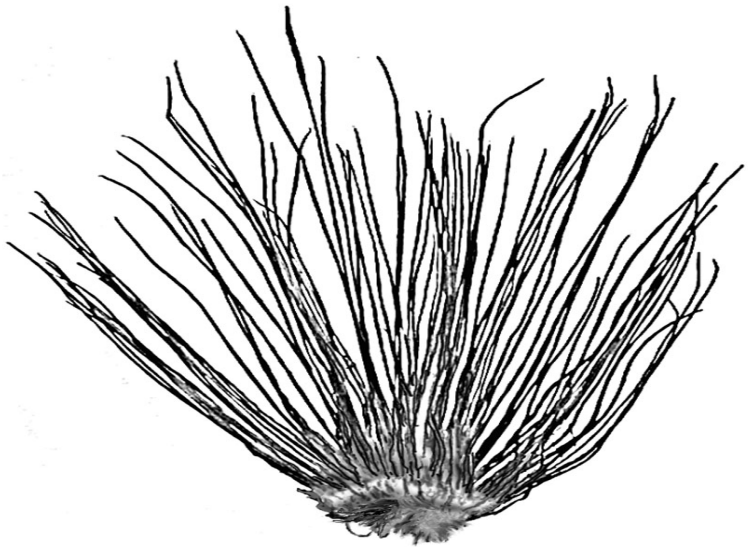
COSEWIC
Assessment and Status Report

on the

Prototype Quillwort
Isoetes prototypus

in Canada



SPECIAL CONCERN
2005

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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Prototype quillwort — Drawing by G. Bishop.

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COSEWIC
Assessment Summary

Assessment Summary – May 2005

Common name
Prototype Quillwort

Scientific name
Isoetes prototypus

Status
Special Concern

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 in Nova Scotia and New Brunswick. The species is found in nutrient-poor, cold, spring-fed lakes. Although several sites have been shown to contain large numbers of plants, one half of the documented sites contain small populations. A wide range of potential limiting factors could impact the species, including changes in water quality, boating and shoreline development.

Occurrence
New Brunswick, Nova Scotia

Status history
Designated Special Concern in May 2005. Assessment based on a new status report.

COSEWIC
Executive Summary

Prototype Quillwort
Isoetes prototypus

Species information

Prototype quillwort (*Isoetes prototypus*), a perennial aquatic fern ally, consists of a clump of straight, brittle quill-like leaves that arise from a bilobed (rarely trilobed) corm. The leaves are swollen at the base where the reproductive spores (megaspores and microspores) are formed. Plants are commonly dislodged from the substrate where they are rooted and float to the surface, often accumulating in shoreline wrack. Identification is principally by the size of the reproductive spores and their surface ornamentation and by chromosome number.

Distribution

Isoetes prototypus is known from thirteen lakes worldwide: nine in Nova Scotia, three in New Brunswick and one in Maine.

Habitat

Often forming dense mats in oligotrophic (nutrient-poor), spring-fed lakes, *I. prototypus* is usually found in 1.5 to 2.5 m of water, rooted in soft, flocculent oozy sediment over sand or gravel. Water colour in these lakes is usually clear but occasionally can be tannin-stained (tea-colored). It most often occurs with other species of rosette-forming aquatic plants, particularly *Eriocaulon aquaticum* and *Isoetes lacustris*.

Biology

Isoetes prototypus is believed to follow the typical life cycle of members of the genus *Isoetes*. The dark-green-quilled sporophytes (the adult stage of the life-cycle with paired chromosomes) produce megaspores (female) and microspores (male) that germinate to form separate gametophytes (plantlets that have a single set of chromosomes and produce the sex cells). Once the eggs within female gametophytes have been fertilized by the spermatozoids of the male gametophytes, a new sporophyte develops directly from the egg.

Little is known on the ecology of this species. Floating, uprooted mats are sometimes found along the shores of lakes where *I. prototypus* occurs. How these plants are dislodged is not known with certainty.

Population sizes and trends

This species was first recognized as a species new to science in 1988 at a single lake in New Brunswick (site 10). Knowledge of its distribution was expanded to five sites (sites 1, 4, 6 in Nova Scotia and site 13 in Maine) through examination of herbarium records by D.M. Britton from 1988-93. He discovered two new locations in Nova Scotia through field exploration between 1989 and 1998 (sites 3 and 7); *Isoetes prototypus* was independently found at one of these locations (site 7) by D.F. Brunton around the same time it was found there by D.M. Britton.

Fieldwork conducted in 2003 for the preparation of this report has added another four locations (sites 2, 5, 8 and 9) in Nova Scotia. Two new sites were identified in New Brunswick in 2004 (sites 11 and 12). None of the *I. prototypus* sites has been specifically monitored for changes in population size. Growing in dense mats with up to 392 plants per sq. metre, fieldwork for this report suggests a very conservative estimate for a total Canadian population of about 250,000 individuals, though the total surface area of lakes in which *I. prototypus* occurs is quite small (<961 ha).

Limiting factors and threats

Although no specific threats were noted at the precise *in situ* locations where *I. prototypus* occurs within the lakes at which it has been found, roadways and/or causeways border or encroach upon the shoreline at three of the lakes, and cottage development and associated shoreline deforestation were at least locally extensive at four of the lakes. The impacts of this development are unknown but such habitat modifications could potentially have a negative impact on *I. prototypus*. Dislodging of plants in the vicinity of underwater moose tracks and as a result of swimming with flippers was observed. Additional potential threats that may possibly impact this species have been documented or considered by other researchers and include direct damage to or uprooting of plants by boating, fishing, the use of anchors, raking swimming areas, the installation of water intake pipes, and the activities of wildlife; and habitat alterations such as changes in water levels by damming or draining, water pollution, eutrophication, siltation, changes in pH and competition by invasive and/or exotic aquatic plant species.

Special significance of the species

This species is an eastern endemic of thirteen small lakes found principally in Nova Scotia and New Brunswick. As one of two native diploid species in northeastern North America, it is likely the ancestor of several other North American species. D.F. Brunton, a specialist in these plants, believes it is ‘a living fossil’ of global significance.

Existing protection or other status designations

Isoetes prototypus is not listed under either the Canadian *Species at Risk Act* or *The Endangered Species Act of 1973* in the United States.

In New Brunswick, *I. prototypus* and its habitat are protected under the provincial *Endangered Species Act.* It is not listed as an endangered species under legislation in Nova Scotia or Maine. None of the Canadian lakes where *I. prototypus* has been found is within a protected area. One site in New Brunswick is on Department of National Defence land. Two lakes (site 13 in Maine and site 1 in Nova Scotia) are protected as sources of public drinking water. The site in Maine is located within Acadia National Park and hence is within a protected area.

Isoetes prototypus is ranked as an S1 species in New Brunswick and Maine, and as an S2 species in Nova Scotia. It is listed as N1? in Canada and N1 in USA and has been assigned a Global Heritage Status Rank of G1?.

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 agencies (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 members and the co-chairs of the species specialist and the Aboriginal Traditional Knowledge subcommittees. The Committee meets to consider status reports on candidate species.

DEFINITIONS (NOVEMBER 2004)

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 it 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 wildlife species for which there is inadequate information to make a direct, or indirect, assessment of its 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.

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

COSEWIC Status Report

on the

Prototype Quillwort

Isoetes prototypus

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2005

TABLE OF CONTENTS

List of figures

List of tables

SPECIES INFORMATION

Name and classification

Scientific name:	*Isoetes prototypus* D.M. Britton
Common name:	Prototype Quillwort, Big Quills, Spike Quillwort
Family:	*Isoëtaceae* (Within the order *Isoëtales* Engler, there is but one genus, currently represented by 143 species and 15 hybrids, although some *Isoetes* authorities have stated that there may be 300+ species of *Isoetes* in the world.)
Bibliographic citation:	D.M. Britton and J.P. Goltz (1991). *Isoetes prototypus*, a new diploid species from eastern Canada. Canadian Journal of Botany, Vol. 69: 277-281.
Synonymy:	Plants of this species had not been recognized as a species new to science until 1988, but had been previously collected and/or identified under a variety of names, e.g., *I. lacustris* (including *Isoetes macrospora?* and *I. hieroglyphica*); *I. tuckermanii*; *I acadiensis*; *I. riparia;* and *Isoetes sp.*
Genetic links?:	Based on very preliminary DNA sequence data, it appears that the *I. prototypus* genome is present in *Isoetes tuckermanii*, *I. acadiensis* and *I. lacustris* (Taylor pers. com. 2003).
Status:	Leading *Isoetes* researchers (Britton 2002, Brunton 2002, Caplen and Werth 2000, Hickey 2003, and Taylor 2003) affirm that *Isoetes prototypus* is indeed a valid species, based on its chromosome number (2*n* = 22), its spore morphology, its isozyme patterns (Caplen and Werth 2000), its invariably straight leaves, its deep water habitat and several rather unique anatomic features, including a distinctive ligule and pronounced labium (Hickey 2003).

