# LIMITED REPORT

# Ten-Year Vegetation Changes at Saskatoon Natural Grassland

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## SUMMARY


- This study analysed the vegetation changes that have occurred at Saskatoon Natural Grassland (SNG) since it was established.
- 81 permanently-marked sample points in grassland and open shrubland, first measured in 1993, were remeasured in 2003 using the same methods and personnel.
- Shrub cover in the sampled area has expanded from 7% to 19%.
- The percent contribution of Kentucky blue grass to the total weight of herbs has increased from 17% to 43%. This species was found in 80% of the samples in 2003, compared to only 38% in 1993.
- Native grasses, including rough fescue, have declined in percent contribution and frequency of occurrence.
- There has been a decline in number of plant species, particularly for forbs (i.e. broad-leaved herbs). Loss of species diversity could be related to the increasing dominance of Kentucky blue grass, as well as the general lack of disturbance.
- Portions of SNG were subject to a single prescribed burn during the ten-year period. Burned areas had significantly slower loss of grass-like species, and significantly slower increase of shrubs and Kentucky blue grass, compared to unburned areas. More detailed monitoring would help to strengthen the evidence on the value of burning in this type of grassland.

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## INTRODUCTION

Saskatoon Natural Grassland (SNG) was created as a separate entity when 13.8 hectares of land was transferred by the City of Saskatoon to the Meewasin Valley Authority (MVA) in 1993. The intent was that this grassland be maintained in a natural state and also be available to the general public. A management plan initiated in 1993 and completed in 1994 provided a vision for the development of the park (Delcan Western Ltd. et al. 1994). Work completed during this study included mapping of community types and detailed sampling of the vegetation by Saskatchewan Research Council (SRC).

In 2001, the vegetation was resampled by MVA, with the results indicating potential undesirable changes to the vegetation communities. To substantiate these changes, MVA requested that SRC resurvey the site in 2003, 10 years after the original survey, using the same personnel and methods as in the original survey. Findings from this study will aid in determining the direction of future management actions.

## METHODS

This study focussed on the grassland portions of SNG. All of the quadrats falling in grassland or open shrubland community types (Delcan Western Ltd. et al. 1994) were resampled, except for one quadrat in Blue Grass Grassland (710N 90W) which had been destroyed by development of a walking path. A total of 81 quadrats were resampled in five community types: 39 in Mixed Grassland, 13 in Blue Grass Grassland, 21 in Open Snowberry, four in Open Snowberry with Other Shrubs, and four in Wolf-willow.

MVA staff relocated and flagged metal posts inserted in the soil along a 30 m survey grid in 1993. The 1993 sample points were located 2 m from these survey markers, as noted in Delcan Western Ltd. et al. (1994). The information in this report was used to relocate the sample points as exactly as possible, so that data from the two sampling periods could be directly compared. During 1993, sampling was conducted between June 23 and July 13. In 2003, we sampled as close to this time period as possible to reduce phenological differences. The 2003 sampling was conducted between July 8 and July 14.

Sampling methods were the same in 2003 as in 1993 (Delcan Western Ltd, 1994). Quadrats of 1.0 $m^2$ for shrubs and 0.25 $m^2$ for herbs were placed at the sample point. Percent cover was estimated for each vegetation layer (shrubs, prostrate shrubs, herbs, club-moss, lichen, and moss). Within the shrub and herb vegetation layers, the percent by weight of each species was estimated visually.

In each year, a subsample of quadrats was clipped and weighed to test the accuracy of estimates. In 2003, eight quadrats were clipped after the estimates for them were completed. The comparison between the estimates and clipped values is reported in Appendix B.

Comparisons of data between the two years were made for the entire set of sample data to determine any overall shifts in vegetation composition. Comparisons were also made for individual community types. The four quadrats from the Open Snowberry with Other Shrubs type were included with the Open Snowberry type for analysis. These community types were similar in composition in 1993. Since the sample locations were the same in 1993 and 2003, differences

between years were analyzed by paired t-tests. Because of the large number of parameters that could be compared between years (cover values and numbers of species for vegetation layers, plus percentage estimates for more than 100 individual species), statistical comparisons were limited to parameters with several non-zero values. While there were overall cover values for all quadrats, most individual species occurred in few quadrats (e.g. skeleton weed, which occurred in only one of 81 quadrats in each year). Because of the limited data for such parameters, differences were not statistically significant. In the comparison using all 81 quadrats, individual species were analysed only if the average percent by weight for the species was greater than 3.5% for one of the sample years, or the species occurred in more than 13% of the quadrats. The same parameters were analysed within individual community types if the species occurred there.

