COSEWIC
Assessment and Update Status Report

on the

Bolander's Quillwort
Isoetes bolanderi

in Canada

THREATENED
2006

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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Previous report:

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Bolander's quillwort — Photograph supplied by D.F. Brunton, Park County, Wyoming.

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COSEWIC
Assessment Summary

Assessment Summary – April 2006

Common name
Bolander's quillwort

Scientific name
Isoetes bolanderi

Status
Threatened

Reason for designation
A small aquatic plant currently known in Canada from only one small lake in southwestern Alberta. The population has a large number of plants but is prone to being extirpated by a single, unpredictable event that could affect the entire population in a short period of time. Another population in a nearby lake has already disappeared over the past 50 years.

Occurrence
Alberta

Status history
Designated Special Concern in April 1995. Status re-examined and designated Threatened in April 2006. Last assessment based on an update status report.

COSEWIC
Executive Summary

Bolander's quillwort
Isoetes bolanderi

Species information

Bolander's quillwort (*Isoetes bolanderi*) is a small, perennial aquatic plant classified as a fern-ally (pteridophyte); it has pale green, simple quill-like leaves arising from a corm embedded in the lake bottom.

Distribution

Isoetes bolanderi is endemic to the Rocky Mountains and the Coast, Cascade and Sierra Nevada mountains of western North America, extending from southwestern Alberta, southward to California, northern Arizona and New Mexico. It was first discovered in Canada in 1946 at Carthew Lakes, Waterton Lakes National Park, Alberta. This population has not been seen again, despite several recent searches. In 1953, a substantial population was discovered in Summit Lake, also in Waterton Lakes National Park. Currently, the entire Canadian population of *Isoetes bolanderi* is confined to the Summit Lake location, a single, small (2 ha), high-elevation lake. Consequently, both the Extent of Occurrence and Area of Occupancy for this species are 2 ha.

Habitat

Isoetes bolanderi grows in upper subalpine to alpine ponds and small lakes with clear, oligotrophic water supporting little or no associated vegetation within *Isoetes* stands. The Summit Lake population occupies a relatively stable situation. Physical impact by large ungulates has been noted but these appear to be localized events. It is not known if habitat change was involved in the extirpation of the Carthew Lakes population. The status and trend of *Isoetes bolanderi* habitat in the USA is unknown. The existing known location of *Isoetes bolanderi* in Canada is entirely within Waterton Lakes National Park and the species is protected by the Canada National Parks Act and Regulations.

Biology

The species grows in almost pure stands in circumneutral to slightly basic, silty sand substrate and extends across virtually all of the bottom of Summit Lake. It

produces large quantities of viable spores and appears to be reproducing successfully within the lake. No vegetative reproduction is known for this species.

Population sizes and trends

In 2002 and 2003, 24 potentially suitable lakes were surveyed in southwestern Alberta and adjacent British Columbia but no additional populations were found. A detailed population survey in 2003 estimated the Summit Lake population to be about 12,000,000 *Isoetes bolanderi* plants. A 2004 survey found no significant change in population size. Rescue effect for this species from populations in the USA is highly unlikely.

Limiting factors and threats

Since *Isoetes bolanderi* is currently known from one 2-ha location in Canada, it is vulnerable to extirpation by a single catastrophic event. There is little impact evident at the Summit Lake site. Some impact by recreational use along a shoreline trail is evident and minor impact has also been noted from native ungulates. The most severe threat to the long-term viability of *Isoetes bolanderi* appears to be an intentional or accidental introduction of a toxic material (petrochemicals, herbicide, fertilizer, etc.), one occurrence of which could extirpate this species from the Canadian flora.

Special significance of the species

The sensitivity of *Isoetes bolanderi* to environmental change suggests that the population at Waterton Lakes National Park may provide a valuable indicator of ecological integrity.

Existing protection

Isoetes bolanderi was previously assessed as a Special Concern species by COSEWIC and is Sensitive in the Canadian National General Status system. The existing population is entirely within Waterton Lakes National Park and is protected from removal, damage or destruction by the Canada National Parks Act and Regulations.

The current NatureServe conservation status is:
Global - G4 (apparently secure)
National - Canada N1 (critically imperiled), USA N4 (apparently secure)
Subnational –
S1 – AB, AZ (critically imperiled)
S1S2 – Navajo Nation (critically imperiled/imperiled)
S2S3 – WY (imperiled/vulnerable to extirpation or extinction)
S3 – NV (vulnerable to extirpation or extinction)
SNR (not ranked) – CA, CO, ID, MT, NM, OR, UT, WA.

