MANAGEMENT PLAN FOR PROTOTYPE QUILLWORT *(Isoetes prototypus* D. M. Britton*)* IN NOVA SCOTIA

A report prepared for the Nova Scotia Department of Natural Resources and Renewables

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Cover illustration: Prototype Quillwort plant form. Photograph by Donald Cameron, available from: https://gobotany.nativeplanttrust.org/species/isoetes/prototypus/

PREFACE

Prototype Quillwort was assessed by the Nova Scotia Species at Risk Working Group in 2005 and listed as Vulnerable under Nova Scotia's *Endangered Species Act* in 2006. The national status of the species was assessed as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2005 and it was listed under Schedule 1 of the *Species at Risk Act* (S.C. 2002, c. 29) in 2006.

This Management Plan was prepared by the responsible jurisdiction, the Nova Scotia Department of Natural Resources and Renewables, in cooperation with the Nova Scotia Aquatic Species and Plants Recovery Teams. The Management Plan outlines the management objectives and actions that are deemed necessary to conserve and manage Prototype Quillwort in Nova Scotia.

Under the *Nova Scotia Endangered Species Act (2007)*, a Management Plan is defined as "…*a statement of needs and actions to be undertaken to keep a vulnerable species from becoming at increased risk.*"

This Management Plan borrows heavily from existing literature, primarily the COSEWIC *Assessment and Status Report on the Prototype Quillwort (Isoetes prototypus) in Canada* (COSEWIC 2005) and the *Management Plan for the Prototype Quillwort (Isoetes prototypus) in Canada* (Environment Canada 2012). The objectives and actions identified in this Management Plan are based upon the best available information on the species and are subject to modifications and/or revisions as new information becomes available. Management of *Vulnerable* species at risk is a shared responsibility and the collaborative approach emphasized in this document is reflective of this.

Implementation of the actions and approaches identified in this plan is subject to budget constraints, appropriations, and changing priorities.

ACKNOWLEDGEMENTS

The province contracted Katie King to draft this Management Plan in consultation with members of the Recovery Teams responsible for this species and the Nova Scotia Department of Natural Resources and Renewables.

The Department would like to thank Environment and Climate Change Canada for use of the federal Management Plan in the preparation of this document. This Management Plan was reviewed by the following members of the Nova Scotia Aquatic Species and Plants Recovery Teams:

Aquatics Recovery Team:

- Dr. Paul Bentzen
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- Shanna Fredericks
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- Andrew Lowles
- Dr. Shannon Sterling
- Dr. Kellie White

Plants Recovery Team:

- Alain Belliveau
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- Dr. Donna Hurlburt
- Dr. Jeremy Lundholm
- David Mazerolle

The Nova Scotia Department of Natural Resources and Renewables would like to thank these individuals for their contributions to the recovery of species at risk in Nova Scotia.

EXECUTIVE SUMMARY

Prototype Quillwort is a fully submerged aquatic perennial plant of small, nutrient poor, usually cold, spring-fed lakes. The species was first described in 1988 from specimens collected at Holland Lake in York County, New Brunswick. Subsequent examination of herbarium specimens and significant survey efforts in potential habitat brought the total number of known occurrences to 20; 9 in Nova Scotia, 6 in New Brunswick and 5 in Maine.

Prototype Quillwort is endemic to the Acadian region, rare in all jurisdictions where it occurs, and is one of the rarest quillwort species. Over 70% of all known occurrences and well over 90% of its recorded global population is found in Canada, with 45% of all known occurrences in Nova Scotia. It was listed as Vulnerable under the Nova Scotia Endangered Species Act and as a Special Concern species under the federal Species at Risk Act in 2006.

Prototype Quillwort is an inconspicuous and difficult species to study, and significant knowledge gaps exist with respect to the species' distribution, population levels and threats. Therefore, threats identified here are based on what is known of aquatic plants in general and other species in the genus, and the magnitude of each threat is somewhat unclear. Identified threats are shoreline development, recreational activities, water pollution, long-term alteration of site hydrology, potential competition from aquatic invasive species, and climate change.

The management objective for Prototype Quillwort is to ensure the persistence and viability of all known occurrences in Nova Scotia and to maintain or improve habitat quality for each. This is consistent with the national management objective as outlined by Environment Canada (2012). Recommended management actions for Nova Scotia include the establishment of a monitoring program to assess species abundance and distribution, supporting research to address knowledge gaps, and promoting public education and outreach to encourage stewardship and best management practices for protection of lakeshore and aquatic habitats.

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1. STATUS ASSESSMENT SUMMARY*

* The following definitions are applicable in this section and elsewhere: NSSARWG (Nova Scotia Species at Risk Working Group); NSESA (Nova Scotia Endangered Species Act); COSEWIC (Committee on the Status of Endangered Wildlife in Canada); SARA (Species at Risk Act).

Date of Assessment: November 2005 (NSSARWG)

Common Name(s): Prototype Quillwort, Spike Quillwort

Scientific Name: *Isoetes prototypus* D. M. Britton

Status: Vulnerable (NSESA)

Reason for Designation: A regional endemic with almost all of its global population in Canada. The species is an aquatic perennial with very specific habitat requirements limiting its occurrence in Canada to about 12 small, unconnected lakes, 9 of which are in Nova Scotia. The species is found in nutrient-poor, cold, spring-fed lakes. Although several lakes have been shown to contain large numbers of plants, one half of the documented sites contain small subpopulations. A wide range of potential limiting factors could impact the species, including changes in water quality, boating and shoreline development.

Occurrence: Nova Scotia occurrence: Annapolis County, Digby County, Colchester County, Cumberland County, Cape Breton County. Native to northeastern North America with the Canadian population restricted to New Brunswick and Nova Scotia.

Status History: Provincially assessed as Vulnerable in Nova Scotia by NSSARWG in November 2005. Federally assessed as Special Concern by COSEWIC in May 2005.

2. SPECIES STATUS INFORMATION

Prototype Quillwort is ranked by NatureServe as globally imperiled/vulnerable (G2), and imperiled (N2) in Canada. At the provincial level, it is considered imperiled (S2) in Nova Scotia and New Brunswick (S2) (NatureServe 2022; Table 1).

Prototype Quillwort was listed as Vulnerable under the *Nova Scotia Endangered Species Act* in 2006 and Endangered under the *New Brunswick Endangered Species Act* in 1996.

In Canada, Prototype Quillwort was assessed as Special Concern by COSEWIC in 2005 and listed as Special Concern under Schedule 1 of the federal *Species at Risk Act* (S.C. 2002, c. 29) in 2006.