During 1996 to 1999, MVA conducted spring prescribed burns over portions of SNG. Most of these areas were burned only once (Luc Delanoy, MVA, personal communication). A map of the burned area was provided by Luc Delanoy (MVA) and the sample points falling within it were determined. The 1993 and 2003 data for these points were compared to see if vegetation changes were different from the grassland as a whole.

Taxonomic names used in this report are the same as those used in 1994. This will facilitate comparisons between the two reports. Common names are used in the report, while scientific names are given in Appendix A.

## RESULTS

Significant differences between 1993 and 2003 over all quadrats are shown in Table 1. Results of a partial resurvey in 2001, also shown in Table 1, are very similar to the 2003 results. Differences between 1993 and 2003 for the individual community types are shown in Tables 2, 3, 4, and 5. Differences are summarized in Table 6.

Shrub cover and number of shrub species per quadrat increased. The increase in cover occurred not just in the Open Snowberry type, where it was higher initially, but also in the Mixed Grassland and Blue Grass Grassland types. Most of this shrub cover is western snowberry, with no significant change in its percent contribution in most types. Expansion of snowberry was not thought to be a concern in the original management plan (Delcan Western Ltd. et al. 1994), but the evidence from this ten-year comparison shows a very real threat of conversion of grassland to shrubland. The increase in shrubs can probably be attributed to the lack of disturbance. Literature showing the role of fire in reducing invasion of grassland by shrubs was reviewed by Delcan Western Ltd. et al. (1994). Generally, this literature shows that burns must be repeated to have the desired effect.

**Table 1 Significant differences over all quadrats between 1993 and 2003 (p<.05, n=81).** Means from the 2001 survey are included for comparison.

| Parameter | 1993 mean | 2003 mean | 2001 mean | Trend since 1993 |
|---|---|---|---|---|
| Number of shrub species per quadrat | 1.0 | 1.5 | | ⇑ |
| Number of herbaceous species per quadrat | 9.4 | 6.4 | 6.4 | ⇓ |
| Number of forb species per quadrat | 3.9 | 2.1 | | ⇓ |
| Number of grass-like species per quadrat | 5.6 | 4.3 | | ⇓ |
| Shrub cover | 7.0 | 18.6 | | ⇑ |
| Herbaceous cover | 30.3 | 39.1 | 35 | ⇑ |
| Clubmoss cover | 8.1 | 2.4 | | ⇓ |
| Wolf-willow (%) | 9.3 | 17.2 | | ⇑ |
| Field chickweed (%) | 0.7 | 0.1 | 0.0 | ⇓ |
| Prairie crocus (%) | 1.7 | 0.2 | 0.5 | ⇓ |
| Low goldenrod (%) | 1.2 | 0.1 | 0.1 | ⇓ |
| Narrow-leaved American vetch (%) | 0.3 | 0.0 | 0.0 | ⇓ |
| Plains rough fescue (%) | 8.3 | 3.0 | 2.8 | ⇓ |
| June grass (%) | 1.7 | 0.3 | 0.1 | ⇓ |
| Kentucky blue grass (%) | 17.3 | 43.2 | 41 | ⇑ |
| Western porcupine grass (%) | 10.3 | 6.7 | 8.2 | ⇓ |

**Table 2 Significant differences in the Mixed Grassland community type between 1993 and 2003 (p<.05, n=39).**

| Parameter | 1993 mean | 2003 mean | Trend since 1993 |
|---|---|---|---|
| Number of shrub species per quadrat | 0.9 | 1.4 | ⇑ |
| Number of herbaceous species per quadrat | 9.9 | 7.4 | ⇓ |
| Number of forb species per quadrat | 3.6 | 2.4 | ⇓ |
| Number of grass-like species per quadrat | 6.3 | 5.1 | ⇓ |
| Shrub cover | 1.4 | 11.0 | ⇑ |
| Herb cover | 26.2 | 39.6 | ⇑ |
| Clubmoss cover | 15.2 | 4.1 | ⇓ |
| Western snowberry (%) | 18.7 | 30.4 | ⇑ |
| Field chickweed (%) | 0.7 | 0.2 | ⇓ |
| Prairie crocus (%) | 2.3 | 0.2 | ⇓ |
| Low goldenrod (%) | 1.7 | 0.1 | ⇓ |
| Awned wheat grass (%) | 0.1 | 1.0 | ⇑ |
| June grass (%) | 2.8 | 0.2 | ⇓ |
| Kentucky blue grass (%) | 0.7 | 23.0 | ⇑ |

