Recovery Strategy for the Mexican Mosquito Fern (*Azolla mexicana*) in British Columbia

Prepared by the Southern Interior Rare Plants Recovery Team

BRITISH COLUMBIA
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Ministry of Environment

July 2008

About the British Columbia Recovery Strategy Series

This series presents the recovery strategies that are prepared as advice to the Province of British Columbia on the general strategic approach required to recover species at risk. The Province prepares recovery strategies to meet its commitments to recover species at risk under the *Accord for the Protection of Species at Risk in Canada*, and the *Canada – British Columbia Agreement on Species at Risk*.

What is recovery?

Species at risk recovery is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

A recovery strategy represents the best available scientific knowledge on what is required to achieve recovery of a species or ecosystem. A recovery strategy outlines what is and what is not known about a species or ecosystem; it also identifies threats to the species or ecosystem, and what should be done to mitigate those threats. Recovery strategies set recovery goals and objectives, and recommend approaches to recover the species or ecosystem.

Recovery strategies are usually prepared by a recovery team with members from agencies responsible for the management of the species or ecosystem, experts from other agencies, universities, conservation groups, aboriginal groups, and stakeholder groups as appropriate.

What's next?

In most cases, one or more action plan(s) will be developed to define and guide implementation of the recovery strategy. Action plans include more detailed information about what needs to be done to meet the objectives of the recovery strategy. However, the recovery strategy provides valuable information on threats to the species and their recovery needs that may be used by individuals, communities, land users, and conservationists interested in species at risk recovery.

For more information

To learn more about species at risk recovery in British Columbia, please visit the Ministry of Environment Recovery Planning webpage at:

<http://www.env.gov.bc.ca/wld/recoveryplans/rcvry1.htm>

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Disclaimer

This recovery strategy has been prepared by the Southern Interior Rare Plants Recovery Team, as advice to the responsible jurisdictions and organizations that may be involved in recovering the species. The British Columbia Ministry of Environment has received this advice as part of fulfilling its commitments under the *Accord for the Protection of Species at Risk in Canada* and the *Canada – British Columbia Agreement on Species at Risk.*

This document identifies the recovery strategies that are deemed necessary, based on the best available scientific and traditional information, to recover Mexican mosquito fern populations in British Columbia. Recovery actions to achieve the goals and objectives identified herein are subject to the priorities and budgetary constraints of participatory agencies and organizations. These goals, objectives, and recovery approaches may be modified in the future to accommodate new objectives and findings.

The responsible jurisdictions and all members of the recovery team have had an opportunity to review this document. However, this document does not necessarily represent the official positions of the agencies or the personal views of all individuals on the recovery team.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that may be involved in implementing the directions set out in this strategy. The Ministry of Environment encourages all British Columbians to participate in the recovery of Mexican mosquito fern.

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The British Columbia Ministry of Environment is responsible for producing a recovery strategy for Mexican mosquito fern under the *Accord for the Protection of Species at Risk in Canada*. Environment Canada's Canadian Wildlife Service participated in the development of this recovery strategy.

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EXECUTIVE SUMMARY

Mexican mosquito fern (*Azolla mexicana*) is a tropical to subtropical species of floating aquatic fern that can form thick extensive mats in lakes, ponds, ditches, and quiet areas of streams. It is found globally in North, Central, and South America, and reaches the northern limit of its range in south-central British Columbia. First discovered in B.C. in 1889 by John Macoun, this threatened species is found today at only three locales in the province: the North Thompson River area, the Shuswap Lake area, and Vernon. In these areas, a total of 11 populations have been reported in the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status report, of which three are now assumed to be extirpated.

The main threats to Mexican mosquito fern in B.C. are due to habitat loss and degradation associated with development and transportation corridor maintenance. In these situations, maintenance activities such as winter road salting, road construction or improvement, and herbicide treatments can either directly kill plants or affect water conditions, changing water chemistry and making sites unsuitable for the species. Other potential threats include events such as chemical and oil spills, water chemistry changes, water level, turbidity, or watercourse alteration.

