PROPOSED

Species at Risk Act
Management Plan Series

Management Plan for Multiple Species of the Athabasca Sand Dunes in Canada

Large-headed Woolly Yarrow
Athabasca Thrift
Mackenzie Hairgrass
Sand-dune Short-capsuled Willow
Felt-leaf Willow
Turnor's Willow
Floccose Tansy

2013

Canada

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Cover illustration: Floccose Tansy (the gray plant) on an active dune. The green plant is the associated species Sand Stitchwort (photo credit Rob Wright).

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PREFACE

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c. 29) (SARA), the federal competent ministers are responsible for the preparation of management plans for listed special concern species and are required to report on progress within five years.

The Minister of the Environment is the competent minister for the management of seven species of special concern found in the Athabasca Sand Dunes of northern Saskatchewan. This management plan was developed in accordance with section 65 of SARA in cooperation with the Government of Saskatchewan, under subsection 66(1) of SARA.

Success in the management of these species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this plan and will not be achieved by Environment Canada, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this plan for the benefit of the seven species of special concern in the Athabasca Sand Dunes and Canadian society as a whole. Implementation of the plan is subject to the appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Note: There are some questions regarding the taxonomy of three of the species in this management plan. The Flora of North America recognizes Large-headed Woolly Yarrow (*Achillea millefolium* var *megacephala*) as an eco-morphotype adapted to the Athabasca Sand Dunes, but only recognizes *Achillea millefolium* as a valid taxon (Trock 2006). The term "eco-morphotype" implies that the plants have a distinctive appearance when they are growing in a particular habitat, but they are not separate enough genetically to be considered a different variety. The taxonomic distinctiveness of Mackenzie Hairgrass (*Deschampsia mackenzieana*) from the widespread Tufted Hairgrass (*Deschampsia caespitosa*) has been questioned in a recent morphological and molecular analysis (Chiapella et al. 2011, but see Purdy and Bayer 1995b); it was considered as a synonym (i.e. the same plant by a different name) of the widespread and common Tufted Hairgrass in a taxonomic treatment (NatureServe 2011, Kartesz 1999). The Flora of North America mentions the Floccose Tansy (*Tanacetum huronense* var. *floccosum*) as occurring in dune habitats on the shore of Lake Athabasca, Saskatchewan, but includes the variety, along with numerous other subspecies and varieties, under Lake Huron Tansy (*Tanacetum bipinnatum),* which has a widespread distribution from the Yukon to New Brunswick and into the United States (Watson 2006). Because these three species are currently listed under the federal SARA they will be included in this management plan; however, the next COSEWIC status updates may no longer recognize them as distinct varieties and may group them with more widespread species that are not considered to be at risk. Should this occur, the management plan will be updated once these species are removed from Schedule 1 of SARA.

ACKNOWLEDGMENTS

This report was written by Jeff Thorpe and Bob Godwin (Saskatchewan Research Council). The initial draft was coordinated by Darcy Henderson (Environment Canada), while revisions were coordinated by Candace Neufeld (Environment Canada). Doug Campbell, Jeannette Pepper, and Gigi Pittoello (Saskatchewan Ministry of Environment), Eric Lamb (University of Saskatchewan), Rob Wright (Saskatchewan Tourism Parks, Culture and Sport) and Mark Wayland and Wendy Dunford (Environment Canada) contributed information, review, and/or ideas. Thanks also to Rob Wright for his photographs.

EXECUTIVE SUMMARY

This management plan addresses a group of seven plants which are listed as species of special concern under the *Species at Risk Act* (SARA), and which are found in the Athabasca Sand Dunes of northern Saskatchewan: Large-headed Woolly Yarrow, Athabasca Thrift, Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Felt-leaf Willow, Turnor's Willow, and Floccose Tansy. The Athabasca Sand Dunes is a complex of active and stabilized dunes on the south shore of Lake Athabasca, in the 1925 km^2 Athabasca Sand Dunes Provincial Park which is located in the northwest corner of Saskatchewan. These plants are endemic (i.e. found nowhere else) to the dune complex, with the exception of one reported location of Felt-leaf Willow in Nunavut, one reported location of Mackenzie Hairgrass in the Northwest Territories (both under review), and a few observations near to the dunes on the shores of Lake Athabasca.

All seven species occur mainly on sparsely vegetated surfaces within the dune complex. Six species are found mainly on active dunes and moist inter-dune slacks, while Athabasca Thrift is found mainly on gravel pavements. Within these habitats, several of these species are relatively common (Mackenzie Hairgrass, Sand-dune Short-capsuled Willow, Felt-leaf Willow), others less common (Turnor's Willow, Floccose Tansy), while some are uncommon (Large-headed Woolly Yarrow, Athabasca Thrift).

The Athabasca endemics have low populations mainly because the area of their habitat is small, although more research is needed on limiting factors within this habitat. There is no evidence that their population size or area of occupancy have declined. However, a number of threats have been identified, including acid deposition, climate change, recreational activities and other human disturbance, invasive alien species, seed collection, and altered hydrology.

The management objective is to maintain the current population density and current area of occupancy for each of these species. Broad strategies needed to attain the management objective include:

1. Develop a monitoring strategy to detect future changes in area of occupancy, population size, and threats from human disturbance and invasive alien species.
2. Fill in the information gaps to broaden our knowledge of the ecology of these species, the biophysical features and geographic extent of their habitats, and the severity and causal certainty posed by various threats.
3. Manage Athabasca Sand Dunes Provincial Park to maintain habitat for, and to protect, the seven species of special concern.
4. Communicate acid deposition and climate change threats to policy-makers.
5. Conduct public outreach with local residents, visitor groups, and the general public regarding these species of special concern.

Conservation measures are described to address these broad strategies.

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1. COSEWIC SPECIES ASSESSMENT INFORMATION

Date of Assessment: May 2000
Common Name (population): Large-headed Woolly Yarrow
Scientific Name: *Achillea millefolium* var. *megacephala*
COSEWIC Status: Special Concern
Reason for Designation: Endemic restricted to two areas in the western region of the Athabasca Sand Dunes.
Canadian Occurrence: SK
COSEWIC Status History: Designated Special Concern in May, 2000.

Date of Assessment: May 2002
Common Name (population): Athabasca Thrift
Scientific Name: *Armeria maritima* ssp. *interior*
COSEWIC Status: Special Concern
Reason for Designation: A Canadian endemic occurring sparsely within a unique sand dune ecosystem of limited geographical extent supporting at least 10 endemic plant species with various threats indicated.
Canadian Occurrence: SK
COSEWIC Status History: Designated Threatened in April 1981. Status re-examined and designated Special Concern in April 1999. Status re-examined and confirmed in May 2002.

Date of Assessment: November 2001
Common Name (population): Mackenzie Hairgrass
Scientific Name: *Deschampsia mackenzieana*
COSEWIC Status: Special Concern
Reason for Designation: An endemic restricted to the Athabasca Sand Dunes.
Canadian Occurrence: SK
COSEWIC Status History: Designated Special Concern in April 1999. Status re-examined and confirmed in November 2001.

Date of Assessment: May 2000
Common Name (population): Sand-dune Short-capsuled Willow
Scientific Name: *Salix brachycarpa* var. *psammophila*
COSEWIC Status: Special Concern
Reason for Designation: Endemic occurring as individual plants or small patches in only five areas of the Athabasca Sand Dunes.
Canadian Occurrence: SK
COSEWIC Status History: Designated Special Concern in May 2000.

Date of Assessment: May 2000
Common Name (population): Felt-leaf Willow
Scientific Name: *Salix silicicola*
COSEWIC Status: Special Concern
Reason for Designation: Endemic restricted almost exclusively to the Athabasca Sand Dunes of Saskatchewan, an ecosystem supporting at least 10 plant endemics.
Canadian Occurrence: NU, SK
COSEWIC Status History: Designated Special Concern in May 2000.

Date of Assessment: May 2000
Common Name (population): Turnor's Willow
Scientific Name: *Salix turnorii*
COSEWIC Status: Special Concern
Reason for Designation: Endemic of the Athabasca Sand Dunes found in low abundance throughout this restricted habitat type.
Canadian Occurrence: SK
COSEWIC Status History: Designated Special Concern in May 2000.

Date of Assessment: May 2000
Common Name (population): Floccose Tansy
Scientific Name: *Tanacetum huronense* var. *floccosum*
COSEWIC Status: Special Concern
Reason for Designation: Endemic to the Athabasca Sand Dunes where it occurs mainly in small clusters of scattered plants.
Canadian Occurrence: SK
COSEWIC Status History: Designated Special Concern in May 2000.

2. SPECIES STATUS INFORMATION

The range of these species, subspecies or varieties occur entirely in Canada (here after referred to as 'species'). All seven species are listed as species of special concern on Schedule 1 of the *Species at Risk Act* (SARA). NatureServe (2011) and the Saskatchewan Conservation Data Centre (2011) have ranked the species of special concern as follows in Table 1.

Table 1. NatureServe global, national and provincial rankings[a].

Species Name	Global Ranking	National Ranking	Provincial Ranking
Large-headed Woolly Yarrow	G5T1	N1	S1
Athabasca Thrift	G5T1T2	N1N2	S1S2
Mackenzie Hairgrass	G2Q	N2	S2
Sand-dune Short-capsuled Willow	G5T2T3	N2N3	S2S3
Felt-leaf Willow	G2G3	N2N3	S2S3
Turnor's Willow	G1G2	N1N2	S1S2
Floccose Tansy	G5T1T3Q	N1N3	S2S3

[a] NatureServe assessment: G=global, N = national, S = subnational (provincial/territorial); T= status of a subspecies or variety below the level of the more common or widespread species represented by G, Q= questionable taxonomy that may reduce conservation priority, 1= critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, and 5 is secure. Two rankings side by side (e.g., S1S2) indicates a range of uncertainty about the status (NatureServe 2011).

3. SPECIES INFORMATION

3.1. Species Description

Large-headed Woolly Yarrow (*Achillea millefolium* L. var. *megacephala* (Raup) Boivin) is a perennial herb in the Aster or Composite Family (Asteraceae) (Figure 1). Plants are densely woolly and bear large, compact clusters (4-10 cm in diameter) of flowers (6 mm or more in diameter) on erect stems that are 30-50 cm high. The finely divided leaves form a cluster at the base of the plant and also occur alternately along the flowering stems. The flower clusters are composed of numerous flower heads, each of which consists of many tiny flowers surrounded by a circle of white rays (Harms 1999a). Large-headed Woolly Yarrow is part of the *Achillea millefolium* complex, which is found over much of the northern hemisphere, and which has evolved a variety of ecological races adapted to specific environments (Purdy and Bayer 1996). It is similar in appearance to Common or Woolly Yarrow (*Achillea millefolium* var. *lanulosa*), but it is more densely woolly overall, and has larger flower heads with larger and more prominent rays (Harms 1999a).

Figure 1. Large-headed Woolly Yarrow (© Rob Wright).

Athabasca Thrift (*Armeria maritima* (P.Mill.) Willd. ssp. *interior* (Raup) Porsild) is a perennial herb in the Leadwort Family (Plumbaginaceae) (Figure 2). It has a branched woody base and one to several clusters of leaves at ground level (rosettes). Flowering stems may arise from each rosette, and the small pink flowers are found in a dense, almost round head. The plant grows in small clusters or as occasional individuals (Argus 1999a).