**Table 3 Significant differences in the Blue Grass Grassland community type between 1993 and 2003 (p<.05, n=13).**

| Parameter | 1993 mean | 2003 mean | Trend since 1993 |
|---|---|---|---|
| Number of shrub species per quadrat | 0.8 | 1.3 | ⇑ |
| Number of herbaceous species per quadrat | 7.7 | 4.5 | ⇓ |
| Number of forb species per quadrat | 2.9 | 1.4 | ⇓ |
| Number of grass-like species per quadrat | 4.8 | 3.1 | ⇓ |
| Shrub cover | 1.1 | 6.6 | ⇑ |
| Sun-loving sedge (%) | 3.4 | 0.6 | ⇓ |
| Kentucky blue grass (%) | 53.7 | 75.8 | ⇑ |

**Table 4 Significant differences in the Open Snowberry community type between 1993 and 2003 (p<.05, n=25).**

| Parameter | 1993 mean | 2003 mean | Trend since 1993 |
|---|---|---|---|
| Number of shrub species | 1.2 | 1.7 | ⇑ |
| Number of herbaceous species | 9.2 | 5.8 | ⇓ |
| Number of forb species | 4.3 | 1.9 | ⇓ |
| Number of grass-like species | 5.0 | 4.0 | ⇓ |
| Shrub cover | 14.6 | 33.0 | ⇑ |
| Herbaceous cover | 29.3 | 38.5 | ⇑ |
| Narrow-leaved American vetch (%) | 0.3 | 0.0 | ⇓ |
| Plains rough fescue (%) | 16.9 | 3.2 | ⇓ |
| Kentucky blue grass (%) | 24.2 | 56.7 | ⇑ |

**Table 5 Significant differences in the Wolf-willow community type between 1993 and 2003 (p<.05, n=4).**

| Parameter | 1993 mean | 2003 mean | Trend since 1993 |
|---|---|---|---|
| Wolf-willow (%) | 72.5 | 58.5 | ⇓ |

**Table 6 Summary of significant differences between 1993 and 2003.**

| | All quadrats | Blue Grass Grassland | Mixed Grassland | Open Snowberry | Wolf-willow |
|---|---|---|---|---|---|
| Number of shrub species per quadrat | ⇑ | ⇑ | ⇑ | ⇑ | |
| Number of herb species per quadrat | ⇓ | ⇓ | ⇓ | ⇓ | |
| Number of forb species per quadrat | ⇓ | ⇓ | ⇓ | ⇓ | |
| Number of grass-like species per quadrat | ⇓ | ⇓ | ⇓ | ⇓ | |
| Shrub cover | ⇑ | ⇑ | ⇑ | ⇑ | |
| Herb cover | ⇑ | | ⇑ | ⇑ | |
| Clubmoss cover | ⇓ | | ⇓ | | |
| Wolf-willow (%) | ⇑ | | | | ⇓ |
| Western snowberry (%) | | | ⇑ | | |
| Field chickweed (%) | ⇓ | | ⇓ | | |
| Prairie crocus | ⇓ | | ⇓ | | |
| Low goldenrod | ⇓ | | ⇓ | | |
| Narrow-leaved American vetch | ⇓ | | | ⇓ | |
| Awned wheat grass | | | ⇑ | | |
| Sun-loving sedge | | ⇓ | | | |
| Plains rough fescue | ⇓ | | | ⇓ | |
| June grass | ⇓ | | ⇓ | | |
| Kentucky blue grass | ⇑ | ⇑ | ⇑ | ⇑ | |
| Western porcupine grass | ⇓ | | | | |

Herbaceous cover increased overall and in two of four types, but numbers of herbaceous species, including forbs (i.e. broad-leaved herbs) and grass-like herbs, decreased in most community types. Kentucky blue grass, which is generally considered to be an exotic invader on most sites, showed a strong increasing trend across all types, increasing its overall percentage from 17% to 43%. Conversely, most of the major native grasses (western porcupine grass, rough fescue, June grass, sun-loving sedge) decreased in at least one community.

Table 7 shows the total numbers of species recorded in each community type. Because the values are totals, there are no statistical comparisons. This shows small changes in numbers of shrub species, increasing in some types and decreasing in others. But numbers of herbaceous species decreased in all types, with the biggest difference in numbers of forb species. The total number of species documented in the 81 quadrats declined (Table 8). This was mainly a decline in native

species, while the number of exotic species actually increased. The decline in native species recorded in the quadrats does not necessarily mean that species have been eliminated from SNG. Many species have probably become less common, but still persist in reduced numbers. However, as a species becomes less abundant, the chance that it will disappear from SNG increases, and it is possible that some species have already been eliminated.