No critical habitat can be identified for Mexican mosquito fern in Canada at this time, but it may be identified at a later date in a federal addendum by Environment Canada, or in a future action plan. It is expected that critical habitat will be proposed following the completion of outstanding work required to quantify specific habitat and area requirements for the species, further research on the biology of the species, and monitoring of the populations to determine population trends. Consultation with affected landowners and organizations will also be necessary.

The recovery goal for Mexican mosquito fern is to protect and maintain extant populations, and to re-introduce the species at extirpated sites, if deemed necessary.

The recovery objectives for this species are:

1. to secure long-term protection for the known populations by 2012;
2. to monitor the known populations to determine population trends by 2012; and
3. to investigate if populations can be re-established at historic sites and, if deemed necessary, re-introduce the species by 2012.

Broad strategies to address the threats are site protection and site management, potential reintroduction and/or restoration at sites, and population monitoring to assess threats.

A recovery action plan will be completed by 2012.

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BACKGROUND

Species Assessment Information from COSEWIC

Date of assessment: May 2000
Common name: Mexican mosquito fern
Scientific name: *Azolla mexicana*
COSEWIC status: Threatened
Reason for designation: Few unprotected populations, restricted geographically, with recently discovered sites of doubtful permanence
Canadian occurrence: British Columbia
COSEWIC status history: Designated Threatened in April 1984. Status re-examined and confirmed in April 1998 and in May 2000. Last assessment based on existing status report.

Description of the Species

Mexican mosquito fern is a tiny species of floating aquatic fern that can form extensive mats on the surfaces of lakes, ponds, streams, sloughs, and ditches, and less frequently in wet marshes (Svenson 1944; Tryon and Tryon 1982; Brunton 1984; Douglas *et al*. 2003; Martin 2008). Mexican mosquito fern is primarily a still-water species usually found in non-saline ponds, lakes, and ditches, and in quiet backwaters and oxbows of rivers. While showing preference for still or sluggish waters, it has also been found in faster-flowing waters both in B.C. and elsewhere (Douglas, 2004; Martin 2008).

The plants may be red or green depending on the time of year, the pH, and temperature of the water. The red colouration of plants can appear in some B.C. populations in July (B. Klinkenberg, pers. observation, 2007). Red colouring is a result of the presence of anthocyanins (water-soluble pigments) that are produced in bright sunlight (Moore 1969; Watanabe 1997). Watanabe (1997) also reported red colouration in *Azolla* species when there is a nutrient deficiency. Lumpkin and Plunknett (1980), too, indicate that plants under stress (i.e., high pH, low temperature) may turn red.

Mexican mosquito fern is described in the status report (Brunton 1984), and by others (Svenson 1944; Gleason 1974; Douglas *et al*. 2002) as:

> A small floating green plant (Figure 1) with simple roots: plants are often 1.0–1.5 cm wide with small, alternate, overlapping leaves and dichotomous (forked branches of equal size) branching. Leaves are divided into two lobes: a smaller floating upper lobe 0.7 mm long, papillose (small rounded projections) on the upper surface, hairs on upper (dorsal) leaf lobes thick, 2–3 celled; lower lobe larger, variously described as submerged or floating. Identification is based on microscopic reproductive parts, and includes glochidia (barbed hairs) with many cross walls, and pitted megaspores (female reproductive organs) 0.4–0.5 mm long. Plants may be green or red in colour. Sporocarps (fruiting bodies) occur in pairs in the leaf axils of older plants.

Figure 1. Mexican mosquito fern, Little Fort, BC. Photo by Brian Klinkenberg.

In spite of several taxonomic treatments of *Azolla* species, taxonomy and identification are generally considered difficult (Moore 1969; Pereira *et al*. 2001; Evrard and Van Hove 2004; A. Ceska, pers. comm., 2005). Pereira *et al*. (2001) indicate that many previously described diagnostic vegetative and reproductive characters are environmentally influenced and vary with the collection site.

