COMMITTEE ON THE
STATUS OF ENDANGERED
WILDLIFE IN CANADA

OTTAWA, ONT. K1A 0H3
(819) 997-4991

COMITÉ SUR LE STATUT
DES ESPÈCES MENACÉES
DE DISPARITION AU
CANADA

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STATUS REPORT ON THE BOLANDER'S QUILLWORT *ISOETES BOLANDERI* ENGELM.

IN CANADA

BY

DANIEL F. BRUNTON

STATUS ASSIGNED IN 1995
VULNERABLE

REASON: HIGHLY RESTRICTED RANGE WITH NO IMMINENT THREATS.

OCCURRENCE: ALBERTA

COSEWIC - A committee of representatives from federal, provincial and private agencies which assigns national status to species at risk in Canada.

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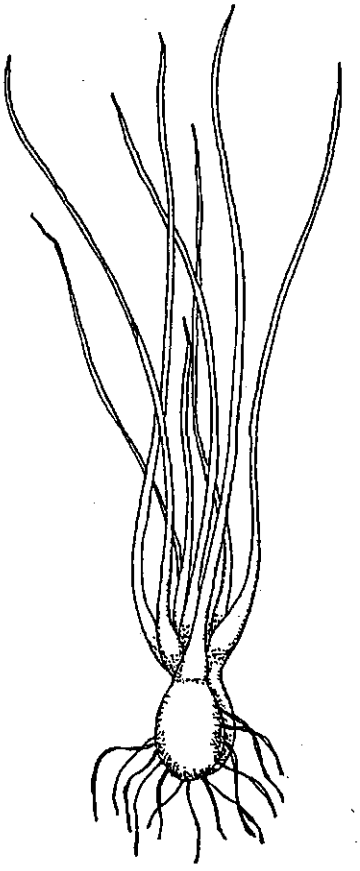
STATUS REPORT ON ENDANGERED WILDLIFE IN CANADA

Bolander's Quillwort



COMMITTEE ON THE STATUS OF ENDANGERED WILDLIFE IN CANADA

COSEWIC

STATUS REPORT ON THE BOLANDER'S QUILLWORT *ISOETES BOLANDERI* ENGELM.

IN CANADA

BY

DANIEL F. BRUNTON
216 LINCOLN HEIGHTS ROAD
OTTAWA, ONTARIO
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JUNE 1994

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DEFINITIONS

SPECIES:	"Species" means an indigenous species, subspecies, variety or geographically defined population of wild fauna and flora.
VULNERABLE: (V)	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
THREATENED: (T)	A species likely to become endangered if limiting factors are not reversed.
ENDANGERED: (E)	A species facing imminent extirpation or extinction.
EXTIRPATED: (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
EXTINCT: (X)	A species that no longer exists.
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Status Report

on

Bolander's Quillwort

(Isoetes bolanderi Engelm.)

EXECUTIVE SUMMARY

Description

Isoetes bolanderi is a small pteridophyte characterized by a cluster of soft, straight leaves projecting 6 to 13 cm from a two-lobed corm. It is a true aquatic, only rarely being found as an emergent along lake shores. Canadian *I. bolanderi* plants are smaller than those known in most of the species range in the United States, typically ranging from 3 to 7 cm in height. Corms of *I. bolanderi* are normally not visible and usually are buried in the lake bottom. The leaves arising from them taper to a very fine point and vary from bright green to brownish-green. They are typically loosely attached, readily separating from the corm in response to even gentle physical impact.

The sporangia are embedded on the inner sides of the pale, inflated leaf bases and each is partially covered (ca. 30%) by a translucent indusium-like velum (or veil). Megasporangia (female sporangia) of *I. bolanderi* contain oval, white megaspores measuring ± 360 μm across. The ornamentation of *I. bolanderi* megaspores is characterized by an abundance of low tubercles that occasionally form very short, isolated crests. The microscopic microspores are ± 26 μm in length and oval in shape. They appear, in mass, as a brownish-gray dust in the microsporangia or loose on the corm. Ornamentation patterns are very subdued, with the surface being spinulose-echinate. Spores mature in late summer (ca. 1 August) and remain intact and with distinctive ornamentation until at least early winter.

Distribution

This species is confined to higher elevation montane and subalpine areas of the western United States Cordillera where it is typically uncommon to rare. In Canada it is known only from the southwestern portion of Waterton Lakes National Park, Alberta.

Population Size and Trends

The population size of *I. bolanderi* in the United States is unknown, though it appears to be regularly occurring and locally abundant in at least northwestern Wyoming. It occurs in two populations in Canada; each is small and occurs in an isolated lake. One of these contains a large number of plants (600,000+). The size of the other Canadian population is unknown.

Habitat

Isoetes bolanderi grows in small, cold-water, oligotrophic lakes in Canada that are situated in small, high elevation (1900 - 2100 m asl) nunatack (unglaciated) areas of Precambrian bedrock. The bedrock contains an atypically high proportion of quartzite. *Isoetes bolanderi* typically grows in silt or silty sand over coarse sand with virtually no associated aquatic vegetation.

General Biology

This perennial species reproduces sexually and frequently establishes large populations of plants which take several years to reach maturity. Each produce large numbers of microsporophylls and megasporophylls when mature. Although hybridization with other *Isoetes* is known in the United States, no associated species occur with Canadian populations and no hybrids are known here. All aquatic *Isoetes* appear to be poor competitors, prospering only on relatively sterile and/or largely unvegetated substrates.

Limiting Factors

Most aquatic *Isoetes* species appear to be very sensitive to water quality degradation and some North American species have been locally extirpated as a result of industrial and/or residential pollution. Large numbers of *I. bolanderi* leaves and some whole plants are found washed up on lake shores, perhaps as a result of animal activity and/or other physical impacts. It is not clear what, if any, long-term impact this wash-up phenomena has on particular *I. bolanderi* populations.

Canadian *I. bolanderi* populations are expected to be vulnerable to relatively minor water quality degradation from pollutants, reflecting their occurrence in high elevation, low nutrient, short growing-season aquatic environments.

Protection

Both sites in Canada occur within undeveloped backcountry areas of a national park. A significant backcountry hiking trail passes both sites, however, and has led to minor shore degradation. Trail access also exposes the populations to potential catastrophic impact from the introduction of toxic or otherwise material (petroleum products, biocides, non-native plants or animals, etc.).

Conclusions

It is recommended that *I. bolanderi* be designated **Threatened** in Canada, reflecting the vulnerability of both Canadian populations to potentially catastrophic impact from habitat degradation. Evaluation of the poorly known older *I. bolanderi* population is considered a protection priority, followed by the preparation of site management plans designed to ensure that recreational activity does not negatively impact protection values at either location.

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ABSTRACT

Isoetes bolanderi is known from two locations in Canada, both in small mountain lakes in very lightly or unglaciated areas of atypically quartzite-rich Precambrian bedrock at relatively high (1900 - 2100 m) elevations in Waterton Lakes National Park, Alberta. It is otherwise a locally common to uncommon aquatic of higher elevation areas of the western United States Cordillera. Although reported from stations in interior or southeastern British Columbia for over a century. All reported *I. bolanderi* from British Columbia is believed to represent misidentified specimens of the rare, lower-elevation emergent quillwort, *I. howellii*.

Isoetes bolanderi is abundant in Summit Lake where a *minimum* of 600,000 to 1.8 million plants are estimated to occur. Present populations in the Carthew Lakes site are unknown.

Although occurring within a national park, both populations are situated in fragile habitats along a relatively heavily-used back-country hiking trail. They are vulnerable to indirect impact from recreational activities through fire, bank erosion and/or water pollution.

It is recommended that *I. bolanderi* be designated **Threatened** in Canada, reflecting the sensitivity of either Canadian population to potentially catastrophic impact from habitat degradation. It is also recommended that confirmation of the size and status of the *I. bolanderi* population at the Carthew Lakes be established.

[**NOTE.** Since no imminent threats were identified and both populations occur within a national park, COSEWIC members designated this species as **VULNERABLE.**]

I. Species Information

1. CLASSIFICATION AND NOMENCLATURE

Scientific name: *Isoetes bolanderi* Engelmann

Bibliographic citation: American Naturalist 2: 214 (1874).

Type specimen: Upper Tuolumne River, little pools, alt. 9,000 - 10,000 ft. 1866. *Bolander 5091* (LECTOTYPE ? MO1852024 - collection of four plants; Isotype ? US) - the MO specimen is marked 'Holotype' but the authority for this is unclear; Engelmann (in Parry 1874) only refers to a series of specimens (Syntypes) from California (" Tuolumne, Mount Dana, Mono-trail, Cisco, Mary's Lake " collected by Bolander in 1866 and Wyoming (" Yellowstone Lake ... Parry 307, 1873.").

Synonyms:
- *Isoetes californica* Engelm. ex Gray (1867) - invalid name - listed in Gray (1867) without supporting information.
- *Isoetes pygmaea* Engelm. (1874); *I. bolanderi* var. *pygmaea* (Engelm.)Clute (1905) - depauperate form.
- *Isoetes bolanderi* Engelm. var. *parryi* Engelm. (1874) - shorter, thin-leaved plants with smaller-than-typical spores.
- *Isoetes bolanderi* Engelm. var. *sonnei* Henderson (1900) - depauperate form from Donner Lake, Calif.

Common name(s): Bolander's Quillwort

Family name: *Isoetaceae*

Common family name: Quillwort Family

Major plant group: pteridophyte (ferns)

Current alternative taxonomic treatments

Isoetes bolanderi appears to be a taxonomically homogeneous diploid entity with a number of minor geographical and/or environmental variants that were previously given distinct names at a subspecific and even specific level (see above). It is ecologically, morphologically and cytologically most similar to *I. howellii* Engelm. (Engelmann 1882; Taylor et al. 1993) and may represent the separate evolution of an isolated population of the latter species.