Table 1. NatureServe conservation status ranks for the Prototype Quillwort in Canada (NatureServe 2022)*

Global (G) Rank[a]	National (N) Rank[b]	Subnational (S) Rank[c]
G2	N2	S2 - Nova Scotia S2 - New Brunswick

[a] G-Rank – Global Conservation Status Rank, G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure

[b] N-Rank –National Conservation Status Rank, N1 = Critically Imperiled; N2 = Imperiled; N3 = Vulnerable; N4 = Apparently Secure; N5 = Secure

[c] S-Rank – Sub-national (provincial or territorial) ranks, S1 = Critically Imperiled; S2 = Imperiled; S3 = Vulnerable; S4 = Apparently Secure; and S5 = Secure.

*More detail on NatureServe Conservation Status Rankings can be found at: http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm

3. SPECIES INFORMATION

The following information is adapted from the COSEWIC *Assessment and Status Report on the Prototype Quillwort (Isoetes prototypus) in Canada* (COSEWIC 2005) and the federal *Management Plan for the Prototype Quillwort (Isoetes prototypus) in Canada* (Environment Canada 2012).

Note that terminology has been updated to reflect current standards and use of “population”, “subpopulation” and “occurrence” follow COSEWIC and NatureServe definitions (COSEWIC 2019; NatureServe 2020). As such, “population” refers to the entire Nova Scotia population, and “subpopulation” and “occurrence” are used interchangeably; each lake where the species is presently known to exist in Nova Scotia is considered to contain one distinct subpopulation or occurrence.

3.1. Species Description

Prototype Quillwort is a perennial, submerged aquatic species of quillwort, an ancient order of spore-bearing vascular plants. As in other species in the genus, Prototype Quillwort plants mainly consist of a small dense rosette of narrow quill-like leaves. The 10 to 25 (rarely to 75) leaves typically range from 4 to 12 cm in length, forming a dense clump from a bilaterally symmetrical two-lobed (rarely three-lobed) corm at the base. The leaves are very straight, rigid, quill-like and brittle and will often break when pressure is applied by pushing downward on their tips. The leaves abruptly taper from a swollen base and then gradually taper to a sharp tip.

Viewed from above, large plants have oval-shaped crowns measuring 8.5 x 20 cm. The leaves are mainly dark green except for a reddish brown or chestnut-coloured base. Spores (which are important in identification of quillworts) are borne in the swollen bases of the leaves. The female spores (called megaspores) are white, 425 to 575 µm (averaging 500 µm) in diameter, and fairly smooth, with low meandering markings sometimes reduced to molded mounds, and very pronounced triradial (three-spoked) and equatorial ridges. The ornamentation continues to the equatorial ridge (the “girdle”). The microspores are pale brown, lenticular, 23 to 32 µm in length and covered with a complex network of spinulose fibres. Spores mature in summer. Prototype Quillwort identification is most reliably based on megaspore morphology and chromosome numbers. Based on spore morphology, *Isoetes prototypus* is most likely to be confused with *I. acadiensis* and the “*I. hieroglyphica*” morphological variant of *I. lacustris*.

3.2. Population and Distribution

An endemic of northeastern North America, Prototype Quillwort is rare in all jurisdictions in which it occurs. The species was first discovered in New Brunswick in 1988 at Holland Lake in York County (Britton and Goltz 1991). Through the examination of herbarium specimens and subsequent survey efforts in potential habitat, a number of additional occurrences have since been discovered. The species is presently known from twenty lakes worldwide, fifteen of which are in Canada and nine in Nova Scotia (see Figure 1).

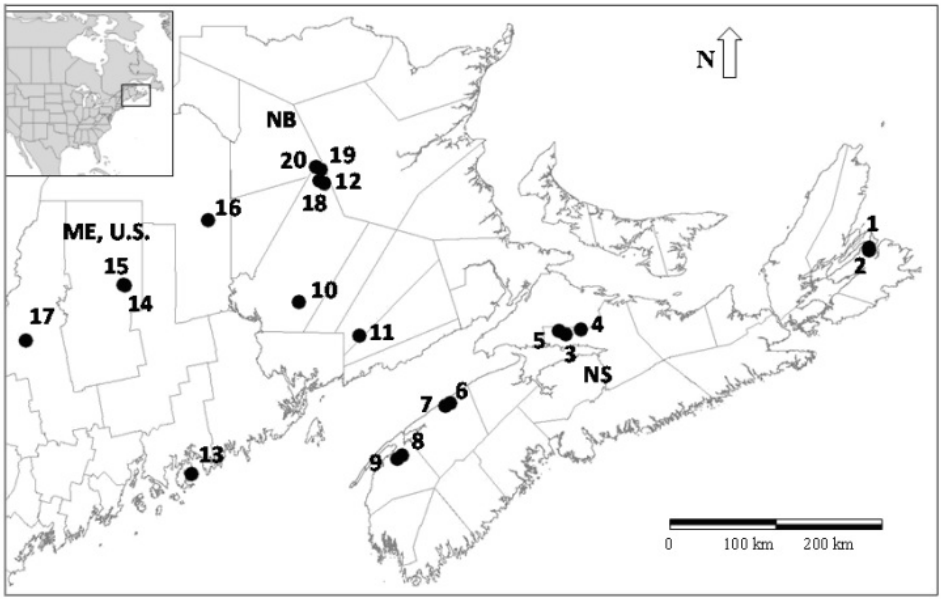

Figure 1. Global distribution of Prototype Quillwort (Environment Canada 2012). Lakes in Nova Scotia are: 1. Pottle Lake, 2. Johnson Lake, 3. Economy Lake, 4. Sutherland Lake, 5. Simpson Lake, 6. Sand Lake, 7. Rumsey Lake, 8. Mallette Lake and 9. Amirault Lake.

3.2.1 Population Size and Trends

The only available population estimates for Prototype Quillwort in Canada are from fieldwork conducted in 2003 and 2004 for the COSEWIC Status Report (COSEWIC 2005). At that time, the species was observed in situ in all previously known sites, and subpopulations seemed to be abundant at half of the sites. The Canadian population was estimated at about 250,000 individuals, with about 25,000 or 10% in Nova Scotia. It was noted that this was a very conservative estimate, however, because the species forms dense mats with up to 392 plants per square meter, making visual counts difficult. The total surface area of lakes in which the species occurs is nevertheless quite small.

The global extent of occurrence for the species is approximately 105,000 km^2, with over 70% of this area within Canadian territory (COSEWIC 2005). The Nova Scotia extent of occurrence and index of the area of occupancy are 11,769 km^2 and 56 km^2, respectively.

Of the nine lakes where Prototype Quillwort occurs in Nova Scotia, almost 95% of the individuals are in two lakes, Pottle Lake in Cape Breton County Sutherland Lake in Cumberland County (Table 2).

