weir, Eighteen Mile Brook, Shingle Lake, Echo Lodge, Wildcat River and Ten Mile Lake subpopulations; Blaney pers. obs.

2009-2015). As noted above, colony vigour at some of these sites appears to be reduced based on leaf size (Blaney pers. obs. 2009-2015). There are also several small subpopulations where Long's Bulrush clones occur amid fairly dense and comparatively tall bog shrubs where long-term succession could see loss of clones (i.e., Bull Moose Lake, Glode Point portion of Kejimkujik National Park subpopulation, Six Mile Bog, Lower Great Brook, Blaney pers. obs. 2009-2015). In the absence of fire or other disturbance, these subpopulations are likely to decline and potentially disappear. For the smallest occurrences experiencing the heaviest competition this might occur within a single generation time, but the robustness of clones and their persistence in sub-optimal conditions suggests significant decline is more likely to occur over multiple decades. Infrequency of sexual reproduction and dispersal reduces resilience of Long's Bulrush in responding to natural habitat succession, incursion of Glossy Buckthorn and other local threats.

Dams and Other Water Level Alteration (7.2)

Water level alteration is likely to change the competitive balance in Long's Bulrush habitats, potentially reducing subpopulations (Hill 1994; Rawinski 2001). Flooding by dams associated with hydroelectric development around Lake Rossignol on the upper Mersey River and on the Tusket River system has almost certainly eliminated some Long's Bulrush occurrences, given the proximity of extant occurrences to areas now flooded (see **Habitat Trends**), but there is no suggestion of major water level changes on the Mersey or Tusket river systems in the near future (Peck pers. comm. 2013).

Historically small dams associated with log driving and local industry were likely significant in flooding Long's Bulrush habitat on the Medway River (i.e., Municipality of the County of Annapolis 2016) and elsewhere, but the continued presence of the species in many floodplain meadows in the 20 km of river below Ponhook Lake suggests that Long's Bulrush has either recovered, or was able to persist because most dams were short-lived or frequently breached. Similar impacts were likely present on other rivers supporting Long's Bulrush.

Roads and Railroads (4.1)

The Reasons for Designation statement within Hill (1994) justifies the assessment of Long's Bulrush as Special Concern as follows: "Restricted range and limited sexual reproduction with significant reduction of one site due to road development". The significance of road development was likely overstated in the Reasons for Designation statement even in 1994, and the significance is much reduced now because of the discovery of many additional unaffected subpopulations. The road development issue is at the Eighteen Mile Brook subpopulation. Within the report text, Hill (1994) actually only states that the construction of provincial Highway 8 (sometime before 1941) through the occupied peatland "probably reduced" numbers at the subpopulation by increasing water levels on the upstream western side and decreasing them on the downstream eastern side, potentially resulting in increasing incursion by Tamarack and Red Maple on the east. There are numerous clones in this subpopulation at fen margins with some or significant shading by trees. These clones are likely threatened by succession over the long term, but there is no evidence that overall numbers at the subpopulation have been reduced since 1994 and there is some tenuous evidence that numbers within the Eighteen Mile Brook subpopulation have increased since 1941 when Weatherby (1942) failed to detect Long's Bulrush

Tourism and Recreation areas (1.3) – Cottage Development

As a species that only rarely occurs on lakeshores, Long's Bulrush is much less affected by cottage and residential development than are other Atlantic Coastal Plain flora Species at Risk such as Redroot (*Lachnanthes caroliniana*; COSEWIC 2009), Plymouth Gentian (COSEWIC 2012c), and Pink Coreopsis (COSEWIC 2012b). Lakeshore beach occurrences subject to development-related threats such as trampling, beach manicuring, construction of docks and swimming areas are only known within the Ponhook Lake subpopulation on Ponhook and Little Ponhook lakes. Sites adjacent to existing cottages or potential future development involve only a small number of individuals out of a very large subpopulation. The small lakeshore peatlands where larger numbers of Long's Bulrush occur are mostly left undisturbed by adjacent cottagers (Blaney pers. obs. 2009-2015), although Hill (1994) noted local mowing for skeet shooting at Grassy Point in Ponhook Lake that has not been observed in recent years. Other local impacts on lakeshore peatlands such as trail construction, dumping of yard waste, or breaching the shoreline ridges of barrier bogs to enhance drainage are sometimes observed in cottage areas (Blaney pers. obs. 2009-2015) and could affect portions of the Ponhook Lake subpopulation. Cottages are not currently in close proximity to known Long's Bulrush sites on other lakes. Based on existing development and road access, future cottage development would be most likely to come close to the species within the Molega Lake, Hog Lake, Shingle Lake, First Christopher Lake, Gilfillan Lake, and Lac de l'École subpopulations.