Populations and Distribution

Mexican mosquito fern is found in disjunct patches in North, South, and Central America (Svenson 1944; Brunton 1984; Douglas 2004). In the United States, it is found in several western and mid-western states (Figure 2): Arizona, Arkansas, California, Colorado, Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, Texas, Utah, Washington, and Wisconsin.

Figure 2. North American distribution of Mexican mosquito fern from Brunton (1984), Environmental Lab (2002), USDA (2007).

In Canada, Mexican mosquito fern is found only in B.C. (Figure 3), where it reaches the northern limits of its distribution (Brunton 1984). It was first collected in the province in Sicamous in 1889, and reported from Salmon Arm in 1890 by John Macoun (Brunton 1984). Since then, it has been reported at an additional nine locations, all in south-central B.C. in the area of Little Fort/North Thompson River, Shuswap Lake, and Vernon (Douglas 2004; B. Klinkenberg, pers. comm., 2007). Less than 2% of the global population is found in Canada (Douglas 2004).

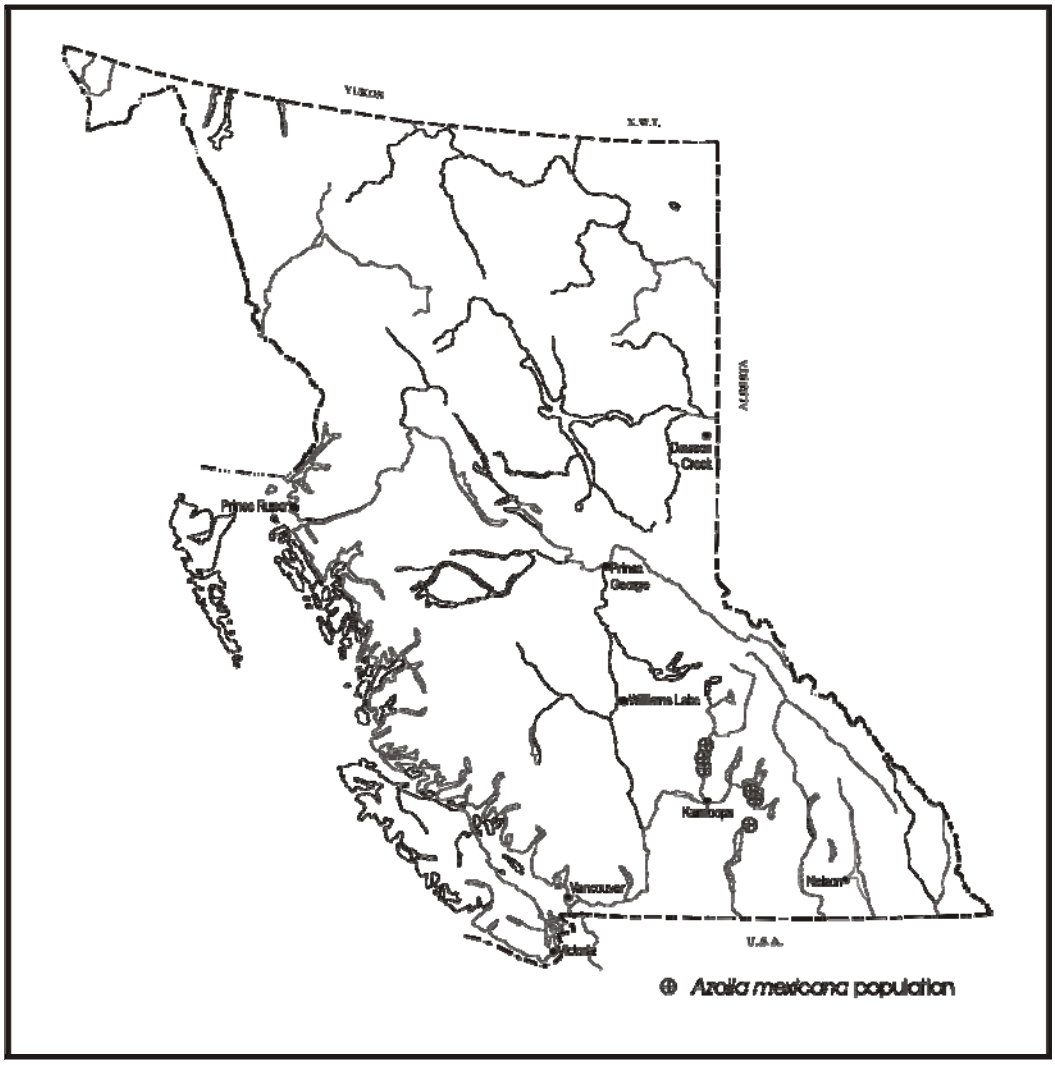

Figure 3. Distribution of Mexican mosquito fern in B.C.

All populations in B.C. lie within the Southern Interior Forest Region (specifically the Okanagan Shuswap and Kamloops forest districts), and within the Montane Cordillera Ecozone (Ogilvie 1998; CCEA 2005). B.C. populations may be a relict from a warmer post-glacial period (Brunton 1984; Martin 2008), although Martin (2008) speculates that it may "be a species still expanding" its range.

Total "population" numbers for this species have varied from 1984 to present, partially due to habitat destruction, and because populations can fluctuate from year to year. "Population" has been redefined using COSEWIC criteria (Table 1). Based on 2007 fieldwork by Klinkenberg, and recognizing annual population fluctuation, there are currently eight extant populations of Mexican mosquito fern in B.C. (Table 2). This represents an increase of four extant populations since 1984. However, two populations discovered since 1984 have since become extirpated, so that currently three populations are considered extirpated.