Morphological description

(For more technical details see Britton and Goltz 1991.)

Isoetes prototypus (Figure 1) is a diploid species (2*n* = 22). It is perennial, and has a bilaterally symmetrical two-lobed (rarely three-lobed) corm (Figure 2) that bears 10-25 (-75) leaves, ranging from 4-12 (-15) cm long (Figure 3). The leaves are very straight, rigid, quill-like and brittle, abruptly tapering from a swollen base and then gradually tapering to a sharp tip (Figure 4). The leaf colour is mainly dark green except for the reddish brown or chestnut-coloured base. There is still some debate as to whether or not this species has a velum. Spores are borne in the swollen bases of the leaves. The female spores (megaspores) are white, 425-575 (mean = 500) µm in diameter, and levigate (fairly smooth) with low meandiform markings sometimes reduced to mere molded mounds, and very pronounced triradial (three-spoked) and equatorial ridges (Figure 5). The ornamentation continues to the equatorial ridge (the “girdle”). The microspores are pale brown, lenticular (monolete), 23-32 (mean = 28) µm in length and covered with a complex network of spinulose fibres (Figure 6). Spores mature in summer (Britton and Goltz 1991).

Figure 1. *I. prototypus* habit, x 0.3 (D. Vail photo).

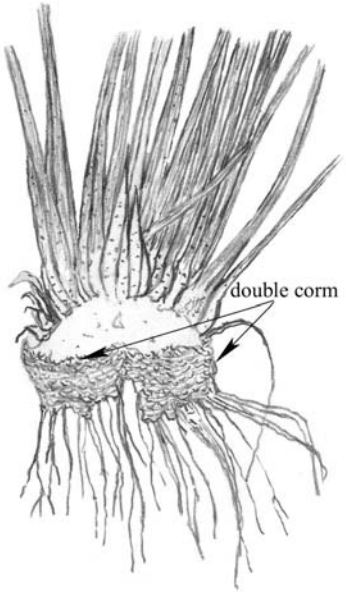

Figure 2. Corm, hemisection of plant, x 1.0 (drawing G. Bishop).

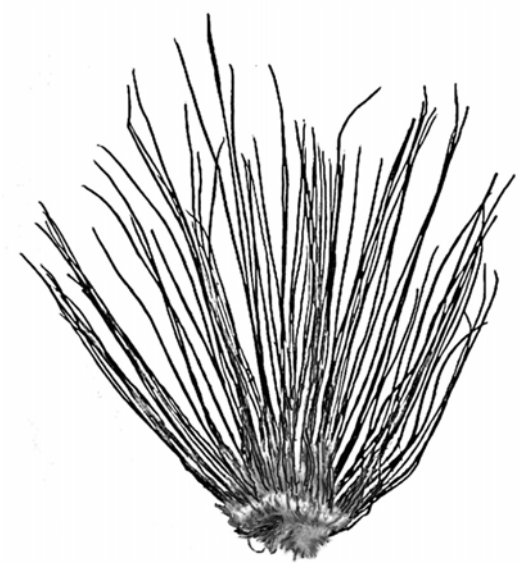

Figure 3. *Isoetes prototypus* habit, from floating plant with no roots, x0.5 (drawing G. Bishop).

Figure 4. Single quill (leaf), x1.0 (drawing G. Bishop).

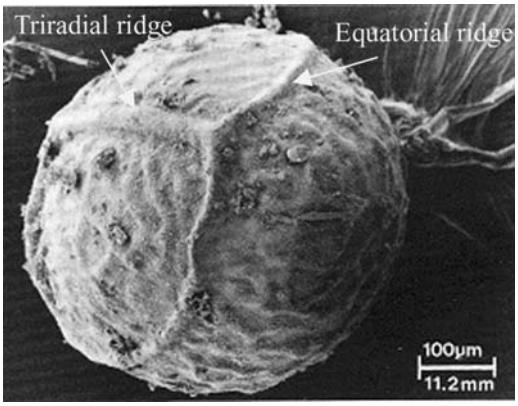

Figure 5. Scanning electron micrograph (SEM) of *I. prototypus* megaspore (Britton and Goltz 1991).

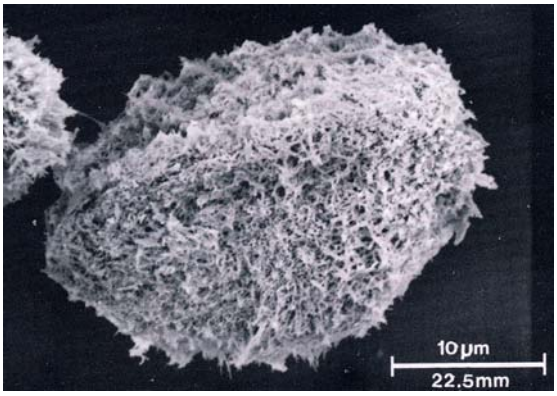

Figure 6. Scanning electron micrograph (SEM) of *I. prototypus* microspore (Britton and Goltz 1991).

When viewed from above, the largest plants of *I. prototypus* have crowns measuring 8.5 x 20 cm with a resulting oval shape, being somewhat laterally compressed.

Although identification of I. prototypus is most reliably based on spore morphology and chromosome numbers at this time, helpful macroscopic characters that resulted in an accurate identification of most plants of this species in the field were as follows:

- The “quills” are straight, stiff and very brittle, often breaking when pressure (e.g., from an outstretched hand) was applied by pushing downward on the tips of the leaves. Other taxa with straight quills, *I. lacustris* and plants of *I*. x *harveyi* with the *I*. x *heterospora* morphology, tended to flex considerably (almost like an archer’s bow), rather than break.

- There is very little white colour near the bases of the leaves of most plants of *I. prototypus*, the bases of the leaves usually having a chestnut colour, and the leaves otherwise mostly having a dark green colour. Straight-quilled plants of *I. lacustris* and plants of *I*. x *harveyi* with *I*. x *heterospora* morphology often tended to have a broad white-coloured zone near the bases of the leaves.

Based on spore morphology, *I. prototypus* is most likely to be confused with *I. hieroglyphica* (now considered a morphological variant of *I. lacustris*) and *I. acadiensis*. However, the megaspores and microspores of *I. prototypus* are smaller than those of *I. hieroglyphica* or *I. acadiensis*. The megaspore ornamentation of *I. prototypus* is of lower relief and less pronounced than in either *I. acadiensis* or *I. hieroglyphica*. Unlike *I. prototypus*, the megaspores *of I. acadiensis* lack an especially smooth area distal to the equatorial ridge.

Since chromosome counts were not done on any of the 2003 or 2004 collections, plants lacking megaspores were identified on the basis of their microspore size (which usually provides an accurate indication of ploidy level) and macroscopic characteristics.

Genetic description

Isoetes prototypus is a diploid species (2*n* = 22; Britton and Goltz 1991). Only one other diploid *Isoetes* species, *I. echinospora*, is known to occur in the Maritime provinces. Hybrids involving *I. prototypus*, if they occur, would have a chromosome number intermediate between their two parents. Research on the DNA of *I. prototypus* and other *Isoetes* species is presently ongoing.

DISTRIBUTION

Global range

Following the 1988 discovery of *I. prototypus* in New Brunswick at site 10, the global range of this species was determined by D.M. Britton through the examination of herbarium specimens. As some of these records were nearly a hundred years old, all locations were subsequently visited by D.M. Britton and/or D.F. Brunton for confirmation that *I. prototypus* was still extant there and additional lakes were surveyed for this species. As of 2002 it was known to be present in 7 lakes throughout the world, all in northeastern North America.

- 1 lake in New Brunswick, Canada
  - Site 10 (York County)
- 5 lakes in Nova Scotia, Canada
  - Site 1 (Cape Breton County)
  - Site 6 (Annapolis County)
  - Site 7 (Annapolis County)
  - Site 4 (Cumberland County)
  - Site 3 (Colchester County)
- 1 lake in Maine, U.S.A.
  - Site 13 in Acadia National Park (Hancock County)

During fieldwork undertaken in 2003 for the purpose of this status report and additional fieldwork in 2004, *I. prototypus* was observed *in situ* in all previously known sites, as well as being discovered in four additional lakes in Nova Scotia and two additional lakes in New Brunswick (Figure 7). *Isoetes prototypus* was discovered at site 12 in flotsam by Dwayne L. Sabine and Mary E.J. Sabine on 5 June, 2004.