Mining and Quarrying (3.2) – Peat Mining

Peat mining could be a locally important future threat to Long's Bulrush habitat and subpopulations. Currently there is no peat mining within the range of Long's Bulrush, but the industry is locally established in Nova Scotia (Anderson 1993) and widely developed in New Brunswick. The extensive peatlands of southern Nova Scotia offer significant potential for mining development, with the region of densest peatland occurrence corresponding very closely with Long's Bulrush range (Anderson 1993). One past proposal for peat mining (which was denied) in Shelburne County was the critical factor in assessing Thread-leaved Sundew (*Drosera filiformis*) as Endangered (Freedman and Jotcham 2001). Long's Bulrush sites within large bogs close to major highways (Quinns Meadow and Blue Hill Bog Brook, plus similar undiscovered sites) would be most susceptible to peat mining.

Recreational Activities (6.1) – All-terrain Vehicle Use

All-terrain vehicle (ATV) use in peatlands is prevalent in southern Nova Scotia, with heavily used trails evident in aerial photography (Google Earth 2016) at many sites, especially in southern Shelburne and Yarmouth counties. ATV damage to Long's Bulrush was recorded in Quinns Meadow and Echo Lodge subpopulations by Hill (1994), who noted some flowering in response to ATV damage but suggested that negative effects of decreased competitive ability might outweigh positive effects of increased flowering. ATV damage has only been observed more recently at the Quinan River subpopulation (AC CDC 2016), where some flowering may have been initiated by the damage. This site is within a very well-used ATV route with over 20 tracks through the subpopulation visible in Google Earth (2016). Where ATV use is intense, it has the potential to eliminate individuals or small subpopulations, and might increase establishment of Glossy Buckthorn and Woolgrass Bulrush. Some ATV impacts are likely affecting undiscovered subpopulations, but ATV use does not currently appear to be having major impacts on the Nova Scotia population of Long's Bulrush as a whole.

Limiting Factors

Available habitat is not a limiting factor for Long's Bulrush in Canada. Within occupied peatlands there is often apparently suitable but unoccupied habitat and within the species' range in southern Nova Scotia, abundant apparently ideal but unoccupied habitat exists (Blaney pers. obs. 2009-2015).

The primary limiting factor for Long's Bulrush appears to be limited flowering and a resultant lack of seed production, dispersal and seedling establishment. The infrequent flowering is clearly an intrinsic characteristic of the species throughout its range, as outlined in Schuyler (1963), Schuyler and Stasz (1985), Hill and Johannson (1992), Hill (1994) and Rawinski (2001), but the extent to which lack of flowering is exacerbated by a human-caused reduction of fire frequency in Nova Scotia is unclear. The distribution of Long's Bulrush in southern Nova Scotia seems rather wide for a species that in present conditions appears to have very limited means of dispersal between watersheds. Some other rare, disjunct Atlantic Coastal Plain flora with limited seed production have much more restricted Nova Scotian ranges. Redroot has consistent but limited seed production and its occurrence in only one watershed probably stems from a single establishment event (COSEWIC 2009). Seed production is entirely lacking in Water Pennywort, *Hydrocotyle umbellata*, and its occupancy of three lakes likely resulted from two colonization events (COSEWIC 2014). Perhaps Long's Bulrush is or was much more frequently dispersed from the United States into Nova Scotia than these species, but that seems unlikely given genetic evidence pointing to a single colonization event having been responsible for occurrences near the northern (Eighteen Mile Brook) and southern (Lac de l'École) margins of its Nova Scotia range (Spalink pers. comm. 2016). The greater Nova Scotia range of Long's Bulrush suggests that there may have been a time when conditions were more favourable to seed production, dispersal (via rhizomes or seeds) and establishment within the province than they are at present.