At and near the periphery of its range *I. bolanderi* interbreeds with hexaploid ($2n=66$) *I. occidentalis* Henderson and diploid ($2n=22$) *I. echinospora* Dur., forming sterile hybrids (Taylor et al. 1993). The most common of these is the sterile tetraploid ($2n=44$) *I. bolanderi* x *occidentalis* found irregularly in the Sierra Nevada Mountains of California (DAO, DFB, MICH, W.C. Taylor, pers. comm). The sterile diploid ($2n=22$) *Isoetes bolanderi x echinospora* is known from a single location in western Montana (MIL,

DFB, W.C. Taylor, pers. comm.). No Canadian *I. bolanderi* hybrids are known.

History of the Taxon

George Engelmann, the famous 19th century American aquatic plant taxonomist, conducted the first comprehensive studies of North America *Isoetes*. He discovered and described a number of new taxa and also sent material to experts elsewhere. He first suggested the existence of this high elevation cordilleran *Isoetes* in 1867 by mentioning but not validly describing *I. californica* Engelm. and *I. pygmaea* Engelm. (a depauperate form of the same taxon) from Californian material (Gray 1867). The species was given a formal description in 1874 along with several related taxa (including a validly described *I. pygmaea*). All of these have subsequently been placed in synonymy within a broadly defined *I. bolanderi* encompassing a wide geographic range within the cordilleran area of the western United States (Lellinger 1985; Taylor et al. 1993).

Field investigations have determined that *Isoetes bolanderi* is, with *I. occidentalis*, one of the most common *Isoetes* in those portions of the cordilleran region of western North America that escaped, or were relatively lightly affected by, the Wisconsin glaciation.

The species was first reported in Canada - erroneously - from the low, semi-arid Shuswap Lake area of interior British Columbia in the late 19th century (Macoun 1890). The two locations noted at that time were the basis for including British Columbia in the range of the species for many years thereafter (e.g. Clute 1905, Taylor 1970, Straley et al. 1985). These have subsequently been established to represent misidentifications of the closely related *I. howellii* Engelm. (See Erroneous reports, below). A population discovered in Akamina Pass in southeastern British Columbia in 1981 has been the recent basis for including *I. bolanderi* in the flora of British Columbia but it is now also considered to represents misidentified *I. howellii* (see Erroneous reports, below).

The first definite Canadian record for *I. bolanderi* was established by A. E. Porsild and A. J. Breitung in 1946 in southwestern Alberta when they obtained a collection from the Carthew Lakes area in Waterton Lakes National Park which they assigned to *I. echinospora Dur.*, a transcontinental species of acidic substrates not otherwise reported from southern Alberta (cf. Moss 1974; Kott and Britton 1983). The specimen was unreported by subsequent investigators - including in Breitung's own (1957) report on the Flora of Waterton Lakes National Park - until included in the *I. echinospora* treatment in Cody & Britton (1989). It was revised to *I. bolanderi* during the present investigation.

A second, larger population of *I. bolanderi* was discovered at Summit Lake, Waterton Lakes National Park, 3.5 km southwest of Porsild and Breitung's original site. This population has been widely reported (e.g. Breitung 1957; Kuijt 1982) and a number of additional collections from the site have been obtained.

As a basic diploid ($2n = 22$; Taylor et al. 1993) in a group where allo- and autopolyploidy is considered to have played a major role in speciation, it forms an important part of the taxonomic foundation of the genus (cf. Britton and Brunton 1991).

2. DESCRIPTION

Certain identification of the various superficially similar *Isoetes* species is normally difficult in the field since identification is usually dependent on an examination of

megaspore ornamentation. This requires dissection of the sporangia. The sporangia are imbedded on the inner sides of the pale, inflated leaf bases (Figure 1B). Each sporangium is partially covered (completely covered in a few species) by a translucent indusium-like velum (or veil). The degree of coverage by the velum in considered to be an important taxonomic characteristic (Marsden 1979; Taylor et al. 1993).

Isoetes bolanderi can easily be confused with the closely allied *I. howellii* and this has occurred throughout its range and particularly in Canada (e.g. Taylor 1970). *Isoetes howellii* is an emergent or amphibious (rarely aquatic) species with strong affinities with the southern and eastern *I. melanopoda* Gay. & Dur. It occurs at lower elevations in isolated, seasonally-inundated sloughs and along emergent lake and rivershores 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* also typically has longer, more narrow, recurved to reflexed leaves which vary from dark green to grayish green and which do not readily separate from the corm.

Figures 1 and 2 illustrate whole plants and spores of *I. bolanderi*. It is a small quillwort characterized by a cluster of soft-textured, straight, leaves projecting to a length of 6 to 13 cm, with extremes of 3 to 25 cm), from a two-lobed corm (Figure 1). It is a true aquatic, only rarely being found as an emergent along lake shores (Engelmann 1882; Underwood 1900; Clute 1905; Pfeiffer 1922; Taylor et al. 1993). Canadian *I. bolanderi* plants are smaller than those known in most of the species' range in the United States, typically ranging from 3 to 7 cm in height (pers. obs.).

Corms of *I. bolanderi* are normally not visible and usually are buried in the lake bottom. The leaves arising from them taper to a very fine point and vary from bright green to brownish-green. They are typically loosely attached, readily separating from the corm in response to even gentle physical impact (wave action, mechanical impact, etc.). Large numbers of washed up or floating leaves (Figure 4) are common at *I. bolanderi* stands at least in Wyoming and Alberta (pers. obs.). The velum coverage of the unmarked sporangium is typically ca. 30%.

Megasporangia (female sporangia) of *I. bolanderi* contain oval, white megaspores measuring ± 361 μm (N=48) across. This is smaller than the ± 451 μm (N= 60) megaspores of *I. howellii.* [1]. The ornamentation of *I. bolanderi* megaspores is characterized by an abundance of low tubercles that occasionally form very short, isolated crests (Figure 2). These tubercles are typically less pronounced than those of *I. howellii*, the latter species commonly exhibiting a more pronounced pattern of short, low, anastomosing ridges as well, particularly on the distal (lower) side of the spore (Engelmann 1882; Pfeiffer 1922; Taylor et al 1993; pers. obs).

The microspores of *I. bolanderi*, as with all *Isoetes*, are microscopic. They are ± 26 μm (N= 141) in length and oval in shape. They appear, in mass, as a brownish-gray dust in the microsporangia or loose on the corm. Ornamentation patterns are very subdued, with the surface being spinulose-echinate (Figure 2). The similar-sized (±27.6 μm -

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[1] Megaspores of Canadian plants are smaller than typical American material for both species, *viz.,* 398 μm (n = 70) for *I. howellii* from British Columbia and 343 μm (n = 20) for *I. bolanderi* from Alberta. Canadian plants also typically exhibit a less complex megaspore ornamentation. For Canadian *I. bolanderi*, this morphology satisfies the description of *I. bolanderi* var. *parryi* (Parry 1874), a taxon now considered to represent a taxonomically insignificant morphological phase of this variable species (cf. Pfeiffer 1922, Taylor et al. 1993.).

N=80) microspores of *I. howellii* are smooth to (more typically) coarsely-echinate. Spores mature in late summer (ca. 1 August) and remain intact and with distinctive ornamentation until at least early winter.

Figure 1: Whole Plant of Isoetes bolanderi
(from Cronquist et al. 1972)

A. whole plant (x 0.5) **B.** Inner side of sporophyll illustrating the megasporangium (below a triangular ligule) partially covered by the velum (x 6) **C.** Two-lobed corm with simple roots radiating outwards (x 2).

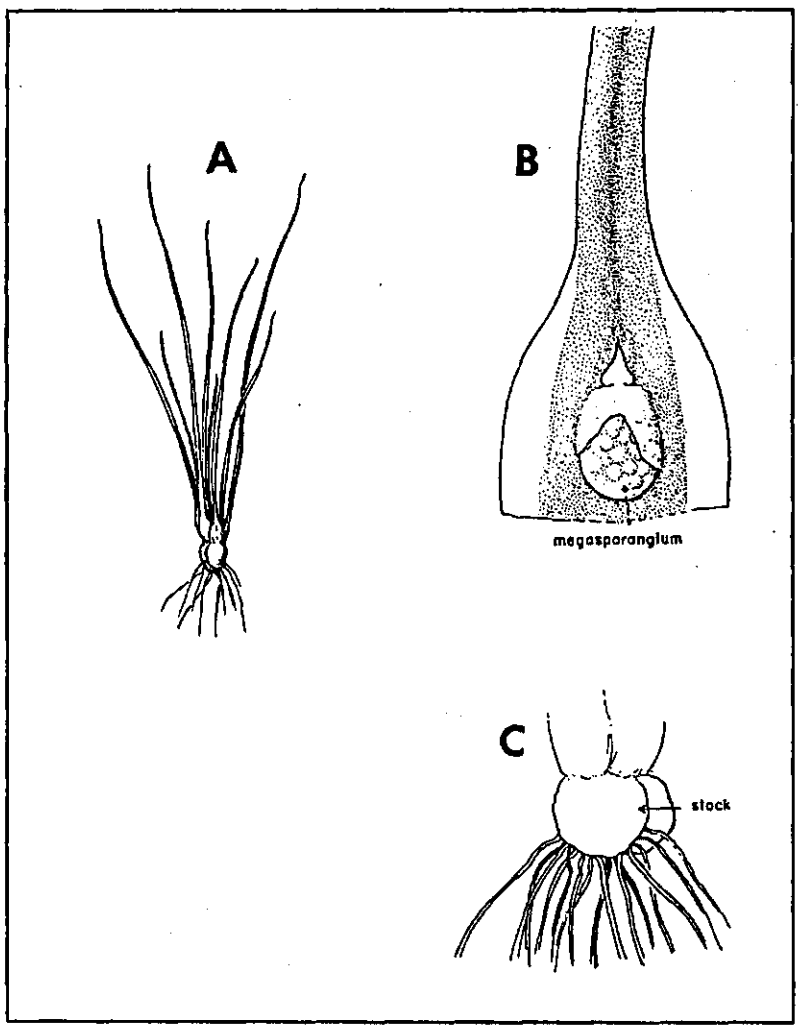


Figure 2: SEM photographs of <u>Isoetes bolanderi</u> spores

[**A:** distal (bottom) megaspore hemisphere showing low tuberculate ornamentation (x 180); **B:** proximal (top) megaspore hemisphere showing triradial ridges (x 180); **C:** lateral view of megaspore showing equatorial ridge (x 430); **D:** coarsely echinate microspore (x 2700) - *D. F. Brunton & K. L. McIntosh 10,833*, Meadowlark Lake, Bighorn National Forest, Wy. (1991)]