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 5th 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS (2006)

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 category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

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

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

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

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

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SPECIES INFORMATION

Name and classification

Scientific name:	*Isoetes bolanderi* Engelmann (1874)
Common name:	Bolander's quillwort
Synonyms:	*Isoetes californica* Engelmann ex Gray (1867) - invalid name - listed in Gray (1867) without supporting information; *Isoetes pygmaea* Engelmann (1874); *I. bolanderi* var. *pygmaea* (Engelmann) Clute (1905) - depauperate form; *Isoetes bolanderi* Engelmann var. *parryi* Engelmann (1874) - shorter, thin-leaved plants with smaller-than-typical spores; *Isoetes bolanderi* Engelmann var. *sonnei* Henderson (1900) - depauperate form from Donner Lake, California.
Family:	Isoetaceae (Quillwort Family)
Major plant group:	Pteridophytes (fern-allies)

The scientific name and concept of this species is clear, with synonyms applying to populations now considered to be insignificant forms (Taylor *et al*. 1993). *Isoetes bolanderi* forms sterile hybrids with *I. occidentalis* Henderson and *I. echinospora* Dur. (*I. xherb-wagneri* Taylor) at its range periphery (Taylor *et al*. 1993). The most common is *I. bolanderi* x *occidentalis,* which occurs irregularly in the Sierra Nevada Mountains of California (DAO; Dfb; MICH; W.C. Taylor, pers. comm.). *Isoetes x herb-wagneri* is known from a single location in western Montana (Taylor 2002). No Canadian *I. bolanderi* hybrids are known.

Morphological description

Isoetes bolanderi is a small quillwort with a cluster of soft-textured, straight, leaves 6-13 cm long, with extremes of 3 to 25 cm, projecting from a two-lobed corm (Figure 1). Corms are usually buried in the lake bottom and are not visible. Leaves typically are attached loosely and readily separate from the corm in response to even gentle physical impact (wave action, mechanical impact, etc.). They taper to a very fine point and vary from bright green to brownish-green. Sporangia, containing either megaspores or microspores, are embedded on the inner sides of the pale, inflated leaf bases. Each sporangium is partially covered (usually about 30%) by a translucent, plain-coloured velum (flap of tissue). The degree of coverage by the velum is an important taxonomic characteristic (Taylor *et al*. 1993, Brunton and Britton 1997, 1998).

Isoetes bolanderi is a true aquatic, occurring underwater and only rarely as an emergent along lakeshores (Engelmann 1882, Clute 1905, Pfeiffer 1922, Taylor *et al*. 1993). Canadian *I. bolanderi* plants are smaller than those in most of the species' range in the United States, typically ranging from 3 to 7 cm in height (D. Brunton, pers. obs.).

Isoetes bolanderi can easily be confused with the closely allied *I. howellii* Engelm., particularly in Canada (e.g. Taylor 1970). *Isoetes howellii* is an emergent or amphibious (rarely aquatic) species. It usually occurs at lower elevations in isolated, seasonally-

inundated sloughs and along emergent lake and river shores in sites with geologically younger, more complex substrates (e.g. the metamorphic bedrock of the Columbia Highlands of the Shuswap Lake area of interior British Columbia). *Isoetes howellii* typically has longer, more narrow, recurved to reflexed leaves that vary from dark green to grayish green and which do not readily separate from the corm, as with *I. bolanderi*.

Figure 1. Single plant of *Isoetes bolanderi*, X1 (Collection #10,841 by D. F. Brunton, Park County, Wyoming, August 1991).

Definitive identification of similar *Isoetes* species is normally difficult in the field since identification usually depends on examining the megaspore ornamentation, which requires dissection of the sporangia and high magnification.

DISTRIBUTION

Global range

Isoetes bolanderi is endemic to western North America, occurring in the Rocky Mountains and the Coast, Cascade and Sierra Nevada mountains of the United States and adjacent Canada (Figure 2). It is known today throughout its historical range.

Figure 2. Global range of *Isoetes bolanderi.*

Canadian range

Isoetes bolanderi is currently known in Canada only from Waterton Lakes National Park in southwestern Alberta (Figure 3). It was first collected by A.E. Porsild and A.J. Breitung in 1946 from the Carthew Lakes area of Waterton Lakes National Park. They identified it as *I. echinospora* and the specimen was unreported by subsequent investigators, including Breitung's own report (Breitung 1957) on the flora of Waterton Lakes National Park, until included as *I. echinospora* in Cody and Britton (1989). The identification was revised to *I. bolanderi* during the original COSEWIC report on this species (Brunton 1994).