- New Nova Scotia locations
  - Site 2 (Cape Breton County)
  - Site 5 (Cumberland County)
  - Site 8 (Digby County)
  - Site 9 (Digby County)
- New New Brunswick locations
  - Site 11 (Queens County)
  - Site 12 (York County)

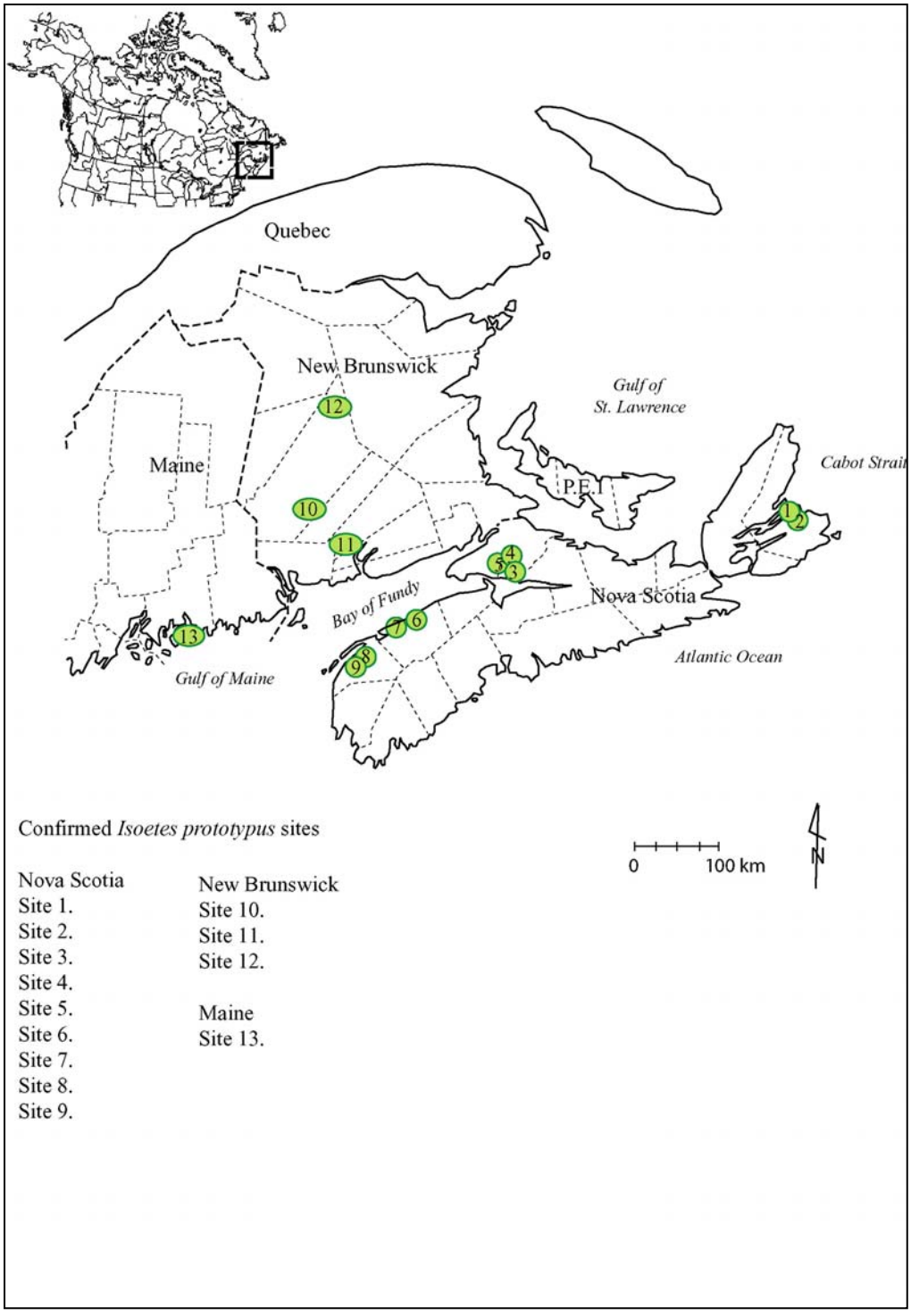

Figure 7. World distribution of *Isoetes prototypus*.

All Nova Scotia and Maine lakes where this species occurs are within 10 to 15 km of the Bay of Fundy / Gulf of Maine coast / Cabot Strait. The New Brunswick lakes

where it has been found are much further inland from the ocean, ranging from approximately 35 to 180 km. from the Bay of Fundy.

Canadian range

As indicated above, 12 of the 13 known locations for *I. prototypus* occur in Canada, nine in Nova Scotia and three in New Brunswick. In Nova Scotia *I. prototypus* is known to occur in five counties, from the northeastern to southwestern ends of the province, but only in a few select locations. In New Brunswick, it is known from three disparate sites spanning nearly one-half of the length of the province. The combined total surface area of all lakes in which *I. prototypus* occurs is quite small (~ 961 ha). The known Canadian populations of *I. prototypus* occupy a total estimated area of about 2.5 ha and is likely less than 5 ha, including portions of populations that might possibly have been missed. The range of the species in Canada has an extent of occurrence of <<5000 km^2. A map of all sites surveyed for *I. prototypus* in 2003 and 2004 is shown Figure 8.

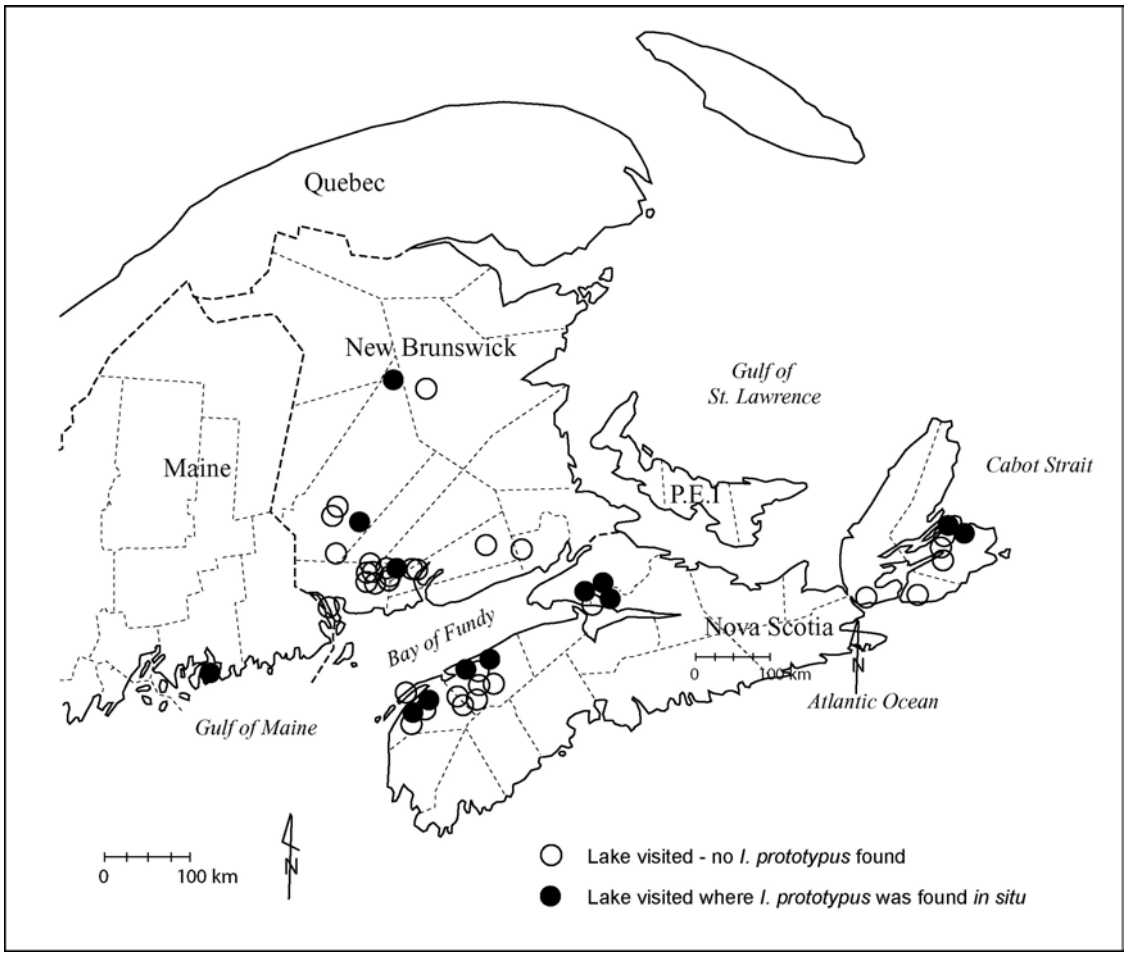

Figure 8. Location of lakes surveyed during 2003 and 2004 *I. prototypus* fieldwork.

HABITAT

Habitat requirements

All available data on lakes where *I. prototypus* is known to occur have been compiled in an attempt to identify common habitat parameters. This information has been provided to COSEWIC as supplementary data that are briefly summarized here.