Because none of the known sites of the species has been monitored for changes in subpopulation size, long-term trends are unknown.

Table 2. Prototype Quillwort subpopulation estimates in Nova Scotia (data from COSEWIC 2005). Lake # corresponds to the map in Figure 1; # Individuals shows the estimated number of individual plants, and Percentage (%) is the percentage of the Nova Scotia population.

Lake #	Lake	County	# Individuals (Estimate)	Percentage (%)
1	Pottle Lake	Cape Breton	13,061	52.15
2	Johnson Lake	Cape Breton	120	0.48
3	Economy Lake	Colchester	202	0.81
4	Sutherland Lake	Cumberland	10,400	41.53
5	Simpson Lake	Colchester	20	0.08
6	Sand Lake	Annapolis	1,000	3.99
7	Rumsey Lake	Annapolis	100	0.40
8	Mallette Lake	Digby	40	0.16
9	Amirault Lake	Digby	100	0.40
Total			**25,043**	**100**

3.3. Species Needs

3.3.1. Habitat Needs

Prototype Quillwort is a submerged aquatic plant of small, oligotrophic (nutrient poor), usually cold, spring-fed lakes. Elevation seems to be a significant habitat factor or correlate, with all known occurrences except for the two Cape Breton lakes at elevations over 200 m. The pH of known lakes ranges from 5.7 to 7.3 and water was clear to fairly clear at all but one lake in 2003-2004 (COSEWIC 2005). Known lakes are typically quite shallow, ranging from 3.5 to 12.2 m in maximum depth. Prototype Quillwort occurs in 1.5 m to 2.5 m of water (minimum and maximum 0.4 m and 4.0 m), often near drop-offs. It most often occurs in soft, flocculent oozy sediment where a swimmer's foot or hand could easily sink 5 to 30+ cm. This sediment is usually found overlying a sandy, gravelly, or rocky bottom. According to Brunton (pers. comm. to Jim Goltz in 2004, cited in COSEWIC 2005), the species is "quite strongly tied to ponds on small sand plain deposits and most probably in post-glacial outwash systems". No other relationship of this species with bedrock or surficial geology or soil type has been suggested. Common Pipewort (*Eriocaulon aquaticum*) is found near all known occurrences and other frequent associates include Lake Quillwort (*Isoetes lacustris*), Water Lobelia (*Lobelia dortmanna*) and Slender Water-Milfoil (*Myriophyllum tenellum*).

3.3.2. Biological Needs and Ecological Role

At the lakes in which it occurs, Prototype Quillwort can be among the most abundant vascular aquatic plant species, comprising 20-50% of biomass within the mats of vegetation where it is present, and forming a large part of the windrows of flotsam that

sometimes wash up on shores. Little else is known of its biological needs or ecological role.

3.3.3. Limiting Factors

It is unclear why Prototype Quillwort is not at least somewhat more widespread. Within the lakes in which it occurs it generally appears to be a reasonably successful competitor. It has no clear dispersal limitations, and its dispersal potential appears similar to other more common quillwort species that are nearly ubiquitous in suitable habitat throughout the same region. Other *Isoetes* species have been found to require birds and other animals as long-distance dispersal vectors (Troia 2016), but there has been no research to confirm if this is the case for Prototype Quillwort. Its apparently restrictive habitat requirements (cold, clear, shallow oligotrophic lakes with a specific pH range) potentially significantly limit the number of lakes in which the species could occur, but they do not fully explain its restricted distribution. Perhaps a very limited survival through the Wisconsinian glaciation has limited post-glacial recolonization. Within a lake, water depth and substrate type are obvious limiting factors for Prototype Quillwort as the species shows a limited optimum range of 1.5 m to 2.5 m depth and a strong affinity to flocculent ooze over sand or gravel.

Nothing is known of predation, disease or other additional potential limiting factors.

4. THREATS

4.1. Threat Assessment

The Prototype Quillwort threat assessment (Table 3) is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threat classification system (IUCN 2012). Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (in this case, the province of Nova Scotia). Limiting factors are not considered during this assessment process. For purposes of the threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats are presented in Section 4.2 *Description of Threats*.

Table 3. Threat calculator assessment.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
1	Residential & commercial development	Unknown	Unknown	Serious	High	
1.1	Housing & urban areas	Unknown	Unknown	Serious	High	The majority of lakes in Nova Scotia that are known habitat for Prototype Quillwort have houses or cottages on some or all of their shoreline (Environment Canada 2012) and demand for lakeshore property development continues to rise. While data are lacking to understand the impacts of shoreline development and human activity on this plant, it can be assumed that direct effects of construction on shoreline and shallow water habitat (e.g., clearing, infilling, rock walls, etc.) would result in destruction of plants. It is not known what proportion of the population is likely to be affected by development, therefore scope

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						is rated unknown and severity is serious. [Indirect effects of development such as sedimentation and water pollution are covered under 9.1].
1.2	Commercial & industrial areas					Not applicable.
1.3	Tourism & recreation areas	Unknown	Unknown	Serious	High	Shoreline development of recreational structures associated with houses and cottages including docks and boat launches has the potential to directly affect Prototype Quillwort. As in section 1.1, it is not known what proportion of the population is likely to be affected, therefore scope is rated unknown and severity is serious.
2	Agriculture & aquaculture	Negligible	Negligible	Unknown	Unknown	
2.1	Annual & perennial non-timber crops					Not applicable.
2.2	Wood & pulp plantations					Not applicable.
2.3	Livestock farming & ranching	Negligible	Negligible	Unknown	Unknown	There is limited agricultural activity near lakes where Prototype Quillwort occurs, however there are several mink farms in Digby County, including one approximately 300 m from Mallette Lake. This lake contains less than 1% of the known population and it is not known what impact, if any, the presence of the farm has on this species.
2.4	Marine & freshwater aquaculture					Not applicable.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
3	Energy production & mining					
3.1	Oil & gas drilling					Not applicable.
3.2	Mining & quarrying					Not applicable.
3.3	Renewable energy					Not applicable.
4	Transportation & service corridors	Unknown	Small-Restricted	Unknown	High	
4.1	Roads & railroads	Unknown	Small-Restricted	Unknown	High	Encroachment upon lake borders by roadways and causeways may pose a threat to Prototype Quillwort, including activities associated with road and culvert construction, use, and maintenance (Environment Canada 2012). Shoreline highway and/or causeway development is present at Pottle, Johnson and Rumsey Lakes, which represent >90% of the Prototype Quillwort population but the proportion of plants impacted in each lake and the nature of impacts from road maintenance activities are unknown, therefore scope is presented as a range (small-restricted) and severity is unknown. [Indirect effects of road construction and maintenance (e.g., sedimentation, runoff) are covered 9.1].
4.2	Utility & service lines					Not applicable.
4.3	Shipping lanes					Not applicable.
4.4	Flight paths					Not applicable.
5	Biological resource use					