**Table 7 The total number of species of shrubs, forbs and grass-like plants recorded in each community type for 1993 and 2003.** Arrows indicate direction of change (increase or decrease).

| Life form | Year | Community Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Blue Grass Grassland | | Mixed Grassland | | Open Snowberry | | Wolf-willow | |
| Shrubs | 1993 | 4 | ⇓ | 5 | ⇓ | 6 | ⇑ | 4 | ⇑ |
| | 2003 | 3 | | 4 | | 8 | | 5 | |
| Forbs | 1993 | 15 | ⇓ | 27 | ⇓ | 28 | ⇓ | 17 | ⇓ |
| | 2003 | 7 | | 20 | | 21 | | 10 | |
| Grass-like | 1993 | 14 | ⇓ | 22 | ⇓ | 21 | ⇓ | 10 | ⇓ |
| | 2003 | 11 | | 19 | | 20 | | 8 | |

**Table 8 Change in number of plant species recorded in 81 quadrats sampled in both 1993 and 2003.**

| Category | Number of plant species | | Percent change since 1993 |
|---|---|---|---|
| | 1993 | 2003 | |
| Native vascular species | 68 | 52 | -24 |
| Exotic vascular species | 7 | 10 | 43 |
| Total species | 75 | 62 | -17 |

Table 9 shows changes in the numbers of quadrats in which individual species occurred. There is a general trend of decrease in species of drier or disturbed habitats, such as little clubmoss, pasture sage, field chickweed, moss phlox, prairie crocus, low goldenrod, western wheat grass, blue grama, June grass, plains reed grass, and common spear grass. Kentucky blue grass showed a major increase in frequency, from 31 quadrats (38% of the total) to 64 quadrats (80%), while most of the native grasses decreased in frequency. Because these numbers come from a large sample of evenly spaced points, they give a good indication that Kentucky blue grass has spread over most of the grassland at SNG.

The results show the spread of Kentucky blue grass as well as the decline in the number of herbaceous species. The decline in species diversity may be a result of Kentucky blue grass invasion, but it may also be related to other factors. Some studies in Canadian grasslands have shown reduced species numbers in the absence of grazing (Willoughby 1995, Bai et al. 1999, 2001), but other studies have shown no change in diversity with grazing (McCanny et al. 1996, Houston

1999). Declines in diversity may result from increasing dominance of certain highly competitive species in the absence of disturbance. The accumulation of plant litter may also create a more homogenous environment which limits some species from becoming established.

**Table 9 Frequency of occurrence of plant species over all quadrats.**

| | Species | Number of quadrats with occurrence in 1993 | Number of quadrats with occurrence in 2003 |
|---|---|---|---|
| Greatest frequency in 1993 | little clubmoss | 36 | 23 |
| | pasture sage | 19 | 12 |
| | milk-vetch species | 16 | 3 |
| | field chickweed | 17 | 7 |
| | moss phlox | 10 | 2 |
| | prairie crocus | 23 | 10 |
| | low goldenrod | 13 | 6 |
| | dandelion | 13 | 0 |
| | narrow-leaved American vetch | 14 | 4 |
| | northern wheat grass | 71 | 50 |
| | western wheat grass | 12 | 7 |
| | blue grama | 17 | 9 |
| | plains reed grass | 10 | 1 |
| | sun-loving sedge | 56 | 38 |
| | Hooker's oat grass | 8 | 0 |
| | June grass | 30 | 11 |
| | common spear grass | 6 | 0 |
| | western porcupine grass | 61 | 39 |
| Greatest frequency in 2003 | wolf-willow | 11 | 27 |
| | low prairie rose | 18 | 38 |
| | western snowberry | 43 | 50 |
| | Kentucky blue grass | 31 | 64 |
| | green needle grass | 4 | 7 |

Kentucky blue grass disappeared from one of the 31 quadrats where it occurred in 1993, but invaded 34 of the 50 quadrats where it did not occur in 1993. In the 31 quadrats with Kentucky blue grass in 1993, its percent by weight increased from 45% in 1993 to 78% in 2003. At the same time, the average number of herbaceous species (including Kentucky blue grass) in these quadrats fell (Table 10). In the quadrats which had no Kentucky blue grass in 1993 (n=50), the average percentage of Kentucky blue grass went from zero in 1993 to 22% in 2003, with 64% of the quadrats being invaded in this period. The number of herbaceous species, including Kentucky blue grass, also fell, but not as dramatically as for the quadrats that already had Kentucky blue grass in 1993

(Table 10). If we consider the subset of the previous data which had no Kentucky blue grass present during either sampling date (n=16), there was a smaller decrease in number of species (Table 10).