Isoetes prototypus is a true submerged aquatic of small, oligotrophic, usually cold, spring-fed sterile lakes. Summer temperature stratification was noted at most lakes surveyed and underwater springs were occasionally observed. The pH of the lakes ranged from 5.7 to 7.2, based on measurements obtained from provincial government databases. Although Secchi measurements are not available for most lakes, it was noted that the water was clear to fairly clear at all but one lake (site 3). Lakes with *I. prototypus* were typically quite shallow, ranging from 3.5 to 12.2 m in maximum depth.

Estimates of water depths suggest that *Isoetes prototypus* most often occurs in 1.5 to 2.5 metres of water. This depth frequently coincided with the point where the lake's bottom dropped quickly off from 2 metres to greater depths. A very few plants were found growing in water as shallow as 0.4 m (at sites 4 and 10), but this is very atypical for the species. It has never been found as a rooted emergent. At site 10, some plants were found as deep as 4 m. The solid mats at sites 10 and 12 often abruptly end at just over 2 m depths of water while scattered plants could be found to 2.5 m.

Isoetes prototypus is most often found in soft, flocculent oozy sediment where a swimmer's foot or hand could easily sink 5 to 30 cm or even more. This sediment was usually found overlying a sandy, gravelly, or rocky bottom, sometimes interrupted by rocky shoals and ridges (e.g., sites 1, 2, 3, 5 and 9). At site 6, some populations were extensively covered with a layer of deciduous leaves at the time of the survey (late August). Brunton's herbarium label data indicates that he found *I. prototypus* growing "in sand and silty-sand over clay in an extensive sand plain" at site 4 and "in sand over clay amongst granite boulders" at site 3. At site 4, we found a few plants rooted directly in sand unaccompanied by flocculent sediment but, in our experience, this was an atypical habitat for this species.

According to Brunton (pers. com. 2004), *I. prototypus* is "quite strongly tied to ponds on small sand plain deposits [e.g., sites 4, 6, 7 and 13] and most probably in post-glacial outwash systems". However, such landscape features do not appear on provincial maps depicting the geology and surficial geology, presumably because the maps are generally not at a fine enough scale. At the level of detail depicted in these available maps, no relationship of this species with bedrock geology or soil type could be identified.

Isoetes prototypus grows either in pure swards, or mixed with *I. lacustris* and/or *Eriocaulon aquaticum*. It is also frequently found in small (<10 sq m) patches of 20 or less plants. In the mats of aquatic vegetation at specific locations where *in situ* populations of *I. prototypus* locally occurred, it typically accounted for at least 50% of

the vegetation mass, except at sites 7 and 11, where it comprised up to 20% (the remainder being almost exclusively *Eriocaulon aquaticum*).

Isoetes prototypus falls in the category of isoetids — a group of small, rosette forming plants associated with poor nutrient conditions in wetlands or water. The only plant species found with *I. prototypus* in all lakes was *Eriocaulon aquaticum.* Other frequent associates growing within 5 m of *I. prototypus* populations included *Isoetes lacustris, Lobelia dortmanna* and *Myriophyllum tenellum*. Additional non-emergent aquatic species often found nearby included *I. tuckermanii*, *Subularia aquatica, Nymphoides cordata, Pontederia cordata, Elatine minima* and *Sagittaria* sp. *I. prototypus* plants were commonly covered with unidentified algae. At site 4, Brunton (pers. com.) found *Subularia aquatica* growing among plants of *I. prototypus*.

Some of the more frequent shoreline species found at lakes where *I. prototypus* occurs were: *Calamagrostis canadensis, Juncus militaris, Lysimachia terrestis, Myrica gale, Sium suave* and *Triadenum fraseri*. Lakes with a very prolific shallow water emergent vegetation rim or extensive boggy margins were thought to be poor candidates *for I. prototypus* because of their more eutrophic nature.

There was no consistent pattern in forest cover around the lakes. Sites 6 and 7 have a predominance of hardwoods, while sites 3, 10 and 12 are mainly surrounded by Acadian softwood forest. The forest cover around most lakes is mixed (e.g., *Abies, Acer rubrum, Acer saccharum, Betula, Picea*).

Lakes with *I. prototypus* are typically good for trout and often have been stocked with Brook Trout, or rarely Rainbow Trout. Many lakes also contain Banded Killifish.

Freshwater sponges were found in almost all *I. prototypus* lakes, rarely even growing on *I. prototypus* plants. Freshwater mussels were also sometimes found near *I. prototypus* populations.

The *Isoetes prototypus* lakes located close to the Bay of Fundy (e.g., sites 3, 4, 5, 6 and 7) often occur on plateaus at elevations over 200 m. Except for sites 1 and 2, the other lakes were all over 100 m in elevation. At sites 10 and 11, a steep rocky cliff face or tall hills border the shoreline at one or more locations.

Habitat trends

There is little information available on habitat trends. *Isoetes prototypus* is still extant at all lakes where it has been found.

Of the three sites in New Brunswick, one is on a landscape that has recently been subject to intensive forestry except for a mandatory buffer strip that was left around the margins of the lake. The other two New Brunswick sites currently have restricted access. One of these sites (site 11) is surrounded by a fairly intact forest, while the other site (site 10) has been maintained as an open field for many years and recently had a permanent residential dwelling built in this field.

In Nova Scotia, cottage development and associated shoreline deforestation were extensive around two sites (4 and 8) and at one end of each of an additional two sites (sites 6 and 7). At three sites, roads and/or causeways border or encroach upon the shoreline at one or more locations. It is not clear what impact these may or may not have had on the populations of *Isoetes prototypus* at these lakes.

Habitat protection/ownership

None of the Canadian lakes where *I. prototypus* has been found is within a protected area. However, site 1 is a source of water supply for a nearby community and is posted against certain activities that might have a negative impact on water quality. No disruptive activities are foreseen for the three sites in New Brunswick.

Sites 3 and 5 occur on Crown land in Nova Scotia, and site 11 occurs on federal (Dept. of National Defence) land in New Brunswick, but the other nine known Canadian lakes where *I. prototypus* is known to occur are on private land. However, in Nova Scotia, the bottom of almost all lakes is considered to be Crown land, even though the shoreline and land around the lake may be privately owned. Hence, all known locations for *I. prototypus* in Nova Scotia are on Crown (public) land. The ownership of the bottom of lakes in New Brunswick is more complicated since the lake bottom (along with fishing rights) was once granted along with the surrounding land grant, and this ownership of the lake bottom transfers with the deed when a property changes hands. This practice evidently changed in 1863, so lands granted after that year did not include ownership of the lake bottom and fishing rights. Without searching the deeds of New Brunswick properties surrounding a lake back to the original grant, it is impossible to ascertain the ownership of the lake bottom for any lake in the province where *I. prototypus* has been found (D.L. Sabine pers. com. 2005).

BIOLOGY

Life cycle and reproduction

Little or nothing is known about the various life cycle stages of *Isoetes prototypus*, or their requirements. Figure 9 shows a generalized illustration of the life cycle of an *Isoetes* sp.

There are apparently no publications on the reproduction and life cycle of *Isoetes prototypus*, and according to Dr. W. Carl Taylor (pers. com. 2003), there is very little information on the reproduction and life cycle of *Isoetes* species in general. According to Caplen and Werth (2000), “information on the natural history of sexual reproduction in *Isoetes* is completely lacking”, but direct observations of sexual reproduction in this genus have been made *in vitro*.

Virtually nothing is known about the factors that affect the survival of *Isoetes prototypus*, the age structure and stability of populations, or its reproductive and

mortality rates. This species has evergreen leaves and is thought to be perennial. However, the *in situ* observations that have been made on *I. prototypus* were during the summer and early autumn.

Cobb (1963) provides one of the most comprehensible accounts of the life cycle and reproduction of *Isoetes* sp. The familiar *Isoetes* plants with the typical "quillwort" morphology are sporophytes that produce two types of spores, large female spores called megaspores, and small male spores called microspores. These spores are borne within sporangia located in the concavities of the lower spoon-shaped portions of the leaves (usually mainly the middle and outer leaves). Although both types of spores are usually produced by the same plant, the megaspores and microspores typically occur in separate sporangia; however, in some species both types of spores may occur together in the same sporangium. Up to 100 or more megaspores may develop within a single sporangium, whereas the number of microspores per sporangium may be as high as several hundred thousand. The spores typically mature in the late summer and are released as the sporangial tissue decays or breaks apart.