Mexican mosquito fern is assigned a global rank of G5 (secure). It is ranked S3S2 (vulnerable) in California; S4 (apparently secure) in Colorado and Illinois, S3 (vulnerable) in Iowa and S2

(imperiled) in Utah. It is not ranked (SNR) in Arizona, Arkansas, Kansas, Minnesota, Missouri, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, Texas, Washington and Wisconsin. In Montana, it is not rankable (SU). It is not assessed nationally in the United States. In Canada, it has a national status of N2 (imperiled) because of rarity due to very restricted range, or very few populations. In B.C., the species is ranked S2, subnationally imperiled (NatureServe 2007).

Table 1. Population numbers of Mexican mosquito fern, 1984 to 2007.

Year	Description
1984	Brunton (1984) lists 4 extant populations of Mexican mosquito fern in Canada in a single locale (Shuswap Lake area), plus 1 population last observed in 1954 and considered extirpated.
1997	Martin (2008) reports 10 extant populations in 3 locales (North Thompson River, Shuswap Lake, and Vernon areas). However, unlike Martin (in press), this strategy identifies the two Vernon populations as a single unit, so the number of extant populations should be reduced to 9.
2004	Of the 9 extant populations reported by Martin (2008), Douglas (2004) confirmed 8 extant populations and reported 2 populations as extirpated (noting also that 1 subpopulation of the Salmon Arm population was "extirpated"). If the two Vernon populations are considered a single unit, then the number of confirmed extant populations as reported by Douglas (2004) would be 7. The total number of extirpated populations is now 3.
2005	Fieldwork for the preparation of this recovery strategy in 2005 confirmed the 2 extirpated populations reported by Douglas (2004), but observed that the Salmon Arm foreshore subpopulation was still present. The total number of extant populations remained at 7.
2007	During 2007 fieldwork for a COSEWIC update status report, one new population (south of Darfield) was discovered. There are now 8 extant populations of Mexican mosquito fern in B.C., and 3 extirpated populations (2 from actual destruction of the sites; one not seen since 1954) (Table 2).

Table 2. Populations of Mexican mosquito fern in B.C. and Canada in 2007.