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
5.1	Hunting & collecting terrestrial animals					Not applicable.
5.2	Gathering terrestrial plants					Not applicable.
5.3	Logging & wood harvesting					Several of the smaller lakes where Prototype Quillwort occurs have largely forested lakeshores; two are entirely surrounded by crown land while others are privately owned. Removal of trees through logging or wood harvesting (either commercial or small scale) is unlikely to directly impact the aquatic Prototype Quillwort, but indirect impacts from increased surface runoff, sedimentation, and altered nutrient regimes are covered in 7.3 and 9.3.
5.4	Fishing & harvesting aquatic resources					Not applicable.
6	Human intrusions & disturbance	Low	Large	Slight	High	
6.1	Recreational activities	Low	Large	Slight	High	The majority of Prototype Quillwort occurrences are in lakes with cottages and developed areas where there is high chance of disturbance from recreational activities such as boating, fishing, swimming, personal watercraft (PWC) and off-highway vehicle (OHV) traffic, which have the potential to cause physical disturbances and movements in the water column resulting in uprooting of plants. Note that boating, fishing and swimming are prohibited in Pottle Lake due to its

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						Protected Water Area Designation (CBRM Water Utility 2013).
6.2	War, civil unrest, & military exercises					Not applicable.
6.3	Work & other activities					Not applicable.
7	Natural system modifications	Unknown	Large	Unknown	High	
7.1	Fire & fire suppression					Not applicable.
7.2	Dams & water management/use	Unknown	Large	Unknown	High	Pottle Lake has over 50% of the known population of Prototype Quillwort in Nova Scotia and is the municipal drinking water source for the surrounding community. As such it is subject to regular water quality monitoring and restricted public access and activities (e.g., boating, fishing, swimming, waste disposal) to ensure safety of the water supply (CBRM Water Utility 2013). While this confers some level of protection on the lake, it also poses a potential threat of changing water flow patterns from their natural range of variation, either deliberately or as a result of other management activities.
7.3	Other ecosystem modifications	Unknown	Unknown	Unknown	Unknown	Shoreline disturbances undoubtedly affect lake ecosystems but impacts on quillworts are poorly understood. Alteration of hydrological processes as a result of housing and road development, recreational activities (e.g., OHV traffic), removal of shoreline vegetation and forestry all have the potential to affect Prototype Quillwort habitat (Environment

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						Canada 2012). [Pollution resulting from these activities is covered in 9.1 and 9.3].
8	Invasive & other problematic species, genes & diseases	Unknown	Unknown	Unknown	Unknown	
8.1	Invasive non-native/alien species/diseases	Unknown	Unknown	Unknown	Unknown	Several aquatic invasive species could pose a threat to Prototype Quillwort, however their presence has not been confirmed in the lakes where Prototype Quillwort occurs, and there has been no research into interspecific competition or other effects on quillworts (Environment Canada 2012). However, the potential for damage is reasonable, and many invasive species known to compete with *Isoetes* spp. have been recorded in other Nova Scotia lakes.
8.2	Problematic native species					Not applicable.
8.3	Introduced genetic material					Not applicable.
8.4	Problematic species/diseases of unknown origin					Not applicable.
8.5	Viral/prion-induced diseases					Not applicable.
8.6	Diseases of unknown cause					Not applicable.
9	Pollution	Unknown	Large	Unknown	Unknown	
9.1	Domestic & urban waste water	Unknown	Large	Unknown	Unknown	The high frequency of cottages and houses along lakeshores where Prototype Quillwort occurs indicates a high probability of domestic pollutants and urban wastewater entering ecosystems and altering water quality. In addition,

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
						lakeshore development may increase sedimentation or erosion and many of the sites have adjacent roads and highways which may lead to salt and other chemicals entering the waterbodies. Boats, PWCs and OHVs used for recreational activities may all release gasoline and other pollutants into the water column. The species' threshold of tolerance for these pollutants is unknown however, and potential impacts on subpopulations are therefore not well understood (Environment Canada, 2012). Note that this should not apply in Pottle Lake where public access and recreational activities are restricted to maintain drinking water quality (CBRM Water Utility 2013).
9.2	Industrial & military effluents					Not applicable.
9.3	Agricultural & forestry effluents	Unknown	Unknown	Unknown	Unknown	It is unclear if runoff from nearby agriculture or forestry is reaching the lakes and what effect it is having on water chemistry, or on Prototype Quillwort. However, indirect impacts of forestry and removal of riparian vegetation on aquatic habitats in general are well documented (e.g., increased surface runoff, sedimentation, altered nutrient regimes, etc.) (e.g., Duffy et al. 2020) and may pose a future threat where lakeshores remain forested.
9.4	Garbage & solid waste					Not applicable.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
9.5	Air-borne pollutants	Unknown	Large	Unknown	Unknown	Changes in water pH due to pollution and acid rain have been documented in Nova Scotia (e.g., Clair et al. 2002; 2011), but the tolerance of Prototype Quillwort to changes in pH is unknown.
9.6	Excess energy					Not applicable.
10	Geological events					
10.1	Volcanoes					Not applicable.
10.2	Earthquakes/tsunamis					Not applicable.
10.3	Avalanches/landslides					Not applicable.
11	Climate change & severe weather	Unknown	Pervasive	Unknown	Unknown	
11.1	Habitat shifting & alteration	Unknown	Pervasive	Unknown	Unknown	Habitat requirements are not sufficiently well understood to predict the severity of anticipated habitat shifts and alterations due to climate change. It is possible that increased droughts, temperature extremes and storms and flooding could all impact Prototype Quillwort but due to lack of information ratings are summarized here (11.1). In particular, the species is known to grow primarily within a certain range of depth (1.5-2.5 m below the surface) and may be threatened by alterations to water levels (e.g., due to droughts, flooding) if it was unable to migrate to ideal depths. In addition, storms and flooding may bring additional debris into the lakes and uproot plants.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Detailed threats
11.2	Droughts					Unknown.
11.3	Temperature extremes					Unknown.
11.4	Storms & flooding					Unknown.
12	Other options					
12.1	Other threat					None identified.

[a] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g.,, if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (e.g.,, timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted; Small; Negligible).

[c] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate; Slight; Negligible; Neutral or Potential Benefit ≥ 0%).