Given the characterization of Long's Bulrush as a pyrophyte (a plant able to withstand or achieve a competitive advantage from fire) and the greatly increased flowering and extensive seedling establishment documented after fire in New Jersey (Schuyler and Stasz 1985) and suggested for the Eighteen Mile Brook subpopulation in Nova Scotia (Hill 1994), absence of fire seems a good explanation for lack of reproduction in Nova Scotia. The link is, however, hard to conclusively demonstrate. In the New Jersey Pine Barrens, Long's Bulrush occurs in a landscape and in habitats (often only a very shallow organic layer over seasonally dry acidic sand) that are much more fire-prone than Nova Scotia peatlands. Fire frequency in Nova Scotia peatlands is not well documented and fire in typical, very wet Long's Bulrush habitats is probably restricted to severe drought periods. In comparing current and past fire frequencies, it is important to note that the European settlement period experienced a very high rate of human-caused fire. The fire return interval for southwest Nova Scotia was calculated by Wein and Moore (1979) at 65 years based on 1910 and 1912 data, with high fire rates continuing up to about 1960 when fire suppression became more effective. This is 615% greater than the fire return interval of 400 years for the same region 6,600 to 2,200 years before present (Green 1976, in Wein and Moore 1979). Both rates would presumably overestimate fire frequency in wet peatlands. A slow decline may thus be occurring in Long's Bulrush subpopulations and habitat back toward pre-European conditions, unless Indigenous people had traditionally practised active peatland management using fire. Such habitat management for berry production, wildlife habitat and improved hunting conditions is well-documented in other habitats in eastern North America (Day 1953; Riley 2013), but is not specifically known in Nova Scotia peatlands.

Number of Locations

Locations are defined by the scale of the most immediate and significant threat. This is considered to be shading caused by Glossy Buckthorn invasion for 34 of 37 subpopulations. The three remaining subpopulations are most immediately threatened by encroachment of native shrubs (see **Threats**). The immediacy of threats (proximity of Glossy Buckthorn, abundance of Glossy Buckthorn in the surrounding area, sensitivity of habitat to Glossy Buckthorn invasion) and the potential for management response (which is low except in Kejimkujik National Park) vary by site and therefore each of the 37 subpopulations is considered a separate location.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In Canada, Long's Bulrush was added to Schedule 3 of the *Species at Risk Act* at the act's proclamation in 2003. This means that it had been assessed by COSEWIC as Special Concern more than two years prior to 2003. Inclusion on Schedule 3 does not confer any protection to a species, nor does it require the preparation of a management plan (Minister of Justice 2015).

Long's Bulrush has been listed as Vulnerable under the *Nova Scotia Endangered Species Act* since 2001. This status does not confer any specific protection but does require preparation of a management plan, with progress to be reviewed every five years, outlining actions required to prevent the species from becoming more at risk (NS DNR 2016).

Long's Bulrush is protected as an Endangered species under the *New Jersey Endangered and Nongame Species Conservation Act* and is also protected in areas of the state managed by the Pinelands Commission under the *Pinelands Protection Act* and in the Highlands Preservation Area under the *Highlands Water Protection and Planning Act* (New Jersey Department of Environmental Protection 2013). Long's Bulrush is Endangered under the Rhode Island *Endangered Species Protection Act* (Enser 2007), State Endangered under the *New Hampshire Endangered Species Act* (New Hampshire Natural Heritage Bureau 2013), Threatened under the *Massachusetts Endangered Species Act* (Massachusetts Natural Heritage and Endangered Species Program 2016) and is a Species of Special Concern under the *Connecticut Endangered Species Act* (a designation offering limited protection that is automatically given to species presumed extirpated, Connecticut Department of Energy and Environmental Protection 2016).

Non-Legal Status and Ranks

The Global Status of Long's Bulrush is G2G3 (Imperilled to Vulnerable), last reviewed and changed in January 2009. National status in the United States is N2 (Imperilled) and in Canada is N2N3 (Imperilled to Vulnerable, assigned January 2012) (NatureServe 2016). Subnational status ranks are SX (Presumed Extirpated) in New York, SH (Potentially Extirpated) in Connecticut, S1 (Critically Imperilled) in Rhode Island and New Hampshire, S2 (Imperilled) in New Jersey, Massachusetts and Maine, and S2S3 (Imperilled to Vulnerable) in Nova Scotia (AC CDC 2016; NatureServe 2016).