Location	Population	Ownership/Protection status	Population description	Status
Little Fort/North Thompson River area	Little Fort, Round Top Road (CDC EO #25545)	Private	Covers pond (approx. 10 x 5 m). July 2005 and 2007 ~500,000 plants	**Extant 2007.**
	Little Fort, south of (CDC EO #25454)	Private	3 subpopulations: (1) shallow pond at south end of pasture (3 x 20m); (2) two oxbow lakes on *west* side of highway south of pasture (20 x 150m) over a million plants; (3) oxbow on *east* side of highway (20 x 60m) sparsely covered.	**Extant 2005.** Subpopulation (1) not observed in 2007, but seen in 2005.
				Extant 2007. Subpopulation (2) extensive cover in 2005 and 2007.
				Extant 2007. Subpopulation (3) not observed in 2005, scattered plants present in 2007.
	Little Fort, north of (CDC EO #25458)	Dunn Peak Provincial Park (based on the Conservation Data Centre Mapping Service map)	Covers two large oxbows on *west* side of highway (30 x 18m); > one million plants in 2004 (Douglas, 2004).	**Extant 2007.** Assumed to be extirpated from oxbow on **east side,** now only present on the **west side**.
	Darfield (CDC EO #25478)	Unknown	Known from a pond on the west side of the highway	**Extirpated.** Douglas (2004) reported the site filled in by highway construction.
	Darfield, south of. New population 2007; 3.6 km to the south of previously known Darfield population	Private	In oxbow on east side of highway only; several 1000 plants	**Extant 2007. New population** (2007) on east side of highway.
Shuswap Lake area	Sicamous (CDC EO #3780)	Private	None	**Extirpated.** Douglas (2004) reported the site filled in.
	Salmon Arm (CDC EO #3782)	Subpopulation 1: Switsemalph Indian Reserve with CPR interests. Possibly also Crown land (lakebed) (based on the Conservation Data Centre Mapping Service map).	Plants in a 5 x 30m area in 2004 (Douglas, 2004).	**Extant 2004.** Not visited in 2005 or 2007. Subpopulation observed in 2004 (Douglas 2004).

Location	Population	Ownership/Protection status	Population description	Status
		Subpopulation 2: Salmon Arm foreshore, Municipality of Salmon Arm	Plants observed in a 3 x 2 m area (2005)	**Extant 2005.** No plants observed in 2007.
	Tappen/White Creek (CDC EO #3786)	North Bay Indian Reserve 5	Small numbers of plants among streamside vegetation along lowest stretch of the creek (1997).	**Extant 1997.** Not visited in 2005 or 2007, no plants observed in 2004 (Douglas 2004), but habitat still intact.
	Eagle River (CDC EO #3784)	Subpopulation 1: Cambie along Eagle River. Private	Plants covering pond (1997).	**Extant 1997.** No plants observed since 1997, but habitat still intact.
		Subpopulation 2: Eagle River/Solsqua. Private, owner unknown	None	**Extirpated.** No plants observed since 1954.
Vernon	Vernon Creek	Subpopulation 1: Okanagan Avenue, Vernon (CDC EO #21875) Private	Two 10 x 2m patches in pasture.	**Extant 2007.** Observed by M. Martin (2007).
		Subpopulation 2: Vernon Creek, (CDC EO #25670) Private or possibly Vernon Airport; also possibly City of Vernon (Marshall Fields recreation area)	Few plants in Sept. 2007, none in August 2007.	**Extant 2007.** Few plants .

Since 1984, seven new populations (those in the Thompson and Vernon areas) have been reported, including a newly discovered population in 2007, representing a range extension for this species of 50–80 km since 1984 (Goward 1994; Douglas 2004; Martin 2008). Two populations (Sicamous EO[1] #3780 and Darfield EO #25478) have been lost as a result of land development and infill from highway construction (BC CDC 2005; Klinkenberg, pers. observation, 2005); one population (Eagle River/Solsqua) has not been seen since 1954 although the habitat remains intact.