**Table 10 Average number of herbaceous species per quadrat (excluding Kentucky blue grass), in relation to presence of Kentucky blue grass in 1993 and 2003 across all 81 quadrats.**

| | 1993 | 2003 | % decrease in number of species present |
|---|---|---|---|
| Kentucky blue grass present in 1993 | 8.8 | 3.4 | 61 |
| Kentucky blue grass absent in 1993, but present in 2003 | 8.9 | 6.5 | 27 |
| Kentucky blue grass absent in 1993 and 2003 | 9.9 | 8.2 | 17 |

These results show that, although species numbers decreased in areas without Kentucky blue grass, there was a substantially greater decrease in invaded areas and the effect was greater the longer that Kentucky blue grass had been present. This may be because the sites already invaded in 1993 are the most suitable habitat (generally the lower, moister slope positions) where Kentucky blue grass is more able to dominate the plant community. In the areas where it has recently invaded, Kentucky blue grass may not be so dominant, because these tend to be higher, drier slope positions. However, by invading these sites, it may produce a larger quantity of longer-lasting litter, thereby altering the soil moisture regime in its favour.

There is no evidence that Kentucky blue grass expansion has stopped. Without management actions to reduce its spread, it could invade most of the remaining grassland and reduce or eliminate some native species. This is an even greater concern for the dense shrub and woodland communities, which were not resurveyed in 2003. These sites are ideal Kentucky blue grass habitat, and most had it in 1993. Therefore, if Kentucky blue grass is still expanding, it has the potential to take over all of SNG with the exception of wetlands.

The increase in Kentucky blue grass, as well as the increase in shrub cover, are probably related to lack of disturbance. However, there is also the possibility of environmental change over the period between measurements. Both of these changes would be expected under conditions of increasing moisture. Records from the SRC climate station, which is less than 2 km from SNG, show that the decade over which vegetation changes occurred actually received less precipitation on average than the previous three decades:

| Decade | Mean annual precipitation |
|---|---|
| 1964 - 1973 | 376 mm |
| 1974 - 1983 | 376 mm |
| 1984 - 1993 | 338 mm |
| 1994 - 2003 | 292 mm |

Another factor is the house construction and tree planting that has occurred over the ten-year period in the area immediately surrounding SNG. This change in the local environment could have reduced wind speed and evapotranspiration, especially near the edges of the grassland. If this effect were

significant, it would tend to keep the site moister, possibly counteracting the effect of declining precipitation. Without microclimatic measurements, this possibility cannot be evaluated.

The changes over the past 10 years have also affected the abundance of rough fescue. Fescue grassland is one of the most threatened vegetation types in Canada. Rough fescue is an important part of some community types at SNG, and indeed SNG may have been fescue-dominated prior to domestic grazing and invasion by Kentucky blue grass. Fescue-dominated grasslands occur within a few kilometres of SNG, on fine-textured soils which have had long-term protection from grazing. In the 81 grassland quadrats resurveyed at SNG, rough fescue decreased significantly from 8% in 1993 to only 3% in 2003. The drop in fescue was most dramatic in the Open Snowberry communities, where it declined from 17% to 3%.

Rough fescue occurred in 12 of the 39 quadrats in the area mapped as Mixed Grassland in 1993. In 2003, rough fescue occurred in 13 of these 39 quadrats. In 1993, the 12 quadrats that had fescue did not include Kentucky blue grass. However, in 2003 Kentucky blue grass occurred in 7 of the 13 quadrats that had rough fescue (the same 12 as had rough fescue in 1993 plus a small amount in an additional one). This is an indication of the spread of Kentucky blue grass from its previously more restricted distribution. There is also reason for concern that if Kentucky blue grass increases in dominance in the areas where rough fescue occurs, it may eliminate it or reduce its abundance. This could happen either by eliminating fescue from all but its optimal habitat, or by reducing fescue abundance at all locations, with remnant populations remaining widespread. While we know of no specific techniques to increase fescue abundance, management that limits the development of Kentucky blue grass may help fescue persist or increase in abundance.

Literature on the use of prescribed burning to control Kentucky blue grass was reviewed by Delcan Western Ltd. et al. (1994). However, most of this literature is from warm-season grasslands, where a spring burn discriminates against the cool-season Kentucky blue grass because of its earlier growth. There is relatively little information on grasslands like SNG where most of the native dominants are also cool-season grasses. Thorpe and Godwin (2002) found that a single spring burn had no significant effect on Kentucky blue grass invasion in two areas in Saskatchewan aspen parkland. Repeated burning may have had stronger effects. Livestock grazing has also been proposed to control exotic grasses in our region. However, Thorpe and Godwin (2002) found that a single heavy grazing treatment in three areas of aspen parkland which had been protected from grazing actually increased the percentage of Kentucky blue grass.