Figure 2. Athabasca Thrift (© Rob Wright).

Mackenzie Hairgrass (*Deschampsia mackenzieana* Raup) is a perennial grass (Grass Family, Poaceae) (Figure 3). The plant consists of a dense bunch of stems growing from fibrous roots. The narrow leaves are mostly at the base of the plant. Ligules (leaf-like structure at the junction of the leaf sheath and blade) are large (3-5 mm long). The flower heads are open branching structures (panicles) which are 10-20 cm long and light straw-coloured. The spikelets (the individual parts of the flowering head) are 6-12 mm long, with 2 or 3 flowers (Harms 1998). Mackenzie Hairgrass developed from the widespread species Tufted Hairgrass (*Deschampsia caespitosa*) by a doubling of the number of chromosomes, leaving it reproductively isolated from its progenitor (Purdy and Bayer 1995b).

Figure 3. Mackenzie Hairgrass (© Rob Wright).

Sand-dune Short-capsuled Willow (*Salix brachycarpa* Nutt. var. *psammophila* Raup) is a shrub in the Willow Family (Salicaceae) (Figure 4). Plants are short and stiffly erect, 90 to 120 cm high, with grayish, erect or spreading branches. The roughly oval-shaped, flat leaves are either stalkless or with short stalks less than 2 mm long. The leaves are 1.5 to 3 cm long, have rounded or heart-shaped bases, and do not have serrated edges. Both their upper and lower surfaces are covered with dense, silky, greyish-white hairs. The flowering heads are catkins (i.e. dense cylindrical clusters of tiny flowers arranged along a stem), with male flowers on some plants and female flowers on others (Harms 1999b, Flora of North America Editorial Committee 1993+). Sand-dune Short-capsuled Willow is a variety with a narrow range, within the more widespread species Short-capsuled Willow (*Salix brachycarpa*) (Harms 1999b).

Figure 4. From left to right, Felt-leaf Willow, Sand-dune Short-capsuled Willow, Tyrrell's Willow, and Turnor's Willow (© Rob Wright).

Felt-leaf Willow (*Salix silicicola* Raup) is a shrub in the Willow Family (Salicaceae) (Figure 4). Plants are erect, 1 to 2 m (sometimes up to 3 m) high, with spreading branches and twigs that are densely covered with felted white hairs. The roughly oval-shaped, flat leaves are borne on 2 to 10 mm long stalks. Leaves are 3 to 6 cm long and 2 to 3.5 cm wide, have a rounded or broadly wedge-shaped base, prominent veins, and no serration along the margins. Both their upper and lower surfaces are covered with thickly felted white hairs. The flowering heads, which are covered with long white hairs, are catkins, with male flowers on some plants and female flowers on others (Harms 1999c, Flora of North America Editorial Committee 1993+). Felt-leaf Willow is thought to have evolved from the more widespread northern species Alaska Willow (*Salix alaxensis*) (Purdy and Bayer 1995). Felt-leaf Willow differs from Alaska Willow by having shorter and broader stipules, and broader, densely pubescent leaves (Harms 1999c).

Turnor's Willow (*Salix turnorii* Raup) is a shrub in the Willow Family (Salicaceae) (Figure 4). Plants are erect and narrow, 1 to 2 m (sometimes up to 4 m) tall, with pale grayish-green bark that is usually smooth on branches that are at least a year old. Younger twigs have reddish or purplish bark that may be hairy at first but then becomes smooth. The elongated, roughly oval, flat leaves are noticeably longer (2 to 3.5 cm) than they are wide (0.5 to 1 cm), and have prominently serrated (toothed) edges. They have a rounded base but come to a sharp point at the tip. Both surfaces are pale green, but the undersurface is paler. They can be hairy at first but become almost smooth when mature. The leaf stalks are 2 to 5 mm long. The flowering heads are catkins, with male flowers on some plants and female flowers on others (Harms 1999d, Flora of North America Editorial Committee 1993+).

Turnor's Willow is thought to have evolved from Yellow Willow (*Salix eriocephala* var. *famelica*), a widespread species of the southern prairies (Harms 1999d). Turnor's Willow differs from Yellow Willow by having redder young twigs, pale gray-green bark on second-year and older stems, shorter and thicker leaves not acuminate-tipped, shorter catkins, more reddish capsules, and longer stipes (Harms 1999d).

Floccose Tansy (*Tanacetum huronense* Nutt. var. *floccosum* Raup) is a perennial herb in the Composite Family (Asteraceae) (Figure 5). Plants are stout and grow 20 to 40 cm high from rhizomes (horizontal stems running through the soil). Plants have finely divided leaves at their bases and alternately along their stems. Leaves and stems are covered by densely matted, white, woolly hairs. The typical composite flower heads have yellow rays and are arranged in loose clusters at the end of the upwardly branching stems (Harms 1999e). Floccose Tansy is a variety with a restricted range, within the more widespread species Lake Huron Tansy (*Tanacetum huronense*) (Harms 1999e). It differs from its nearest relative (*Tanacetum huronense* var. *bifarium*) by the hairiness of the leaves and stems (Harms 1999e).

Figure 5. Floccose Tansy (© Rob Wright).

3.2. Populations and Distribution

All of these species are endemic to (found only in) the Athabasca Sand Dunes in Saskatchewan, with the exception of a specimen of Felt-leaf Willow collected in Nunavut in 1966 (Argus 2010, G. Argus, pers. comm.), a specimen of Mackenzie Hairgrass collected in the Northwest Territories in 1927[1] (B. Bennett, pers. comm.), and a few incidental observations nearby on the shores of Lake Athabasca (see below). The Athabasca Sand Dunes is a complex of active and stabilized dunes extending about 100 km east-west along the south shore of Lake Athabasca, a large lake in the northwest corner of Saskatchewan (Figures 6 and 7). The complex is made up of a series of large dune fields, including (from west to east) the William River, Thomson Bay, Cantara Lake, Archibald Lake, and MacFarlane River dune fields, plus other smaller areas (Figure 7). Athabasca Sand Dunes Provincial Park (ASDPP) which encompasses almost all of the ranges of the seven species, has an area of 1925 square kilometres (Figure 6). The park is in a remote area with no road access, and the few visitors arrive by float-plane or by boat from communities such as Uranium City and Fond du Lac, Saskatchewan. It is located in the Boreal Shield Ecozone and has a northern boreal climate. The town of Cree Lake, located about 200 km southeast (Figure 6), has mean January temperature of -22.7°C, mean July temperature of 15.7°C, and annual precipitation of 446 mm (1971-2000 normals; Environment Canada 2011). The vegetation on stabilized soils in the area consists mainly of open jack pine forest.

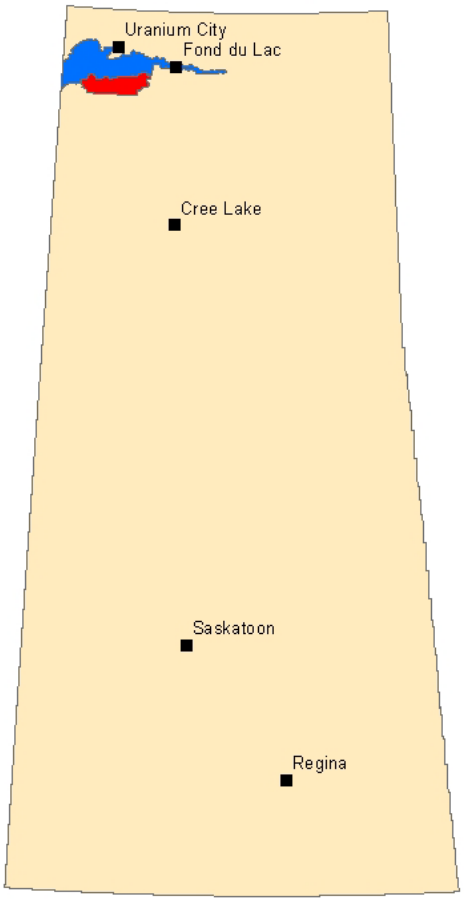

Figure 6. Map of Saskatchewan showing Athabasca Sand Dunes Provincial Park (red) on the south shore of Lake Athabasca (blue).

Lamb et al. (2011) reported on surveys done in 2009-2010. A total of 224 transects (250 m long) were surveyed in the William River, Thomson Bay, Cantara Lake, Archibald Lake, and

[1] These records require further review to positively confirm identification. As both of these specimens were collected more than 25 years ago with identification uncertain and no recent confirmations of either the species presence at these sites or suitable habitat still existing, this management plan will only deal with the occurrences within the Athabasca Sand Dunes until further information becomes available. Although Large-headed Woolly Yarrow is recorded in NatureServe (2011) as also being in NWT and AB, Harms (1999a) refutes these claims. Alberta has records of *Tanacetum bipinnatum* ssp. *huronense* in the Lake Athabasca region and think it may be the same as what Saskatchewan refers to as *Tanacetum huronense* var. *floccosum* but are unable to confirm that (J. Gould, pers. comm. 2011; see preface) so it is not being included in this plan; Harms (1999e) refers to the Alberta population as Tanacetum huronense var. *bifarium,* stating that var. *floccosum* only occurs in SK but that var. *bifarium* also occurs in the Saskatchewan Athabasca Sand Dunes alongside var. *floccosum,* likely hybridizing with it.

MacFarlane River dune fields. Changes in habitat type along the transects were recorded, and numbers of individuals of endemic plants were counted in a belt 10 m wide for willows and 4 m wide for herbaceous species. The relative abundances of the endemic species are shown in Table 2. These relative abundances were calculated from the total number of individual plants observed, with willow numbers adjusted to account for the wider search area. However, Lamb et al. (2011) cautioned that the number of willow individuals may be inflated due to the counting of stems rather than clumps.

Figure 7. Major dune fields referred to in the text: A – William River; B – Thomson Bay; C - Cantara Lake; D – Archibald Lake; E – MacFarlane River. The red line is the boundary of Athabasca Sand Dunes Provincial Park.

Table 2. Percent relative abundances of the seven species of special concern in the Athabasca Sand Dunes Provincial Park, based on 2009-2010 surveys (after Lamb et al. 2011).

Species Name	% Relative Abundance
Mackenzie Hairgrass	30%
Sand-dune Short-capsuled Willow	24%
Felt-leaf Willow	20%
Turnor's Willow	13%
Floccose Tansy	12%
Large-headed Woolly Yarrow	1%
Athabasca Thrift	0.6%

Mackenzie Hairgrass is the most abundant of the herbaceous endemics (Table 2). It is widely distributed across all of the dune fields that were surveyed, and is also found on the beaches of Lake Athabasca (Lamb et al. 2011, Lamb and Guedo 2012, Figure 8). It occurs as scattered large tufts or in small groups of 3-5 or more plants (Harms 1998). There is no population trend information available but no indication that the population is declining (Harms 1982). Mackenzie Hairgrass has also been observed on active dunes just outside of the Park boundary south of the William River dune field (B. Godwin, personal observation), and on beaches at the Gunnar mine site on the north side of Lake Athabasca (Harms 1982).