Population trends for each population are difficult to assess for this species. Douglas (2004) states that abundance in the Shuswap area over the last 13 years has not changed significantly, although in 2004 he does report only observing a very limited number of plants. Abundance for two of the sites in the North Thompson River area has not changed over a period of years, although in 2005 Mexican mosquito fern was found in oxbows on the west side of the highway

[1] BC Conservation Data Centre Element Occurrence (EO) defined as: an area of land/or water in which a species is, or was present.

south of Little Fort, while they were previously reported only from oxbows on the east side of the highway. In 2007, plants were again found in an oxbow on the east side of the highway south of Little Fort, as well as from the oxbows on the west side.

Existing data and observations indicate that this species' "presence" at a site fluctuates from year to year. Lack of observation does not indicate lack of a viable population or extirpation. Extirpation for this species can only be concluded where complete loss of the wetland/site has occurred.

Needs of the Mexican Mosquito Fern

Habitat and biological needs

Douglas (2004) and Brunton (1984) summed up the species needs as preferring cool, slightly acidic, partially shaded, phosphorus-rich, nutrient poor, still waters with low salinity. Existing habitat provides the slow-moving, partially shaded, protected waters needed for this species' survival—wind and wave action is reported to eventually fragment and kill Mexican mosquito ferns (Lumpkin and Plunknett 1980). Low salinity and pH values within the appropriate range are also required (as observed by Brunton 1984). Periodic annual flooding no doubt aids dispersal (Martin 2008).

Water depth
Mexican mosquito fern is a species of relatively narrow growing requirements that is susceptible to changes in water levels and composition (Douglas 2004). Mexican mosquito fern grows well when the water depth is only a few centimetres and the roots can touch the substrate (Wagner 1997; Watanabe 1997). This may correspond to summer drawdown in areas of deeper water. Throughout its range, it grows with other, often pioneering, aquatic species, including *Lemna minor* (common duckweed), *Phalaris arundinacea* (reed canarygrass), and *Riccia fluitans* (crystalwort) (Keddy 1976, cited by Brunton 1984).

Water chemistry
Mexican mosquito fern grows best in slightly acidic waters, growing most abundantly in waters with a pH ranging between 6.0 and 7.0 (Johnson 1986); this range allows greatest survival of young seedlings and greatest production of megasporocarps (Nayak and Singh 2004). pH levels below 3.5 and above 10.0 are lethal. Other authors report the fern's preference for "slightly" acidic conditions, with optimal growth in water with a pH ranging from 4 to 7.1 (Watanabe 1997), although it can survive in water with a pH ranging from 3.5 to 10 (Lumpkin and Plunknett 1980). Sensitivity to turbidity changes is unknown, but all sites examined in 2005 have clear water. Excessive turbidity may inhibit spore germination. Phosphorus and iron are critical elements for Mexican mosquito fern survival (Lumpkin and Plunknett 1980, cited by Brunton 1984) and may be limiting factors for growth and population establishment.

Most variants of Mexican mosquito fern can tolerate very low levels of salinity, but are killed by high levels (Moore 1969; Johnson 1986). A 1.3% salt (33% of sea water) prevents growth.

Brunton (1984) reported high conductivity[2] in the Sicamous and Salmon Arm stations (169 and 500, respectively[3]).
Mexican mosquito fern is reported to be more tolerant of sodium chloride (NaCl) salinity than of other salts including: magnesium sulphate ($MgSO_4$), magnesium chloride ($MgCl_2$), potassium sulphate (K_2SO_4) potassium chloride (KCl), sodium sulphate (Na_2SO_4) and calcium chloride ($CaC1_2$) (Johnson 1986).

Brunton (1984) reports that the Shuswap populations occur on glacial outwash plains with locally distributed calcareous deposits. Brunton (1984) tested the pH of the water and reported it as ranging from 6.5 (Sicamous population) to 8.1 (Salmon Arm population).