Habitat Protection and Ownership

The following nine Long's Bulrush subpopulations (numbers correspond to those in Table 1) occur fully within protected areas:

1) Smith Lake (3 clones, 355 shoots; Smith Lake Nature Reserve – provincial);

11) Bull Moose Lake (7 clones; Lake Rossignol Wilderness Area – provincial);

19) Kejimkujik National Park, Kejimkujik – George – Loon Lakes (92 clones at 18 widely spread sites; Kejimkujik National Park – federal);

20) Dunraven Bog North (17 clones, ~500 shoots; Dunraven Bog Nature Reserve –provincial);

21) Dunraven Bog South (107 clones at 8 widely spread sites; Dunraven Bog Nature Reserve – provincial);

32) Bloody Creek (dense patch 300 m x 75 m; Quinns Meadow / Clyde River Conservation Lands – Nature Conservancy of Canada);

37) Wilsons Lake (45 clones; Wilsons Lake Conservation Lands – Nova ScotiaNature Trust).

Additionally, the 100 clones in the Wildcat River subpopulation are entirely on federal land, where the site is informally protected by a community well-informed about the species.

Four additional subpopulations are partially within protected areas:

18) Wentworth Brook (3 sites with unknown numbers on Medway River Conservation Lands – Nova Scotia Nature Trust; these are potentially large occurrences given their habitat and the size of nearby sites, but they may include hybrids because they are near the Wentworth Brook hybrid site);

30) Tidney River (~7 clumps and 140 shoots out of 120,000 shoots in the subpopulation; Tidney River Wilderness Area – provincial);

35) Lac de l'École (a small number protected – about 25% of the subpopulation, which is roughly 90% composed of hybrids; Lac de l'École Conservation Lands – Nature Conservancy of Canada).

The following sites are entirely or almost entirely on provincial Crown land:

3) McGowan Lake (2 clones);
5) Shingle Lake (213 of 215 clones in four sites are on Crown land, 2 clones on private land);
11) Bull Moose Lake (2 clones);
15) Moosehorn Lake (7 clones);
17) Murray Meadows (southern subsite only, 29 clones, 2240 shoots; northern Dean Brook subsite is private);
23) Ten Mile Lake (4 or 5 clones at four widely spread sites);
26) DeWolfe Brook (1 clone); Hagen Meadow (~25 clones); and Blue Hill Bog (100+ clones).

At the Eighteen Mile Brook subpopulation (#14), 58% (42 of 73) of records are on provincial Crown land and these probably include an equivalent proportion of the very large numbers on the site. The Ponhook Lake subpopulation (#16) has one clone with 50 shoots on provincial Crown land, out of a subpopulation with tens of thousands of shoots.

There are 16 subpopulations entirely or almost entirely on private land. These include the three largest subpopulations: 6) Eel Weir Stillwater, 30) Tidney River and 16) Ponhook Lake, and the relatively large 36) Quinan River, 2) Seven Mile Lake, 10) Echo Lodge, and 33) Quinns Meadow subpopulations.