[d] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2. Description of Threats

Prototype Quillwort is an inconspicuous and difficult species to study and its ecology is not fully understood. Threats listed in this section are therefore based on what is known of aquatic plants in general, and other species in the genus. Because of knowledge gaps, it is difficult to effectively classify threats according to their severity. More research is required to investigate the importance of individual threats and their likelihood of occurring on the landscape.

Prototype Quillwort is found in a limited number of lakes that have similar pH, water clarity, depth, and temperatures. While there is currently insufficient research to determine how this species reacts to changes in any of these habitat factors, it is important to make note of the high frequency of human activity on the lakeshores where it occurs, including homes, cottages, docks, causeways, roads, and recreational activity such as swimming, boating and recreational vehicle use. All of these activities have the potential to affect Prototype Quillwort occurrences by disturbing the soft sediment and damaging or uprooting the small plants, as well as indirectly through pollution and other changes to aquatic ecosystems. The ever-increasing demand for lakeshore properties makes new development highly likely, and maintenance or renovation of existing structures may also result in damage to this species and its habitat. Effects of acid rain are unknown and potential future introductions of aquatic invasive species are difficult to estimate. Threats associated with climate change are beyond the scope of actions that could be addressed within a provincial management plan for the species but are briefly mentioned due to their importance.

The overall threat impact to Prototype Quillwort is Low, with the caveat that most threats are currently scored as “unknown”. A description of the major threats to Prototype Quillwort is provided below. As they cannot be ranked with any degree of certainty, they are listed in the order they appear in the Threat Calculator Assessment (Table 3).

Residential & commercial development – Housing and urban areas (Unknown)

Cottage and shoreline development were identified in the COSEWIC Status Report (COSEWIC 2005) and federal Management Plan (Environment Canada 2012) as being potential threats to Prototype Quillwort. Of the nine lakes where the species is known to occur in Nova Scotia, at least four have been altered to varying degrees by development. Significant cottage development was documented at Sutherland, Mallette, Sand and Rumsey Lakes (Environment Canada 2012). Given the fact that lakeshore properties are increasingly in high demand both for cottage development and for recreational purposes, it is anticipated that the level of impact from this threat and the proportion of the population affected will increase in the future. In addition to the damage caused during construction of new structures, it can be reasonably assumed that there will be ongoing disturbance as part of regular upkeep or additional renovations to existing properties.

Residential & commercial development – Tourism & recreational areas (Unknown)

In addition to residential buildings, recreational structures such as docks and boat launches have been built on Prototype Quillwort habitat. It is likely that there will continue to be such structures added to current developments, as well as the upkeep and maintenance of existing structures. All these pose direct threats to Prototype Quillwort through both the disturbance of the plants and the soft sediment in which they grow, and through the obstruction of light in the areas where the structures are built.

Agriculture & aquaculture – Livestock farming and ranching (Unknown)

There is limited agricultural activity near lakes where Prototype Quillwort occurs, however there are several mink farms in Digby County, including one approximately 300m from the lakeshore of Mallette Lake. It is unknown what impacts, if any, the presence of the nearby mink farm has on Prototype Quillwort. Recent research indicates that mink farms in Nova Scotia are a source of contamination in nearby ecosystems, showing elevated levels of mercury, polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT) in lakes with mink farms in their catchments (Gregory et al. 2022), however it is not known if this would affect plant growth.

Transportation & service corridors – Roads & railroads (Unknown)

Encroachment upon lake borders by roadways and causeways was identified in the COSEWIC status report and federal Management Plan as a potential threat to Prototype Quillwort (COSEWIC 2005; Environment Canada 2012). Shoreline roadway and/or causeway construction was observed near Pottle Lake, Johnson Lake and Sutherland Lake. There is no evidence for future road development proposed along Prototype Quillwort lakeshores, however the upkeep and use of existing roads and associated structures (e.g., culverts) may still be damaging to plants.

Human intrusions & disturbance – Recreational activities (Low)

Lakes adjacent to developed areas commonly experience higher levels of recreational activity such as boating, fishing, swimming, personal watercraft (PWC), and off-highway vehicle (OHV) traffic (Environment Canada 2012). Movements in the water column caused by boat and PWC traffic could uproot individuals. Although the species typically grows in relatively deep water, swimmers could also destroy or uproot individual plants, as could boat anchors. Indirect effects of recreational activities (e.g., water pollution, erosion, siltation) are discussed in section *9.1 Pollution – Domestic & urban waste water*.

Natural system modifications – Dams & water management/use (Unknown)

Pottle Lake is managed by the Cape Breton Regional Municipality as the drinking water supply for the urban areas of the Northside (CBRM Water Utility 2013). As such, the

lake has been subject to extensive research and planning to maintain water supply and quality. Water levels are managed using a stop log structure at the only outflow, water quality is monitored on a regular basis, and activities such as boating, fishing and swimming are prohibited in the lake in accordance with its Protected Water Area Designation (CBRM Water Utility 2013). While the level of management and oversight by CBRM offers opportunities to collaborate on conservation activities, there is potential for conflicting interests, such as artificial drawdown to meet water demands in drought conditions which could expose plants in shallow areas. It is unknown how such changes would affect Prototype Quillwort, but it is notable that this lake contains >50% of the known Nova Scotia population.

Natural system modifications – Other ecosystem modifications (Unknown)

Prototype Quillwort appears to have a very limited range of water depth in which it occurs (typically 1.5-2.5 m). Lakes located near developed areas or roads could be affected by lasting alterations to lake water levels such as draining, damming, disturbance of tributaries or outflows, or the filling or disturbance of shoreline wetlands, all of which could have a significant impact. Removal of shoreline vegetation for development, for logging and wood harvesting, or from recreational activities (e.g., OHV use) could also cause hydrological changes (note that pollution from these activities is discussed in 9.1). It is thought that any lasting alteration of hydrological processes could result in declines in subpopulation size and viability and even localized extinctions if the Prototype Quillwort is unable to migrate to ideal depths (Environment Canada 2012).

Invasive & other problematic species, genes, & disease – Invasive non-native/alien species/diseases (Unknown)

Disturbances related to shoreline development and recreational activities typically lead to increases in the number and abundance of exotic species present, through habitat alteration that favours exotics and through deliberate or inadvertent introduction of exotic species. Exotic species can also spread into undisturbed lakes through natural dispersal (Environment Canada 2012). Several invasive aquatic exotic species could pose a threat to Prototype Quillwort if introduced, including Smallmouth Bass (*Micropterus dolomieu*) (through predation), Zebra Mussels (*Dreissena polymorpha*) (through changes to water quality), or aquatic plants such as Yellow Floating-heart (*Nymphoides peltata*), Eurasian Water-milfoil (*Myriophyllum spicatum*), Curly Pondweed (*Potamogeton crispus*) and European Frog-bit (*Hydrocharis morsus-ranae*) (through competition). Of these, only Smallmouth Bass and Yellow Floating Heart are currently known from Nova Scotia, and not from lakes where Prototype Quillwort occurs. Although they are considered highly invasive in other regions, it is uncertain to what extent these species could become established and proliferate in cool, oligotrophic lakes supporting Prototype Quillwort.