(courtesy of D. M. Britton, U. of Guelph)

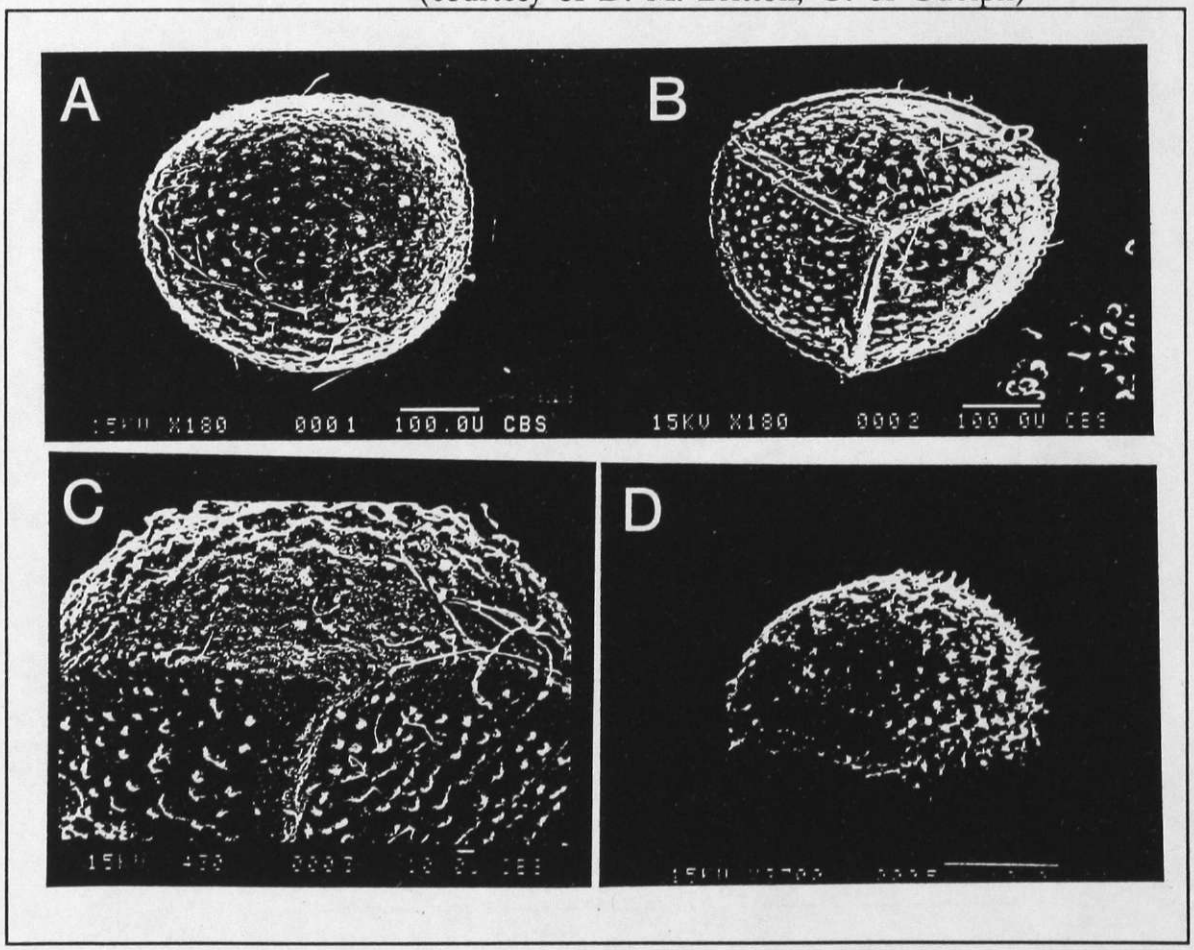


Figure 3: Site for large population of Isoetes bolanderi at Summit Lake.
(abundant in the shallow water about the observer - August 1992)

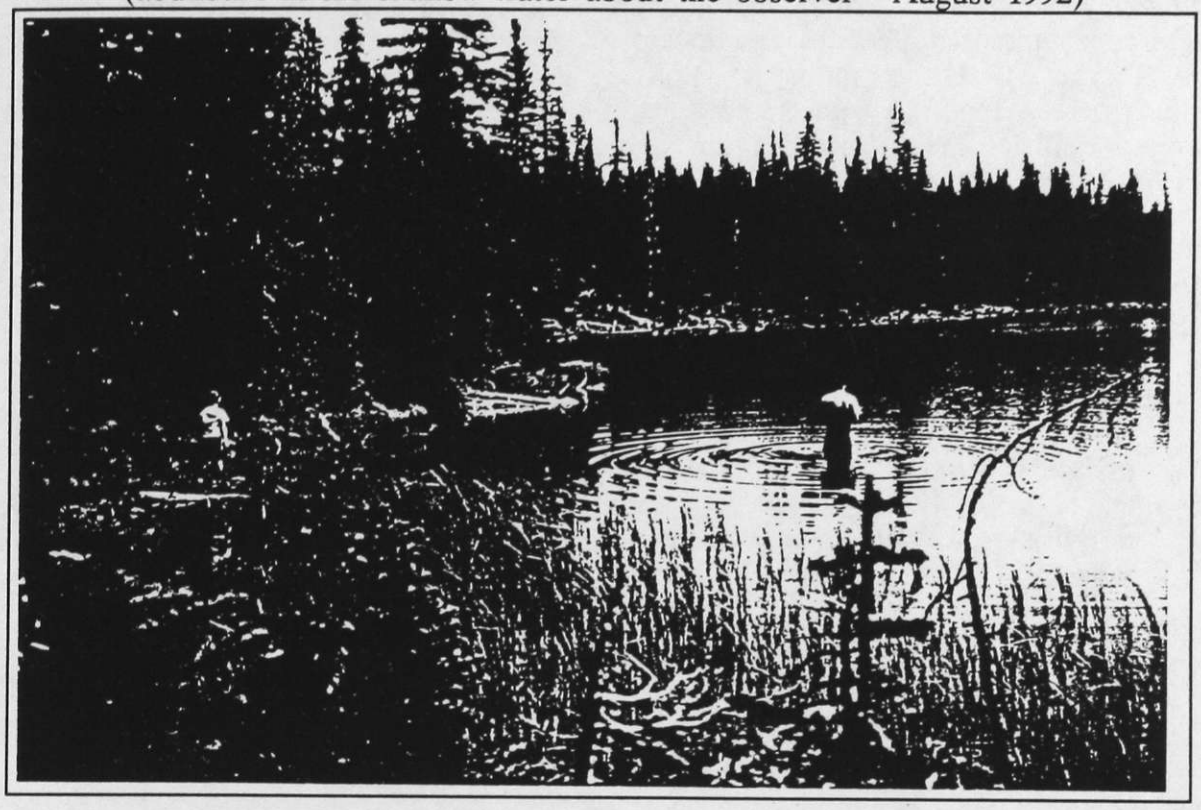


Figure 4: Floating I. bolanderi leaves amongst sedge stems.
(Summit Lake, Waterton Lakes National Park, August 1992)

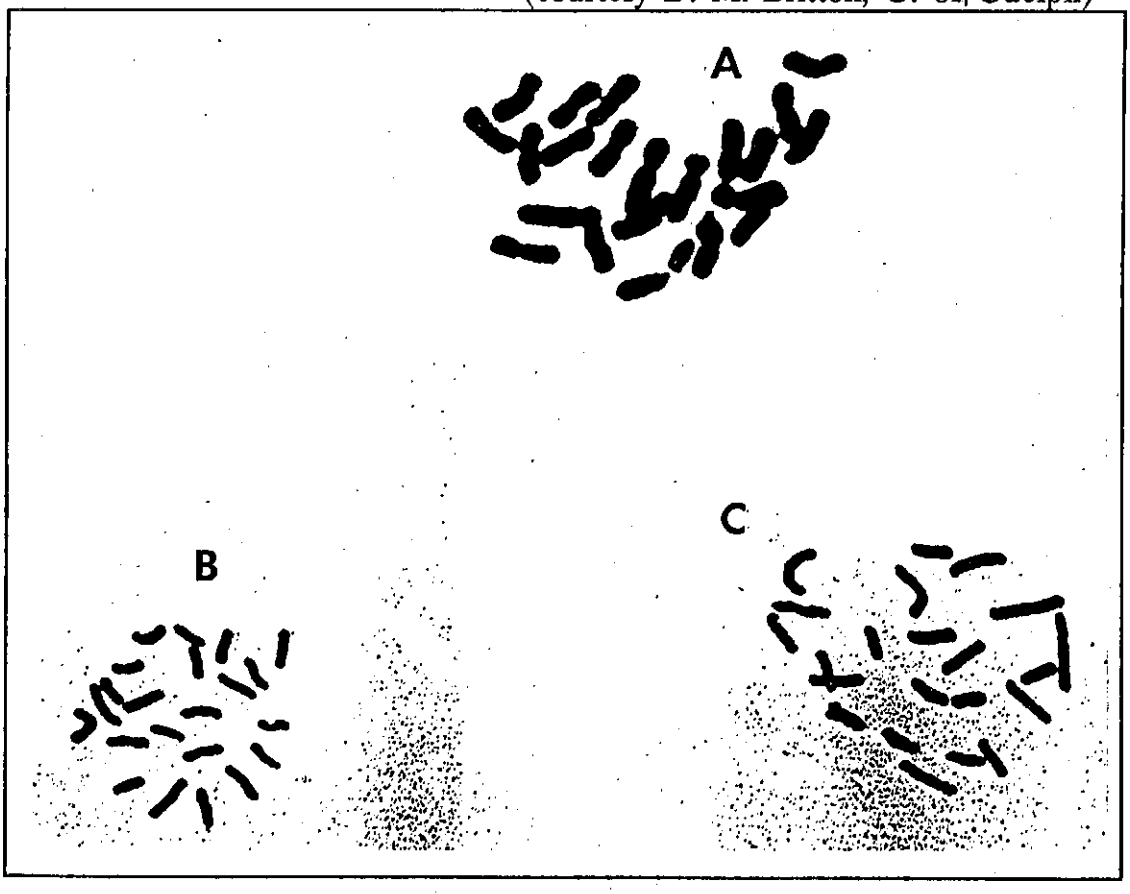
Although clearly not a useful field character, chromosome size and form may be useful in separating *I. bolanderi* from other diploids ($2n=22$). The chromosomes of *I. bolanderi* from Wyoming, for example, appear to be thicker in proportion than *I. howellii* from British Columbia (Figure 5). As the methods employed in producing the illustrations of the two species illustrated in Figure 5 were somewhat different, however, interpretation of shape and size difference between the *I. howellii* and *I. bolanderi* figures must be undertaken with caution (D. M. Britton, pers. comm.).