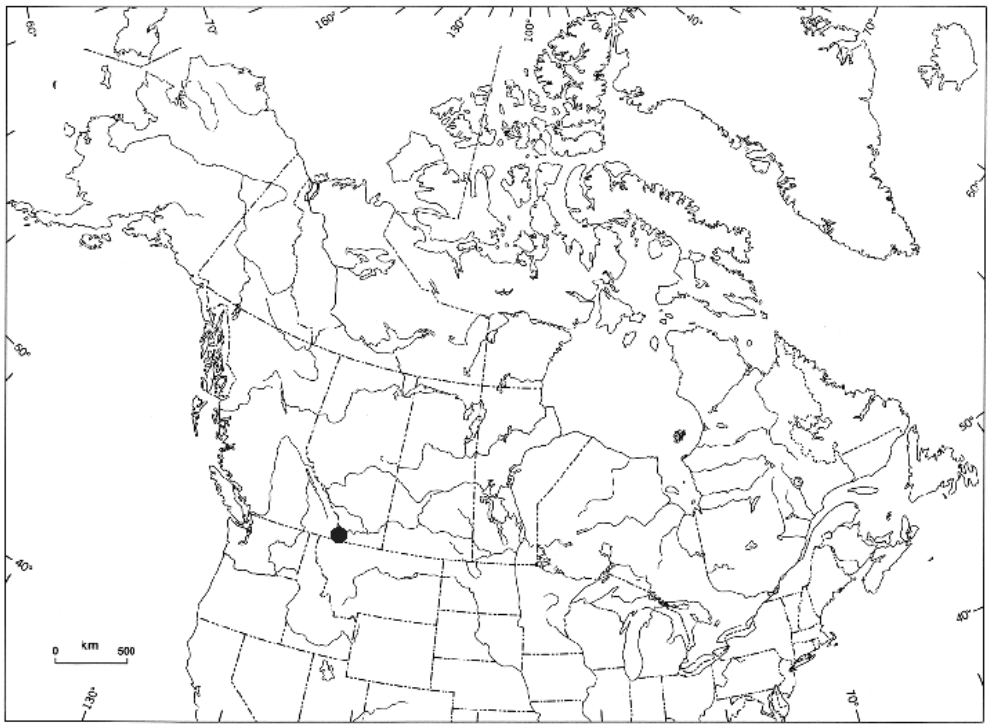

Figure 3. Canadian location of *Isoetes bolanderi*.

The Carthew Lakes area was searched unsuccessfully for *I. bolanderi* in 1995, 1996, 2002 and 2003 by Peter Achuff. The unusually high elevation of the Carthew Lakes site and absence of any subsequent *I. bolanderi* reports from there raised questions as to the legitimacy of the original 1946 discovery. An examination of Canadian Museum of Nature archives determined, however, that the collectors were indeed at that site on that day (Brunton 2002). The Carthew Lakes population is now considered extirpated since recent, thorough searches have failed to find it. The cause of the extirpation is not apparent but can be regarded as a stochastic event that befell a small population even though in a strict protected area.

A second population of *Isoetes bolanderi* was discovered by Breitung on 14 August 1953 at Summit Lake, Waterton Lakes National Park, 3.5 km southwest of Porsild and Breitung's original Carthew Lakes site. This population has been widely reported since (e.g. Breitung 1957, Kuijt 1982, Achuff 1997).

Isoetes bolanderi is known today in Canada only from the Summit Lake population. The nearest known population is in the USA at Dutch Lakes in Glacier National Park, Montana, about 30 km southwest of Summit Lake (Lesica 2002).

The close similarity of *Isoetes bolanderi* to *I. howellii* has resulted in three erroneous reports of *I. bolanderi* in British Columbia, all of which have been re-identified as *I. howellii*:

1) "... abundant in a marshy pond on the Indian Reservation at Kamloops ... partly in and partly out of the water ... " (Macoun 1890).

The ephemeral sage-flats pool in which the Macoun collection was apparently taken (50^{o} 41'N, 120^{o} 15'W, 200 m W of Highway 5, 400 m N of South Thompson River, Kamloops Indian Reserve 1) has been severely impacted by in-filling, habitat alteration by *Typha latifolia* and sewage run-off from an adjacent trailer park. No *Isoetes* was apparent in August 1992 (D. Brunton, pers. obs.). The Macoun report was regarded as *I. bolanderi* by Taylor (1970) and Scoggan (1978). Macoun's collection (in pools on the Indian Reserve, Kamloops. *John Macoun s.n.,* 24 July 1889 [CAN5536; CAN 5535]) has been revised to *I. howellii* (Cody and Britton 1989).

2) "... quite common in Shushwap [sic] Lake at Sicamous ..." (Macoun 1890).

The report is repeated and mapped by Taylor (1970) and Scoggan (1978). No subsequent reports of *Isoetes bolanderi* from the Sicamous area or elsewhere in interior British Columbia are known. Macoun's collection (In the water near the railway bridge, Shushwap [sic] Lake, Sicamous, *John Macoun s.n.*, 17 July 1889, CAN 5534) has been revised to *I. howellii* (Cody and Britton 1989).