Pollution – Domestic & urban waste water (Unknown)

Lakes located in residential, recreational, and agricultural areas are affected by nutrient enrichment through effluent and surface runoff. This represents a considerable threat to Prototype Quillwort as accumulation of nutrients from anthropogenic sources can degrade habitat by increasing plant and algal growth to the point that their decay severely reduces available oxygen in the water body. Under such conditions, floating and emergent competitor species often reduce light availability and outcompete submerged species and could thus cause Prototype Quillwort population declines and local extinctions (Environment Canada 2012).

On-shore ATV traffic could lead to loss of shoreline vegetation, destabilization of banks and erosion which can contribute to the indirect threat of increased runoff and siltation. Erosion and larger runoff volumes can modify underwater substrates and increase water turbidity, thereby reducing light penetration in the water column. Diminished light availability could result in poorer quillwort performance and lower recruitment (Environment Canada 2012).

Lakeshore roadways and causeways can result in toxic runoff containing road salt or petroleum products and their presence increases potential for major toxic spill events. Recreational activities such as boating and PWC use can also contribute pollutants to lake water. Aquatic quillworts in general are regarded as being quite vulnerable to water pollution (Brunton and Britton 1993). In addition to road and vehicle-related pollution, herbicides, either from direct application to the water body to control aquatic weeds or from surface runoff, could also negatively impact individuals and subpopulations. Any contamination leading to a significant change in water pH or salinity could be detrimental (Environment Canada 2012).

Pollution – Agricultural & forestry effluents (Unknown)

It is unclear if runoff from nearby agriculture or forestry is reaching the lakes and what effect it is having on water chemistry, or on Prototype Quillwort. However, indirect impacts of forestry and removal of riparian vegetation on aquatic habitats in general are well documented (e.g., increased surface runoff, sedimentation, altered nutrient regimes, etc.) (e.g., Duffy et al. 2020) and removal of trees through logging or wood harvesting may pose a future threat where lakeshores remain forested. Current *Wildlife Habitat and Watercourses Protection Regulations* under the Nova Scotia *Forests Act* limit forestry activity within a 20 m buffer (special management zone) along boundaries of a watercourse.

Pollution – Air-borne pollutants (Unknown)

Based on an analysis done from 1983 to 1997 (Clair et al., 2002), and another from 1986 to 2007 (Clair et al., 2011), it was shown that air pollution and acid rain resulted in an increase in pH of lakes in the Canadian maritime provinces, and that effects are still present despite decreases in acid deposition, due to the region's poorly buffering soils

and bedrock. However, there is insufficient research to know how sensitive Prototype Quillwort is to changes in pH so the severity of this threat is unknown.

Climate change & severe weather – Habitat shifting & alteration (Unknown)

It is possible that habitat shifting and alteration, increased droughts, temperature extremes and storms and flooding due to climate change could all impact Prototype Quillwort although there is currently no data to support this. Habitat requirements for Prototype Quillwort are not well understood and it is unknown how this species responds to changes in conditions such as water levels, temperature, pH, and dissolved nutrients. Because it is known to grow primarily within a certain range of depth (1.5-2.5 m below the surface) it may be threatened by droughts that lower water levels and expose plants to shallower depths than are suitable. Increased frequency of storms and flooding could also cause changes in water levels and may bring disturbances and additional debris into the lakes and uproot plants. It is unknown what tolerances Prototype Quillwort has for changes in temperature, what thresholds it can withstand, and how the global rise in temperatures will affect this species over time.

5. MANAGEMENT OBJECTIVE(S)

The management objective for Prototype Quillwort in Nova Scotia is to ensure the persistence and viability of all known subpopulations and to maintain or improve habitat quality for each. This is consistent with the national management objective as outlined by Environment Canada (2012). The current lack of information about the Nova Scotia population and trends over time makes it difficult to establish more specific goals. A commitment to regular monitoring and development of consistent field protocols will be a key element in determining whether this objective is being met over time.

The status of Prototype Quillwort as a globally rare regional endemic with over 70% of all known occurrences and well over 90% of its global population in Canada highlights the importance of monitoring known subpopulations and managing threats to this species. Given its restricted range, specific habitat requirements, and the fact that some of the documented occurrences may contain relatively small numbers of individuals (a few hundred or less), the prevention of declines in subpopulation sizes, areas of occupancy and habitat quality is a priority (Environment Canada 2012).

6. GENERAL APPROACHES TO MANAGEMENT

6.1. Actions Completed or Underway

To date, few if any direct management initiatives have been undertaken. All efforts concerning this species in Nova Scotia have been directed towards the surveying of potential habitat. No new information has been collected on this species in the province since 2003-2004.

Targeted fieldwork and surveys for Prototype Quillwort in Nova Scotia have been conducted as follows:

- D.M. Britton surveyed a total of 43 lakes, one river and one creek in Nova Scotia in 1989-2000 resulting in the discovery of two previously unknown occurrences (Economy Lake and Rumsey Lake).
- J. Goltz and G. Bishop surveyed all lakes where species is known to occur and 19 previously unsurveyed lakes in Nova Scotia in 2003-2004. These surveys led to the discovery of four previously unknown occurrences (Johnson, Simpson, Mallette and Amirault Lakes).

A number of lakes have also been visited in a more cursory and less methodical fashion by people knowledgeable about the species. No additional sites were recorded as a result of these visits. Although only detailed surveys including underwater checks can rule out the presence of Prototype Quillwort at a lake, any information collected through these checks can be beneficial in identifying sites of interest and can lead to the discovery of unknown subpopulations (Environment Canada 2012).

6.2. Recommended Management Actions

Table 4 provides the recommended conservation measures for achieving management objectives for the species and the timeframe for completing these actions. Conservation measures are organized according to the following categories: Habitat protection, management and stewardship; surveys and monitoring; communication, outreach, and education; law, policy, and enforcement; and research to address knowledge gaps.

Table 4. Conservation measures in support of management objectives and implementation schedule.