Portions of SNG received a prescribed burning treatment during 1996 to 1999. Twenty-eight of the sample points fell within the burned area: 17 in Mixed Grassland, six in Blue Grass Grassland, four in Open Snowberry and one in Wolf-willow. The distribution of sample points among community types was somewhat different between burned areas and unburned areas, with Blue Grass Grassland being slightly over-represented in the burn, and Open Snowberry being definitely under-represented (Table 11).

**Table 11 Percentages of community types within burned and unburned areas.**

| | **burned** | **unburned** | **total** |
|---|---|---|---|
| Mixed Grassland | 61% | 42% | 48% |

| | | | |
|---|---|---|---|
| Blue Grass Grassland | 21% | 13% | 16% |
| Open Snowberry | 14% | 40% | 31% |
| Wolf-willow | 4% | 6% | 5% |

Changes in vegetation variables from 1993 to 2003 were compared between burned and unburned areas by unpaired t-tests (Table 12). Homogeneity of variance was checked by Bartlett's and Levene's tests, and the t-test calculation was adjusted accordingly. Over all quadrats, the number of grass-like species per quadrat decreased less in burned than unburned areas. Shrub cover and the percentage of Kentucky blue grass increased significantly less in burned than unburned areas. Tests were also attempted on the subsets of burned and unburned quadrats in each community type. Differences were significant only in the Open Snowberry type, where shrub cover and the percentage of Kentucky blue grass again increased significantly less in burned than unburned areas. These results provide an indication that a single burning treatment within a 10-year period had a significant effect in slowing the expansion of shrubs and Kentucky blue grass. The only limitation on this conclusion is that the burned and unburned areas did not include exactly the same mix of community types (Table 11). More detailed experimental design and monitoring of burning effects would help to strengthen this conclusion.

**Table 12 Changes from 1993 to 2003 that were significantly different between burned and unburned areas.**

| | **burned areas (n=28)** | **unburned areas (n=53)** |
|---|---|---|
| Change in number of grass-like species per quadrat | -0.71 | -1.55 |
| Change in shrub cover | 5.0 | 15.1 |
| Change in percent of Kentucky blue grass | 15.1 | 31.7 |

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## Appendix A Scientific and common names of plant species referred to in the report.

| | |
|---|---|
| *Agropyron smithii* | western wheat grass |
| *Agropyron subsecundum* | awned wheat grass |
| *Agropyron dasystachyum* | northern wheat grass |
| *Artemisia frigida* | pasture sage |
| *Astragalus spp.* | milk-vetch species |
| *Bouteloua gracilis* | blue grama |
| *Calamagrostis montanensis* | plains reed grass |
| *Carex filifolia* | thread-leaved sedge |
| *Carex pensylvanica* | sun-loving sedge |
| *Cerastium arvense* | field chickweed |
| *Comandra umbellata* | pale comandra |
| *Elaeagnus commutata* | wolf-willow |
| *Erigeron caespitosus* | tufted fleabane |
| *Festuca altaica* ssp. *hallii* | plains rough fescue |
| *Helictotrichon hookeri* | Hooker's oat grass |
| *Koeleria cristata* | June grass |
| *Phlox hoodii* | moss phlox |
| *Poa pratensis* | Kentucky blue grass |
| *Pulsatilla ludoviciana* | prairie crocus |
| *Rosa arkansana* | low prairie rose |
| *Selaginella densa* | little clubmoss |
| *Solidago missouriensis* | low goldenrod |
| *Stipa curtiseta* | western porcupine grass |
| *Stipa comata* | common spear grass |
| *Stipa viridula* | green needle grass |
| *Symphoricarpos occidentalis* | western snowberry |
| *Taraxacum officinale* | dandelion |
| *Thermopsis rhombifolia* | golden-bean |
| *Vicia sparsifolia* | narrow-leaved American vetch |

## Appendix B Comparison of percentage estimates with clipping.

In 1993, selection of the clipped quadrats was determined on a day-by-day basis. Two staff from MVA visited the site sporadically during the time period when the quadrat estimates were being made. At this time, the person doing the estimates would take them to the last quadrat that was sampled, and help them position the quadrat in the exact location it had originally been placed.

In 2003, eight quadrats, chosen randomly from those sampled, were clipped. These quadrats were clipped by a MVA staff member several days after the estimates were completed. The locations for the plots that were to be clipped following the survey were marked with a flagged nail inserted into the ground at the centre of the quadrat location. However, after several quadrats it became apparent that the exact area that was estimated was not being clipped. This was a result of difficulties in placing the quadrat exactly as it had been placed originally, resulting in some plants that had been included when the estimates were made being excluded in the clipping process. For one quadrat (680N 420W), an extremely large western porcupine grass plant was included in the southern edge of the quadrat for the estimate purposes and this plant dominated the vegetation of the quadrat. However, the clipped quadrat had only a relatively small percentage of this species in the results, suggesting that the boundary of the quadrat was placed through the base of the plant or excluded it altogether. Consequently, for the last two quadrats to be clipped, the four corners were marked rather than just the centre point prior to removal of the sample frame after the estimates were made. This allowed more precise placement of the frame delineating the area to be clipped.