No other species of *Isoetes* grow with *I. bolanderi* at the Canadian sites, essentially eliminating the possibility of hybrid plants complicating the identification challenge.

Figure 5: Chromosomes of diploid Isoetes bolanderi and I. howellii

A. *I. bolanderi* - Silver Lake pond #2, Carbon Co., Wyoming (*W. H. and F. S. Wagner s.n.*).
B. *I. howellii* - Shuswap Lake, British Columbia (*A. & O. Ceska 4664*).
C. *I. howellii* - Akamina Pass, British Columbia (*A. Polster, s.n.*).

(courtesy D. M. Britton, U. of Guelph)



3. BIOLOGICAL AND ECONOMIC IMPORTANCE

This species is important to on-going research into a complex of basic diploid and derivative taxa in North America (Hickey, Taylor & Luebke 1989; Britton and Brunton 1989; Taylor et al. 1993; Brunton, Britton & Taylor 1994) that has significant implications

for understanding the taxonomy and phylogeny of *Isoetes* on this continent and beyond. A variety of morphological, cytological and electrophoretic research into its origins and relationships with other *Isoetes* taxa is on-going (Taylor et al. 1993; D. M. Britton, pers. comm., pers. obs.).

While living material can readily be obtained across the western United States, the northern Canadian populations are particularly valuable because of their isolation from many of the associated southern taxa which complicate the genetic and morphological conditions found in the central and southern portions of its range.

The ecological requirements of *Isoetes* species in North America have only recently been given considered attention, largely as a result of the study of hybrids in eastern North America (Britton and Brunton 1989; 1991; Brunton and Di Labio 1989; Brunton and Taylor 1990). The Canadian populations of *I. bolanderi* offer important opportunities for investigation of the ecological requirements and segregation of western cordilleran *Isoetes* species.

Canadian *I. bolanderi* represents the most northerly populations of this species in North America. Investigations of the dispersal mechanisms resulting in this distribution will contribute to an understanding in dispersal mechanisms of aquatic plants. This in turn could provide valuable scientific information as well as providing economically important data concerning the control of aquatic 'weeds".

4. DISTRIBUTION

Summary

Figure 6 illustrates the North American and world distribution of *I. bolanderi.* Although considered uncommon through much of this range, it appears to be common in at least the foothills and lower mountain lakes of western Wyoming (pers. obs.).

The Canadian distribution of *I. bolanderi* is confined to two locations in southwestern Waterton Lakes National Park, Alberta (Figure 7).

Locality Citations

Precise locality data and land ownership is on file with COSEWIC and Parks Canada. This information is generally available unless the localities are considered to be publicity-sensitive.

Extant populations:

1. ALBERTA: Summit Lake, Waterton Lakes National Park (Kuijt 1982).

2. ALBERTA: Carthew Lakes, Waterton Lakes National Park (as *I. echinospora* in Cody & Britton 1989).

Figure 6: North American Distribution of Isoetes bolanderi
(adapted from Taylor et al. 1993)

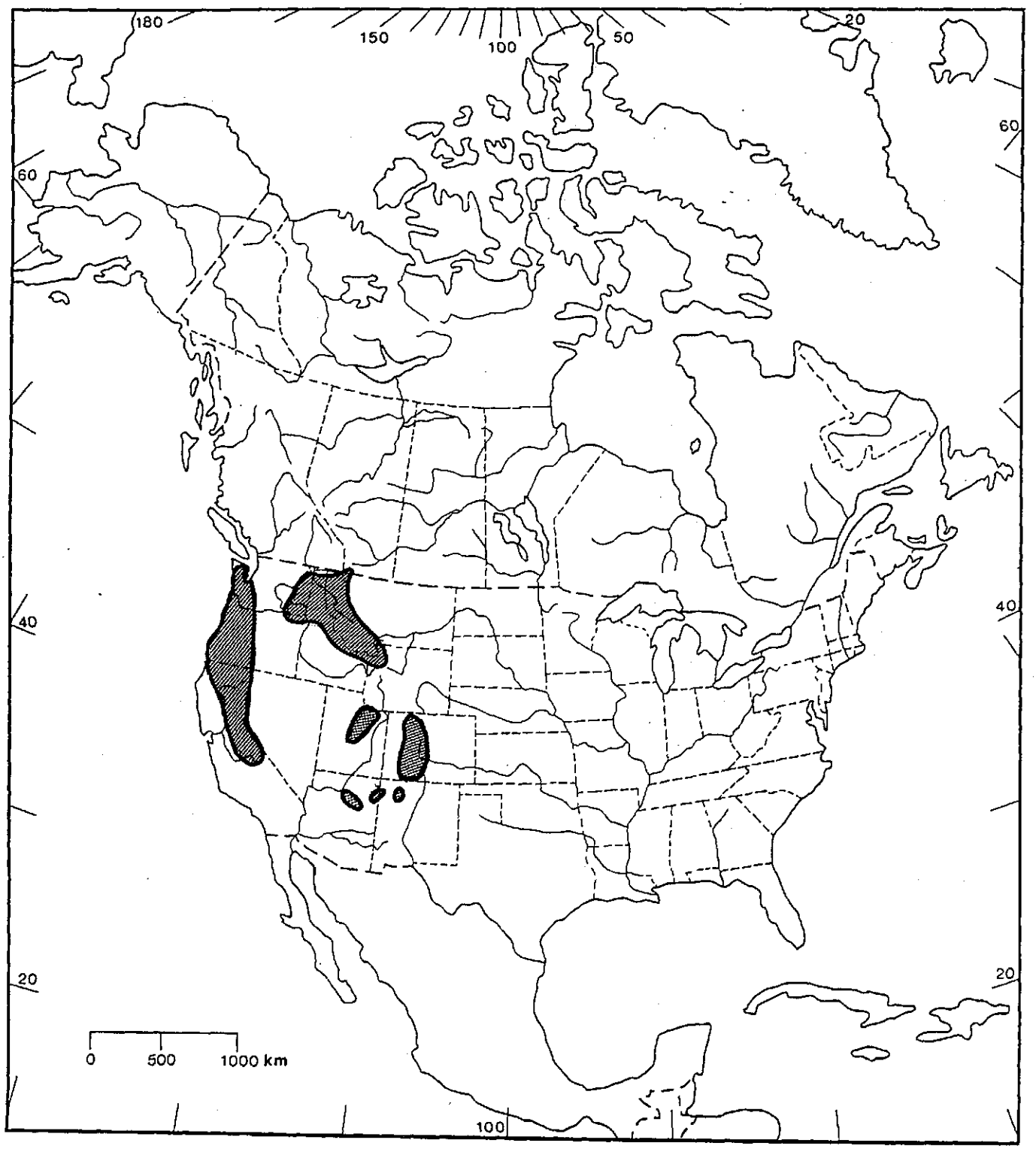
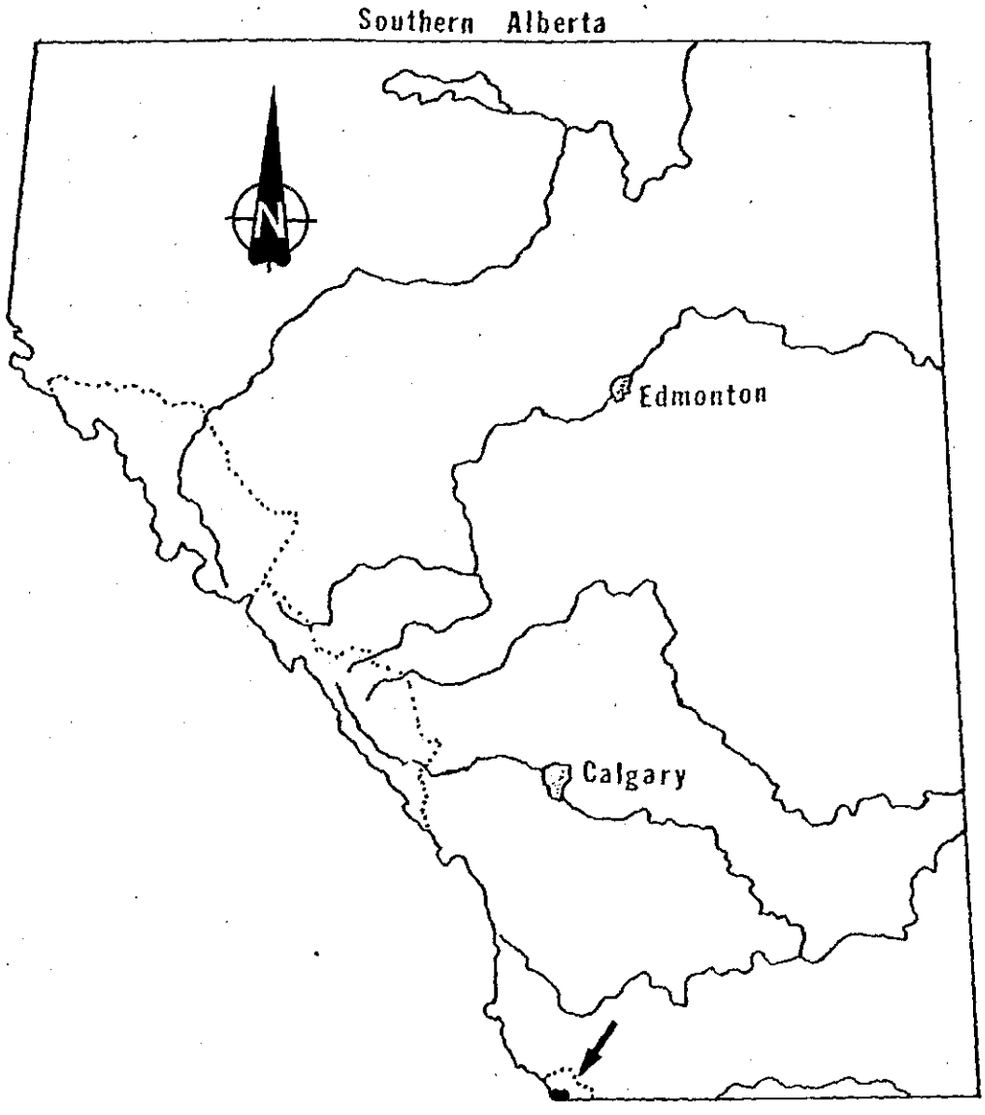