3) 49^{o} 01.5 N' 114^{o} 03.5 W'; 50 m W of Akamina Pass Trail, 120 m W of Alberta border, Akamina - Kishinena Recreation Area, East Kootenay Region.

This is the basis for recent reports of *Isoetes bolanderi* occurring in British Columbia (e.g. Straley *et al*. 1985, Argus and Pryer 1990, Taylor *et al*. 1993, Ceska 2000). Plants from this population were first collected 24 August 1976 by D. Polster as *I. echinospora (*UV 94753) - *fide* R.T. Ogilvie. Additional material, obtained in August 1981 by A. Polster for cytological investigations by A. Ceska and D.M. Britton, was identified as atypical *I. bolanderi* (cf. Kuijt 1982). Subsequently, this population has been determined to be *I. howellii* (Brunton 1994, Douglas *et al*. 1998, Ceska 2000) and was still extant in 2004 (P. Achuff, pers. obs.).

Since the Carthew Lakes population is extirpated, the current *Extent of Occurrence* and *Area of Occupancy* consist solely of the Summit Lake location, which is about 2 ha.

HABITAT

Habitat requirements

Isoetes bolanderi grows in unshaded, upper subalpine to alpine ponds and small lakes. Both Canadian sites occur within the Upper Subalpine Ecoregion (Achuff *et al*. 2002), with the Summit Lake site at 1,950 m and the historic, Carthew Lakes site at 2,200 m. *Isoetes bolanderi* sites appear to be associated with clear, oligotrophic water supporting little or no associated vegetation within *Isoetes* stands. The water at Summit

Lake is somewhat calcareous (pH 7.3), but was the least basic of 21 lakes with pH values examined during 2002 and 2003, which ranged from pH 7.4 to 9.1 (Appendix 1). The substrate around *Isoetes* roots, a 3-14 cm layer of silt and silty-sand over a coarser sand, is likely more acidic than pH 7.3. *Isoetes bolanderi* plants appear to occupy most of the bottom of Summit Lake and occur in shallow water to a depth of at least 1.5 m (Smith and Bradley 2003).

Habitat trends

The subalpine habitat of *Isoetes bolanderi* in Canada apparently has been stable for many decades. However, in recent decades, the forests on the slopes surrounding Summit Lake have changed due to the death of many whitebark pine (*Pinus albicaulis*) from white pine blister rust (*Cronartium ribicola*), an introduced disease. No effect on the *I. bolanderi* population has been noted.

The Summit Lake population occupies a relatively stable, shallow-water situation and is not directly affected by an inlet stream, intensive wave action or other dynamic site elements. Physical impact by large ungulates has been noted but these appear to be localized events. No water level controls are present.

It is not known if habitat change was involved in the extirpation of the Carthew Lakes population. The status and trend of *Isoetes bolanderi* habitat in the USA is unknown.

Habitat protection/ownership

The existing and historically known locations of *Isoetes bolanderi* in Canada are entirely within Waterton Lakes National Park and the species is protected by the Canada National Parks Act and Regulations, which provide for the protection of flora, including prohibiting removal, damage or destruction of plants. *Isoetes bolanderi* has been identified as a special feature within Waterton Lakes National Park (Achuff 1997) and has been recognized for special consideration in planning and environmental assessment, including the most recent Park Management Plan (Parks Canada 2000).

BIOLOGY

General

Isoetes bolanderi develops slowly, the plant resulting from the joining of a microspore and megaspore on the lake bottom. Microspores and megaspores mature by late summer and are released into the lake bottom environment when the leaves decay in late summer or early fall. Leaves apparently do not persist over winter, with the plant dying back to the corm top each autumn. This species grows in extensive, sometimes rather dense stands.

Life cycle and reproduction

Isoetes bolanderi is a sexual diploid that produces viable spores. Apogamy has not been detected in North American *Isoetes* (Brunton and Taylor 1990, Brunton and Britton 1999) nor are other forms of vegetative reproduction known in North American aquatic *Isoetes* (Kott and Britton 1983, Taylor *et al*. 1993). *Isoetes bolanderi* likely requires 3-5 years to mature sufficiently to produce viable microspores or megaspores. The longevity of mature plants is unknown but other North American *Isoetes* have been maintained in cultivation for 10 to 15 years (W.C. Taylor, pers. comm.). The length of time that free-floating *Isoetes* spores are viable is unknown but is expected to be considerable. Megaspores apparently containing intact and fluid contents have been observed on *Isoetes* herbarium specimens dating back to the late 19th century (D. Brunton, pers. obs.).