Figure 8. Distribution of Mackenzie Hairgrass in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

Sand-dune Short-capsuled Willow is the most abundant of the endemic special concern willows (Table 2). It is widely distributed in the Thomson Bay dune field, common around the margins of the William River, MacFarlane River, and Archibald Lake dune fields, and is also found on the beaches of Lake Athabasca (Lamb et al. 2011) (Figure 9). It has also been recorded on the tailings at the Gunnar mine site on the north side of Lake Athabasca (B. Godwin, pers. comm.). No population trend data are available, but the population is believed to be stable (Harms 1999b). It is relatively widespread on active dunes, where it is often associated with Felt-leaf Willow (Hermesh 1972).

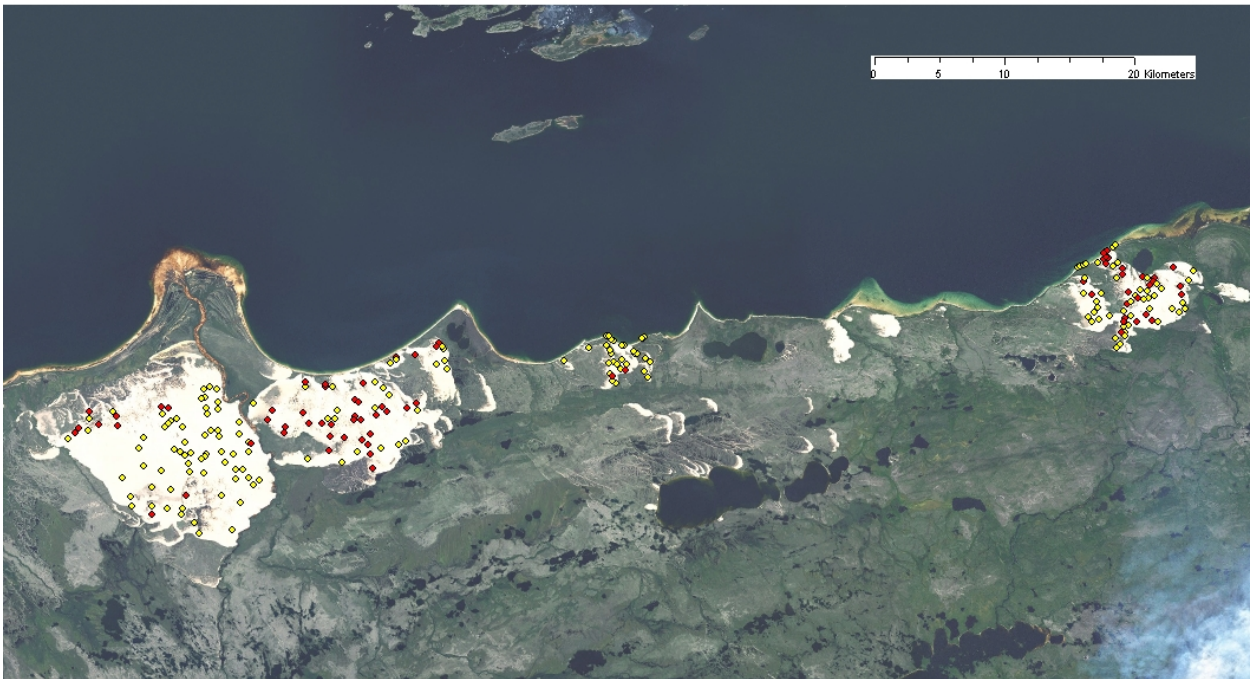

Figure 9. Distribution of Sand-dune Short-capsuled Willow in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

Felt-leaf Willow is relatively common, comparable to Sand-dune Short-capsuled Willow (Table 2). It is widely distributed in the Thomson Bay and MacFarlane River dune fields, common around the margins of the William River and Archibald Lake dune fields, and is also found on the beaches of Lake Athabasca (Lamb et al. 2011) (Figure 10). Although no population trend data are available, the population is believed to be stable (Harms 1999c). Felt-leaf Willow has been observed outside of the Park, westward along the shoreline of Lake Athabasca (B. Godwin, pers. comm.). Little is known about the reported occurrence of this species at Pelly Lake in Nunavut (Harms 1999c, Argus 2010).

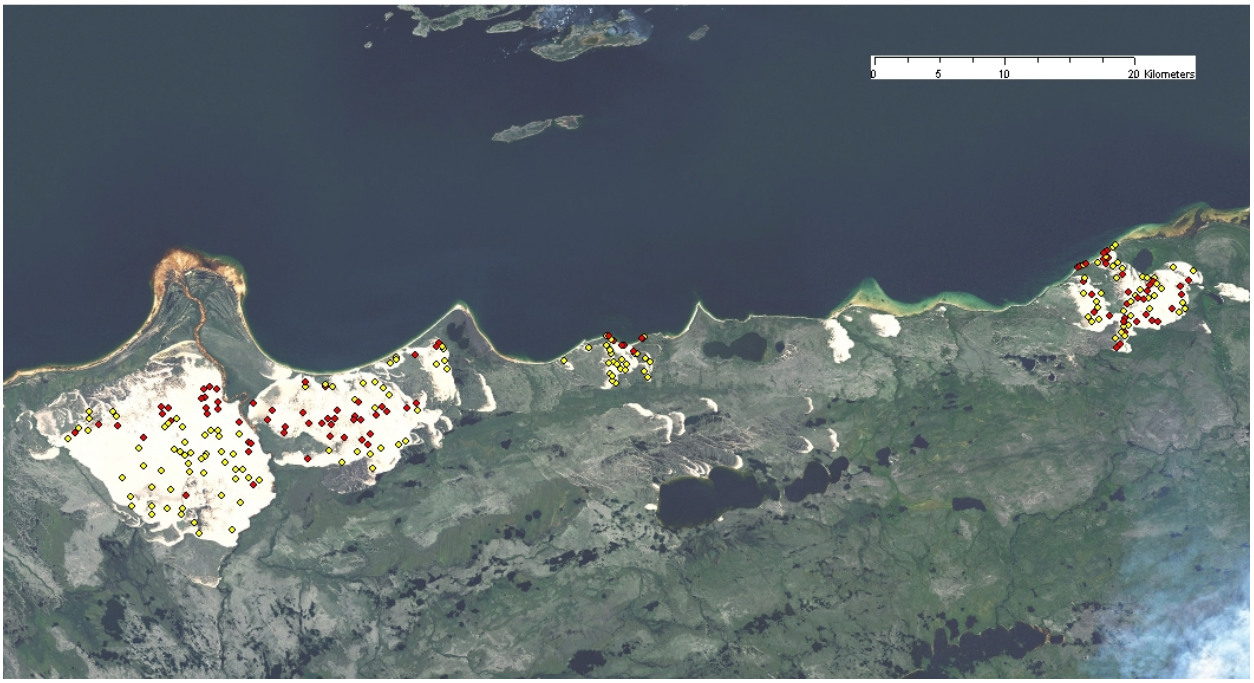

Figure 10. Distribution of Felt-leaf Willow in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

Turnor's Willow is less abundant than the other willows (Table 2). It is widely distributed in the Thomson Bay and MacFarlane River dune fields, common around the margins of the William River dune field, but present only on beaches at the margin of the Archibald Lake dune field (Lamb et al. 2011) (Figure 11). It occurs scattered over active dunes (Harms 1999d). Although no population trend data are available, the population is believed to be stable (Harms 1999d).

Floccose Tansy is relatively common, but less so than Mackenzie Hairgrass or the willows (Table 2). It is widely distributed across all of the dune fields, as well as on the beaches of Lake Athabasca (Lamb et al. 2011) (Figure 12). It occurs as individuals, or more often as small clonal clusters varying from several to more than a dozen plants (Harms 1999e). Although no population trend data are available, the population is believed to be stable (Harms 1999e).

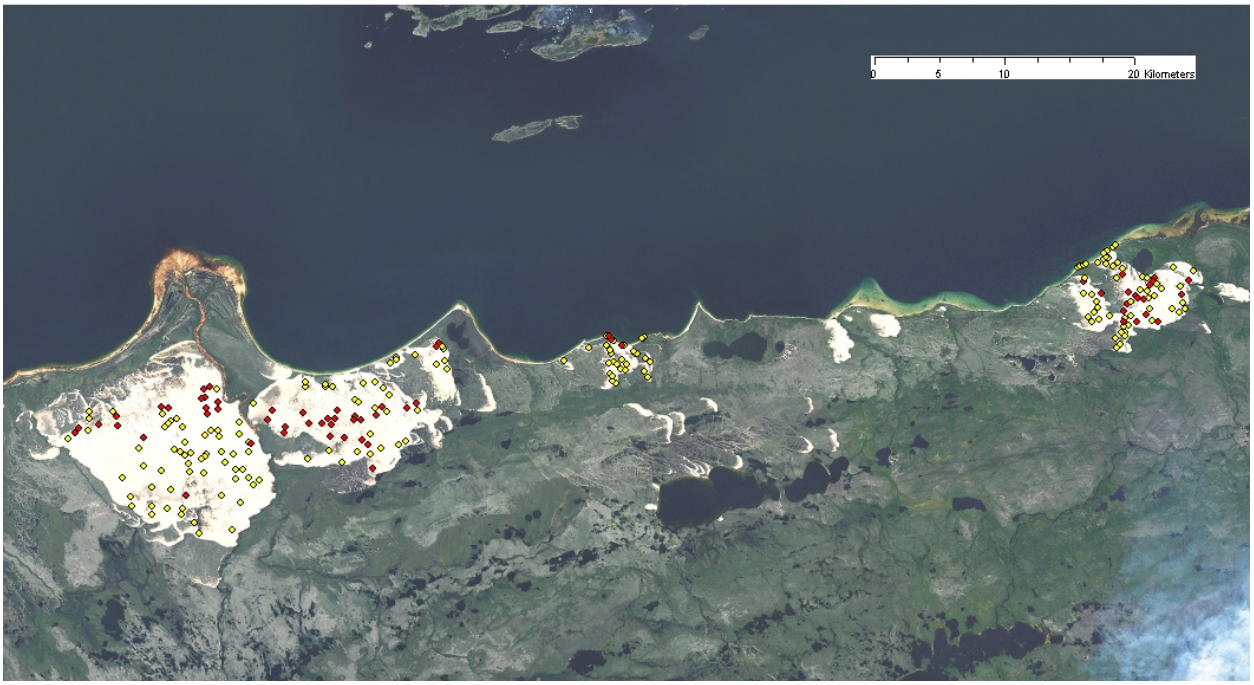

Figure 11. Distribution of Turnor's Willow in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