Figure 7: <u>Isoetes bolanderi</u> in Alberta (arrow)



Extirpated populations

None.

Historical populations of unknown status

None.

Erroneous reports

The close similarity of *I. bolanderi* with *I. howellii*, a species of ephemeral pools and emergent shores in the foothills and at lower elevations of the western North American cordilleran region (see Description, above), has resulted in the long-standing misidentification of *I. bolanderi* in British Columbia. The major reports/records are as follows:

BRITISH COLUMBIA:

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 collection was apparently taken (50° 41'N, 120° 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, site domination by cat-tail (*Typha latifolia*) and sewage run-off from an adjacent trailer park. No evidence of *Isoetes* was apparent in August 1992 (pers. obs.). The Macoun report revised and mapped 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]) was recently revised to *I. howellii* (Cody & Britton 1989).

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

The report is repeated and mapped by Taylor (1970) and Scoggan (1979). No subsequent reports of *I. bolanderi* from the Sicamous area or from anywhere in interior British Columbia have been forthcoming. 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 & Britton 1989). It is actually a mixed sheet comprising two *I. howellii* plants and one larger plant representing *I. howellii x maritima* (pers. obs.).

3) - 49° 01.5 N' 114° 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 sole basis for recent reports of *I. bolanderi* occurring in British Columbia (e.g. Straley et al. (1985), Ceska (1989), Argus and Pryer (1990), Taylor et al. (1993), etc.). Plants from this population were first collected 24 August 1976 by D. Polster as *I.*

echinospora (UV 94753) - *fide* R. T. Ogilvie. Additional live material was obtained in August 1981 by A. Polster for cytological and SEM investigations by A. Ceska and D. M. Britton. They were determined to constitute diploid ($2n = 22$) plants (D. M. Britton, pers. comm.) and were identified as atypical *I. bolanderi* (cf. Kuijt 1982).

This population was re-examined during the present study on 16 August 1991; ca. 4000 large, weak-leaved plants were found growing in thin (1 - 3 cm) silty sand over coarse sand on wet, emergent mud with no associated vegetation about and in a small, very-shallow, isolated spring-fed, *Carex vesicaria*-dominated swale in *Picea engelmannii - Pinus contorta - Abies lasiocarpa* forest at 1,784 m asl. (Above Sea Level). Investigations of living and dried plants (*D. F. Brunton & K. L. McIntosh 10,851; 10,855*), including examination of the atypically tuberculate spores by SEM and the chromosomes (Figure 5), have concluded that these plants represent *I. howellii* and that *I. bolanderi* has not been confirmed as an element of the flora of British Columbia.

Status and location of presently cultivated material

None.

Potential sites for investigation

- small oligotrophic lakes in *lightly or unglaciated subalpine areas* of extreme southwestern Alberta and southeastern British Columbia underlain by Precambrian argillite, siltstone and dolomite substrate with locally atypically high quartzite bedrock constituent (Sheppard Formation) (Price 1962; Harrison 1976).

1) ALBERTA: Waterton Lakes National Park - a series of small lakes along the Continental Divide - Upper Rowe, Lone, Lost and Twin Lakes.

2) ALBERTA: Castle River headwaters - small subalpine lakes near the Continental Divide north of Waterton Lakes National Park (e.g. Bovin Lake).

2) BRITISH COLUMBIA: Akamina-Kishinena Recreation Area - shallow water of Forum and Wall Lakes and the un-named lake in the cirque immediately west of Bicuitboard Creek, along south side of Akamina Pass.

Biogeographical and phylogenetic history of the species

Isoetes is an ancient genus, being a member of the Class Lycopsida that was initiated in the middle to upper Devonian period *ca.* 350 million years B. P. when the 5 m high Isoetalean lycopsid tree *Lepidostegillaria whitei* was extant (Benson 1979; Pigg 1992). Fossil *Isoetes* very much like modern taxa were known (frequently under the name *Isoetites*) from the Triassic era (200-225 million yrs B.P. = years Before Present) (Pigg 1992).

Of the ca. 150 species of *Isoetes* in the world, 25 species occur in North America and 12 in Canada (Taylor et al 1993; pers. obs.). Most have traditionally been found in temperate areas, although new taxa are being regularly described (Marsden 1979; Hickey 1981; Luebke 1992;

Brunton, Britton & Taylor 1994). Although subgeneric groupings have been identified, these are largely artificial categories designed primarily to sort morphological variation rather than attempting to delineate evolutionary groupings (Pfeiffer 1922; Marsden 1979).

While many *Isoetes* species of hot, dry climates are plants of ephemeral water bodies and wet meadows, most northern taxa (including most Canadian taxa) are true aquatics of lakes and rivers - including *I. bolanderi*.

Little is known concerning refugia or the post-glacial migration routes of *Isoetes* in Canada as a whole or in this area in particular. The area in which *I. bolanderi* is known is one of the most ancient post-Wisconsin landscape in southern Canada (Dyke and Prest 1987), providing an atypically long opportunity for colonization by presumably slowly dispersing plants such as *Isoetes*.

The Cordilleran glaciation complex which eliminated virtually all vegetation in the mountain region of western Canada during the Wisconsin glaciation impacted the Waterton Lakes National Park area only lightly. Small unglaciated areas (nunatacks) occurred along the Continental Divide, exposing the landscape above ca. 2000 - 2200 m. elevation a.s.l. (Clague 1989). Several such areas existed ca. 18,000 yrs B.P.(Dyke and Prest 1987). These till-free, quartzite-rich, Precambrian bedrock nunatacks include the sites of both known *I. bolanderi* stations. The sites suggested as having potential for additional *I. bolanderi* populations (except those on the British Columbia side of the Continental Divide) are also closely associated with nunatacks.

It is highly unlikely that *I. bolanderi* would have existed at any of the known or suspected Canadian sites (even in nunatacks) until at least towards to end of the Wisconsin glaciation. An extreme Wisconsin climate here is indicated by the evidence for sparse herbaceous, graminoid-dominated tundra vegetation between 15,000 and 12,000 yrs B.P. By about 12,000 yrs B.P., however, coniferous forest locally mixed with Trembling Aspen groves was recolonizing lower valleys in the Waterton Lakes National Park area. As Lodgepole Pine (*Pinus contorta*) had become established to near tree-line by about 9,700 yrs B.P., it appears that contemporary ecological conditions were well established by then (Clague and MacDonald 1989).

It seems reasonable to assume that revegetation of lakes in the Waterton Lakes National Park area could have been widespread by about 12,000 - 10,000 yrs B.P., sooner in the higher mountain areas in and about nunatacks and later (9,000 - 7,000 yrs B.P. ?) in lower mountain valleys affected longer by remnant glaciers. Revegetation would have been from unglaciated cordilleran regions to the south. This relatively long revegetation history may contribute to an explanation of the presence of a large number of vascular plant taxa (over 100) confined in Canada to extreme southeastern British Columbia and/or adjacent southwestern British Columbia (cf. Ogilvie 1962).

5. GENERAL ENVIRONMENT AND HABITAT CHARACTERISTICS

Summary

Isoetes bolanderi grows in subalpine areas with cool, relatively wet climates and in sites with exceedingly short growing season (< 60 days). Both populations occur in open, unshaded, unglaciated ponds near the tree-line. Water quality at these sites appears to

be high, with clear oligotrophic water supporting little or no associated vegetation in *Isoetes* stands. Although some site disturbance is evident from native ungulate movements and recreational activity, the sites appear to be structurally stable. Populations of *I. bolanderi* in Waterton Lakes National Park do not appear to require dynamic site features.