Water temperature
Additionally, low winter temperatures result in die-off at northern stations (Tryon and Tryon 1982, cited by Brunton 1984), and this has been observed by the author. Although *Azolla* species generally are reported to show resistance to cold, freezing of the water surface results in death (Tsujimura, Ikeda and Tukamoto 1957, cited by Moore 1969). Lumpkin (1993) indicates that this species is less cold tolerant and has a narrower environmental range than eastern mosquito fern (*Azolla caroliniana*). Mexican mosquito fern is a species that is sensitive to desiccation (Watanabe 1997; Douglas 2004; B. Klinkenberg, pers. observation 2007). It is killed by high temperatures (Vitousek *et al*. 2002).

Water levels
While Brunton (1984) described fluctuating water levels are required for the species, Martin (2008) indicated that its presence at sites with flowing water in B.C. "may undermine that presumption."

Light
Lumpkin and Plunknett (1980, cited by Brunton 1984) reported that 50% sunlight is optimal for species' growth. This fern is frequently found in partially shaded and sheltered sites, and in sites adjacent to wet meadows and other wetlands.

Reproduction
Populations of Mexican mosquito fern in B.C. show dramatic differences in size and prevalence of sporophytes that may reflect variation in water chemistry, shade versus sunlight conditions, water currents, or founder effects. Lumpkin (1993) indicates that Mexican mosquito fern and eastern mosquito fern are closely related and are similar vegetatively.

Dispersal
Dispersal may occur by wind, by flowing water, by animal transport or by human transport (Moore 1969; Lumpkin and Plunknett 1980). Populations typically carpet areas where they occur.

[2] Conductivity is a water quality measurement used to measure mineralization (total dissolved solids).
[3] The natural range for conductivity in fresh waters is about 20–1500. Fish and macroinvertebrates would find it difficult to survive in waters with a conductivity above 500 (US EPA 2006).

Ecological role

The ecological role for this species is currently unknown.

Limiting factors

Mexican mosquito ferns reproduce both vegetatively and via spore production with vegetative reproduction being the more common form of reproduction (Moore 1969). However, Mexican mosquito fern spores can also lie dormant for many years (Lumpkin and Plunknett 1980) until the conditions are optimal for germination. If there is limited spore production and/or germination, then the species will be restricted genetically if reproduction is mainly vegetative. As well, Brunton (1984) speculates that outbreeding may occur, though rarely, and this may be the critical factor in allowing for new population establishment.

Mexican mosquito fern is sensitive to cold temperatures which may account for population fluctuations from year to year. The species is also sensitive to changes in pH, salinity and water temperatures, as well as phosphorus and iron content of the water. Changes in these levels could also account for fluctuations in populations and restrict distribution.

Threats

Description of the threats

Habitat loss and degradation - development: The most significant known threat to Mexican mosquito fern is habitat loss due to site development and in-filling/conversion of habitat on private land and transportation rights-of-way.

Habitat loss and degradation – transport corridor maintenance: Populations/subpopulations may also be threatened by transportation corridor maintenance activities and/or construction such as road salting, run-off, herbicide drift, as well as road and track maintenance and development.

Other potential threats: Events such as chemical and oil spills, water chemistry changes, water level, turbidity, or watercourse alteration may also impact populations.

Although mentioned in the COSEWIC status report as threats, neither dumping garbage nor cattle grazing is seen as seen as current threats to this species.

Actions Already Completed or Underway

Other than inventorying for the COSEWIC status report update, no other actions are completed or underway.

Knowledge Gaps

1. Tenures of extant sites need to be confirmed.
2. Detailed ecological knowledge of the habitat conditions required for the species.

3. Taxonomic and genetic research to confirm taxa in populations/subpopulations.

RECOVERY

Recovery Feasibility

The recovery of Mexican mosquito fern in B.C. is considered biologically and technically feasible with minimal effort for recovery. Reproduction (by spores or vegetatively) partially depends on abiotic/biotic conditions; however, the common method is vegetative and currently this is not limiting to the species. The current habitat is sufficient for continued maintenance of the species, but re-introduction at appropriate historic or potential sites should be investigated. Recovery techniques are available for recovery of this species, and real and potential threats are likely to be easily mitigated.