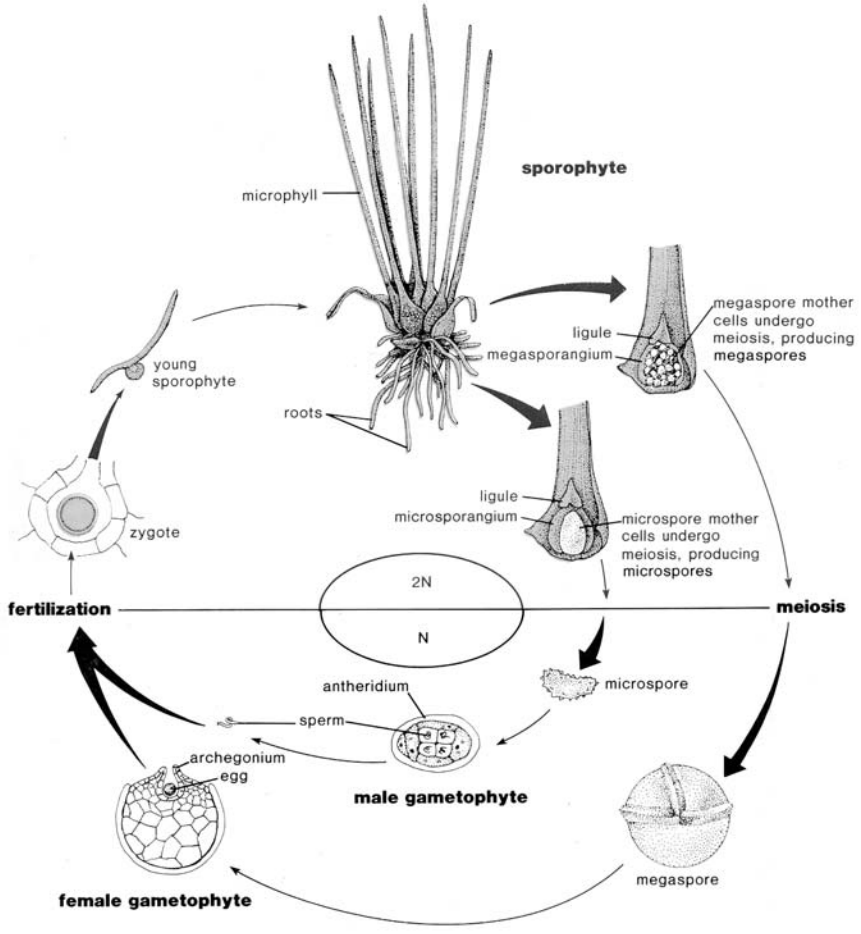

Figure 9. Life cycle of *Isoetes* (from Stern 1985; used by permission, McGraw-Hill Education).

Microspores and megaspores each give rise to their own gametophytes or prothalli. The male gametophyte usually produces four motile spermatozoids, which are elongate, tiny and bear four cilia, two at either end. The female gametophyte is round and multicellular, and bears eggs along its dorsal aspect. The eggs are located at the bases of small funnel-like structures (archegonia) that open when the eggs are ready for fertilization and close after fertilization has occurred. The young sporophytes develop directly from the fertilized eggs.

The reproduction of *Isoetes* species is thought to be almost entirely sexual, by virtue of their heterosporous nature. However, Caplen and Werth (2000) speculate that "the close proximity of megasporangia and microsporangia coupled with the gradual release of spores through decay of sporangial tissue ..... might allow for significant levels of intergametophytic (i.e., sporophytic) selfing analogous to self-pollination in seed plants."

Although many *Isoetes* hybrids have recently been reported in the literature and there is preliminary evidence that *I. prototypus* may have been a progenitor of *I. tuckermanii*, *I. acadiensis* and *I. lacustris* (Taylor 2003, pers. com.), no hybrids involving *Isoetes prototypus* have yet been detected.

Herbivory

It is not known if this species is a food source for animals but grazing by Mallards has been noted for other species of *Isoetes* (Brunton and Britton 1999).

Physiology

Little is known about the physiologic requirements of *I. prototypus*, other than the habitat data compiled in this report. No comprehensive study on the ecology of this species has been undertaken.

Dispersal/migration

Populations of aquatic species of *Isoetes* often exist in isolation from one another since the waterways or bodies of water where they occur are not interconnected (Caplen and Werth 2000). The movement or dispersal of *Isoetes* propagules has evidently never been observed in the field, but could occur by water flow within rivers and streams, or by the transport of propagules via animals such as beavers, muskrats or waterfowl (Caplen and Werth 2000, Brunton and Britton 1999), or possibly by moose. For example, Mallards have been seen grazing on other *Isoetes* and Common Loons have been seen uprooting and possibly eating *Isoetes* (Brunton and Britton 1999). Brunton (pers. com. 2004) also suggests that "fish and turtles are at least as likely vehicles of disturbance and transport".

There is apparently very little information on the movement or dispersal of *Isoetes prototypus*. However, at many lakes where it has been found, it was first detected by the presence of uprooted plants floating along the edges of the lake or washed up on shore. Brunton and Britton (1993) speculate that *Isoetes* plants may be dislodged by

motor boats, fishing lines, anchors, swimmers, bottom-feeding waterfowl, muskrats, wintering reptiles and amphibians, and/or spawning fish. D.L. Sabine (pers. com. 2004) suggested that moose may perhaps play a role in dislodging plants of *I. prototypus* since well developed moose trails extend as deep as 1.5 to 2.0 m. in some New Brunswick lakes where *I. prototypus* occurs (e.g., site 12). Brunton (pers. com. 2002) has also proposed that the formation of gas pockets and/or the seasonal inversion of water may be responsible for dislodging *Isoetes* plants. In Holland Lake, plants of *I. prototypus* were sometimes easily dislodged by water currents that were created by the use of flippers, and partially dislodged mats of plants were sometimes found near the edges of underwater springs. Some of the dislodged floating plants are missing their corms and roots, but often still have microspores and macrospores (Goltz, personal observation). It is possible that movement and dispersal of floating plants of *I. prototypus* by wind and water currents could result in the deposition of spores and the formation of colonies at new sites within the lakes where this species occurs.

Interspecific interactions

Isoetes prototypus appears to be confined to oligotrophic lakes, where it typically grows in soft flocculent sedimentary ooze.

The writers confirmed that *I. prototypus* may form extensive swards on its own, but often is intermixed with swards of other *Isoetes* species and hybrids, especially *I. lacustris* and *I*. x *harveyi*, and dense mats of *Eriocaulon aquaticum.*

No hybrids involving *I. prototypus* have yet been found, including during fieldwork conducted by the writers during the summers of 2003 and 2004. However, such hybrids would best be detected by performing chromosome counts, and very few live specimens were collected for this purpose. It is very likely that this species does hybridize, or at least did in the past, since DNA analysis done by Dr. W. Carl Taylor suggests that *I. prototypus* has been involved in the genome of *I. lacustris*, and possibly *I. acadiensis* and *I. tuckermanii*.

Adaptability

Nothing is known about how well *Isoetes prototypus* tolerates environmental degradation or adapts to disturbance or change. It generally grows at depths exceeding 1.5 m. in cool oligotrophic spring-fed lakes, so it is speculated that it could be negatively impacted by water pollution, eutrophication, decreased water levels and changes in water temperature.

POPULATION SIZES AND TRENDS

Search effort

Plants of the genus *Isoetes* have been collected throughout much of Nova Scotia during the past 100 plus years. Determination to species for most of these collections was unlikely to have been made at the time of collection as most collections are identified post fieldwork; thus the plants collected might well represent a relative

abundance of various *Isoetes* species in that province. Although *I. prototypus* had been collected in Nova Scotia in the past, along with other species of *Isoetes*, the number of pre-1990 collections of this species is by far the lowest of any species of *Isoetes* known to occur in the province. This seems more likely to indicate a genuine rarity, and not just undercollection of the species.

In an attempt to find *I. prototypus* and other species of *Isoetes*, D.M. Britton had checked 43 lakes, 1 river and 1 creek in Nova Scotia during fieldwork conducted between 1989 and 2000. His fieldwork uncovered two previously unknown sites for *I. prototypus*, sites 3 and 7. *I. prototypus* was independently discovered at site 7 by D.F. Brunton and Dr. Karen McIntosh around the same time it was found there by D.M. Britton. Brunton and McIntosh have checked at least 50 lakes in New Brunswick and Nova Scotia for *I. prototypus*, other *Isoetes* species and various *Isoetes* hybrids, and more than 20 additional lakes in Maine, New Hampshire and Massachusetts. The fact that these very targeted searches resulted in so few populations of *I. prototypus* being found attests to the rarity and selective nature of this species (Brunton pers. com. 2004).

A total of 50 lakes (1 in Maine, 25 in New Brunswick, 24 in Nova Scotia) were searched for *I. prototypus* during survey work conducted for this status report in 2003 and additional field work in 2004. Excluding travel time, at least 46 hours were spent investigating lakes having *I. prototypus* populations, while at least 56 hours were spent investigating lakes where *I. prototypus* was not found. Twenty days were spent conducting fieldwork, and approximately 5075 km were travelled. A total of 170 collections were made in 2003, 124 from the genus *Isoetes*, 27 representing *I. prototypus*; numbers of collections made in 2004 have not yet been tallied.

No reference sources (e.g., maps, databases, etc.) enabling the identification of lakes that may have suitable habitat characteristics for *I. prototypus* are readily available. Attempts to identify potential candidate lakes were made by consulting provincial government agencies that record lake survey data (mainly for fisheries); by consulting biologists and ecologists who have a good knowledge of lakes in New Brunswick and Nova Scotia, and/or have reviewed aerial photos and topographic (elevation) maps or viewed potential sites by air; by consulting local fishermen; and by consultation with Dr. D.M. Britton. Very little effort was made to survey lakes that were not oligotrophic or nutrient poor.