Climate

Both populations are found in subalpine areas characterized by short, cool summers, semi-permanently frozen soil and conditions in which frost is possible throughout the season. An early lake freeze-up (September - cf. Lawrence 1983) and frequent, strong westerly winds is typical of the area (Gadd 1986). Winters are long with continuously sub-freezing temperatures, the break-up of lake ice likely not occurring before early June. Annual precipitation in this area is the highest in Alberta, exceeding 75 cm/annum (Breitung 1957; Longley 1967). The Waterton Lakes National Park area also experiences an exceptional frequency of strong, drying westerly winds.

Both Canadian sites apparently benefit by a sheltered aspect favouring air drainage and by higher hills to the north and east emphasizing the southern exposure. These factors likely combine to increase summer water temperatures during the growing season

Water Quality

Few water quality data are available. At Summit Lake, Alberta the water in late summer is clear and cool with virtually no aquatic vegetation beyond a shore fringe of emergent sedges (*Carex* sp.). *Isoetes bolanderi* stations in Yellowstone National Park and Bighorn National Forest, Wyoming appear to be much the same. Such water appears to be oligotrophic and nutrient-poor. Floristic associates of *I. bolanderi* stations in Wyoming (see Biological Conditions, below) suggest slightly acidic water and substrate conditions.

Edaphic Features

All growing *I. bolanderi* observed in this study were found in a thin to thick (3 to 14 cm) layer of silt and silty-sand over a coarser sand substrate. It appears that the organic component of this silt layer may be high. The Summit Lake Alberta silt layer varied considerably, with the densest population of *Isoetes* in silt ca. 8 to 10 cm deep (Figure 8).

Dependence on Dynamic Features

The Alberta and Wyoming populations examined occupy well established and relatively stable shallow-water situations not directly effected by inlet stream, intensive wave action or other dynamic site elements. No artificial impediments or controls are evident at any of these sites.

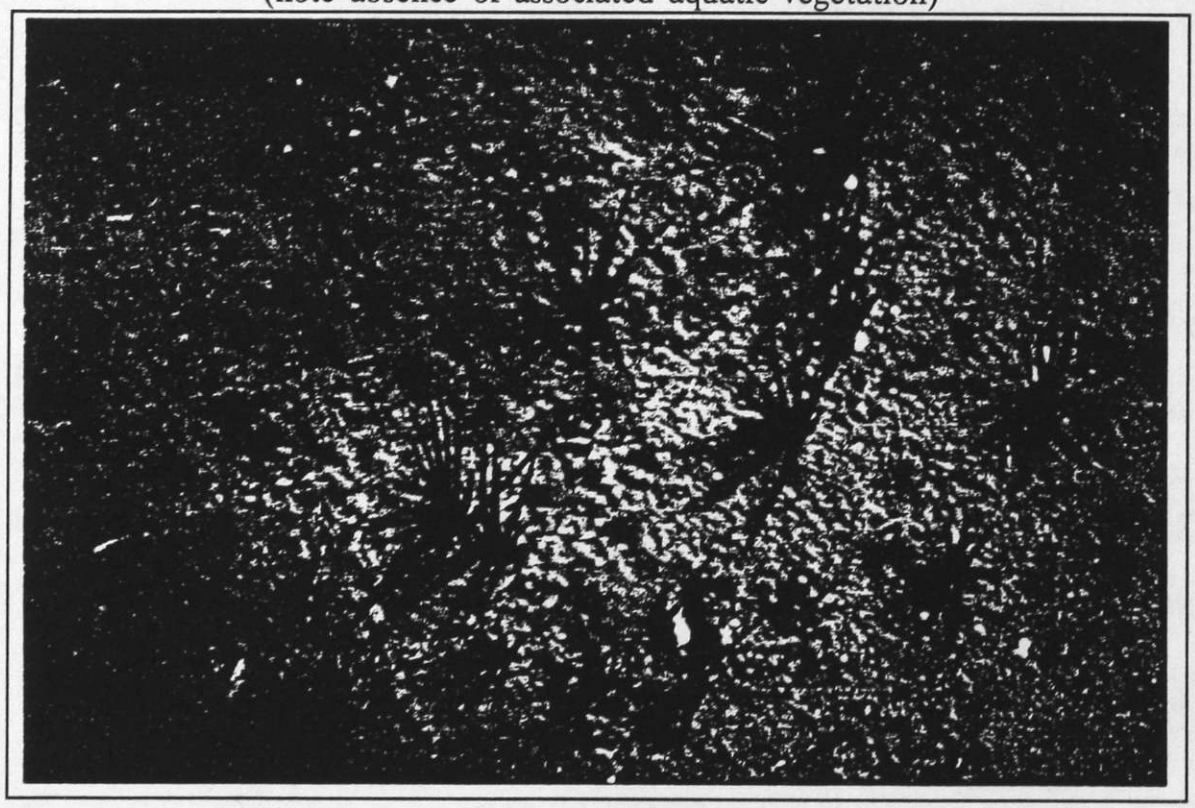
Many recently imprinted hoof marks from passing elk (wapiti) were observed in the silt of the Summit Lake *I. bolanderi* site. As noted previously (see Negative Interactions, above), this activity has disturbed some plants but it is not clear how significant an

impact that might have on such a large population.

Biological Characteristics

Both Canadian sites occur within the Subalpine Forest Region at the extreme southern end of the East Slope Rockies Forest District (Rowe 1972). This mountain equivalent of the boreal forest is the final forested areas below treeline and is conifer-dominated vegetation with graminoid and heath alpine tundra clearing throughout. Engelmann Spruce and Subalpine Fir dominate, with Alpine Larch being a locally important secondary dominant.

Figure 8: Density of Isoetes bolanderi in Summit Lake.
(note absence of associated aquatic vegetation)



The severe climatic conditions here result in the growing season for aquatic vegetation being very limited (<60 days), undoubtedly contributing to the absence of associated aquatic flora at Summit lake and paucity of associates in Wyoming stations (pers. obs.).

Plants at Summit Lake grow individually but in large numbers with no associated vegetation in the silty substrate (Figure 8). In Wyoming, *I. bolanderi* is found with scattered plants of *Potamogeton alpinus* and small patches of *Eleocharis acicularis* (pers. obs.). Few data on competitive ability of *Isoetes* species are documented but preliminary information in North America (Brunton and Di Labio 1989; Brunton and Taylor 1990; pers. obs.) suggest that they are poor competitors with other aquatic vegetation.

Isoetes in Canada typically grows in shallow water in open sites where light levels are high. Only the eastern and northern *I. macrospora* Dur. routinely grows below 2 m in depth. No *I. bolanderi* was observed in water shallower than 0.2 m in Canada or the western United States during this study (more typically, 0.4 - 1.0 m), but references to emergent plants do exist, including a 1958 observation at Summit Lake (E. H. Moss, ALTA).

6. POPULATION BIOLOGY

Summary

Isoetes bolanderi is present in huge numbers at Summit Lake but the other size of the other known Canadian site is unknown. A *minimum* of 600,000 plants is estimated to exist at Summit Lake.

Potential habitat destruction and water pollution from recreation activities are considered the most significant threat to the Canadian populations.

Demography

1) Summit Lake - between 600,000 and 1.8 million are estimated to occur along half to 90% of the shoreline of Summit Lake. That estimate is based on plants observed growing to a depth of ca. 1.5 m. While population density was declining at that depth, it seems probable that plants extend to a greater depth than was observed in August 1991. Accordingly, this estimate constitute a minimum population figure.

2) Carthew Lakes - unknown size: a comparable number of plants to those on Breitung's original Summit Lake collection are found on Porsild & Breitung's Carthew Pond collection, suggesting that plants were not difficult to obtain at the latter site either. The Carthew Lake pond is smaller than Summit Lake, however, suggesting that the *Isoetes* population there would be less than at the larger, lower, dense Summit Lake site.

Observations at both sites have not been conducted consistently enough over a sufficient period of time to determine population trends. Observations concerning the Summit Lake population since the 1950s consistently refer to *I. bolanderi* as common or abundant, however. It was remarkably abundant in August 1992. This population status was comparable to that of sites observed in Wyoming during the same period (pers. obs.).

Phenology

Canadian plants of *I. bolanderi* have mature megaspores by early August (pers. obs., 1992). Plants of shallower water likely mature at an earlier date than those in deeper water.

Reproductive Ecology

Isoetes bolanderi is a sexual diploid that produces viable spores. Apogamy has not been detected in North American *Isoetes* (Brunton and Taylor 1990). Vegetative reproduction is not reported for any of the *Isoetes* species of North America (Kott and Britton 1983; Taylor et al. 1993).

Dispersal

Dispersal of spores begins when the sporangium is ruptured, either by physical impact or by decay at the end of the growing season. The frequency of dense stands, such as that in Summit Lake, British Columbia, suggests that spores are typically dispersed only a short distance. This dispersal presumably occurs during the late summer and fall period.

Shorebirds may unintentionally transport the somewhat adhesive spores of *Isoetes* on their feet, although neither Canadian location is suitable feeding habitat for migratory shorebirds.

Large wading animals such as elk could accidentally carry spores and/or mixed collections of sediment and spores during travel or feeding activity. Dispersal could also be significantly aided by the transport of whole plants (or at least, entire sporophylls) by waterfowl. Canada Geese are reported to browse on some aquatic species of *Isoetes* (W. C. Taylor, pers. comm.). The Common Loon is reported to dislodge (and eat ?) *Isoetes* plants from rocky lake bottoms in late fall in central British Columbia (T. Goward, pers. comm.).

Survival and Nature of Mortality

There is no literature on the mortality of *Isoetes* before the sporophyte stage and even at this point such information is only preliminary. There appear to be few natural predators of these plants, perhaps in part because they typically grow in rather sterile situations. As noted above, some waterfowl have been reported to feed (or at least, dislodge) fully developed plants, but it is not clear if such events are common or have a significant effect.

Habitat degradation is certainly the most significant known cause of *Isoetes* mortality. Filling of wetland areas is a serious cause of destruction of natural habitat for numerous plant species in Ontario and across Canada, including *Isoetes*. Pollution of water sources in major industrial areas of the eastern United States has eradicated *Isoetes* populations, including those in the type location for several taxa (e.g. *I. riparia* - Proctor 1949). The effects of levels and types of water pollutants has not been examined in regards to *I. bolanderi* populations, however.