Conservation Measures	Threat(s) Addressed*	Priority**	Timeline
Habitat Protection, Management, and Stewardship			
Create detailed distribution maps of location occurrences within lakes with known subpopulations	All	High	2022-2025
For each subpopulation, identify key threats and opportunities for partnerships and stewardship actions	All	High	2022-2025
Develop best management practices and promote stewardship activities that address threats and sustain subpopulations	1.1, 1.3, 6.1, 7.3, 9.1, 9.3	Medium	2025-2027
Consider stewardship agreements with private landowners that encourage best practices for shoreline protection	1.1, 1.3, 6.1, 7.3, 9.1, 9.3	Medium	2025-2032
Develop a cooperative agreement with CBRM to incorporate Species at Risk considerations in water management planning for Pottle Lake.	7.2	High	2023-2025
Surveys and Monitoring			
Establish baseline population information, including: • detailed estimates of individuals at known sites • measurement of subpopulation densities	All	High	2023-2025

Develop and implement a standardized monitoring protocol to monitor changes in abundance, distribution and habitat characteristics over time, including: • species ID (fact sheet and contact info for experts) • field techniques • required monitoring frequency • establishment of permanent transects or plots	All	High	2022-2023
Develop and implement a habitat quality monitoring protocol for measuring water quality and threats, including: • pH • dissolved oxygen • temperature • light penetration • sedimentation • condition of shoreline and riparian zones • presence of disturbances • presence/abundance of invasive species	All	Medium	2023-2025
Survey for new occurrences • develop list of criteria for potential new occurrences • identify lakes of potential occurrence based on current knowledge of broad habitat requirements • prioritize and survey potential sites	All	Medium	2025-2032
Communication, Outreach, and Education			
Develop information on identifying this species • ID guides • workshops and field outings	All	Medium	2023-2032
Public Outreach • develop education and awareness programs targeting landowners on Prototype Quillwort lakes • contact community and stakeholder groups to foster a climate of cooperation • hold public information and Q+A sessions • encourage citizen science and collaboration (e.g., iNaturalist project, lake bioblitz), • consider development of a pocket field guide and specific outreach program for children and families to make them aware of this unique species • engage with the Mi'kmaw Conservation Group, who are already a key partner in freshwater mussel surveys in the province • develop a Prototype Quillwort species ID card could be distributed to partners to assist them in keeping an eye out for this species during their mussel survey work	1.1, 1.3, 6.1, 7.3, 9.1, 9.3	Medium	2023-2032
Law, Policy, and Enforcement			
Conservation planning • communicate the presence and needs of Prototype Quillwort to municipalities, conservation officers and inspectors responsible for municipal planning and policies regulating shoreline development • protect water quality and water courses • protect wetlands and riparian buffer zones	1.1, 1.3, 2.3, 4.1, 7.3, 9.1, 9.3	High	2022-2026
Implement compliance promotion programs consistent with existing laws and policies	1.1, 1.3, 2.3, 4.1, 7.3, 9.1, 9.3	Medium	2024-2032

Research to Address Knowledge Gaps			
Conduct research on the biology and ecology of the species, including: • habitat • ecological requirements • tolerance to various stressors • factors limiting its distribution • life history • reproduction • impacts of invasive aquatic species	All	High	2022-2032
Encourage research supporting development of monitoring techniques, including: • field techniques • eDNA primers • molecular key	All	Medium	2022-2032
Collaborate with Cape Breton University to explore possible associations between Prototype Quillwort and Yellow Lampmussel	All	Medium	2022-2025

*Threat or Limitation should refer to the IUCN Threat Classification Table Rankings. Either the first level or second level threat ranking can be used depending on how the Broad Strategy affects the threat. Multiple threats can be addressed under a single Recovery Measure.

**Priority should be classified as High(H), Medium(M), or Low(L). “Priority” is a qualitative measure of the relative degree to which an approach will have a positive impact on the recovery objective. High priority conservation approaches are considered those most likely to have an immediate and/or direct influence on reaching the management objective for the species. Medium priority conservation approaches may have a less immediate or less direct influence on reaching the management objective but are still considered important measures to implement. Low priority conservation approaches will likely have an indirect or gradual influence on reaching the management objective and are more tied to increasing knowledge or public perception/education.

6.3. Narrative to Support the Management Actions Planning Table

The significant knowledge gaps that exist with respect to Prototype Quillwort's distribution, biology, ecology, habitat requirements and threats highlight the importance of research and information gathering in the management of the species. In particular, the acquisition of baseline population information and development and implementation of survey and monitoring protocols are the highest priorities and will be critical steps in effectively mitigating threats and conserving the species. Stewardship planning, communication and public outreach and education are also recommended to promote better land and lake stewardship practices and may offer the best opportunities to benefit the species.

Habitat Protection, Management and Stewardship

At present, there is a significant lack of information needed to develop tools for effective management. In an effort to contribute to better informed decision-making and prioritization of active conservation measures, it would be useful to establish and implement an appropriate subpopulation ranking system using criteria such as subpopulation size, area of occupancy, habitat quality and presence of threats.

To support this initiative, detailed maps accurately identifying areas occupied by the species should be developed. To a certain extent, maps have already been produced through the preparation of the COSEWIC status report (COSEWIC 2005) and species at risk mapping recently done by the Atlantic Canada Conservation Data Centre. However, these are based on incomplete information, as many subpopulations have never been thoroughly surveyed. Further research and monitoring is an important step towards the creation of such management tools.

In the longer term, as new information on the biology and ecology of the species becomes available, resources should be devoted to the production of a conservation plan and standard best practice guide for the management of subpopulations and habitats. Outreach to private landowners could encourage voluntary stewardship and best practices, and stewardship agreements could be put in place to encourage shoreline protection.

The importance of stewardship in the conservation and management of Prototype Quillwort subpopulations must be recognized. As many subpopulations are immediately adjacent to waterfront private lands, voluntary and cooperative conservation efforts are essential. Ultimately, the persistence of subpopulations may largely depend on landowners, NGOs, municipalities and members of the public acting as responsible stewards who engage in the conservation of Prototype Quillwort. There is a great potential for the public to play an important role in the protection of this species.

Efforts should be made to promote stewardship activities that encourage:

- minimally destructive land use;
- the restoration of heavily disturbed shorelines and riparian zones;
- the conservation of undisturbed sections of shoreline and riparian zones; and
- the proper disposal of wastewater.

To conserve habitat, conservation initiatives at all known locations should aim to discourage the alteration of hydrological processes such as damming of tributaries or outflows and artificial drawdown from excessive water use. In addition, efforts should be made to construct docks and similar structures away from areas where individuals occur.

As a significant portion of the known Nova Scotia population of Prototype Quillwort occurs in Pottle Lake, a cooperative agreement with Cape Breton Municipality could help ensure that Species at Risk considerations are taken into account in water management.