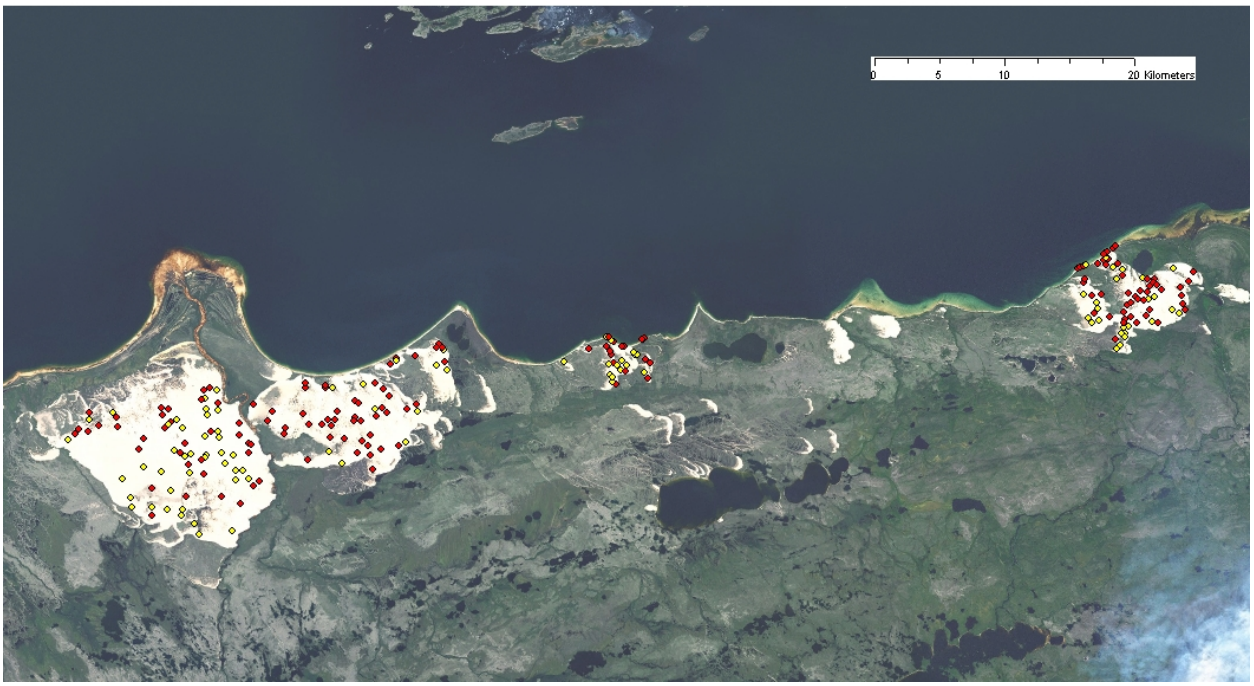

Figure 12 . Distribution of Floccose Tansy in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

Large-headed Woolly Yarrow, like Athabasca Thrift, is less common than the other endemic species (Table 2). According to Harms (1999a), Yarrow is more common locally but more restricted in distribution, while Thrift is sparser locally but has a wider distribution. Large-headed Woolly Yarrow is patchily distributed in the Cantara Lake, Thomson Bay, and William River dune fields, but absent from the Archibald Lake and MacFarlane River dune fields (Lamb et al. 2011) (Figure 13). It also occurs on beaches of Lake Athabasca (Rob Wright, personal observation), but was not recorded on beach transects (Lamb et al. 2011). Although no population trend data are available, the population is believed to be stable (Harms 1999a).

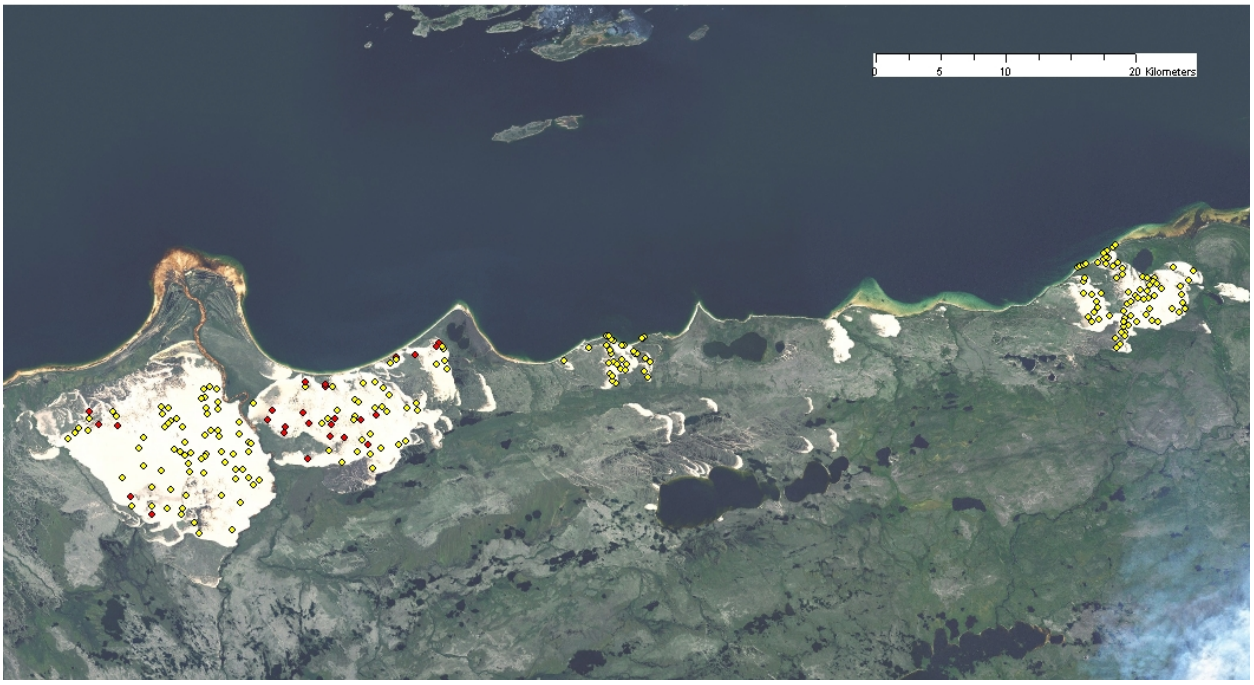

Figure 13. Distribution of Large-headed Woolly Yarrow in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

Athabasca Thrift is the least common of the Athabasca endemics (Lamb and Guedo 2012, Table 2). It is concentrated in the northeastern sector of the William River dune field, patchily distributed in the Thomson Bay and MacFarlane River dune fields, and absent from the Archibald Lake dune field (Lamb et al. 2011) (Figure 14). While no population trend data are available, there is no evidence to suggest that it has declined in recent years (Argus 1999a). Argus (1999a) considered the rarity of this plant to be related to the rarity of its gravel pavement habitat. Lamb et al. (2011) suggested that it may be particularly vulnerable because of its preferred habitat, growth form, and low population size.

Figure 14. Distribution of Athabasca Thrift in the Athabasca Sand Dunes (after Lamb et al. 2011). Red dots represent transects where present, and yellow dots represent transects where absent.

3.3. Needs of the Species

3.3.1. Habitat and biological needs

The main habitats used by most of the Athabasca endemics are active dunes (with a variety of aspects and slope positions) and moist inter-dune areas referred to as dune slacks. Another distinctive habitat is gravel pavement. This is a highly localized and fragile habitat created by wind action on a sandy gravel till. As the sand was winnowed out of the material by wind erosion, the surface became covered by a single layer of stones, a lag concentrate, which reduced subsequent erosion (Argus 1999a). Less commonly used habitat types include sandy beach ridges along Lake Athabasca and stabilized dunes covered by forest or lichen-crowberry heath occurring in proximity to the active dunes (Lamb et al. 2011, Lamb and Guedo 2012).

It is important to note the dependence of these species on naturally disturbed habitats. Dune stabilization would in fact eliminate the habitat for these species. This is a major concern in the dunes of the southern Prairie Provinces, where reduced disturbance has led to increased vegetation cover, reducing the habitat for active-sand specialists. However, there is no evidence of a trend towards stabilization in the Athabasca Sand Dunes. The human impact is much lower than in the southern Prairies, so whatever factors produced the active dunes are probably still in play. Disturbance by forest fires is probably one of these factors. Bihun (1998) observed charred wood in some open sand areas, suggesting that fire contributes to expansion of active dunes. The Athabasca region is still subject to a largely natural fire regime, because forest fires are not suppressed in this zone of Saskatchewan unless they threaten settlements (Parisien et al. 2004).

Another factor that has been thought to affect dune stabilization is hydrological change (see Section 4.2, Altered Hydrology). More research is needed on the historic stabilization/destabilization trends in the Athabasca Sand Dunes.

The 2009-2010 field survey classified habitat types along transects (Table 3). The densities of endemic plant species by habitat type are shown in Table 3, while the percentages of habitat units (i.e. contiguous stretches of a given habitat type along a transect) with at least one individual of a given species are shown in Table 4.

Table 3. Mean density (individuals ha^{-1}, ± standard deviation) of the species of special concern in each habitat type, based on 2009-2010 surveys (after Lamb et al. 2011). Note that the densities for Saline Inter-dune Slack may be unreliable because they are based on a small sample area.

	High-slope Dune[1]	Low-slope Dune[2]	Wet Inter-dune Slack[3]	Saline Inter-dune Slack[4]	Gravel Pavement[5]	Lichen-Crowberry Heath[6]	Woodland[7]
Large-headed Woolly Yarrow	3 (±32)	28 (±294)	390 (±1350)			59 (±397)	26 (±101)
Athabasca Thrift	5 (±58)	11 (±122)	9 (±39)	9 (±27)	50 (±274)	2 (±20)	11 (±80)
Mackenzie Hairgrass	310 (±839)	1126 (±4320)	1018 (±4093)	741 (±1480)	446 (±2136)	27 (±182)	3 (±27)
Sand-dune Short-capsuled Willow	499 (±2067)	978 (±5677)	3083 (±8239)	3843 (±9202)	123 (±1363)	989 (±4100)	514 (±4292)
Felt-leaf Willow	648 (±2497)	820 (±5718)	8189 (±41193)	75 (±145)	58 (±389)	177 (±906)	11 (±101)
Turnor's Willow	433 (±1985)	586 (±6159)	2333 (±7808)	2903 (±5718)	51 (±378)	75 (±427)	26 (±154)
Floccose Tansy	1199 (±6938)	360 (±1130)	3082 (±8550)	604 (±1675)	35 (±181)	217 (±678)	154 (±474)

[1] Dry high slope gradient dune. The dominant substrate is open sand with slopes generally greater than 15-20°.
[2] Dry low slope gradient dune. The dominant substrate is open sand with slopes generally less than 15-20°. Relatively level areas between dunes without evidence of a high water table were included in this category.
[3] A level or nearly level habitat with a high groundwater table and moist soils. Open water is occasionally present. It may have sandy substrate or more or less extensive herbaceous or bryophyte ground cover.
[4] Same description as for Wet Inter-dune Slack, but with evidence of salt deposits on the soil surface.
[5] Dominant surface cover is rocks or pebbles lying on a sandy substrate.
[6] Dry areas with well developed layers of lichens, bryophytes, and low-growing ericaceous shrubs over the soil surface, but without extensive tall shrub or tree cover.
[7] Extensive woody vegetation (generally jack pine forest or birch scrub). Substrates between trees generally similar to Lichen-Crowberry Heath.