7. POPULATION ECOLOGY

Summary

Because of the difficulty experienced in separating taxa of *Isoetes* in the field, few data have been gathered concerning the population ecology of the group or of individual

species. Being a species of relatively sterile aquatic substrates, however (Brunton and Di Labio 1989), it likely experiences relatively fewer interactions with other aquatic organisms than do species of less ecologically restrictive sites.

Negative Interactions

As noted previously, a few waterfowl species have been observed to disturb *Isoetes* populations. Although interactions with birds may serve to provide a long-distance dispersal mechanism it seems unlikely that avian predation is intense enough to affect serious widespread population losses.

At Meadowlark Lake, Bighorn National forest, Wyoming and at Summit Lake, British Columbia, large numbers of up-rooted plants and/or individual leaves of *I. bolanderi* are found along shores. The cause of these "wrecks" (common in parts of Maritime Canada and New England (pers. obs.) and central British Columbia (T. Goward, pers. comm.)) is unknown but it seems likely that another organism is dislodging deep-grown plants. Spawning fish, hibernating turtles or amphibians and bottom-feeding waterfowl are considered to be possible causes of this.

Barrow's Golden-eye were observed on Meadowlark and Summit Lakes during the Aug 1991 field examination. This diving species typically feeds on aquatic insects (75%), aquatic vegetation (25%) and bottom-dwelling amphipods (11%) during the breeding season (Cannings et al. 1987). Several pair of Red-necked Grebes - a diving species with a similar bottom-scouring summer diet to that of Barrow's Golden-eye (Salt and Salt 1976), were noted actively diving in Meadowlark Lake, Wyoming. Only a few individuals or nesting pairs of these diving waterfowl may be required for a substantial amount of upheaval within beds of loosely anchored *I. bolanderi*.

The recent passage of an Elk along shallow near-shore waters of Summit Lake up-rooted a large number of *I. bolanderi* plants and fragmented many more (see Figure 4) at the time of the August 1991 field examination - as did observer movements. Frequent passage of large ungulates or wading activity by people could have a seriously detrimental impact on near-shore *Isoetes* populations.

On rare occasions, weevil larvae remains (Superfamily Curculionoidea) have been found in the sporangia of old herbarium specimens in *Isoetes* species, though not *I. bolanderi* to date. A live adult of a tiny (<1 mm long) species was also observed on plants of the Georgia endemic *Isoetes tegetiformans* Rury (pers. obs.). The spores in these empty sporangia have apparently been eaten by these larvae, presumably at an immature stage. No weevil species are known to inhabit *Isoetes*, implying that these animals likely constitute undescribed taxa (J. D. Lafontaine, pers. comm.). Even assuming that aquatic weevil taxa capable of feeding *I. bolanderi* exist, the rarity of the discovery of these insect remains suggests that it is unlikely any such predation would constitute a significant mortality factor.

Recreational activity was evident at the Meadowlark Lake, Wyoming site (fishing, motor boats, swimming) and this likely would be contributing to the up-rooting of shallow-water populations of *I. bolanderi* there. This is not seem as a likely potential impact on Canadian populations, however.

Hybridization

Isoetes bolanderi hybridizes with *I. echinospora* and *I. occidentalis* in Montana and California, respectively but no evidence of hybridization has been detected in Canada. Since no other quillwort species grows at the Canadian sites, the possibility of hybrids here is extremely remote.

8. LAND OWNERSHIP AND MANAGEMENT RESPONSIBILITIES

Both populations are in undeveloped (back-country) areas of Waterton Lakes National Park. No formal structures or facilities are present, although informal resting/camping sites and fire-rings are found along lakeshores.

9. MANAGEMENT PRACTICES

Current Management Policies and Actions

Both sites are within areas of Waterton Lakes National Park managed for un-mechanized, low intensity dispersed recreational activity; pedestrian recreational activity is the only regular human impact at and near the sites.

Future Land Use

No significant change to the landscape is anticipated at either site.

10. EVIDENCE OF THREATS TO SURVIVAL

Summary

No significant immediate threat to the Canadian populations of *I. bolanderi* has been identified although the implications of a substantial increase of the minor recreational impacts presently being experienced are potentially catastrophic. Existing wildlife pressures on the population (e.g. physical impact from wading ungulates, competition from associated aquatic plants, etc.) are at a low and apparently insignificant level.

Habitat destruction or modification

No destruction or modification of habitat is indicated but both populations are vulnerable to virtual or total elimination by the intentional or accidental introduction of toxic materials (particular petroleum products, herbicide/biocide, etc.) or potentially competeting non-native vegetation or fauna.

Physical impacts on the populations constitute the greatest apparent immediately threat to *I. bolanderi* in Canada. Bank erosion has occurred at recreationally preferred sites along Summit Lake to a minor degree, leading to very localized degradation of the

shore and adjacent shallow-water sites (pers. obs., Aug 1992). Evidence of recreational wading (swimming ?) was also evident through the disturbance to the substrate. These impacts are highly localized and insignificant at present but would become important degradation factors were they to be increased through greater recreational activity.

Over-utilization

Collection of vouchers by professional and amateur botanists is the only conceivable human consumption of *I. bolanderi* in Canada. This has been undertaken at an ecologically unimportant scale to date. No problem in this regard is being experienced with the Summit Lake population, although the Carthew Lakes Pond population could theoretically be small enough to be vulnerable from collections. *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).

Disease or Predation

Diseases affecting *Isoetes* are unknown and predation by insects and birds (see Negative interactions, above) is considered to be insignificant. No disease or predation has been noted in Canadian *I. bolanderi.*

11. PRESENT LEGAL OR OTHER FORMAL STATUS

Summary

Isoetes bolanderi is uncommon to common in much of the cordilleran region of the western United States, although it is considered rare in a number of individual states (Arizona, Nevada - Argus and Pryer (1990) and probably also New Mexico - cf. Taylor et al. 1993).

It enjoys no specific legal protection in Canada, although a significant measure of protection is afforded by the inclusion of both populations within a national park area.

International Status

The Nature Conservancy rating of G3 for *I. bolanderi* listed in Argus and Pryer (1990) suggests that it is globally rare or uncommon (21 to 100 occurrences. G3 overstates the rarity of *I. bolanderi* (see below) and it is likely better considered to support a G4 world status, *viz.,* "secure with many occurrences" (Argus and Pryer 1990).

National Status

Canada

Isoetes bolanderi is listed as Rare in Canada (Argus and Pryer 1990), given a Nature Conservancy ratings of N1, meaning Critically Imperiled at the Canadian and provincial

level because of its rarity. Listing by the Rare and Endangered Plants Project of the National Museum of Nature, however, imparts no regulatory status or protection.

United States

Isoetes bolanderi is rated as uncommon to rare (N3) in the United States by the United States Nature Conservancy (cf. Argus & Pryer 1990). Cronquist et al. (1972), however, describe it as " ... our only common species..." in the Intermountain West and even within areas where it has been described as uncommon (e.g. Dorn & Dorn 1972), new populations can be discovered with relative ease (pers. obs.).

An N4 status ("apparently secure with many occurrences") is considered to be a more accurate description of the status of *I. bolanderi* in the United States (this study). It is not recommended for listing under the United States Endangered Species Act.

Provincial Status

Alberta

Isoetes bolanderi is given the Nature Conservancy rating S1, meaning Critically Imperiled in Alberta (Argus and Pryer 1990). It is also included on the list of rare vascular plants of Alberta (Argus and White 1982). Listing by the Rare and Endangered Plants Project of the National Museum of Nature, however, imparts no regulatory status or protection.

II. Assessment of status

12. GENERAL ASSESSMENT

The populations of *I. bolanderi* are very restricted in Canada although the species is abundant in at least one of the two known sites (*viz.*, Summit Lake).

It appears that the Summit Lake population of *I. bolanderi* is stable and showing no sign of decline. No recent site information exists for the Carthew Lakes pond population, however.

13. STATUS RECOMMENDATION

It is recommended that *I. bolanderi* be declared **Threatened** in Canada despite the large population at Summit Lake, in recognition of its rarity, its vulnerability to catastrophic population decline from single degradation events and the limited potential for many other populations to be discovered.

14. RECOMMENDED CRITICAL HABITAT

The critical habitat for *I. bolanderi* in Canada is the shallow-water lake shore sites with sparse associated vegetation in unglaciated subalpine lakes in areas of relatively quartzite-rich, Precambrian gneissic bedrock in Waterton Lakes National Park.

15. CONSERVATION RECOMMENDATIONS

The author's conservation recommendations have been transmitted separately to the land management jurisdiction involved (Parks Canada). All enquiries regarding these recommendations should be directed to the appropriate jurisdiction (Parks Canada or COSEWIC) and further details are available at the discretion of these agencies.

III. Information Sources

16. REFERENCES CITED

Argus, G. W. and K. M. Pryer. 1990. Rare Vascular Plants in Canada: Our Natural Heritage. Botany Division, Canadian Museum of Nature, Ottawa.

Argus, G. W. and D. J. White. 1982. The Rare Vascular Plants of Alberta. Syllogeus 17, National Museum of Natural Sciences, Ottawa.

Benson, L. 1979. Plant Classification (Second ed.) D.C. Heath & Co., Toronto.

Breitung, A. J. 1957. Plants of Waterton Lakes National Park, Alberta. Canadian Field-Naturalist 71: 39-71.

Britton, D. M. and D. F. Brunton. 1989. A New *Isoetes* hybrid (*Isoetes echinospora x riparia*) for Canada. Canadian Journal of Botany 67:2995-3002.

Brunton, D. F. and B. M. Di Labio. 1989. Diversity and Ecological Characteristics of Emergent Beach Flora along the Ottawa River in the Ottawa-Hull Region, Quebec and Ontario. Naturaliste canadien 116: 179-191.