Surveys and Monitoring

Acquisition of baseline distribution and population information and development of a regular monitoring protocol should be prioritized. Given the difficulties associated with assessing fully submerged aquatic plant populations, the development and implementation of a standardized monitoring protocol may pose unique challenges. The protocol produced through this initiative should outline appropriate techniques and offer recommendations pertaining to monitoring frequency, consistency, and measurement of trends over time.

Appropriate methods for assessing subpopulations may involve canoe and snorkel-based work, whereas areas known to be occupied by the species could be surveyed intensely by snorkeling and the remaining areas surveyed through exploratory snorkeling dives at suitable habitat locations. Efforts to evaluate total subpopulation size and area of occupancy should be augmented with additional monitoring using permanent transects or plots. Through more systematic methods, detailed counts of individuals would provide a more statistically sound measurement of densities and subpopulation size. This will provide detailed and reliable baseline data on which to base a monitoring plan and assess changes over time.

It is recommended that monitoring also address habitat quality and include measurements of water quality, pH, dissolved oxygen, temperature, light penetration, sedimentation, condition of shoreline and riparian zones, and threats such as disturbances and presence and abundance of invasive species.

Surveys for unknown occurrences of Prototype Quillwort guided by current knowledge of broad habitat requirements are also recommended.

Communication, Outreach and Education

Outreach and communication are key in the conservation of Prototype Quillwort. Several potential threats to the species involve the behavior of landowners and other lake users and could be at least partially mitigated through education and advocacy for more appropriate land-use and stewardship practices. The implementation of education and outreach programs targeting landowners of waterfront properties at subpopulation lakes is an essential step towards raising awareness and discouraging potentially detrimental activities.

Prototype Quillwort can be hard to detect and difficult to identify. It would therefore be beneficial to enhance expertise and provide for the transfer of knowledge necessary to identify the species. Providing educational opportunities to develop necessary skills through workshops and field outings would increase the capacity to carry out effective survey and monitoring efforts.

Public outreach efforts should be implemented near known subpopulations in order to foster a climate of cooperation with targeted community and stakeholder groups such as cottage owner associations, recreational anglers, amateur naturalist groups, environmental non-governmental organizations (NGOs), and school groups. Efforts could take the form of information and consultation sessions serving as a venue for presentations, public discourse and the voicing of any concerns by stakeholder group and members of the public. As part of a cooperative approach to the planning and implementing of conservation measures, this process should aim to actively engage specific groups and the general public to take part in the conservation of Prototype Quillwort. For example, there is an opportunity to involve children and families and promote excitement about finding and protecting this obscure and ancient plant. Citizen science approaches could include developing a dedicated project on iNaturalist, or hosting lake bioblitzes.

Educational tools such as fact sheets, pamphlets, media releases and signage would help increase awareness of the species and its threats to greater audiences in areas where the species occurs. Educational material should focus on threats such as invasive aquatic species and what can be done to help stop their spread. Educational signage should be developed and installed near all known subpopulations. Beyond indicating the nearby presence of a protected plant species, these signs should clearly identify potentially detrimental activities such as the use of motorized vehicles on shorelines and in riparian zones as well as the impacts of recreational activities and the use of anchors in areas where the species is found.

Law, Policy and Enforcement

Prototype Quillwort is listed as Vulnerable under the Nova Scotia *Endangered Species Act,* however the Act does not confer direct protection on Vulnerable species.

Compliance promotion with laws and policies regulating shoreline development and pertaining to the protection of water quality, watercourses, wetlands and riparian buffer zones will help protect both the Prototype Quillwort and its habitat. Therefore, compliance promotion programs consistent with existing laws and policies should be a priority.

Research to Address Knowledge Gaps

The many knowledge gaps in the species' distribution and ecology need to be addressed through research. Perhaps most importantly, resources should be devoted to the identification of all lakes of potential occurrence based on our current knowledge of broad habitat requirements, followed by the prioritizing and systematic survey of these lakes.

Lack of information on the biology and ecology of the species and the factors limiting its distribution, including the potential impacts of threats such as aquatic invasive species and climate change, are important obstacles. Detailed study of the species' ecological requirements and tolerance to various disturbances and stressors is therefore necessary. Such efforts would lead to a better understanding of suitable habitat and the significance of particular threats. This would in turn contribute to improving the effectiveness and efficiency of threat mitigation measures and conservation measures in general.

Coordination with partners studying other aquatic Species at Risk in Nova Scotia such as freshwater mussels may provide opportunities to collaborate on habitat research and monitoring. For example, the co-occurrence of Prototype Quillwort with Yellow Lampmussel in Pottle Lake highlights opportunities to collaborate with researchers at Cape Breton University to explore potential habitat associations between the two species, and techniques of overlapping relevance (e.g., sampling, field surveys, and monitoring protocols for underwater species).

7. MEASURING PROGRESS

7.1. Performance Indicators

The performance indicators identified below are a means by which progress towards management goals and objectives can be measured. Success of the implementation of this management plan will be evaluated against the following indicators:

- Improved understanding of the species' distribution and abundance
- Improved information on the species ecological requirements
- Reduced, mitigated, or removed threats
- Secured subpopulations and their habitats

Performance will be assessed through the completion of actions identified under Table 3 of Section 6.2 *Recommended Management Actions***.**

Table 5. Performance measures used to determine whether Prototype Quillwort management objectives are being met.

Performance Measure	Check-In
Planning:	
Number of Recovery Team meetings to discuss activities and assess performance to date (minimum one per year).	Annually.
Number of initiatives and groups involved in delivering conservation messaging.	Annually.
Number of individuals or teams assigned to, or supported to implement, recovery-related projects such as monitoring and surveys, habitat mapping, research, production of educational materials, land protection efforts etc.	Annually.
Review of Management Plan	Every five years.
Conservation:	
Total amount of lakeshore habitat protected.	Every five years.
Total amount of private land or number of landowners involved in stewardship.	Every five years.

7.2. Monitoring

A monitoring plan for Prototype Quillwort will require some immediate research to optimize any data collected during monitoring efforts. However, monitoring should begin immediately with site surveys and baseline data collection. Adjustments to the protocols can be made as new findings about habitat requirements, biological needs, and impact of threats come to light.

Conducting surveys on 3 lakes each year will would see that each lake was monitored every 4 years on a rotation, and would simplify the workload these tasks require:

- Subpopulation estimates every 4 years; and,
- On-site threats assessment every 4 years; and
- Water quality monitoring every 4 years in partnership with other initiatives where available

In addition to the monitoring done on rotation, assessing the status of the entire Nova Scotia population can be done through:

- Efforts to estimate overall population size every 10 years;
- Desktop monitoring of large-scale disturbances and habitat change using satellite imagery or aerial photos.

Success of this monitoring plan will be reviewed and adjusted as needed and as management actions change. A field checklist and more detailed methodologies will be developed.

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