Table 4. Percentage of habitats units (contiguous stretches of a given habitat type along a transect) with at least one individual of a given species (after Lamb et al. 2011). Note that the percentages for Saline Inter-dune Slack may be unreliable because they are based on only 8 habitat units of this type.

	High-slope Dune	Low-slope Dune	Wet Inter-dune Slack	Saline Inter-dune Slack	Gravel Pavement	Lichen-Crowberry Heath	Woodland
Large-headed Woolly Yarrow	1	3	18	0	0	8	10
Athabasca Thrift	1	2	7	13	8	1	2
Mackenzie Hairgrass	28	46	22	38	35	7	1
Sand-dune Short-capsuled Willow	11	15	49	50	6	18	12
Felt-leaf Willow	18	19	33	38	14	18	2
Turnor's Willow	17	13	18	38	10	7	6
Floccose Tansy	43	31	64	38	9	26	20

Athabasca Thrift appears most dependent on gravel pavement (Tables 3 and 4). It appears poorly adapted to moving sand habitats because of its cushion-like growth form (Lamb et al. 2011). According to Argus (1999a), seedlings become established both on gravel pavements and on moist to wet dune slacks. Plants growing in dune slacks are young and vigorous, but are not able to grow up through sand and are eventually buried by moving dunes. Old plants are only found on the relatively stable gravel pavements. Lamb et al. (2011) observed that many of the plants recorded on dune slopes were adjacent to gravel pavements.

The other six species of special concern have generally been described as occurring on active dune slopes and dune slacks, as well as sandy beach ridges along Lake Athabasca (Harms 1998, 1999a, 1999b, 1999c, 1999d, 1999e). The 2009-2010 surveys (Tables 3 and 4) provided a more quantitative basis for describing habitat preferences. Strikingly, all of these species except Mackenzie Hairgrass had higher density and frequency on wet inter-dune slacks than on low-slope or high-slope dune habitats (Tables 3 and 4). Although the wet inter-dune slack habitat comprises a relatively small proportion of the total dunal area, it is thought to be important for seedling establishment for many of these species (Argus 1998, Lamb et al. 2011).

Felt-leaf Willow, **Turnor's Willow**, and **Sand-dune Short-capsuled Willow** showed similar patterns, with highest density on wet inter-dune slack, and lower density on low-slope dune followed by high-slope dune. The pattern for Felt-leaf Willow and Turnor's Willow is consistent with establishment of young plants on wet inter-dune slacks, with mature individuals persisting on dune slopes as large clumps following burial by moving sand (Lamb et al. 2011). Willows continue to grow vertically as their lower parts are buried (Abouguendia et al. 1981). However, Lamb et al. (2011) observed that mature Sand-dune Short-Capsuled Willows were more concentrated than the other willows in wet inter-dune slacks, and related this to the shorter stature of this species. Sand-dune Short-capsuled Willow was also more abundant in lichen-crowberry heath and woodland habitat types than the other willows (Table 3). All three willows also occur along the beaches of Lake Athabasca (Lamb et al. (2011).

Floccose Tansy is most dependent on wet inter-dune slacks, followed by high-slopes dunes (Tables 4 and 5). Tansy was also found on the upper margins of the beaches of Lake Athabasca (Lamb et al. 2011). It is similar to the willows in that it appears to germinate in wet inter-dune slacks, with mature individuals persisting as large clumps on dune slopes following burial by moving sand (Lamb et al. 2011).

By contrast, **Mackenzie Hairgrass** occurred more often (Table 5) and at slightly higher density (Table 4) on low-slope dunes than on wet inter-dune slacks. Lamb et al. (2011) observed that Mackenzie Hairgrass frequently forms large stands of seedlings on areas of open sand, suggesting that it is more successful at establishment on dune slopes than the other species. The active dune habitat of Mackenzie Hairgrass contrasts sharply with the marshy habitat used by the close relative Tufted Hairgrass (*D. cespitosa*) (Harms 1998). However, Mackenzie Hairgrass was found on the beaches of Lake Athabasca (Lamb et al. 2011).

At the other extreme, **Large-headed Woolly Yarrow** appeared to be most dependent on wet inter-dune slacks and was almost absent from dune slopes (Tables 3 and 4), suggesting low tolerance for burial by moving sand (Lamb et al. 2011). Wet inter-dune slacks are clearly the most important habitat type for this species (Lamb et al. 2011). There was more Yarrow than expected on the small areas of stabilized habitats (lichen-crowberry heath and woodland) included in the 2009 survey (Tables 3 and 4).

With respect to other biological requirements, Large-headed Woolly Yarrow, Floccose Tansy, Athabasca Thrift and the willows rely on insects for pollination, whereas Mackenzie Hairgrass is wind-pollinated. Yarrow, tansy and the willows also spread vegetatively from rhizomes or from branches buried by moving sand. By contrast, Mackenzie Hairgrass and Athabasca Thrift are bunch-like plants, lacking the ability to spread vegetatively, and therefore depend on seed for seedling establishment to expand and disperse. Mackenzie Hairgrass seeds apparently require a winter cold-treatment prior to germination in spring. A long-day photoperiod seems needed for flowering induction. Numerous seeds and seedlings have been observed in nature, and seed viability appears high (Harms 1998).

3.3.2. Limiting factors

The obvious limiting factor for these species is the small spatial extent of their habitat. This implies that their populations are relatively small, which in turn implies that they are more vulnerable to extinction as a result of habitat change or stochastic events, compared to species with larger or more widespread populations. Moreover, at least two species (Felt-leaf Willow and Mackenzie Hairgrass) have reduced genetic diversity compared with their wider-ranging relatives (Purdy et al. 1994, Purdy and Bayer 1995a, 1995b), which may mean they have reduced capacity to adapt to habitat change (e.g. climate change).

More specific limiting factors are not yet understood. It has been suggested that some species may be limited by the small area and relative proportion of wet inter-dune slack habitat, which is important for seedling establishment (Argus 1998, Lamb et al. 2011).

4. THREATS

4.1. Threat assessment

Threats are similar for all the species of special concern in the Athabasca Sand Dunes. Therefore, the threats are not presented separately by species.

Table 5. Threat Assessment Table

Threat	Level of Concern[a]	Extent[b]	Occurrence[c]	Frequency[d]	Severity[e]	Causal Certainty[f]
Pollution						
Acid Deposition	medium	widespread	current/anticipated	continuous	medium	low-medium
Climate and Natural Disasters						
Climate Change	medium	widespread	anticipated	continuous	medium	medium
Disturbance or Harm						
Recreational activities and other human disturbance	low	localized	current/anticipated	seasonal	low	low
Exotic, Invasive or Introduced Species/Genome						
Invasive Alien Species	low	unknown (probably none at present)	anticipated	unknown	unknown	low-medium
Biological Resource Use						
Seed Collection	low	localized	historic, anticipated	recurrent	low	low
Changes in Ecological Dynamics or Natural Processes						
Altered Hydrology	low	unknown	unknown	unknown	low	low

[a] Level of Concern – indicates whether the threat is an overall high, medium, or low concern for recovery of the species, taking into account extent, occurrence, frequency, severity, and causal certainty.

[b] Extent – indicates whether the threat is widespread, localized, or unknown across the species range.

[c] Occurrence – indicates whether the threat is historic (contributed to decline but no longer affecting the species), current (affecting the species now), imminent (is expected to affect the species very soon), anticipated (may affect the species in the future), or unknown.

[d] Frequency – indicates whether the threat is a one-time occurrence, seasonal (either because the species is migratory or the threat only occurs at certain times of the year), continuous (on-going), recurrent (reoccurs from time to time but not on an annual or seasonal basis), or unknown.

[e] Severity – indicates whether the level of severity of the threat is high (very large population-level effect), medium, low, or unknown.

[f] Causal Certainty – indicates whether the best available knowledge about the threat and its impact on population viability is high (evidence causally links the threat to stresses on population viability), medium (correlation between the threat and population viability, expert opinion, etc.), or low (assumed or plausible threat only).

4.2. Description of threats

Acid Deposition

The impact of acid deposition in Canada has been thoroughly reviewed by the Meterological Service of Canada (MSC 2004). Most evidence of significant impacts on ecosystems comes from eastern Canada, where higher pollution levels coincide with large areas of sensitive ecosystems. However, increases in emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) from oil sands operations in the Fort McMurray, Alberta area, (about 300 km to the southwest), as well as other sources, are raising concerns that impacts could increase in the northern parts of the Prairie Provinces (Whitfield et al. 2010). Much of northern Saskatchewan is geologically sensitive to acid deposition, but MSC (2004) found that there is insufficient data on deposition rates and ecosystem sensitivity to evaluate impacts.

According to MSC (2004), the most important effect of acid deposition on terrestrial ecosystems is reduction in soil fertility because of leaching of base cations. Other indirect effects of soil acidification include increased plant uptake of metals such as iron and aluminum, which can reach toxic levels (MSC 2004). Direct effects of acid deposition on foliar surfaces are only evident at levels which are rarely found in Canadian environments (MSC 2004). Potential impacts are evaluated by determining whether levels of acid deposition exceed the critical load (i.e. the load below which there are no significant harmful effects to sensitive biological components). In soils, the critical load depends on the supply of base cations as well as other factors. The soils of the Precambrian Shield generally have low critical loads, meaning that they could be adversely affected by relatively low levels of acid deposition (MSC 2004).
WBK and Associates (2006) presented maps of estimated acid deposition in the Prairie Provinces in 1995, 2000, and 2010 (projected). Acid deposition for sulfur and nitrogen was estimated to be relatively low in the Lake Athabasca area compared to many other regions in the Prairie Provinces. In spite of the fact that aerial deposition of base cations (which have a neutralizing effect) is also low, this area was mapped in the lowest class of potential acid input (acid deposition minus base deposition) in all three years: 0.00 – 0.10 keq H^+/ha/yr, which is below the critical load estimated for sandy soils supporting jack pine forests in Alberta (Foster et al. 2001). WBK and Associates (2006) also compared acid input to soil-based critical load, for Alberta only. In the northeast corner of the province, adjacent to the Athabasca Sand Dunes in Saskatchewan, acid deposition was estimated to be 0-30% of the critical load in all three years. Similarly, Aherne (2008) found that most soil map units in Alberta had deposition below the critical load. However, Whitfield et al. (2010), using the most recent atmospheric deposition data and regionally calibrated rates of base-supply from weathering, found that several sites near the Athabasca Sand dunes already exceed the critical load. While the earlier results suggest that acid deposition is not high enough yet to cause concern, the more recent study indicates a significant impact on soils. Moreover, future expansion of oil sands operations will increase the downwind deposition of acids (Whitfield et al. 2010).

In the Fort McMurray, Alberta area, where acid deposition levels are considerably higher than they are further north, monitoring of vegetation plots showed no measurable effects on forest health (AGRA 1999, AMEC 2002, 2003). These plots were on sandy soils with low buffering capacity, as are the soils in the Athabasca Sand Dunes. Despite this research, the effects on the

Athabasca endemic species in particular are not yet known. Preliminary investigations at the University of Saskatchewan suggest that root growth rates of Athabasca Thrift would be substantially impaired following germination on an acidified substrate (Lamb et al. 2011). Lamb et al. (2011) also suggested that acid deposition is likely to threaten Mackenzie Hairgrass, because it commonly germinates on open sand following precipitation events.