Brunton, D. F. and D. M. Britton. 1991. *I. x hickeyi* (*Isoetes echinospora x macrospora*) in Canada. The Fern Gazette 14: 17-23; 14: 82-83.

Brunton, D. F., D. M. Britton and W. C. Taylor. 1994. *Isoetes hyemalis*, sp. nov.; a new *Isoetes* (Isoetaceae) from the southeastern United States. Castanea 59(1) in press.

Brunton, D. F. and W. C. Taylor. 1990. *Isoetes x brittonii* hyb. nov. (*Isoetaceae*): A Naturally Occurring Hybrid (*I. engelmannii* x *I. riparia*) in the Eastern United States. American Fern Journal 80: 82-89.

Canning, R. A., R. J. Canning and S. J. Canning. 1987. Birds of the Okanagan Valley, British Columbia. Royal British Columbia Museum, Victoria.

Ceska, A. 1989. Isoetaceae *in*, G. W. Douglas, G. B. Straley and D. Meidinger. 1989. The vascular plants of British Columbia. Ministry of Forests, Victoria.

Clague, J. J. 1989. Cordilleran Ice Sheet; *in* R.J. Fulton (ed.) Chapter 1: Quaternary Geology of the Canadian Cordillera, in Quaternary Geology of Canada and Greenland. Geology of Canada no. 1, Geological Survey of Canada, Energy, Mines and Resources Canada, Ottawa.

Clague, J. J. and G.M. MacDonald. 1989. Paleoecology and palaeoclimatology (Canadian Cordillera); *in* R.J. Fulton (ed.) Chapter 1: Quaternary Geology of the Canadian Cordillera, in Quaternary Geology of Canada and Greenland. Geology of Canada no. 1, Geological Survey of Canada, Energy, Mines and Resources Canada, Ottawa.

Clute, W. N. 1905. The Fern Allies. F. A. Stokes Co., New York.

Cody, W. J. and D. M. Britton. 1989. Ferns and Fern Allies of Canada. Publication 1829/E, Research Branch, Agriculture Canada, Ottawa.

Cronquist, A., A. H. Holmgren, N. H. Holmgren and J. L. Reveal. 1972. Intermountain Flora: vascular plants of the Intermountain West, U.S.A. Volume 1. New York Botanical Garden, New York.

Dorn, R. D. and J. L. Dorn. 1972. The Ferns and other Pteridophytes of Montana, Wyoming, and the Black Hills of South Dakota. Department of Botany, University of Wyoming, Laramie.

Dyke, A. S. and V. K. Prest. 1987. Paleogeography of northern North America, 18,000 - 5,000 years ago. Map 1703A, Sheet 1: 18 000 - 12 000 years B.P.. Geological Survey of Canada, Ottawa.

Engelmann, G. 1882. The Genus *Isoetes* in North America. Transactions of the Academy of Sciences of St. Louis 4: 358-390.

Erichsen-Brown, C. 1979. Use of Plants for the Past 500 Years. Breezy Creek Press, Aurora.

Gadd, B. 1986. Handbook of the Canadian Rockies. Corax Press, Jasper.

Gray, A. 1867. Manual of Botany of the Northern United States (Fifth Ed.). Ivison, Blakeman & Co., New York.

Harrison, J. E. 1976. Evolution of a Landscape; the quaternary period in Waterton Lakes National Park. Geological Survey Miscellaneous Report 26, Energy, Mines and Resources Canada, Ottawa.

Hickey, R. J. 1981. A New *Isoetes* for Jamaica. American Fern Journal 71: 69-71.

Hickey, R. J., W. C. Taylor and N. T. Luebke. 1989. The Species Concept in Pteridophyta with Special Reference to *Isoetes*. American Fern Journal 79: 78-88.

Kott, L. S. and D. M. Britton. 1983. Spore morphology and taxonomy of *Isoetes* in northeastern North America. Canadian Journal of Botany 61:3140-3163.

Kuijt, J. 1982. A flora of Waterton Lakes National Park. University of Alberta Press,

Edmonton.

Lawrence, R. D. 1983. Canada's National Parks. Collins Publishers, Toronto.

Lellinger, D. B. 1985. A Field Manual of the Ferns and Fern Allies of the United States and Canada. Smithsonian Institution Press, Washington.

Longley, R. W. 1970. Climate and Weather Patterns *in*, W. G. Hardy (ed.), Alberta: A natural history. Hurtig Publishers, Edmonton.

Luebke, N. T. 1992. Three New Species of Isoëtes for the Southeastern United States. American Fern Journal 82: 23-26.

Macoun, J. 1890. Catalogue of Canadian Plants. Part V - Acrogens. William Foster Brown & Co., Montreal.

Marsden, C. R. 1979. Morphology and Taxonomy of *Isoetes* in Australia, India, North-east and South-east Asia, China and Japan. Dept. of Botany, University of Adelaide, Adelaide (Phd thesis).

Moss, E. H. 1974. Flora of Alberta (with supplement). University of Toronto Press, Toronto.

Ogilvie, R. T. 1962. Notes on Plant Distribution in the Rocky Mountains of Alberta. Canadian Journal of Botany 40: 1091-1094.

Parry, C. C. 1874. Botanical Observations in western Wyoming, No. 4 - Appendix; description of new species, etc. American Naturalist 8: 211-215.

Pfeiffer, N. 1922. Monograph on the Isoetaceae. Annals of the Missouri Botanical Garden 9: 79-233.

Pigg, K. B. 1992. Evolution of Isoetalean Lycopsids. Annals of the Missouri Botanical Garden 79: 589-612.

Price, R. A. 1962. Fernie Map Area, East Half, Alberta and B. C. - 82G E½. Geological Survey of Canada Paper 61-24, Energy, Mines and Resources Canada, Ottawa.

Proctor, G. R. 1949. *Isoetes riparia* and its variants. American Fern Journal 39: 110-121.

Rowe, J. S. 1972. Forest Regions of Canada. Canadian Forest Service, Ottawa.

Salt, W. R. and J. R. Salt. 1976. The Birds of Alberta. Hurtig Publishers, Edmonton.

Scoggan, H. J. 1978. The Flora of Canada Part 2: Pteridophyta, Gymnospermae, Monocotyledoneae. National Museum of Natural Sciences Publications in Botany 7(2), Ottawa.

Straley, G. B., R. L. Taylor and G. W. Douglas. 1985. The Rare Vascular Plants of British Columbia. Syllogeus 59, National Museum of Natural Sciences, Ottawa.

Taylor, T. M. C. 1970. Pacific Northwest Ferns and Their Allies. University of Toronto

Press, Toronto.

Taylor, W. C., N. T. Luebke, D. M. Britton, R. J. Hickey and D. F. Brunton. 1993. *Isoetaceae* in, (Editorial Ct'ee, eds). 1993. Flora of North America, Volume 2. Oxford University Press, New York.

Underwood, L. M. 1900. Our Native Ferns and Their Allies. (Sixth Edition, Revised). Henry Holt & Company, New York.

Wherry, E. T. 1972. The Fern Guide. Morris Arboretum, University of Pennsylvania, Philadelphia.

17. COLLECTIONS CONSULTED

Centre for Land and Biological Research, Ottawa (DAO)
Daniel F. Brunton personal herbarium, Ottawa (DFB)
Missouri Botanical Garden, St. Louis (MO) - *fide* D. M. Britton
Canadian Museum of Nature, Ottawa (CAN)
Royal British Columbia Museum, Victoria (VIC)- *fide* A. Ceska
University of Victoria, Victoria (UV) - *fide* R. T. Ogilvie
University of Guelph, Guelph (OAC) - *fide* D. M. Britton
University of British Columbia (UBC) - *fide* R. T. Ogilvie
University of Alberta, Edmonton (ALTA) - *fide* D. M. Britton

18. FIELDWORK

Examinations of a number of northwestern Wyoming *I. bolanderi* populations, selected low elevation water bodies in Waterton Lakes National Park, Alberta and an investigation of the Akamina Pass, B.C. *I. howellii* population, were undertaken between 13 August and 16 August 1991. A further investigation of low elevation water bodies in Waterton Lakes National Park and northward in Kananaskis Country and an examination of the Summit Lake population were undertaken, as was an investigation of *I. howellii* populations in interior British Columbia, between 12-14 August 1992. The site visits resulted in living and dried vouchers being collected, population estimates being made and 35 mm colour slide and black and white photographs being obtained.

20. OTHER KNOWLEDGEABLE PERSONS

D. M. Britton, Department of Molecular Biology and Genetics, University of Guelph, GUELPH, Ontario N1G 2W1 (519) 822-3941.
- authority on *Isoetes* genetics and taxonomy; has examined material of all North American *Isoetes* species; conducted cytological and SEM investigations utilized in this investigation and examined ALTA and *I. bolanderi* Type material.

W. C. Taylor, Curator of Vascular Plants, Milwaukee Public Museum, MILWAUKEE, Wisconsin 53233-1478 (414) 278-2760.
- authority on American species of *Isoetes*; has undertaken (unpublished) investigations of *I. bolanderi* and its hybrids.

A. Ceska, Herbarium, Royal British Columbia Museum, 601 Belleville Street, Victoria, B.C. V8V 1X4 (604) 387-3701.
- authority on British Columbia pteridophytes and aquatic plants; has conducted extensive (unpublished) taxonomic research on cordilleran *Isoetes* in Canada and the northwestern United States.

21. OTHER INFORMATION SOURCES

None.

22. SUMMARY OF MATERIALS ON FILE

The literature cited in this study provides a full summary of known material concerning these areas and this taxon in Canada. In addition, the author has a number of black and white and 35 mm colour slide photographs of the site.

IV. Authorship

23. INITIAL AUTHORSHIP

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24. MAINTENANCE OF THE STATUS REPORT

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