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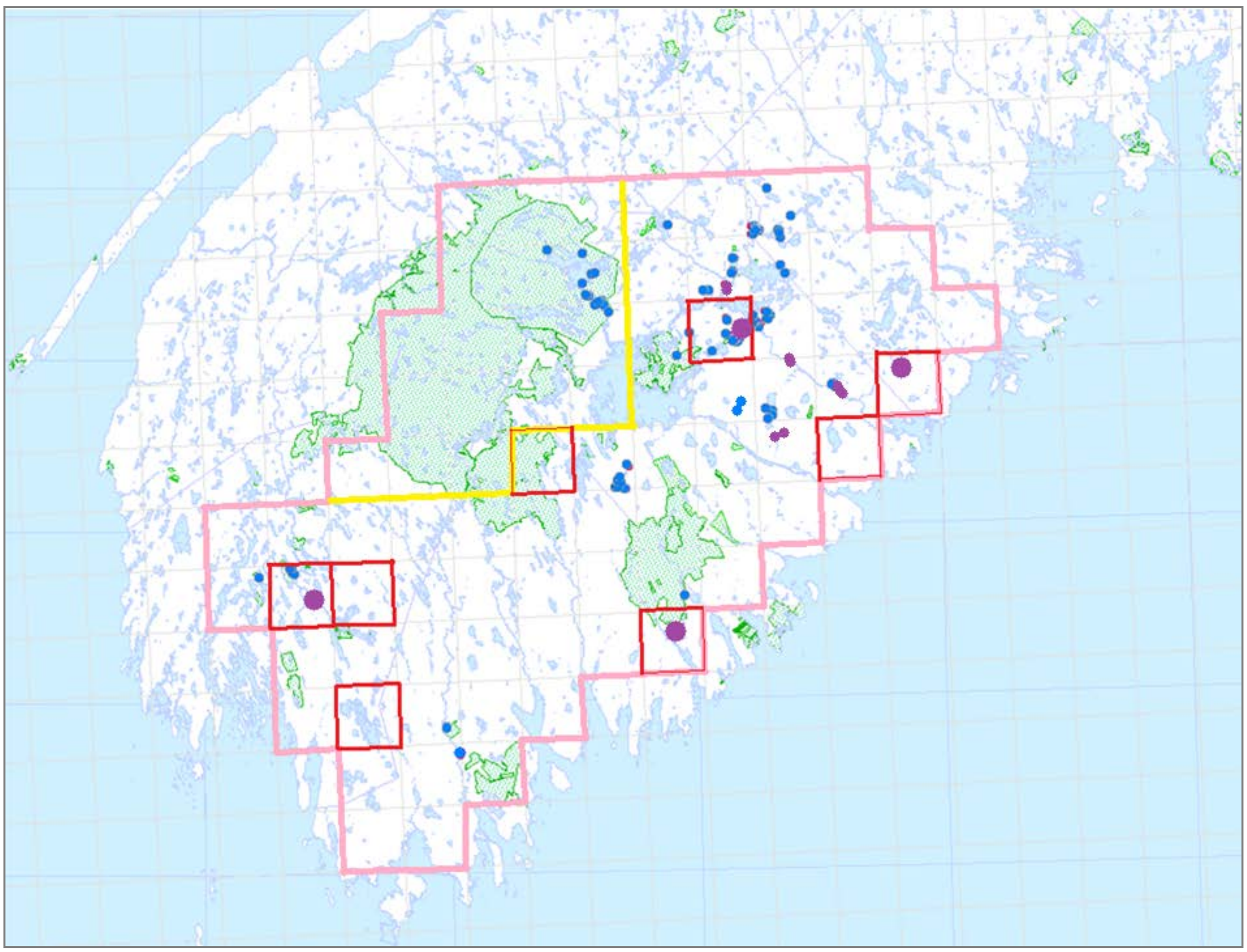
COLLECTIONS EXAMINED

All Canadian collections of Long’s Bulrush have been databased in AC CDC (2016), so no collections were examined.

Appendix 1. Survey area for 2015 fieldwork for Long's Bulrush occurrences. Blue dots are Long's Bulrush sites known prior to 2015. The pink outline represents the sampled area within the presumed potential range of Long's Bulrush, with the area in the northwest portion, outlined in yellow, being excluded because of poor road access or extensive previous coverage (eastern Kejimkujik National Park). The UTM 10 km grid is in grey and 10 km grid squares randomly selected for survey are outlined in red. Large purple dots are new Long's Bulrush occurrences found within randomly selected squares, and small purple dots are Long's Bulrush occurrences discovered in 2015 in non-random searches. Green shading indicates protected areas.



Appendix 2. How number of clones and number of shoots within those clones were derived at each subpopulation, with observers and dates of relevant counts.