Climate Change

The most serious concern related to climate change is the effect on growing conditions for plants. Presumably the endemic plants are adapted to the prevailing range of temperatures and other climatic variables in the region. If the climate were to rapidly become much warmer, as is predicted, the endemics might find themselves increasingly maladapted. While this is a threat to a wide range of organisms, the Athabasca endemics may be particularly vulnerable because of low genetic diversity and restricted ranges. Two cases have been studied in which the sand dune endemics have less genetic diversity than their more widespread relatives: Felt-leaf Willow (*Salix silicicola*) vs. Alaska willow (*S. alaxensis*) (Purdy and Bayer 1995a), and Mackenzie Hairgrass (*Deschampsia mackenzieana*) vs. Tufted Hairgrass (*D. cespitosa*) (Purdy and Bayer 1995b. By contrast, Large-headed Woolly Yarrow (*Achillea millefolium* ssp. *megacephala*) maintains more variability than its widespread relative, Common or Woolly Yarrow (*A. millefolium* ssp. *lanulosa*) (Purdy and Bayer 1996). Those species with reduced genetic diversity may have reduced capacity to shift their physiological tolerances to adapt to warmer climates. Small population size may further increase the vulnerability of these species to habitat change. Moreover, because their ranges are so restricted, there is no potential for northward migration of southern ecotypes that are already adapted to warmer climates, and there are few active dune habitats to the north to which the existing populations could migrate. A warming, drying climate trend could create more habitat if currently vegetated dune fields become active, but it could also reduce the already limited area of wet inter-dune slacks which are thought to be important for establishment of the endemics

Continuing gene flow with wide-ranging relatives could be one means by which the endemics could overcome this restriction. Gene flow is prevented between Felt-leaf Willow and Alaska Willow because their current ranges do not overlap, and between Mackenzie Hairgrass and Tufted Hairgrass because the former is a tetraploid (i.e. having four sets of chromosomes) that is reproductively isolated from its diploid (i.e. having two sets of chromosomes) progenitor (Purdy et al. 1994, Purdy and Bayer 1995a, 1995b).

Future climate change could alter the hydrology of Lake Athabasca and its connecting streams through effects on precipitation, snowmelt, or ice-damming of rivers during spring runoff (Leconte et al. 2006, Pietroniro et al. 2006, Toth et al. 2006) with possible effects on activity or stability of the dunes (see Altered Hydrology). However, the impact of these hydrological changes on the dune landscape will depend on their magnitude. When climatic scenarios for doubling of atmospheric CO_2 were applied to a hydrological model of the Peace-Athabasca system, the changes in the average level of Lake Athabasca were on the order of a few tens of centimetres, which would be unlikely to affect the amount of dune activity (Leconte et al. 2006, Pietroniro et al. 2006, Toth et al. 2006). Climate change could also alter wind patterns, which might change the dynamics of the dunes.

Recreational Activities and Other Human Disturbance

COSEWIC assessments of the endemic species have emphasized the threat from physical habitat disturbance and trampling (Harms 1998, 1999a-e, Argus 1999a). Factors mentioned as contributing to this threat include:

- Increasing tourism, including ecotourism trips and canoe trips down the William and McFarlane Rivers with visitors camping in the Park and hiking on the dunes. Park regulations designate campsites and acceptable activities on the dunes, but the effectiveness of these regulations is unknown.
- Increasing research activities by scientists or park staff.
- All-terrain vehicle traffic by residents of the Lake Athabasca region, despite regulations against it, which may not be enforceable.
- Recreational boat traffic from the Fort McMurray area using the Athabasca River to access Lake Athabasca and the dunes (Bihun 1998).
- The winter road on the west side of the park, which provides snowmobile access from the Cluff Lake, Saskatchewan area, possibly leading to disturbance of the dunes or the endemic plants by snowmobile traffic. At one time there was also a concern that this route would be developed as an all-weather road, but the construction of the road from Points North to Stony Rapids, Saskatchewan makes another road to Lake Athabasca unlikely (Argus 1999a).
- Proximity of the general area to uranium mining in Saskatchewan. Geophysical surveys were done in the area in 1997-98 (Argus 1999a). If mining did become economically feasible, it could take place up to the edge of the Provincial Park, which borders the active dunes. The greatest concern with mine development would be increased visitor traffic to the dunes. However, in the case of an organized entity like a mine, it should be possible to restrict off-site travel by workers.
- Administrative inability to control access, even if regulations are in place, because of lack of staff or resources.
- Possible future loss of political will to protect the Park because of pressure from resource industry or tourism interests.
- Sensitivity to disturbance of the gravel pavements, on which tracks remain visible for years. Disturbance of the gravel veneer could increase the rate of surface erosion. This is the habitat most important for Athabasca Thrift.

However, the severity of the threat posed by recreational activities and other human disturbances may be moderated by two factors:

- The dunes are in an isolated location, with low visitation because access is difficult and expensive for most people. The 2009-2010 surveys found only three ATV tracks, which were relatively straight indicating an individual traveling to a destination rather than joyriding (Lamb et al. 2011). No impacts from camping or other activities were observed.
- The endemics are disturbance-adapted species. The dunes, which are their main habitat, are inherently unstable substrates which are constantly disturbed by natural wind erosion. Adaptation to this disturbed habitat is what differentiates the endemics from their wide-ranging relatives. In this context, the threat posed by visitor-induced disturbance is less than it would be for disturbance-sensitive species.

Invasive Alien Species

This is a possible threat, but one for which there is no evidence at present. One of the consequences of increased traffic into the Athabasca Sand Dunes could be the introduction of invasive alien plants. In many biomes, alien plants have become invasive in natural plant communities, crowding out the native species. However, the risk of significant invasion in the Athabasca Sand Dunes is unknown. In northern biomes, while alien weeds can be found in human-disturbed habitats such as roadsides, there appear to be few cases of invasion into natural communities (Mosquin 1997, Simberloff 2001, Sumners and Archibold 2007). Most invasives are intolerant of shade, so are more likely to appear in open habitats (including floodplains, burnovers, and cutovers) than in closed forests. Invasion of the Athabasca Sand Dunes would clearly not be limited by shade. In the prairies of southern Saskatchewan, the introduced forage grass Crested Wheatgrass (*Agropyron cristatum*) and the introduced invasive alien forb Leafy Spurge (*Euphorbia esula*) have invaded some active dunes and threatened to stabilize them (Godwin and Thorpe 2006). Over the long term, climate change could make invasions like this more likely in the north.

There are apparently no alien plant invasion problems in the Athabasca Sand Dunes at present (Lamb and Guedo 2012). The species list from the Saskatchewan Research Council (SRC) study of the dunes in the 1970s included Kentucky Bluegrass (*Poa pratensis*) (which could be of either native or alien origin) and the annual Lamb's Quarters (*Chenopodium album*) (Abouguendia et al. 1981). Field surveys in 2009-2010 recorded no potentially invasive species either on the dunes or on the beaches of Lake Athabasca (Lamb and Guedo 2012). Additional alien plants recorded on disturbed sites in the Uranium City area on the north side of the lake include Smooth Brome-grass (*Bromus inermis*), White Sweet-clover (*Melilotus alba*), White and Alsike Clover (*Trifolium repens, T. hybridum*), Scentless Chamomile (*Matricaria maritima*), and Dandelion (*Taraxacum officinale*) (Harms 1982). ATV traffic is a possible vector for introduction of these invasive alien plants to the dunes because of seed-bearing mud on the tires of ATVs. Moist dune slacks are perhaps the most likely habitat for establishment of alien plants.

Seed Collection

According to Argus (1998a) there is an interest in using sand dune endemics for reclamation of oil sand operations. Companies have collected seed from the Park, a practice which Argus considered incompatible with protection of these species and is an illegal practice according to Saskatchewan's "The Parks Act". However, a factor that moderates this threat is that such collection is likely to involve small amounts of seed intended for propagation, not bulk quantities intended for direct use. Menges et al. (2004) suggested that 10% of the seed crop could be harvested once every 10 years to ensure at least a 95% probability of population persistence for most species of perennials.

Altered Hydrology

The threat posed to the Athabasca Sand Dunes by hydrological change was apparently one of the major concerns during the SRC study in the 1970s (Abouguendia et al. 1981). According to David (1981) the extent of active dunes in the Athabasca Sand Dunes is controlled by the height

of the water table, because of the stabilizing effect of saturation with water. The water table is in turn affected by the height of Lake Athabasca, which is continuous with the shallow surface aquifer of the dunes. Therefore, rising lake levels would result in increased stabilization of dunes. The effect would be greatest in areas that already have a low proportion of active dunes because of shallow depth to the water table, whereas the large William River dunes would be little affected because of their high topographic position (David 1981). Rising water tables would flood dune slacks, increasing the proportions of hydric[2] and mesic[3] habitats and reducing xeric[4] habitats (Abouguendia et al. 1981). Falling lake levels would result in gradually increasing dune activity (David 1981), which would increase the habitat for species of active dunes (Abouguendia et al. 1981). However, Argus (1998) pointed out that reducing the extent of wet dune slacks would also eliminate important seedbeds for the endemic plants. Abouguendia et al. (1981) suggested that the least favourable situation would be alternating high and low lake levels, which would cause unstable conditions leading to reduced vegetation cover and species diversity. Argus (1998) suggested that water control structures on the rivers feeding Lake Athabasca could have deleterious effects such as increasing shoreline erosion.

The level of Lake Athabasca is controlled by the complex hydrological relationships of the Peace-Athabasca Delta at the west end of the lake. If the level of the Peace River is low, Lake Athabasca drains freely into it, whereas if the river is high it impedes the outflow, resulting in high lake levels. Since 1968 the Peace River has been controlled by the Bennett Dam in northern British Columbia, and in the past this was suspected of causing a shift to low lake levels. However, a time series from 1934 to 1996 shows that maximum annual lake levels fluctuated from high to low (over a range of about 3 metres), both before and after construction of the dam (Prowse et al. 2006). If anything, the dam appears to have moderated these fluctuations somewhat (Prowse et al. 2006), reducing any concern about adverse affects of alternating high and low lake levels.

Over a longer time period, studies using paleolimnological methods have shown that Lake Athabasca was relatively low during the “Late Medieval Drought” from 1100 to 1600, relatively high during the “Little Ice Age” from 1600 to 1900, and declined again during the 20th century (Wolfe et al. 2008, Sinnatamby et al. 2009). These authors argued that natural, climate-driven changes overwhelm any effect of dam construction on lake levels. The fact that the sand dune endemics have survived through naturally varying levels over the centuries tends to moderate concerns over any effects of water development.

5. MANAGEMENT OBJECTIVE

The endemic plants of the Athabasca Dunes have small populations mainly because they are restricted to a habitat of small spatial extent. There is no evidence showing that these plants have declined in area of occupancy or population size. They are in a remote location with limited human impact, so are mainly affected by natural processes. While a number of threats have been

[2] Characterized by an abundance of moisture
[3] Characterized by a moderate amount of moisture
[4] Charaterized by a small amount of moisture

identified, these are largely potential or speculative threats, with no concrete evidence that they are currently affecting populations of these species.