The Summit Lake population is currently producing new plants as indicated by the substantial number of very small plants with two to four leaves and immature (or no) sporangial development.

Herbivory

Plants in Summit Lake occasionally have been uprooted by moose (*Alces alces*) feeding (Brunton 1994; C. Smith, pers. comm. 2003) but this does not appear to be a major impact. Such impacts are apparently localized and the movement of whole leaves may redistribute *I. bolanderi* along the lakeshore.

Barrow's Goldeneye (*Bucephala islandica*), bottom-feeding waterfowl which may also contribute to uprooting quillworts, have been observed feeding in Summit Lake (Brunton 1994).

Physiology

No information known.

Dispersal

Spore dispersal in late summer and autumn occurs with rupture of the sporangium, either by physical impact or by decay. The frequency of dense stands suggests that spores are typically dispersed only a short distance

Shorebirds may unintentionally transport the spores of *Isoetes* on their feet. Spotted Sandpipers have been observed at Summit Lake (pers. obs) but migratory shorebirds are unlikely to use the area regularly. Large wading animals, such as moose, could carry spores during travel or feeding activity. Dispersal of whole plants could also occur by waterfowl, such as Barrow's Goldeneye.

Isoetes plants are readily transported by water currents and many *I. bolanderi* plants were noted floating along the shores of Summit Lake (Brunton 1994) and in its outlet stream (C. Bradley, pers. comm.).

Long-distance dispersal of *Isoetes bolanderi* spores can be inferred from its geographic distribution pattern, which contains some large gaps. This process is not well understood and the agents and frequency of dispersal are not clear. Given this, it seems highly unlikely that the *rescue effect* – re-establishment in Canada by naturally dispersing *I. bolanderi* plants from US populations if the Canadian population should be extirpated – would occur.

Interspecific interactions

A diversity of other aquatic plant species occur with *Isoetes bolanderi* and share many of its life history characteristics. Since *Isoetes* species tend to be poor competitors, they are quickly replaced by more competitive species (e.g. *Potamogeton* spp., *Ceratophyllum* spp.) when organic matter and nutrient levels are increased. The *Isoetes bolanderi* population at Summit Lake has few other associated species (Brunton 1994, Smith and Bradley 2003).

Adaptability

Isoetes bolanderi is associated with high water quality and limited competition from other aquatic species. Other aquatic quillwort species have been eliminated from large areas of their former range in eastern North America as a result of their inability to respond to such changes (Brunton 2000) and a similar sensitivity can be expected for *I. bolanderi*.

While emergent *Isoetes* species can be maintained in cultivation for prolonged periods (9+ years), aquatic species are more difficult to cultivate, likely due to their cold temperature requirements. *Isoetes bolanderi* plants from Wyoming were successfully maintained in cultivation for less than two years (D. Brunton, pers. obs.).

POPULATION SIZES AND TRENDS

Search effort

Surveys for *Isoetes bolanderi* were done in 2002 and 2003 of lakes in Waterton Lakes National Park and in Akamina Provincial Park in adjacent British Columbia (Appendix 1). Initially, a list of 32 potentially suitable lakes was assembled and screened against criteria based on similarity of environmental characteristics with Summit Lake. A detailed search of the most likely 26 lakes was done, occupying usually 1-3 hours per lake, by Cheryl Bradley, Cyndi Smith and Peter Achuff, but failed to find any additional populations.

Abundance

The first population estimate of *Isoetes bolanderi* at Summit Lake was a minimum of 600,000 and a maximum of 1.8 million along 50-90% of the shoreline, based on plants observed growing to a depth of ca. 1.5 m (Brunton 1994). This suggests a maximum of about 4 million plants, based on 1.8 million for 50% of the shoreline.

> A comprehensive survey was done in August 2002 (Smith and Bradley 2003). "Ten transects were randomly established, and data were collected from 101 quadrats. About 78% of the quadrats (79 of 101) contained at least one *I. bolanderi* plant and only those quadrats were included in calculations because the plants are not randomly distributed around the lake. Quadrats with coarse rocky substrate, or that supported other vascular plant species, did not contain *I. bolanderi* plants. Six thousand plants were counted, and the mean number per quadrat was 75.9 (S.E. ± 6.5). The range was 1 to 265, and the median number was 61."
>
> "To estimate the population size from the sample mean, we had to calculate the total number of possible sampling units. Transects did not extend beyond 1.2 m depth, but along all transects *I. bolanderi* plants were observed beyond that depth. As the maximum depth of the lake is 2.0 m, we assumed that there were no depth limitations to where plants would be found. We also assumed the same average frequency of quadrats with *I. bolanderi* as in the quadrats that we sampled."
>
> "We sampled 10.1 m^2 (0.5%) of the 2.03 ha lake. The lake could have approximately 203,000 sampling units (quadrats at 0.1 m^2), but as only 78% of the quadrats had *Isoetes bolanderi* plants present, we estimate the total number of possible sampling units to be 158,340. We multiplied these 158,340 possible quadrats by the sample mean of quadrats with plants (75.95) to estimate the population size for Summit Lake to be 12,025,923 plants ± 2,058,614 (95% C.I.)."