The discovery *of I. prototypus* at sites 2 and 5 was a result of D.M. Britton's encouragement that these lakes had high potential for this species. Its discovery at sites 8 and 9 came from discussions with Sean Doucette, a local fisherman, who suggested that several lakes in this part of Nova Scotia were good for trout fishing and were spring-fed. It was discovered in flotsam at site 12 by Dwayne L. and Mary E.J. Sabine during a late spring fishing expedition. Its discovery at site 11 was a result of systematic checking of high elevation, clear water lakes that seemed to be good candidates when viewed from the air by Dedreic Grecian.

As a result of the fieldwork in 2003 and 2004, it seems likely to expect populations of *I. prototypus* in more lakes than the 13 known to date. Nova Scotia offers the

greatest potential, especially in the small 'kettle' ponds near Digby (Brunton, pers. com.), and perhaps in the lakes near site 3. Consultation with fisheries biologists and trout fishermen may provide helpful guidance for discovering new sites. The lakes in southwestern New Brunswick and those within 30 km of the Maine coast certainly have not been extensively explored for this species and offer numerous high potential sites. The recent discovery of the species in a lake in central New Brunswick indicates a large new region of potential habitat in the province.

Given its predilection for clear water, boreal-type ponds and lakes and scattered occurrence within its known range, *I. prototypus* could be expected to occur elsewhere over a wide area of northeastern North America including northern New Brunswick, eastern Maine and the Gaspé Peninsula in eastern Quebec (D.F. Brunton pers. com. with E. Haber, May, 2005).

Since *I. prototypus* was first described in 1991, considerable time, effort and resources have been expended in intentional searches for this and other *Isoetes* species (Britton pers. com. 2003, Brunton pers. com. 2004). Part of the elusiveness of *I. prototypus* has been its preference for deep water (1.5 m or more). In many lakes, visibility from the water's surface is rarely greater than 2 m, and more frequently less. Site 3 has tea-coloured water, obscuring visibility beyond 0.5 m. Searching using a glass-bottomed bucket can be successful in lakes with clearer water on sunny days; however, *I. prototypus* is often covered with algae, making it extremely difficult to see or definitively recognize from the surface. Populations of *I. prototypus* can readily be confused with or obscured by other species of deep water *Isoetes* (e.g., *I. lacustris*) or mat-forming aquatics such as *Eriocaulon aquaticum* and *Myriophyllum tenellum*.

In the past, combing shoreline flotsam for plants dislodged through natural processes was mainly how specimens of *I. prototypus* were collected, and how most site occurrences were detected. According to D.M. Britton (pers. com. 2003), wracks of *I prototypus* are most commonly seen in July, while Brunton (pers. com. 2004) has observed that these are most abundant later in the season, in August and September. Floaters have been seen at site 10 at all times of the year when there is no ice (Goltz, pers. observation). However, in 2003, only one floating clump of *I. prototypus* was found at site 10; none of ten *I. prototypus* lakes had any floaters. Low numbers of floating plants of this species were found at site 12 in June and September of 2004, but none was seen there in the spring of 2003. Thus surveying flotsam is an unreliable survey method, though convenient when plants are found.

The following search techniques were employed while doing fieldwork for this status report:

- examining flotsam along lake shores
- dragging of anchor or paddle
- surface viewing from air mattress and from canoe
- use of glass bottom bucket from canoe
- wading

- swimming with mask (and snorkel), and
- scuba diving (sites 10 and 12 only)

Techniques such as dragging a boat anchor to dislodge plants, which then float to the surface, have had success in several lakes (Britton 2002, pers. com.). Swimming and scuba diving proved to be the most reliable methods for the detection of *I. prototypus*. These allow increased visibility of the lake's bottom, with easy access to vegetation to verify potential populations. Except for a few plants in site 4 and site 10, all plants were found in 1.5 metres of water or deeper. The greatest depth of water that plants of the genus *Isoetes* were collected from was 5 m, which is challenging even for a swimmer wearing a wet suit. However, the majority of *I. prototypus* plants were located in water 1.5 to 2.5 m deep, within reach of a surface swimmer. Surveying with scuba equipment allows greater detail and exploration at greater depths, but is also considerably more expensive and cumbersome.

At the depths preferred by *I. prototypus*, a swimmer can often do a preliminary survey with his feet while bobbing in the water, for even with water slippers on, it is possible to discern between *Eriocaulon* mats and *Isoetes*, as one can feel the stiff quill tips breaking off, as well as the prickly texture of *I. prototypus*, *I. lacustris*, and other straight-quilled *Isoetes* that may possibly be of hybrid origin. Some dense mats of robust *Myriophyllum tenellum* had a similar texture to straight-quilled populations of *Isoetes*, necessitating retrieval of plants from the bottom to be certain of their identification. In two lakes (site 8 and 9), *I. prototypus* was almost completely obscured by a tremendous abundance of *Utricularia purpurea*, and was only detected by palpating (by hand or foot) the lake bottom beneath these other plants.

In most of the lakes where *I. prototypus* was known to occur or was discovered during fieldwork in 2003 and 2004, it seldom took more than five minutes to find the species *in situ*, except for at sites 1 and 3, where many hours were spent before this species was seen.

Abundance

Prior to 2003, *I. prototypus* had been seen *in situ* in only four Canadian lakes (sites 1, 4, 6, 10) and the single locality in Maine (site 13). There had been no quantitative studies on the sizes of *Isoetes prototypus* populations in any of the Canadian lakes, nor had the populations been studied over time at any site where this species occurs. The occurrence of *I. prototypus* in most lakes had mainly been documented by collections of plants that had been uprooted and found floating near the lakeshore or washed up on shore.

Gradually more is becoming known of the size of *I. prototypus* populations. *In situ* populations typically occur in large uniform swards, measuring up to 200 X 50 m, at depths of ± 2 m. Comprehensive population studies on *I. prototypus* were made in 2000 at site 13, in Maine, where plants were estimated to grow at a density of 50 per square metre, and covered a total area of about 134 sq. m (Weber 2003, pers. com.). Since sampling was insufficient to get a firm estimate of the number of plants per sq. m, Weber suggested that a conservative estimate of the population size at the Maine site is 8775 to 10,000 plants.

Within one of the dense swards of *I. prototypus* at site 10, a 0.25 m^2 quadrat area was found to contain 30 plants. This count was made in 2003 without the aid of scuba gear. Based on this count, it was estimated that 120 plants would occur within an area of 1 m^2. The crown of one of the largest *I. prototypus* plants from site 10 measured 20 by 8.5 cm or 0.20 by 0.085 m, and therefore would cover an area of 0.017 sq. m; this means that there could be about 59 plants of this size in an area of 1 m^2. As this plant was roughly double the size of most plants of this species, our estimate of about 120 plants per m^2 seemed realistic. However, Brunton (pers. com. 2004) believes that our estimate of the density of plants of this species within the mats is far too conservative and suggests that the average density figure should be at least doubled, since it is typical for the leaves of adjacent plants of aquatic *Isoetes* to overlap considerably, and the density calculation does not make allowance for such overlap.

At site 12, counts of *I. prototypus* within the 0.25 m^2 quadrat area were done while using scuba gear in 2004. Counts made in one of the swards of *I. prototypus* ranged from 54 to 98 (mean 80.3) per 0.25 m^2, or 216 to 392/m^2. It would be interesting to determine how counts at all sites might differ if done consistently with the assistance of scuba gear.

It had been hoped that more accurate population estimates could be determined for all sites, and that a GPS reading could be made for all populations in each lake. However this proved to be impossible. Populations of *I. prototypus* often grew intermixed with other *Isoetes* sp. and it was often not feasible to determine identity *in situ* under water, since the morphology and colour of the other quillwort species were superficially so similar. More precise counts might have been achieved through uprooting large numbers of plants but such practice would be unethical for a species that is potentially at risk. At site 3, the strongly pigmented water made it extremely difficult to find populations *in situ*. At sites 8 and 9 plants were almost completely obscured by *Utricularia purpurea*. Since most populations were ultimately detected by swimming, the use of GPS equipment was prohibited.

Table 1 has been compiled from 2003 and 2004 fieldwork and Weber's estimate for the Maine locality. The estimates provided in Table 1 do not purport to reflect total *I. prototypus* populations in any of the lakes. A thorough survey to record all populations of *I. prototypus* at the lakes where this species is known to occur would have required considerably more time than was available, especially given the dual objective of trying to find new sites for this species. The most thorough population survey was done at site 10; otherwise, the total area surveyed in the other lakes seldom exceeded one-fourth of the area of any lake. Some lakes (sites 2, 8, 9 and 11) were only surveyed until plants morphologically resembling *I. prototypus* were discovered. Sites 6 and 7 were only briefly surveyed to confirm that *I. prototypus* populations were still extant and to locate the species *in situ*. Plant density, and the length and width of *I. prototypus* populations were estimated while swimming. Actual populations in all lakes are most likely considerably higher than reported here. According to D.F. Brunton (pers. com. 2004), who has considerable field experience with many species of *Isoetes*, "counting aquatic quillworts is notoriously difficult and inaccurate" and "numbers are undoubtedly larger in virtually all cases".