In this context, the management objective is to maintain the current population density (as indicated by the results in Table 3) and the current area of occupancy (as indicated by the results in Table 4) of each of the seven species of special concern. Achievement of this objective would be assessed by future resurvey of the same transects as used in the 2009-2010 survey, or a similar survey effort, with a statistically significant decrease in density or area of occupancy indicating that the objective had not been met.

6. BROAD STRATEGIES AND CONSERVATION MEASURES

6.1. Actions Already Completed or Underway

The main provincial action to protect these plants (as well as other ecosystem values) was the establishment of the ASDPP in 1992. This park encompasses almost the entire known ranges of the seven species of special concern. Within the Saskatchewan provincial park system, it is classified as a "wilderness park", and is to be "used primarily for the preservation of natural landscapes in a natural state and the pursuit of outdoor recreational activities that are consistent with that use" (Bihun 1998, Parks Branch 1988). Endemic plants, along with other wildlife, inside the Park are protected under *The Parks Regulations, 1991*.

A draft management strategy was developed for ASDPP in the 1990s (Bihun 1998) and continues to be used by the Government of Saskatchewan to manage the Park. This strategy lists the endemic plants, as well as the active sand dunes, braided river channels, and desert pavements, as unique features which ASDPP was established to protect. The strategy outlines specific measures aimed at controlling visitor impacts and protecting against human-caused disturbances.

A quantitative survey of the Athabasca endemics was conducted in 2009-2010, by a cooperative effort among Saskatchewan Tourism, Parks, Culture and Sport, Saskatchewan Environment, Environment Canada, and the University of Saskatchewan. The results of this survey have been analyzed and reported by Lamb et al. (2011), and show locations where each species was observed as well as population density by habitat type. This survey provides an excellent foundation for future monitoring.

6.2. Broad Strategies

Strategy 1: Develop and implement a monitoring strategy to detect future changes in area of occupancy, population size, and threats from human disturbance, and invasive alien species. There is currently no information on trends in occupancy or population size of the Athabasca endemics. The 2009-2010 survey (Lamb et al. 2011) provides baseline quantitative data, and will form the basis for development of a monitoring plan to detect changes from that baseline.

Strategy 2: Fill in information gaps to broaden our knowledge of the ecology of these species, the biophysical features and geographic extent of their habitats and the severity and causal certainty posed by various threats. Refer to to Lamb et al. (2011) for priorities for future research activities.

Strategy 3: Manage Athabasca Sand Dunes Provincial Park to maintain habitat for, and to conserve, these seven species. Reports on the Athabasca endemics have recommended conservation measures such as regulating and controlling movements of visitors, and prohibiting use of ATVs (Argus 1999a, Harms 1998, 1999a, 1999b, 1999c, 1999d, 1999e). Such measures are already included in the draft Park Management Strategy (Bihun 1998). In addition, the reports have recommended providing a buffer zone around the Park, particularly south of the William River dunes, to prevent mining or recreational developments (Argus 1999a, Harms 1998, 1999a-e), and the Athabasca Sand Dunes Provincial Park Management Strategy recommended increasing the size of the park for this purpose (Bihun 1998).

Strategy 4: Communicate acid deposition and climate change threats to policy-makers. These threats are beyond the control of the agencies responsible for managing species at risk. However, at higher levels in the government hierarchy, policies are being developed to address them. If research provides more specific evidence of threats to the Athabasca endemics from these causes, then this information may inform policy-makers and should be communicated to them.

Strategy 5: Conduct public outreach with local residents, visitor groups, and the general public regarding the species of special concern. There is a need for public education on the Athabasca Sand Dune endemics, particularly among local people in the Lake Athabasca area, tourists and ecotour operators. It is unlikely that protection of these species can be achieved by enforcement alone, given the limited government resources in the area. This makes it especially important that local people be convinced of the need to protect the species and their habitat, and for outside users, including researchers, ecotourists and canoe trippers, to understand the value of the species and the sensitive habitat (particularly the desert pavements) and their potential impact even during a short period.

6.3. Conservation Measures

Table 6. Conservation Measures and Implementation Schedule

Conservation Measure	Priority	Threats or concerns addressed	Timeline
Strategy 1: Monitoring			
1.1 Select a subset of the 250 m transects from the 2009-2010 population surveys for use as long-term monitoring transects.	Medium	Knowledge gaps	2013
1.2 Remeasure the populations of the SARA species on these transects at ten-year intervals.	Medium	Knowledge gaps	Ongoing
1.3 Continue opportunistic reporting of occurrence of ATV tracks in the Park.	Medium	Recreational Activities and Other Human Disturbance	Ongoing
1.4 Continue opportunistic reporting of the occurrence of alien plant species in the Park.	Low	Invasive Alien Species	Ongoing
Strategy 2: Fill in information gaps			
2.1 Map the habitat types on the dunes and calculate their areas	High	Knowledge gaps	2013-2017
2.2 Study stabilization/activation trends on the dunes using remote sensing data	Medium	Knowledge gaps	2013-2017
2.3 Evaluate the impact of acid deposition on soils of the Athabasca Sand Dunes.	Medium	Acid deposition	2013-2017
2.4 Evaluate the capacity of endemic plants to adapt to rising temperatures.	Low	Climate change	2013-2017
Strategy 3: Park management			
3.1 Continue to designate and manage ASDPP as a “wilderness park”.	Medium	Recreational Activities and Other Human Disturbance	Ongoing
3.2 Continue the measures detailed in the draft park management strategy (Bihun 1998) aimed at controlling numbers and impacts of park visitors.	Medium	Recreational Activities and Other Human Disturbance	Ongoing
3.3 Review park management practices related to protection of the SARA species, and make any revisions indicated by new information from research or monitoring (e.g. increased frequency of ATV traffic), at intervals of no more than five years.	Low	Recreational Activities and Other Human Disturbance	Ongoing
3.4 Enforce and track permitting for collection of seeds or other plant material from the SARA-listed species, and limit the volume of seed collected on those permits to sustainable levels.	Low	Seed Collection	Ongoing
3.5 Continue the policy of not controlling forest fires in the region of the Park.	Medium	Maintenance of habitat to meet species’ needs	Ongoing
3.6 Depending on the results of alien species monitoring, design a program for controlling any invasive alien plant species that appear.	Low	Invasive Alien Species	Unknown, future

Conservation Measure	Priority	Threats or concerns addressed	Timeline
Strategy 4: Communicate acid deposition and climate change threats			
4.1 If research on effects of acid deposition on the Athabasca endemics provides evidence of harmful effects, communicate this information to federal and provincial policy-makers.	Low	Acid deposition	Unknown, future
4.2 If research on effects of climate change on the Athabasca endemics provides evidence of harmful effects, communicate this information to federal and provincial policy-makers.	Low	Climate change, Altered hydrology	Unknown, future
Strategy 5: Conduct public outreach			
5.1 Continue to consult with the Fond Du Lac Denesuline First Nation on Park management.	High	Recreational Activities and Other Human Disturbance	Ongoing
5.2 Prepare educational materials on the SARA species for use in northern schools.	Medium	Recreational Activities and Other Human Disturbance	2013-2015
5.3 Involve local people, including school teachers, in surveys of the SARA species.	Medium	Recreational Activities and Other Human Disturbance	2013-2015 and ongoing
5.4 Prepare educational materials and "codes of conduct" related to protection of the SARA species and distribute them to recreational visitors or researchers (ecotourists, canoe-trippers).	Medium	Recreational Activities and Other Human Disturbance	2013-2015

7. MEASURING PROGRESS

The performance indicator presented below will provide a way to define and measure progress towards the achievement of the management objective. Success in implementing this management plan will be evaluated every five years on the basis of the following performance indicator:

- the current population density and area of occupancy are maintained for each of the seven species of special concern.

8. REFERENCES

Abouguendia, Z.M., R.C. Godwin, V.L. Harms, J.H. Hudson, J.S. Rowe, and R. Wright. 1981. Plant ecology and taxonomy. pp. 155-199 in *Athabasca Sand Dunes in Saskatchewan* (Z.M. Abouguendia, editor). Mackenzie River Basin Study Report Supplement 7.

AGRA. 1999. Terrestrial environmental effects monitoring program: 1998 jack pine vegetation assessment. AGRA Earth and Environmental Limited. Submitted to Wood Buffalo Environmental Association.

Aherne, J. 2008. Calculating critical loads of acid deposition for forest soils in Alberta: critical load, exceedance and limitations. Final Report. Canadian Council of Ministers of the Environment. 14 pp.

AMEC. 2002. Vegetation stress survey in the vicinity of the Syncrude and surrounding oil sands leases August 2001. AMEC Earth and Environmental Limited. Submitted to Wood Buffalo Environmental Association.

AMEC. 2003. 2002 forest health assessment of the jack pine soil acidification monitoring plots. AMEC Earth and Environmental Limited. Submitted to Wood Buffalo Environmental Association.

Argus, G.W. 1998. Status report on species at risk in Canada: Tyrrell's Willow (*Salix tyrrelli*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Argus, G.W. 1999a. Update COSEWIC status report on the Athabasca Thrift *Armeria maritima* ssp. *interior* in Canada. in COSEWIC assessment and update status report on the Athabasca thrift Armeria maritima ssp. interior in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-12 pp.

Argus, G.W. 1999b. Addendum to the updated COSEWIC status of *Salix tyrrellii*. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Argus, G.W. 2010. *Salix silicicola*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford. Vol. 7, pp. 147-148. Website: http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=242445873 [Accessed September 2011].

Argus, G.W., and J.W. Steele. 1979. A re-evaluation of the taxonomy of *Salix tyrrellii*, a sand dune endemic. Systematic Botany 4:163-177.

Bihun, G. 1998. Athabasca Sand Dunes Provincial Park. Park Management Strategy. Draft document from Saskatchewan Parks Service.

Chiapella, J.O., V.L. DeBoer, G.C. Amico, and J.C. Kuhl. 2011. A morphological and molecular study in the *Deschampsia cespitosa* complex (Poaceae; Poeae; Airinae) in northern North America. American Journal of Botany 98:1366-1380.

David, P.P. 1981. The aeolian environment. pp. B-19- B-56 in The Athabasca Sand Dunes of Saskatchewan – a multidisciplinary study. Vol.2 (Appendices). Saskatchewan Research Council Publication No. C-805-21-E-80.

Environment Canada. 2011. Canadian Climate Normals or Averages 1971-2000. Website: http://climate.weatheroffice.gc.ca/climate_normals/index_e.html [Accessed Aug. 18, 2011].

Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford.

Foster, K.R., K. McDonald, and K. Eastlick. 2001. Development and application of critical, target and monitoring loads for the management of acid deposition in Alberta, Canada. Water, Air, and Soil Pollution: Focus 1: 135–151.

Godwin, B., and J. Thorpe. 2006. Plant species at risk surveys in Elbow, Dundurn, and Rudy-Rosedale PFRA Pastures. Saskatchewan Research Council Publication No.11997-1E06.