The difference (12 million vs. 4 million) is almost certainly due to differences in estimation techniques, not a three-fold increase in population size.

In 2004, the population was monitored using the presence/absence of plants in random quadrats. The protocol was designed to have a 95% probability of detecting a 30% change in presence, with a 10% chance of making a false-change error (Smith and Bradley 2003). The 2004 survey had an 87% presence, compared with 78% in 2002 (Smith pers. comm.) This difference is not significant and the population apparently is stable over the two-year period.

Fluctuations and trends

The Summit Lake population appears to be stable over the period 2002-2004.

Trends of *Isoetes bolanderi* populations in the USA are unknown. However, the species has not been considered to present a significant conservation concern on a global scale (Cronquist *et al*. 1972, Lellinger 1985, Taylor *et al*. 1993).

Rescue effect

The only extant population currently known in Canada is at Summit Lake. The nearest population is at Dutch Lakes, Glacier National Park, Montana, about 30 km away (Lesica 2002). The status of this population is unknown.

Colonization from the Dutch Lakes population to suitable habitat in Canada is highly unlikely given the limited dispersal capacity of this species. Although plants from Dutch Lakes probably would be adapted to survive in southern Canada, it is not clear that sufficient, suitable habitat for migrants to establish exists in Canada outside of Summit Lake. Summit Lake is the most northerly population of *Isoetes bolanderi* and, presumably, other suitable habitat would already have been colonized from the Summit Lake population.

In summary, rescue effect from outside populations is highly unlikely.

LIMITING FACTORS AND THREATS

There is little available information on *Isoetes bolanderi* survival requirements. It is clear, however, that water quality degradation, particularly increased nutrients, increased water temperature, and excessive competition from associated aquatic plants has caused dramatic losses in plant vitality and population size in other species of aquatic quillworts, both in Europe and North America (Voge 1997, Britton and Brunton 1989).

The cause of the apparent extirpation of the Carthew Lakes population is unknown, and no impacts are apparent at the site. This is best regarded as a stochastic event to which small populations are vulnerable. The single remaining population of *Isoetes bolanderi* in Canada is also vulnerable to extirpation by a single catastrophic event.

Physical impacts, likely from recreational use, on the Summit Lakes population are the greatest immediate threat to *Isoetes bolanderi* in Canada. The lakeside location of the main recreational trail at Summit Lake may result in bank erosion, which has occurred along Summit Lake, leading to localized degradation of the shore and adjacent shallow-water sites (Brunton 1994). Some evidence of recreational wading was also evident. These impacts are highly localized and insignificant at present but could become significant were they to increase through greater recreational activity.

Another possibility is impacts from using Summit Lake as a water source for fire management. Fire pump or helicopter bucketing operations could physically disturb the

plants and a fuel spill could affect the entire population of this small lake. Parks Canada has taken measures to minimize these disturbances.

Collection of plants by professional and amateur botanists is the only conceivable intentional human consumption of *Isoetes bolanderi* in Canada. This has occurred at an insignificant scale to date and is regulated by the Parks Canada research/collecting permit process. *Isoetes* are not cultivated for any but research purposes (Wherry 1972, Lellinger 1985) and are not recognized as having medicinal or herbal value (Erichsen-Brown 1979).

The most severe potential threat to the long-term viability of the Summit Lake population would be introduction of a toxic material (e.g. petrochemical, herbicide, fertilizer) which would either affect the population directly or encourage growth of competing aquatic species. One such event could extirpate this species from Canada.

SPECIAL SIGNIFICANCE OF THE SPECIES

The *Isoetes bolanderi* population at Summit Lake is the northernmost in North America. Due to their susceptibility to environmental changes, such as temperature change and water chemistry, aquatic *Isoetes* provide excellent ecological integrity indicators (Voge 1997). Accordingly, the size and health of the *I. bolanderi* population at Waterton Lakes National Park could provide a valuable indicator of environmental change.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Isoetes bolanderi was previously assessed as Special Concern by COSEWIC and is Sensitive in the Canadian National General Status system. While these statuses provide no direct protection, the existing population is within Waterton Lakes National Park and is protected by the Canada National Parks Act and Regulations. *Isoetes bolanderi* has been identified as a special feature within Waterton Lakes National Park (Achuff 1997) and is receiving special consideration in planning and environmental assessment.