Recovery Goal

The recovery goal for Mexican mosquito fern is to protect and maintain extant populations, and to re-introduce the species at extirpated sites, if deemed necessary.

Rationale for the Recovery Goal

Mexican mosquito fern population levels fluctuate from year-to-year, and there is no long-term population trend data available. As well, this species is at the northern limits of its range in North America and is peripheral to the main species range, thus it is not currently possible to set a quantitative population goal.

Recovery Objectives

1. To secure long-term protection[4] for the known populations by 2012.
2. To monitor the known populations to determine population trends by 2012.
3. To investigate if populations can be re-established at extirpated sites, and if deemed necessary, re-introduce the species by 2012.

[4] Protection can be achieved through various mechanisms including: voluntary stewardship agreements; conservation covenants; sale by willing vendors on private lands; land use designations; and legal and other protection on federal, provincial, and local government lands.

Approaches Recommended to Meet Recovery Objectives

Recovery planning table

Table 3. Recovery planning table.

Priority	Objective #	Threat addressed	Broad strategy to address threat	Recommended approaches to meet recovery objectives
High	1	Habitat loss or degradation; water quality and quantity	Site protection; site management	❑ Identify and contact all stakeholders and landowners and land managers. ❑ pursue conservation covenants or stewardship agreements with private landowners. ❑ Conduct outreach activities with targeted sectors to communicate presence of Mexican mosquito fern ❑ Assess, prepare, and implement best management practices for all sites including transportation corridors
Medium	3	Habitat loss or degradation	Reintroduction/ restoration	❑ Identify and select suitable introduction sites using plant ecology data for site parameters to determine suitability.
Medium	2	All	Population monitoring	❑ Establish annual monitoring protocols for future monitoring to assess threats and collect ongoing data on site parameters that will allow interpretation of population change.

Performance Measures

- Protection of all extant populations has been secured by 2012 (Objective 1).
- Population monitoring indicates by 2012 that the number of plants at the occupied sites are stable or increasing over the long term, and threats have been assessed (Objective 2).
- Need for re-introduction has been assessed and potential habitat investigated by 2012 (Objective 3).

Critical Habitat

Identification of the species' critical habitat

No critical habitat can be identified for Mexican mosquito fern in Canada at this time, but it may be identified at a later date in a federal addendum by Environment Canada, or in a future action plan. It is expected that critical habitat will be proposed following the completion of outstanding

work required to quantify specific habitat and area requirements for the species, further research on the biology of the species and monitoring of the populations to determine population trends. Consultation with affected landowners and organizations will also be necessary.

It is expected that critical habitat will be proposed within a recovery action plan following: (1) consultation and development of stewardship options with affected landowners and organizations, and (2) completion of outstanding work required to quantify specific habitat and area requirements for these species.

Recommended schedule of studies to identify critical habitat

1. Identify habitat attributes for Mexican mosquito fern by 2010.
2. Using established survey and mapping techniques, delimit the boundaries of all occupied habitats by 2010.
3. Identify, map, and rate potential reintroduction sites for restoration potential by 2011.

Existing and Recommended Approaches to Habitat Protection

There are no existing habitat protection measures; however, one of the Salmon Arm subpopulations occurs within a provincial park (Table 1).

At other sites, future habitat protection for Mexican mosquito fern will require a combination of initiatives including stewardship agreements with private landowners; development and adoption of best management practices and Special Management Zones; as well as outreach to targeted sectors such as provincial agencies, rail and road maintenance contractors, and adjacent land users.

Effects on Other Species

No effects on other species are known (Douglas 2004).

Socioeconomic Considerations

Socioeconomic effects are considered minimal due to the limited area of occurrence extent of the species. This will be further assessed in the recovery action plan.

Recommended Approach for Recovery Implementation

A single-species approach is most appropriate for the Mexican mosquito fern recovery strategy, since it has a limited and specific distribution in B.C. No other currently designated “at risk” species occurs in the same habitat.

Statement on Action Plans

A recovery action plan will be completed by 2012.

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