Harms, V.L. 1982. A plant taxonomic survey of the Uranium City region, Lake Athabasca north shore, emphasizing the naturally colonizing plants on uranium mine and mill wastes and other human-disturbed sites. Report submitted to Saskatchewan Dept. of Environment. University of Saskatchewan.

Harms, V.L. 1996. Status report on Impoverished Pinweed (*Lechea intermedia* var. *depauperata*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Harms, V.L. 1998. Status report on species at risk in Canada: Mackenzie Hairgrass (*Deschampsia mackenzieana*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Harms, V.L. 1999a. Status report on species at risk in Canada: Large-headed Woolly Yarrow (*Achillea millefolium* var. *megacephala*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Harms, V.L. 1999b. Status report on species at risk in Canada: Sand-dune Short-capsuled Willow (*Salix brachycarpa* var. *psammophila*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Harms, V.L. 1999c. Status report on species at risk in Canada: Felt-leaf Willow (*Salix silicicola*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Harms, V.L. 1999d. Status report on species at risk in Canada: Turnor's Willow (*Salix turnorii*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Harms, V.L. 1999e. Status report on species at risk in Canada: Floccose Tansy (*Tanacetum huronense* var. *floccosum*). Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Hermesh, R. 1972. A study of the ecology of the Athabasca Sand Dunes with emphasis on the phytogenic aspects of dune formation. M.Sc. Thesis, Department of Plant Ecology, University of Saskatchewan. Saskatoon.

Jonker, P. no date. Range, habitat, and status of the rare and endemic flora found in Lake Athabasca Sand Dunes Provincial Wilderness Park – literature review and recommended prioritization of taxa for conservation. Extension Division, University of Saskatchewan. Saskatoon.

Kartesz, J.T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. *In*: Synthesis of the North American Flora, Version 1.0. *Edited by:* Kartesz, J.T., and C.A. Meacham. North Carolina Botanical Garden, Chapel Hill, NC.

Lamb, E.G., J. Mischkolz, and D. Guedo. 2011. The distribution and abundance of the endemic vascular plant taxa of the Athabasca Sand Dunes of northern Saskatchewan. Department of Plant Sciences, University of Saskatchewan. Saskatchewan. 75 pp.
Available at: www.npss.sk.ca/docs/2_pdf/Athabasca_Occupancy_Survey_2011.pdf

Lamb, E.G., and D. D. Guedo. 2012. The distribution, abundance, and environmental affinities of the endemic vascular plant taxa of the Athabasca Sand Dunes of Northern Saskatchewan. Ecoscience19:161-169.

Leconte, R., D. Peters, A. Pietroniro, T. Prowse. 2006. Modelling climate change impacts in the Peace and Athabasca Catchment and delta: II - variations in flow and water levels with varying winter severity. Hydrological Processes 20:4215:4230.

Line, J., G. Brunner, R. Rosie, and K. Russell. 2008. Results of the 2007 invasive plants roadside inventory in Yukon. NatureServe Yukon. Whitehorse, Yukon. 38 pp.
Available at: www.env.gov.yk.ca/.../InvasivePlantsRoadsideInventory_nov14_2.pdf

Macdonald, S.E., C.C. Chinnappa, D.M. Reid, and B.G. Purdy. 1987. Population differentiation of the *Stellaria longipes* complex within Saskatchewan's Athabasca sand dunes. Canadian Journal of Botany 65:1726-1732.

Menges, E.S., E.O. Guerrant, Jr., and S. Hamze. 2004. Effects of seed collection on the extinction risk of perennial plants. Pp. 305-324 in E.O. Guerrant, Jr., K. Havens, and M. Maunder (eds.). Ex situ plant conservation: supporting species survival in the wild. Society for Ecological Restoration International and Center for Plant Conservation. Island Press, Covelo, CA.

Mosquin, T. 1997. Management guidelines for invasive alien species in Canada's national parks. Ecospherics International Ltd.
Available at: www.ecospherics.net/exoticspecnew.htm.

Meterological Service of Canada. 2004. Canadian acid deposition science assessment. Environment Canada, Meteorological Service of Canada.

NatureServe. 2011. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Website: http://www.natureserve.org/explorer [Accessed: January 19, 2012].

Parisien, M.A., K.G. Hirsch, S.G. Lavoie, J.B. Todd, and V.G. Kafka. 2004. Saskatchewan fire regime analysis. Canadian Forest Service, Northern Forestry Centre, Information Report NOR-X-394.

Parks Branch. 1988. Park land zoning. Saskatchewan Parks, Recreation and Culture, Report 88-13.

Pepper, J. 2009. Species at risk in Saskatchewan. Saskatchewan Conservation Data Centre.

Pietroniro, A., R. Leconte, B. Toth, D.L. Peters, N. Kouwen, F.M. Conly, T. Prowse. 2006. Modelling climate change impacts in the Peace and Athabasca catchment and delta: III - integrated model assessment. Hydrological Processes 20:4231-4245.

Prowse, T.D., S. Beltaos, J.T. Gardner, J.J. Gibson, R.J. Granger, R. Leconte, D.L. Peters, A. Pietroniro, L.A. Romolo, and B. Toth. 2006. Climate change, flow regulation and land-use effects on the hydrology of the Peace-Athabasca-Slave System; finding from the Northern Rivers Ecosystem Initiative. Environmental Monitoring and Assessment 113:167-197.

Purdy, B.G., and R.J. Bayer. 1995a. Allozyme variation in the Athabasca sand dune endemic *Salix silicicola*, and the closely related widespread species *S. alaxensis*. Systematic Botany 20:179-190.

Purdy, B.G., and R.J. Bayer. 1995b. Genetic diversity in the tetraploid sand dune endemic *Deschampsia mackienzieana* and its widespread diploid progenitor *D. cespitosa* (Poaceae). American Journal of Botany 82:121-130.

Purdy, B.G., and R.J. Bayer. 1996. Genetic variation in populations of the endemic *Achillea millefolium* ssp. *megacephala* from the Athabasca sand dunes and the widespread ssp. *lanulosa* in western North America. Canadian Journal of Botany 74:1138-1146.

Purdy, B.G., R.J. Bayer, and S.E. Macdonald. 1994. Genetic variation, breeding system evolution, and conservation of the narrow sand dune endemic *Stellaria arenicola* and the widespread *S. longipes* (Caryophyllaceae). American Journal of Botany 81:904-911.

Saskatchewan Conservation Data Centre. 2011. Saskatchewan vascular plant tracked species list. Website: www.biodiversity.sk.ca (Accessed Aug. 24, 2011).

Simberloff, D. 2001. Management of boreal forest biodiversity – a view from the outside. Scandinavian Journal of Forest Resources 3:105-118.

Sinnatamby, R.N., Yi Yi, M.A. Sokal, K.P. Clogg-Wright, T. Asada, S.R. Vardy, T.L. Karst-Riddoch, W.M. Last, J.W. Johnston, R.I. Hall, B.B. Wolfe, T.W. D. Edwards. 2009. Historical and paleolimnological evidence for expansion of Lake Athabasca (Canada) during the Little Ice Age. Journal of Paleolimnology 43:705-717.

Sumners, W.H., and O.W. Archibold. 2007. Exotic plant species in the southern boreal forest of Saskatchewan. Forest Ecology and Management 251:156–163.

Toth, B., A. Pietroniro, F.M. Conly, N. Kouwen. 2006. Modelling climate change impacts in the Peace and Athabasca catchment and delta: I - hydrological model application. Hydrological Processes 20:4197-4214.

Trock, D. 2006. *Achillea millefolium*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford. Vol. 19, 20 and 21, pp. 491-493. Website: http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=200023010 (Accessed September 2011).

Villano, K.L., and C.P.H. Mulder. 2008. Invasive plant spread in burned lands of interior Alaska. National Park Service – Alaska Region and National Aeronautics and Space Administration.

Watson, L. 2006. *Tanacetum bipinnatum*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford. Vol. 19, 20 and 21, pp. 489-490. Website: http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=250067699 (Accessed September 2011).

WBK & Associates Inc. 2006. 2004 Acid deposition assessment for Alberta. A report of the Acid Deposition Assessment Group. Prepared for Alberta Environment. Edmonton, Alberta. 82 pp.

Whitfield, C.J., J. Aherne, S.A. Watmough, and M. McDonald. 2010. Estimating the sensitivity of forest soils to acid deposition in the Athabasca Oil Sands Region, Alberta. Journal of Limnology 69: 201-208.

Wolfe, B.B., R.I. Hall, T.W.D. Edwards, S.R. Jarvis, R.N. Sinnatamby, Y. Yi, and J.W. Johnston. 2008. Climate-driven shifts in quantity and seasonality of river discharge over the past 1000 years from the hydrographic apex of North America. Geophysical Research Letters vol. 35, L24402.

Personal Communications:

Argus, G. 2011. Personal communication; email correspondence on *Salix silicicola* to B. Bennett, 4 Feb 2011, and forwarded by B. Bennett to C. Neufeld, 13 April 2011. Researcher Emeritus, Canadian Museum of Nature, Ottawa, ON.

Bennett, B. 2011. Personal communication; email correspondence on *Deschampsia mackenzieana* to C. Neufeld, 13 April 2011 and 24 August 2011. Co-chair, Vascular Plant Subcommittee, COSEWIC, Whitehorse, YK.

Gould, J. 2011. Personal communication; email correspondence on *Tanacetum* to C. Neufeld, 14 Sept 2011. Science Coordinator, Alberta Tourism, Parks and Recreation, Edmonton, AB.

APPENDIX A. EFFECTS ON THE ENVIRONMENT AND OTHER SPECIES

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that plans may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the plan itself, but are also summarized below.

Continued protection of Athabasca Sand Dunes Provincial Park will have generally benign effects on the other native species of the area, although the threats to these species are generally low. Three species with restricted ranges have traditionally been associated with the seven species of special concern, although they are not currently listed by SARA: Tyrrell's Willow (*Salix tyrrellii*), Sand Stitchwort (*Stellaria arenicola*), and Impoverished Pinweed (*Lechea intermedia* var. *depauperata*). Tyrrell's Willow and Sand Stitchwort are both species of active dunes, with Tyrrell's Willow considered to be the dominant shrub on these sites (Macdonald et al. 1987, Argus 1998, Argus 1999b). Therefore, maintaining habitat for the seven species of special concern that are active dune species should also benefit these two species. Impoverished Pinweed, on the other hand, is found (rarely) in open jack pine stands and wetlands (Harms 1996), so its habitat requirements are different from the species of special concern. Nevertheless there is nothing in the management plan that would adversely affect Impoverished Pinweed. Other SARA-listed species that could occur in the area of the Athabasca Sand Dunes include Woodland Caribou ((*Rangifer tarandus* - threatened), Common Nighthawk (*Chordeiles minor* - threatened), Olive-sided Flycatcher (*Contopus cooperi* - threatened), Rusty Blackbird (*Euphagus carolinus* - special concern), Yellow Rail (*Coturnicops noveboracensis* - special concern), Short-eared Owl (*Asio flammeus* – special concern), and Northern Leopard Frog (*Lithobates pipiens* - special concern). Because the management plan mainly deals with conservation of natural ecosystems and processes, rather than any intensive habitat manipulation, it is unlikely that it will have negative impacts on these species.