The global NatureServe ranking for *Isoetes bolanderi* is G4. It is N1 in Canada and S1 in Alberta (ANHIC 2005).

In the USA, it is N4 overall and is S1 in AZ, S1S2 in the Navajo Nation, S2S3 in WY, and S3 in NV. It is SNR (not ranked) in CA, CO, ID, MT, NM, OR, UT and WA. This lack of a state rank may reflect an absence of information or that it is not considered to be of conservation concern.

TECHNICAL SUMMARY

Isoetes bolanderi
Bolander's quillwort isoète de Bolander
Range of Occurrence in Canada: Alberta

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* [a single locality]	<< 1 km² (2 ha)
• *Specify trend in EO*	Decline
• *Are there extreme fluctuations in EO?*	No
• *Area of occupancy (AO) (km²)* [area of the single lake]	<< 1 km² (2 ha)
• *Specify trend in AO*	Decline
• *Are there extreme fluctuations in AO?*	No
• *Number of known or inferred current locations*	1
• *Specify trend in #*	Decline
• *Are there extreme fluctuations in number of locations?*	No
• *Specify trend in area, extent or quality of habitat*	Stable
Population Information	
• *Generation time (average age of parents in the population)*	ca. 3-5 years
• *Number of mature individuals*	12,000,000± 2,000,000
• *Total population trend:*	stable 2002-2004
• *% decline over the last/next 10 years or 3 generations.*	N/A
• *Are there extreme fluctuations in number of mature individuals?*	No
• *Is the total population severely fragmented?*	Yes; 1 population disjunct from USA populations
• *Specify trend in number of populations*	Decline
• *Are there extreme fluctuations in number of populations?*	No
• List populations with number of mature individuals in each: Summit Lake, AB 12,000,000± 2,000,000	
Threats (actual or imminent threats to populations or habitats)	
Minor physical disturbance at present Potential stochastic event	
Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* **USA:** N4, some states higher (S1-S3); nearest USA population ca. 30 km away, status unknown	
• *Is immigration known or possible?*	Highly unlikely
• *Would immigrants be adapted to survive in Canada?*	Probably
• *Is there sufficient habitat for immigrants in Canada?*	Not likely
• *Is rescue from outside populations likely?*	No
Quantitative Analysis [provide details on calculation, source(s) of data, models, etc]	N/A
Current Status COSEWIC: Special Concern (1995) Threatened (2006)	

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code**: D2

Reasons for Designation:
A small aquatic plant currently known in Canada from only one small lake in southwestern Alberta. The population has a large number of plants but is prone to being extirpated by a single, unpredictable event that could affect the entire population in a short period of time. Another population in a nearby lake has already disappeared over the past 50 years.

Applicability of Criteria

Criterion A: (Declining Total Population): Not applicable. No decline data

Criterion B: (Small Distribution, and Decline or Fluctuation): Not applicable. Present at a single locality but continuing decline has not been shown nor can be inferred; extreme fluctuations are unknown.

Criterion C: (Small Total Population Size and Decline): Not applicable. Population is too large

Criterion D: (Very Small Population or Restricted Distribution): Meets Threatened D2 based on the presence of a single population within a small lake of only 2 ha where the population is at risk from stochastic events, in part due to the presence of a hiking trail beside the lake.

Criterion E: (Quantitative Analysis): Not available.

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Authorities contacted

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Peter L. Achuff has degrees in Botany (systematics and plant ecology) from the University of Montana, New York Botanical Garden-Columbia University, and University of Alberta. He has worked mainly in western and northern North America over the last 35 years on a variety of projects involving natural resource inventory and monitoring, protected areas management, rare species, and plant conservation. He is currently the Species Assessment Biologist for the Parks Canada National Office, Ecological Integrity Branch and is a member of COSEWIC.

Daniel Brunton is an ecological consultant and naturalist based in Ottawa, Ontario. He was educated in Ontario (Carleton University, Geography) and worked for a number of years in the provincial parks systems of Ontario and Alberta in various capacities, including interpretive planner, ecological inventory specialist and natural areas planner. Brunton has been an independent ecological consultant since 1979 and has worked on a wide variety of projects in Ontario, Quebec, Nunavut, British Columbia and Alberta. These range from impact assessments of various residential, municipal and transportation development proposals, to endangered plant species studies, natural areas, park planning, and ecological program audits.

Brunton's personal interest in vascular plants and pteridophytes, in particular, has directed much of his production of biological literature. He has published over 300

natural history titles, including over 100 papers on vascular plants. In the course of such investigations, he has also developed one of the largest private herbariums in Canada, presently containing over 15,000 fully curated specimens.