Subpopulation / Observer & Count Year	Clone / Shoot Counts	Counting Methods
1) Smith Lake Sean Blaney 2010	3 clones; 355 shoots	Full, precise count of clones and shoots
2) Seven Mile Lake Sean Blaney 2014	~100? clones; prob. low 10,000s shoots	Rough estimate based on area occupied
3) McGowan Lake Brad Toms 2011	2 clones; ? shoots	Full count of clones, no count of shoots
4) Barren Meadow Brook Sean Blaney 2011	7 clones; 145 shoots	Full, precise count of clones and shoots
5) Shingle Lake Sean Blaney 2011; Nick Hill 2011	215 clones; low 10,000s shoots	Careful visual estimate of number of clones in one large occurrence, plus precise counts of clones elsewhere; very rough estimate of number of shoots
6) Eel Weir Stillwater Sean Blaney & David Mazerolle 2009	198+ clones [count likely quite incomplete]; prob. 100,000s or more shoots	Number of clones counted for many GPS points but not for entire subpopulation. Very rough estimate of shoots based on very large area occupied
7) Molega Lake Duncan Bayne 2006; Tom Neily 2010	21 clones; ? shoots	Full count of clones, no count of shoots
8) Wildcat River Sean Blaney, Shalan Joudry & Sarah Jermey 2013	100 clones; ~10,000 shoots	Precise count of clones, rough estimate of shoots based on 100 shoots/clone
9) Hog Lake David Mazerolle 2010	13 clones; ? shoots	Full count of clones, no count of shoots
10) Echo Lodge Sean Blaney & Alain Belliveau 2015	24 clones; ~360 shoots	Full count of clones, fairly precise count of shoots with some extrapolation (average number of shoots/clone) for clones without shoot counts
11) Bull Moose Lake Sean Blaney & David Mazerolle 2009	7 clones; ? shoots	Full count of clones, no count of shoots
12) Little Rocky Lake David Mazerolle 2010	2 clones; ? shoots	Full count of clones, no count of shoots
13) First Christopher Lake David Mazerolle 2010	2 clones; ? shoots	Full count of clones, no count of shoots
14) Eighteen Mile Brook Sean Blaney 2012; B. Burnie (Ron MacKay student) 2013; David Mazerolle 2015	sev 100 clones; prob. 100,000s shoots	Very rough estimate of clones and shoots; large number of shoots reflects large area occupied fairly densely plus many smaller subsites, some of which are well counted
15) Moosehorn Lake David Mazerolle 2012	7 clones; low 100s shoots	Full count of clones, no count of shoots
16) Ponhook Lake Tom Neily 2010 Sean Blaney 2010 Nick Hill 2012	mid-100s? clones; prob. low to mid-10,000s shoots	Very poorly counted for both clones and shoots and perhaps highly underestimated. Nick Hill estimated 9,000 shoots at Grassy Point. Large portions of the site have no shoot estimates.

Subpopulation / Observer & Count Year	Clone / Shoot Counts	Counting Methods
17) Murray Meadows + Dean Brook Sean Blaney & Alain Belliveau 2015	41 + sev 100 clones; 2,100 shoots + 29,000 shoots	Precise count of clones & partly counted, partly estimated (m^2 occupied x est. density) shoots at Murray Meadows subsite; Dean Bk site estimated by A. Belliveau (estimated m^2 occupied x estimated density) for shoots & very rough estimate for clones
18) Wentworth Brook + Hemlock Run Sean Blaney & Alain Belliveau 2015	~100 clones; 70,600 shoots [16% of observed total at Wentworth Brook subsite based on hybridization rates of MacKay *et al*. (2010)]	Differing methods of A. Belliveau (m^2 occupied x estimated density) and S. Blaney (number of clones x estimated average of 75 shoots/clone) produced very different results in different parts of the Hemlock Run subsite (Belliveau numbers much higher). Unsure which method best reflects reality. The Wentworth Brook subsite number of shoots was extrapolated by the same estimated density x area methods by A. Belliveau, then multiplied by 0.16 – the proportion of pure *S. longii* at the site in MacKay *et al*. (2010). The same 0.16 was multiplied by the many hundreds of clones roughly estimated at the Wentworth Brook subsite.
19) Loon Lake / George Lake, Kejimkujik NP David Mazerolle 2012; Sean Blaney & Alain Belliveau 2013; David Mazerolle & Alain Belliveau 2016	93 to 95 clones; low 1000s shoots	Full count of clones, very rough estimate of shoots
20) Dunraven Bog North Sean Blaney 2012	17 clones; ~500 shoots	Full count of clones, fairly precise count of shoots with some extrapolation (average number of shoots/clone) for clones without shoot counts
21) Little Sixteen Mile Bay Brad Toms 2009	1 clone; ? shoots	Full count of clones, no count of shoots
22) Upper Great Brook Terry Power & Steve van Wilgenberg 1993	10 to 20 clones; ? shoots	Rough count of clones, no count of shoots
23) Ten Mile Lake Sean Blaney & David Mazerolle 2009	4 to 5 clones; 100s shoots	Full count of clones, shoots roughly estimated, not counted
24) Six Mile Bog Sean Blaney 2015	1 clone; 1 shoot	Full, precise count
25) Lower Great Brook Sean Blaney 2015	1 clone; 13 shoots	Full, precise count
26) DeWolfe Brook David Mazerolle 2015	1 clone; 150-200 shoots	Full count of clones, fairly accurate estimate of shoots
27) Hagen Meadow Sean Blaney 2012	~25 clones; 1000s shoots	Full count of clones, rough estimate of shoots
28) Dunraven Bog South David Mazerolle & Sean Blaney 2012	107 clones; ~1500 shoots	Full count of clones, fairly precise count of shoots with some extrapolation (average number of shoots/clone) for clones without shoot counts
29) Wilkins Lake Ruth Newell 1999	1 clone; ? shoots	Full count of clones, no count of shoots
30) Tidney River Alain Belliveau & David Mazerolle 2015	many 100s to 1000+ clones; 120,000 shoots	No count of clones; number of shoots roughly extrapolated from patch sizes and estimated densities per m^2