The results of the clipping show an average difference between the species estimates and clipped values of 5.7%. This is higher than the 3% difference in the 1993 sampling. The average difference per species across all quadrats was 1.4 % which is also higher than the 0.8% measured in 1993. The highest differences were for western porcupine grass and Kentucky blue grass. If these differences are applied to the entire sample of 81 quadrats, western porcupine grass is overestimated in 2003 by 9.0%, making the actual decline since 1993 more dramatic than shown in the report. Kentucky blue grass was also overestimated, but not to the same degree as western porcupine grass. The average overestimate was 6.6% for Kentucky blue grass in 2003, compared with an overestimate of 2.3% in 1993, for a net difference of 4.3% between years. Correction for this error would reduce the difference between years, but not enough to affect the conclusions, given that Kentucky blue grass increased by about 25% over the 10-year period.

**Table B.1 Comparison of actual species percentages based on clipping and weighting with visual estimates.**

| | Actual Percent | Estimated Percent | Absolute Difference |
|---|---|---|---|
| **500 N 300 W** | | | |
| *Vicia sparsifolia* | 0.3 | 0.0 | 0.3 |
| *Carex obtusata* | 1.0 | 0.5 | 0.5 |
| *Carex pensylvanica* | 0.7 | 0.5 | 0.2 |
| *Festuca altaica* | 15.2 | 5.0 | 10.2 |
| *Poa pratensis* | 82.9 | 95.0 | 12.1 |
| *Galium boreale* | 0.0 | 0.5 | 0.5 |
| *Agropyron subsecundum* | 0.0 | 0.5 | 0.5 |
| **620 N 060 W** | | | |
| *Galium boreale* | 11.5 | 4.0 | 7.5 |
| *Comandra umbellata* | 1.0 | 0.5 | 0.5 |
| *Thermopsis rhombifolia* | 10.7 | 3.0 | 7.7 |
| *Poa pratensis* | 74.6 | 92.0 | 17.4 |
| *Carex obtusata* | 0.2 | 0.0 | 0.2 |
| *Carex eleocharis* | 0.1 | 0.0 | 0.1 |
| *Agropyron subsecundum* | 2.0 | 0.5 | 1.5 |
| *Agropyron repens* | 0.0 | 1.0 | 1.0 |
| **560 N 270 W** | | | |
| *Carex eleocharis* | 0.4 | 0.5 | 0.1 |
| *Poa pratensis* | 52.0 | 64.0 | 12.0 |
| *Stipa viridula* | 7.4 | 6.0 | 1.4 |
| *Agropyron dasystachyum* | 40.3 | 30.0 | 10.3 |
| **680 N 420 W** | | | |
| *Carex eleocharis* | 28.2 | 7.0 | 21.1 |
| *Stipa curtiseta* | 18.8 | 67.0 | 48.3 |
| *Poa pratensis* | 34.8 | 15.0 | 19.8 |
| *Agropyron subsecundum* | 7.7 | 5.0 | 2.7 |
| *Agropyron dasystachyum* | 1.6 | 0.0 | 1.6 |
| *Galium boreale* | 3.8 | 5.0 | 1.2 |
| *Solidago missouriensis* | 0.6 | 0.5 | 0.1 |
| *Artemisia frigida* | 2.4 | 0.5 | 1.9 |
| *Psoralea argophylla* | 1.5 | 1.0 | 0.5 |
| *Unknown* | 0.2 | 0.0 | 0.2 |
| *Pulsatilla ludoviciana* | 0.6 | 0.5 | 0.1 |
| **650 N 180 W** | | | |
| *Stipa curtiseta* | 15.7 | 20.0 | 4.4 |
| *Carex pensylvanica* | 8.3 | 3.0 | 5.3 |
| *Festuca altaica* | 4.5 | 11.0 | 6.5 |
| *Carex obtusata* | 3.0 | 3.0 | 0.0 |
| *Agropyron dasystachyum* | 68.6 | 63.0 | 5.6 |
| **560 N 360 W** | | | |
| *Stipa curtiseta* | 33.6 | 40.0 | 6.4 |
| *Agropyron dasystachyum* | 12.2 | 7.0 | 5.2 |
| *Poa pratensis* | 6.4 | 5.0 | 1.4 |
| *Carex pensylvanica* | 10.0 | 18.0 | 8.0 |