Table 1. *Isoetes prototypus* population estimates.

Site	Area of *I. prototypus* population (m^2)	Density	Estimated number of plants
Site 1, total population			13,061+
Sub-population #1	*-*	*very rare*	*1*
Sub-population #2	*200 X50*	*scattered*	*70+*
Sub-population #3	*-*	*not in dense mats*	*60+*
Sub-population #4	*30 X5*	*-*	*50+*
Sub-population #5	*100 X 20*	*< 48/ sq m*	*10,000+*
Sub-population #6	*10 X 6*	*48+ / sq m*	*2,880+*
Site 2, total population			120+
Sub-population #1	*-*	*to 32 / sq m*	*100+*
Sub-population #2	*-*		*20+*
Site 3, total population			202+
Sub-population #1	*15 X 3*	*-*	*100+*
Sub-population #2	*50 – 60 X 5 -10*	*scattered*	*100+*
Sub-population #3	*?*	*uprooted with paddle*	*2*
Site 4. total population			10,400+
Sub-population #1	*100 X 35*	*dense mats*	*10,000+*
Sub-population #2	*50 X 20*	*-*	*400+*
Site 5. total population			20+
Sub-population #2	*50+ X 5 -10*	*very few* I. prototypus *among dense mats of other* Isoetes *sp. and hybrids with straight quills*	*10+*
Sub-population #3	*150 X 5 -10*	*very few* I. prototypus *among dense mats of other* Isoetes *sp. and hybrids with straight quills*	*10+*
Site 6.	>200 X 5	continuous mats parallel to shoreline (20 m out from water's edge	1,000+
Site 7.	200 X 10	scattered mats, largest being 5 X 5 m	100+
Site 8.	5 X 10	scattered patches	40+
Site 9.	30 X 5	no mats, scattered individual plants or small clumps	100+
Site 10. total population			32,210+
Sub-population #1	*Floaters*		*10*
Sub-population #2	*26 X 10*	*120 / sq m*	*31,200+*
Sub-population #3	*12 X 4*		*1,000+*
Site 11.	50 X 20	no mats seen	1,000+
Site 12. total population			192,700+
Main sub-population	*20 X 30*	*pure, dense population*	*192,600+*
Smaller mixed population	*60 X 20*	*scattered individuals, or small clumps*	*100+*
Site 13. (Maine, USA)	134	two mats found	9,000+
Total (including US population)	25,797		Conservative estimate 259,953+

Brunton (pers. com. 2004) considers our population estimates to be extremely low, except perhaps at site 4, where he suggests that our population estimate may be a bit high based on his personal observations. He believes that "there are tens of thousands of plants at site 7 alone, for instance", based on his "observations in 1998 of *I. prototypus* leaves piled up in 5-20 cm deep 'drifts' that extended along several hundred metres of shoreline". He found similar wracks of plants along shorter stretches of shoreline at site 1 in the mid to late 1990s. At the bottom of site 13 in Maine, he observed that "it forms a dense, virtually pure lawn of plants extending over a large area".

In summary, our attempts to quantify the sizes of *I. prototypus* populations at all locations were woefully inadequate and the numbers in Table 1 should be regarded as only best estimates, despite our concerted efforts. Brunton (pers. com. 2004) suggested that population estimates for aquatic *Isoetes* might best be described within a numerical range (e.g., 12 million ±2 million estimate for *I. bolanderi*, an Alberta species) rather than trying to provide more precise totals, since the latter could well prove to be inadequate, inaccurate and totally misleading.

Fluctuations and trends

Isoetes prototypus populations are still extant in all lakes where this species has been found. In many lakes it seems to be abundant. D.M. Britton (pers. com. 2003) is concerned that populations may have declined at sites 1, 4 and 6, but good populations were still found there in 2003. D.F. Brunton (pers. com. 2004) suggests that the populations at site 7 have plummeted if our 2003 population estimate is compared to the shoreline drifts that were found there in 1998. Since none of the *I. prototypus* populations has been studied over time, it is impossible to ascertain any trend. Even though the population at site 10 has been monitored more than others, with submerged plants it is very difficult to determine whether or not populations are increasing or decreasing without monitoring permanent quadrats over time. Brunton (pers. com. 2004) cautions that further speculation could be dangerous because "it could encourage a false sense of security in regards to the long-term stability of these very fragile and sensitive populations".

Unlike many of the other lakes, populations *of I. prototypus* at sites 5, 8, 9 and 11 appeared to be much lower. Plants of *I. prototypus* at site 5 were extremely difficult to discover among the swards of other *Isoetes* species and hybrids. Further study of these four lakes is warranted.

Rescue effect

Isoetes prototypus is still extant and locally abundant at the single known location in the United States. It is possible that spores of this species from plants growing *in situ* or from dislodged plants washed up along shorelines could be ingested by migratory waterfowl, shorebirds or songbirds and transported to a suitable lake in Atlantic Canada. It is also plausible that spores from dislodged plants might be inadvertently transported

in mud and organic material caked on boats, footwear (boots) or tires of vehicles used to launch boats, although Brunton (pers. com. 2004) cautions that "there is no documented incident (or suggestion) anywhere of an aquatic *Isoetes* being successfully transported by the unintentional actions of humans". Spores of *I. prototypus* from the Maine site (site 13) are evidently being preserved in a seed bank (Greene, Weber and Rooney 2002).

Since most of the globally known sites for this species occur in Canada, it is more likely that the Canadian sites and populations could serve as a source of distribution for *I. prototypus* to expand further into the United States, rather than vice versa.

All known populations of *I. prototypus* are present within lakes that do not drain into one another and are therefore discontinuous and fragmented. Most of the lakes have cottages and most have been stocked with trout. The lakes are used for fishing and boating occurs on most lakes. Spores could spread by clinging to boats or through waterfowl movements but such events are presumed to occur infrequently. Brunton (pers. com. 2004) believes that *I. prototypus* has an extremely "tough time getting around and everything points to local populations being ancient and only rarely moved beyond where the water currents can take them". He considers that the potential for dispersal by the agents suggested above would be "extremely rare", as evidenced by the fact that sub-populations of more wide-ranging *Isoetes* taxa (e.g., *I. engelmannii* and *I. appalachiana*) are strikingly genetically dis-similar.

LIMITING FACTORS AND THREATS

Brunton and Britton (1993) speculate that the occurrence of *I. prototypus* in deep, cold, nutrient-poor lakes "may reflect a particularly strict set of site requirements and/or the species' inability to tolerate significant competition", and that its distributional potential may be limited by its restrictive habitat requirements. Regardless of the population size at any location, Brunton (pers. com. 2004) cautions that the entire population at each location will only remain extant and viable if the ecological integrity of its supporting aquatic habitat is maintained.

Lakes where *I. prototypus* grows often have excellent water quality and are in high demand as sources of drinking water (e.g., sites 1 and 13) or for cottage development and recreation (e.g., sites 4 and 6). Threats to *I. prototypus* may include direct disturbance of populations or habitat alteration. Plants may be damaged or uprooted by swimming, boating, fishing, the use of anchors, raking swimming areas, the installation of water intake pipes, or the activities of wildlife (Britton and Brunton 1991). At one of the sites, bushels of wrack, comprised largely of plants of *I. prototypus*, are removed from a 30+ m stretch of beach every year (Britton 2002, pers. com.). Raking and removal of wrack can reduce the reproductive potential of the population. While the extent of this activity may currently be a minor factor involving less than 1% of the shoreline of the lake, it is worth noting its potential effect since floating plants tend to be concentrated in small areas depending upon the wind direction and wave action.

Habitat modifications that could potentially have a negative impact on *I. prototypus* include cottage and shoreline development, changes in water levels by damming or draining, water pollution, eutrophication, siltation, changes in pH and competition by invasive and/or exotic aquatic plant species (New Brunswick Museum 1994). Aquatic *Isoetes* species are evidently vulnerable to water pollution (Brunton and Britton 1993).

At sites 1, 2 and 4, roadways and/or causeways border or encroach upon the shoreline at one or more locations. Cottage development and associated shoreline deforestation were extensive around much of sites 4 and 8, and at one end of sites 6 and 7. It is not known if these disturbances to the surrounding habitat have had any impact on the populations of *I. prototypus* in these lakes. Further shoreline development is unlikely to occur at two of the three New Brunswick sites (sites 11 and 12).