Investigations of the genus *Isoetes* has been a particular interest since the late 1980s. In association with retired University of Guelph geneticist Donald M. Britton, Brunton has published over 30 scientific papers on the taxonomy, ecology and distribution of *Isoetes* species in North America, Asia and Europe. Over a dozen new North American taxa have been described in these papers, including several new species. He is a co-author of the *Flora of North America* treatment of the Isoetaceae.

COLLECTIONS EXAMINED

Canadian Museum of Nature (Gatineau, Quebec)
Daniel F. Brunton herbarium (Ottawa, Ontario)
University of Guelph (Guelph, Ontario)

Appendix 1. Lakes surveyed for *Isoetes bolanderi* in 2002 and 2003.

Lake	Ecosites[1]	Calcareousness[2]	pH[3]	Spec. Cond.[3]	Near shore substrate[4]	Emergent vegetation	Date dd-mm-yy
High Priority							
Carthew, Lower	RW4, SU2	non-calc & calc	8.3	86	rock, coarse gravel	N	10-08-02
Carthew, Upper	AV1, RW1, RW4	non-calc & calc	8.2	50	rock, coarse gravel	N	10-08-02
Carthew Pond[5]	SU2	calc	8.3	80	silty sand	Y	10-08-02 16-08-03
Forum					rock, coarse gravel	N	15-08-03
Lone	SU4, RW2	non-wk calc	8.1	030	rock, coarse gravel with some sand/silt	N	19-08-02
Rowe, Lower	SU5	non-calc	8.2	62	rock, gravel, coarse sand; one area of silty clay	N	13-08-02
Rowe, Middle	SU5	non-calc	8.1	25	rock, coarse gravel and sand	N	13-08-02
Rowe, Upper	SU4	non-calc	7.9	26	rock, coarse gravel and sand	Y – small area	13-08-02
Summit[6]	SU4	non-calc	7.3	6	silty sand	Y	11-08-02
Twin, Lower	SU3	non-calc	7.6	76	silty sand	N	18-08-02
Twin, Upper	SU4	non-calc	7.4	40	rock with some silty sand	N	18-08-02
Wall					rock, coarse gravel	N	15-08-03
Medium Priority							
Akamina	CR5, BA3	non-calc & calc	8.0	80	silty clay	Y	13-08-02
Alderson	SU2, RW1	non-calc & calc	8.1	118	rock, coarse gravel	N	10-08-02
Blue Grouse (Peck's) Basin	SU2, SU3, LN4	non-calc & calc	8.3	57	silt/clay	Y	18-08-02
Crandell	HG2, BA5	non-calc & calc	8.3	219	rock, coarse gravel and sand	N	17-08-02
Goat	SU3, RW1	non-wk calc	8.1	84	rock, coarse gravel; some silt/sand	N	18-08-02
Lineham "Hourglass"	SU4, SU5	non-calc	8.1	77	silt/clay over rock; rock, coarse gravel	N	11-08-03
Lineham, North	SU5, CW2, LN2	non-wk calc	8.2	79	rock, coarse gravel	N	11-08-03
Lineham, South	SU5, SU1	non-calc	8.1	61	rock, coarse gravel	N	11-08-03
Ruby	SU3, RW4	non-wk calc	8.4	175	rock, coarse gravel; some silt/sand	N	01-09-02

Lake	Ecosites[1]	Calcareousness[2]	pH[3]	Spec. Cond.[3]	Near shore substrate[4]	Emergent vegetation	Date dd-mm-yy
Unnamed pond south of Akamina Pass	CR5	non-calc			silty clay	Y	25-08-02
Unnamed pond north of Akamina Pass	CR5	non-calc			silty clay	Y	25-08-02
Low Priority							
Bertha	RW1, RW4, CW1, LN1	non-calc & calc	8.2	87	rock, gravel	N	19-08-02
Alderson Valley Ponds	SU4, RW1	non-wk calc					
Crooked Creek Headwaters	MW4	calc					
Crypt	RW1, SU2	non-calc & calc	8.1	52			
Deer	CR3	non-wk calc					
Linnet	HO1	calc	8.3	220			
Lonesome	OB3	non-calc & calc	9.1	178			
Lost	LN1, RW4	non-calc & calc	7.9	76	silt/clay over rock	N	17-08-02

[1]Ecosites for WLNP from Achuff *et al*. (2002).
[2]Calcareousness was determined from ecosite descriptions: calc = calcareous, non = non-calcareous, non-wk = non- to weakly-calcareous in Achuff *et al*. 2002.
[3]pH and specific conductance from Anderson and Donald 1976a, b.
[4]Determined during field surveys.
[5]Previous collection of *Isoetes bolanderi* in 1946.
[6]Previous collections/records of *I. bolanderi* in 1957, 1981, 1982, 1992, 1994-1996, 2002-2004.