| | Actual Percent | Estimated Percent | Absolute Difference |
|---|---|---|---|
| *Carex eleocharis* | 1.0 | 0.0 | 1.0 |
| *Carex obtusata* | 14.4 | 20.0 | 5.6 |
| *Erigeron caespitosus* | 21.7 | 10.0 | 11.7 |
| *Campanula rotundifolia* | 0.8 | 0.5 | 0.3 |
| | | | |
| **650 N 120 W** | | | |
| *Heuchera richardsonii* | 34.4 | 15.0 | 19.4 |
| *Thermopsis rhombifolia* | 13.7 | 6.0 | 7.7 |
| *Carex obtusata* | 0.4 | 0.5 | 0.1 |
| *Agropyron dasystachyum* | 8.5 | 3.0 | 5.4 |
| *Poa pratensis* | 43.1 | 76.0 | 32.9 |
| | | | |
| **590 N 330 W** | | | |
| *Carex pensylvanica* | 19.1 | 12.0 | 7.1 |
| *Agropyron dasystachyum* | 15.1 | 10.0 | 5.1 |
| *Galium boreale* | 15.1 | 15.0 | 0.1 |
| *Carex eleocharis* | 10.6 | 0.0 | 10.6 |
| *Bouteloua gracilis* | 8.9 | 3.0 | 5.9 |
| *Stipa curtiseta* | 6.9 | 20.0 | 13.1 |
| *Poa pratensis* | 0.2 | 0.0 | 0.2 |
| *Festuca altaica* | 8.4 | 20.0 | 11.6 |
| *Koeleria cristata* | 5.0 | 11.0 | 6.0 |
| *Cerastium arvense* | 0.2 | 0.5 | 0.3 |
| *Carex obtusata* | 1.8 | 1.0 | 0.8 |
| *UNKWN HERB* | 0.1 | 0.0 | 0.1 |
| *Stipa comata* | 0.2 | 0.0 | 0.2 |
| *Thermopsis rhombifolia* | 3.0 | 3.0 | 0.0 |
| *Aster falcatus* | 1.7 | 2.0 | 0.3 |
| *Solidago missouriensis* | 2.6 | 3.0 | 0.4 |
| *Comandra umbellata* | 0.3 | 0.5 | 0.2 |
| *Artemisia frigida* | 0.2 | 0.5 | 0.3 |
| Average of individual differences | | | 5.6 |
| | | | |
| **Average across eight quadrats** | | | |
| *Poa pratensis* | 36.7 | 43.4 | 6.6 |
| *Agropyron dasystachyum* | 18.3 | 14.1 | 4.1 |
| *Carex* spp. | 12.4 | 8.3 | 4.1 |
| *Stipa curtiseta* | 9.4 | 18.4 | 9.0 |
| *Heuchera richardsonii* | 4.3 | 1.9 | 2.4 |
| *Galium boreale* | 3.8 | 3.1 | 0.7 |
| *Festuca altaica* | 3.6 | 4.5 | 0.9 |
| *Thermopsis rhombifolia* | 3.4 | 1.5 | 1.9 |
| *Erigeron caespitosus* | 2.7 | 1.3 | 1.5 |
| *Agropyron subsecundum* | 1.2 | 0.8 | 0.5 |
| *Bouteloua gracilis* | 1.1 | 0.4 | 0.7 |
| *Stipa viridula* | 0.9 | 0.8 | 0.2 |
| *Koeleria cristata* | 0.6 | 1.4 | 0.7 |
| *Solidago missouriensis* | 0.4 | 0.4 | 0.0 |
| *Artemisia frigida* | 0.3 | 0.1 | 0.2 |
| *Aster falcatus* | 0.2 | 0.3 | 0.0 |
| *Psoralea argophylla* | 0.2 | 0.1 | 0.1 |

| | Actual Percent | Estimated Percent | Absolute Difference |
|---|---|---|---|
| *Comandra umbellata* | 0.2 | 0.1 | 0.1 |
| *Campanula rotundifolia* | 0.1 | 0.1 | 0.0 |
| *Pulsatilla ludoviciana* | 0.1 | 0.1 | 0.0 |
| *Vicia americana* | 0.0 | 0.0 | 0.0 |
| *Stipa comata* | 0.0 | 0.0 | 0.0 |
| *Cerastium arvense* | 0.0 | 0.0 | 0.0 |
| UNKNOWN HERB | 0.0 | 0.0 | 0.0 |
| *Agropyron repens* | 0.0 | 0.1 | 0.1 |
| ***Average difference*** | | | 1.4 |