Wildlife (e.g., moose) has been observed as a source of disturbance, yet the animal species noted at these sites are not new to the landscape and their significance on populations of *I. prototypus* is unknown.

Although *Isoetes prototypus* is of great interest to Isoëtologists, the leading researchers on this genus are very concerned about ensuring that this species is not harmed by overzealous collecting and place great importance on its conservation. Unfortunately, this and other *Isoetes* species can seldom be identified with certainty in the field, and must be collected for identification and verification.

SPECIAL SIGNIFICANCE OF THE SPECIES

Brunton (pers. com. 2002 and 2004) considers this species to be a very primitive *Isoetes* species “of ancient origins”, “a living fossil” that is morphologically “as simple as it gets” and “dramatically different from all other members of its 'stable' genus”, with “nothing else like it in the world”. He thinks it is likely the rarest *Isoetes* species in North America, and the most globally significant aquatic plant in Canada, an Acadian endemic with an incredibly narrow geographic range and an extremely sensitive habitat. Since this species does have a very restricted range and 92% of its known sites occur in Canada, it is important that all populations of this species remain viable and extant.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Isoetes prototypus is not listed under either the Canadian Species at Risk Act or The Endangered Species Act of 1973 in the United States. It is not listed in the IUCN Red Book or by the Convention on International Trade on Endangered Species of Wild Fauna and Flora (CITES).

In New Brunswick, *I. prototypus* and its habitat are protected under the provincial *Endangered Species Act.* It is not listed as an endangered species under legislation in

Nova Scotia. The state of Maine has no equivalent endangered species legislation that protects plant species (Linda Gregory 2003, pers. com.). None of the Canadian lakes where *I. prototypus* has been found is within a protected area. One site in New Brunswick is on Department of National Defence land. Two lakes (site 13 in Maine and site 1 in Nova Scotia) are sources of public drinking water and are subject to restrictions to safeguard water quality, e.g., the banning of swimming and the prohibition of boats and/or motorized boats. The site in Maine is located within Acadia National Park and hence is within a protected area.

Isoetes prototypus is ranked as an S1 species in New Brunswick (3 sites) and Maine (1 site), and as an S2 species in Nova Scotia (9 sites). It is listed as N1? in Canada (26 Oct. 2001) and N1 in USA (19 Apr. 1997), and has been assigned a Global Heritage Status Rank of G1? (26 Feb. 2001).

The IUCN Pteridophyte Group has ranked *I. prototypus* as one of the rarest pteridophyte species in North America (Brunton pers. com. 2004).

TECHNICAL SUMMARY

Isoetes prototypus
Prototype Quillwort isoète prototype
Range of Occurrence in Canada: Nova Scotia, New Brunswick.

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* **General estimate of total area encompassed within polygons including extant localities and excluding major areas of non-suitable habitat (total area of lakes where the species occurs is only 959.4 ha)**	<<5000 km^2 (at this time there is no evidence to suggest that the range is continuous over the geographic area where the plants have been found)
• *Specify trend in EO*	unknown, but suspect it may be stable
• *Are there extreme fluctuations in EO?*	unknown
• *Area of occupancy (AO) (km²)* **Combined area covered by *I. prototypus* populations**	0.25 km²
• *Specify trend in AO*	unknown
• *Are there extreme fluctuations in AO?*	unknown but likely fluctuates based on extensive drifts of uprooted plants noted in some years at some sites
• *Number of known or inferred current locations*	12 in Canada, 1 in USA
• *Specify trend in #*	unknown; still extant at the 4 lakes where it was collected about 50 years ago or more, 4 new sites found in 2003, 2 additional new sites found in 2004
• *Are there extreme fluctuations in number of locations?*	unknown
• *Specify trend in area, extent or quality of habitat*	possibly stable but cottage development and recreational activities have likely increased over the last 50 years and may have had some impact on habitat quality on some lakes
Population Information	
• *Generation time (average age of parents in the population)*	unknown
• *Number of mature individuals*	perennial: >250,000 in Canada; 9,000 in USA
• *Total population trend:*	unknown
• *% decline over the last/next 10 years or 3 generations.*	-
• *Are there extreme fluctuations in number of mature individuals?*	fluctuations of a potentially large magnitude may have occurred at some sites
• *Is the total population severely fragmented?*	Yes. (The 12 Canadian populations are dispersed within 6-7 areas and none of the lakes in these areas where the species occurs are joined through intermediary connections.)
• *Specify trend in number of populations*	unknown; likely stable

• *Are there extreme fluctuations in number of populations?*	unknown

• List Canadian populations with number of mature individuals in each:

Site	**Estimated number of plants**	
Site 1 NS		13,061
Site 2 NS		120+
Site 3 NS		202+
Site 4 NS		10,400+
Site 5 NS		20+
Site 6 NS		1,000+
Site 7 NS		100+
Site 8 NS		40
Site 9 NS		100+
Site 10 NB		32,210+
Site 11 NB		1,000+
Site 12 NB		192,600+
Total	very conservative estimate	>250,853

Threats (actual or imminent threats to populations or habitats)

The following threats are primarily potential in nature or of uncertain impact

- lake border encroached upon by roadways and causeways
- habitat modifications through cottage and shoreline development
- changes in water levels by damming or draining
- plants potentially damaged or uprooted by swimming, boating, fishing, the use of anchors, the installation of water intake pipes, or the activities of wildlife, road construction
- water pollution, eutrophication, siltation, changes in pH
- competition by invasive and/or exotic aquatic plant species

Actual impacts observed:

- Major uprooting likely due to natural disruption of the lake bottoms as evidenced by extensive drift lines along lakeshores
- Localized raking of swimming areas to remove plants

Rescue Effect (immigration from an outside source)

• *Status of outside population(s)?*
USA: 1 population in Maine (site 13 which is discussed within this report)

• *Is immigration known or possible?*	not likely – potential spread by waterfowl, mammals, botanists, boaters, fishermen
• *Would immigrants be adapted to survive in Canada?*	likely
• *Is there sufficient habitat for immigrants in Canada?*	likely
• *Is rescue from outside populations likely?*	No, since all but one of the occurrences are in Canada, and the USA locality is considerably disjunct.
Quantitative Analysis (Table 4 from COSEWIC Assessment Process and Criteria)	unknown % probability of extirpation

Current Status

COSEWIC: Special Concern

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code**: N/A

Reasons 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 in Nova Scotia and New Brunswick. The species is found in nutrient-poor, cold, spring-fed lakes. Although several sites have been shown to contain large numbers of plants, one half of the documented sites contain small populations. A wide range of potential limiting factors could impact the species, including changes in water quality, boating and shoreline development.

Applicability of Criteria

Criterion A (Declining Total Population): No data available for decline.

Criterion B (Small Distribution, and Decline or Fluctuation): Not met.

Criterion C (Small Total Population Size and Decline): Not met

Criterion D (Very Small Population or Restricted Distribution): Not met.

Criterion E (Quantitative Analysis): Not applicable.

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Steve Currie and Pam Seymour, New Brunswick Department of Natural Resources – lake survey and data report for site 10.
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Authorities Contacted

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

James P. Goltz has a Ph.D. in veterinary pathology and works as Manager of Veterinary Laboratory Services for the New Brunswick Dept. of Agriculture, Fisheries and Aquaculture. He has been an active field botanist for nearly 30 years, and has a special interest in pteridophytes, orchids, emergents, rare and endangered species, and the flora of Muskoka District (in Ontario). He co-authored with Dr. D.M. Britton the paper describing Prototype Quillwort, *Isoetes prototypus*, as a species new to science, based on collections that they made of this species in New Brunswick. Dr. Goltz has also published reports on the discovery of Curly-grass Fern in New Brunswick, Southern Beech Fern in Muskoka, and European Twayblade in Wellington County, Ontario, and revised the ORCHIDACEAE section in Hinds' second edition of the Flora of New Brunswick.

Gart Bishop holds a B.Sc. and has been actively working as a field botanist since 1994. As a partner in B & B Botanical, he has conducted inventories and made collections of vascular plants at a variety of sites in New Brunswick, Nova Scotia and Maine, including provincial and national parks. He has participated in surveys for several endangered plant species including *Pedicularis furbishiae, Aster anticostensis* and *Listera australis,* assessing their population size, recording associated species, determining habitat requirements and developing search guidelines.

COLLECTIONS EXAMINED

The known collections of *I. prototypus* have all been examined by D.M. Britton and/or D.F. Brunton, and there is little value in examining them further: The herbaria where these collections are housed are as follows: ACAD, BM, CAN, DAO, DFB, GH, HCOA, MIL, NBM, NY, OAC, UNB.

It is highly unlikely that collections of *I. prototypus* made prior to 1992 have been overlooked by *Isoetes* researchers, since *Isoetes* specimens from all major herbaria in northeastern North America have been critically examined by D.M. Britton, W.C. Taylor and/or D.F. Brunton.

The identity of *I. prototypus* specimens collected in 2003 from all Canadian sites was confirmed by D.M. Britton.