Subpopulation / Observer & Count Year	Clone / Shoot Counts	Counting Methods
31) Blue Hill Bog John Klymko & Sarah Robinson 2013	100+ clones; ? shoots	Rough estimate of clones, no count of shoots
32) Bloody Creek Alain Belliveau 2010	~20 clones; 1000s shoots	Numbers estimated from memory (A. Belliveau)
33) Quinns Meadow B. Burnie (Ron MacKay student) 2013	~100? clones; 1000s shoots	Numbers very roughly estimated based on number of GPS points recorded and area occupied
34) Gilfillan Lake Nick Hill 2014	1 clone; ~400 shoots	Full count of clones, careful visual estimate of shoots
35) Lac de l'École Alain Belliveau 2011	~38 clones; ~1500 shoots [15% of observed total, based on ratio of pure *S. longii* to hybrids, MacKay (pers. comm. 2016)]	Original number of shoots (6,500) roughly extrapolated from patch sizes and estimated densities per m^2, then multiplied by 0.15 to reflect ~85% hybridity rate found by MacKay (pers. comm.). Same 0.15 x the very roughly estimated "100s" of clones, which was rounded to 250
36) Quinan River Alain Belliveau 2015	41 clones; 4,500 shoots	Full count of clones, with individual visual estimates or counts of shoots in each clone
37) Wilsons Lake David Mazerolle 2011	45 clones; ? shoots	Full count of clones, no count of shoots

Appendix 3. Threats Classification Table for Long's Bulrush

THREATS ASSESSMENT WORKSHEET			
Species or Ecosystem Scientific Name	Long's Bulrush (*Scirpus longii*)		
Element ID		Elcode	
	05/10/2016		
Assessor(s):	Nick Hill, Ron MacKay, Sean Blaney, David Mazerolle, Bruce Bennett, Jim Pojar, Dan Brunton		
References:			

Overall Threat Impact Calculation Help:		Level 1 Threat Impact Counts	
Threat Impact		high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	0	0
D	Low	2	2
Calculated Overall Threat Impact:		Low	Low
Assigned Overall Threat Impact:		D = Low	
Impact Adjustment Reasons:			
Overall Threat Comments			

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Lakeshore beach occurrences subject to development-related threats are only known within the Ponhook Lake subpopulation on Ponhook and Little Ponhook lakes (not more than 3.5% of Canadian population).
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining		Not Calculated (outside assessment timeframe)	Small (1-10%)	Extreme (71-100%)	Low (Possibly in the long term, >10 yrs)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil & gas drilling						
3.2	Mining & quarrying		Not Calculated (outside assessment timeframe)	Small (1-10%)	Extreme (71-100%)	Low (Possibly in the long term, >10 yrs)	No active peat mining proposals currently known, but peat mining is a longer-term possibility. Long's Bulrush sites within large bogs close to major highways (Quinns Meadow and Blue Hill Bog Brook, plus any similar undiscovered sites; 2.8% of Canadian population) would be most susceptible to peat mining.
3.3	Renewable energy						
4	Transportation & service corridors	D	Low	Small (1-10%)	Slight (1-10%)	High - Moderate	
4.1	Roads & railroads	D	Low	Small (1-10%)	Slight (1-10%)	High - Moderate	Hill (1994) and the 1994 Designation Statement indicated altered drainage from highway construction as a significant threat. This was because of the Eighteen Mile Brook subpopulation being bisected by a long-standing highway (probably since 1950 or earlier). Although some clones at that site are affected by shading from encroaching Red Maples that could be associated with lower water levels, there is no evidence of reduced population size on this site since 1994, and with the discovery of new occurrences elsewhere the Eighteen Mile Brook population now represents a much lower proportion of the known Canadian total. No other significant transportation corridor effects are known.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Restricted - Small (1-30%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.1	Recreational activities		Negligible	Restricted - Small (1-30%)	Negligible (<1%)	High (Continuing)	Hill (1994) noted some flowering in response to ATV damage but suggested that negative effects of decreased competitive ability might outweigh positive effects of increased flowering. ATV damage has only been observed more recently at the Quinan River subpopulation (AC CDC 2016). ATV use does not currently appear to be having major impacts on the Nova Scotia population of Long's Bulrush.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications		Unknown	Unknown	Unknown	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Unknown	Unknown	High (Continuing)	Fire frequency is reduced from unnaturally high levels in period from European settlement (~1750) to ~1950, but current rate vs. pre-settlement rate in peatland habitats is not well understood. Absence of fire can cause slow-moving (decade or decades scale) succession effects and may limit flowering frequency, thereby reducing dispersal potential from seed.
7.2	Dams & water management/use						Appears to be historical with no threats expected in the next 10 years.
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes	D	Low	Large - Small (1-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species	D	Low	Large - Small (1-70%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	Glossy Buckthorn effects are via shading, resulting in reduced vigour and likely slow loss of individuals over the decade or decades time scale. No losses yet known, but Glossy Buckthorn is extensively present in proximity to populations and rapidly spreading. Locations are determined based on Glossy Buckthorn as the most significant threat, with currently affected locations as follows: Category 1) Long's Bulrush occurrence is within 1 km of a documented population of Glossy Buckthorn, no management likely. Subpopulations (numbers correspond to those in Table 1 and Figure 4): 6 - Eel Weir Stillwater; 8 - Wildcat River; 10 - Echo Lodge. (29.3% of known Canadian population). Location Category 2) Long's Bulrush occurrence is within 1 km of a documented population of Glossy Buckthorn, with management likely. 21 - Loon Lake - Kejimkujik National Park subpopulation. (0.6% of known Canadian population). Location Category 3) No Glossy Buckthorn documented near Long's Bulrush, but within Caledonia region of frequent Glossy Buckthorn occurrence and within 15 km of documented heavy invasion in AC CDC (2016). Subpopulations: 1 - Smith Lake, 2 - Seven Mile Lake, 3 - McGowan Lake, 4 - Barren Ground Brook, 5 - Shingle Lake, 7 - Molega Lake, 9 - Hog Lake, 12 - Little Rocky Lake, 13 - First Christopher Lake, 14 - Eighteen Mile Brook, 15 - Moosehorn Lake, 16 - Ponhook Lake, 17 - Murray Meadows, 18 - Wentworth Brook. (47.6%). The proportions of individual clones affected by Glossy Buckthorn would be less than the proportions above because some habitats (especially open, non-shoreline bogs) are less susceptible to Glossy Buckthorn invasion.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species		Unknown	Unknown	Unknown	High (Continuing)	Extent of hybridization with the common and disturbance-associated Woolgrass Bulrush (*Scirpus cyperinus*) is not fully understood. Sites known to have significant introgression were selected for genetic study specifically because of their unusual morphology and flowering frequency meaning that levels of introgression documented in those sites may be exceptional for Nova Scotia. Little or no introgression was found at the few non-riverine peatland sites genetically investigated. The threat caused by anthropogenically enhanced hybridization would vary by site based on proximity to roads and other disturbances that increase Woolgrass Bulrush habitat. The longevity of Long's Bulrush clones and the infrequency of flowering that would allow hybridization means this threat is a long-term issue unlikely to have significant effects in the next one to two decades. For threat assessment here, effects of competing shrubs and trees are considered to be primarily covered under 7.1 (Fire Suppression).
8.3	Introduced genetic material						
9	Pollution						
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10	Volcanoes						
10	Earthquakes/tsunamis						
10	Avalanches/landslides						
11	Climate change & severe weather						
11	Habitat shifting & alteration						
11	Droughts						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Temperature extremes						
11	Storms & flooding						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							