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Effects of management on species dynamics of Canadian aspen parkland pastures

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Abstract

The effects of grazing, fertilizing, and seeding on persistence of herbaceous species was monitored by point quadrat about every second year from 1975 to 1989 in a low-fertility pasture in the aspen parkland vegetation zone of east-central Saskatchewan, Canada. Ground cover response to continuous grazing was contrasted with that of 4- and 6-paddock rotationally-grazed areas fertilized in the fall of every other year with 90 kg N, 45 kg P_2O_5, 10 kg S ha^{-1}. The original vegetation in 2 paddocks of the 6-paddock system was replaced with Russian wildrye (*Psathyrostachys juncea* (Fisch.) Nevski) in 1976, and in 1 of the other 4 paddocks in turn with smooth brome (*Bromus inermis* Leyss.)-alfalfa (*Medicago sativa* L.) in 1979 and 1981, crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) in 1983, and a meadow brome (*Bromus riparius* Rehm.)-alfalfa mix in 1985. Initially, smooth brome and creeping red fescue (*Festuca rubra* L.) dominated the vegetation with ground cover estimates of 10–20% and 40–60%, respectively. Alfalfa ground cover was less than 1%. With the changes in management, Kentucky bluegrass (*Poa pratensis* L.) replaced creeping red fescue. Alfalfa increased until 1980 and then declined to its original level, apparently in response to precipitation trends. Russian wildrye almost died out and was replaced by brome and Kentucky bluegrass. Reseeding with smooth bromegrass-alfalfa did not consistently increase brome ground cover beyond that obtained by rotational grazing and fertilization, and increased alfalfa only temporarily. Cultivation during the summer before spring seeding resulted in partial recovery of the old vegetation and invasion by Kentucky bluegrass. Total ground cover varied from year to year in response to spring precipitation. Forbs usually increased after reseeding, but declined to their original levels within 5 years.

Key Words: *Bromus inermis*, *Medicago sativa*, *Psathyrostachys juncea*, *Agropyron cristatum*, *Bromus riparius*, grazing system, seeding, fertilizing

Resumen

Los efectos de pastoreo, fertilización y siembra en la persistencia de especies herbáceas fue determinado desde 1975, por muestreo en cuadrículas aproximadramente cada dos años, en una pastura establecida en un suelo de baja fertilidad en la zona de los parques de álamo tremblón (chopo) en el centro este de Saskatchewan, Canadá. La respuesta de la cubierta vegetal al pastoreo continuo fue comparado con aquella observada bajo pastoreo rotativo en sistemas de 4- y 6- parcelas fertilizadas cada segundo año en el otoño con 90 kg N, 45 kg P_2O_5 y 10 kg S ha^{-1}. La vegetación original de dos parcelas del sistema de y-parcelas fue reemplazada con *Psathyrostachys juncea* (Fisch.) Nevski en 1976, dos parcelas fueron sembradas con un mezcla de *Bromus inermis* Leyss. y *Medicago sativa* L., una en 1979 y la otra en 1981, otra parcela fue sembrada con *Agropyrum cristatum* (L.) Gaertn. en 1983, y la parcela restante fue sembrada con una mescla de *Bromus riparius* Rehm. y *Medicago sativa* en 1985. Inicialmente, *Bromus inermis* y *Festuca rubra* L. dominaban L. dominaban la vegetación, cubriendo 10–20% y 40–60% de la superficie, respectivamente. *Medicago sativa* cubría menos del 1% de la superficie. Con los cambios introducidos en el manejo, *Poa pratensis* L. Reemplazó *Festuca rubra*. *Medicago sativa* incrementó el porcentaje de superficie cubierta hasta 1980, para luego disminuir hasta alcanzar sus niveles originales, aparentemente, esto fue en respuesta a variaciones pluviométricas durante el período del estudio. *Psathyrostachys juncea* desapareció casi completamente y fue reemplazada por *Bromus* sp. y *Poa pratensis*. Resembrando una mezcla de *Bromus inermis* y *Medicago sativa* no aumentó la proporción de la superficie cubierta por *Bromus inermis* mas allá de la obtenida por medio del pastoreo rotativo y fertilización, e incremento temporalmente el porcentaje de la superficie cubierta por *Medicago sativa*. Labranza del suelo en el verano anterior a la siembra de primavera produjo una recuperación parcial de la vegetación antigua y una invasión de *Poa pratensis*. El porcentaje de la superficie del suelo cubierta por vegetación vario de año en año, dependiendo del régimen pluviométrico en la primavera. Especies herbáceas de joja ancha normalmente aumentaron después de la resiembra, para luego disminuir hasta sus niveles originales dentro de cinco años.

In the grass-forest transition zone of western Canada, commonly called the aspen parkland, grazing areas have been developed from aspen-conifer forest, rough fescue (*Festuca hallii* (Vasey) Piper) grasslands, and abandoned farmland. Each pasture is a unique mixture of original vegetation, tree regrowth, moist meadows, ponds, lakes, and swamps. The unifying aspect is the dominance of the seeded forages: smooth bromegrass (*Bromus inermis* Leyss.), creeping red fescue (*Festuca rubra* L.), and alfalfa (*Medicago sativa* L.). Looman (1976) concluded that the

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seeded forages have established an equilibrium with the environment after about 20 years. Even though soil fertility has declined to low levels, smooth bromegrass remains a dominant component of the pastures because of the environmental similarity to its native Eurasia.

Recommendations for increasing pasture productivity in the aspen parkland (Tremblay 1995) include the use of alfalfa in spite of the risk of bloat (Beacom 1991), rotational grazing although evidence for its value is inconsistent (Cooke et al. 1965, Walton et al. 1981), and fertilization which has only a 1 to 2 year benefit (Nuttall et al. 1991). Above-ground dry matter measures of species productivity used in these reports have not shown clearly the effects of management on the relationships among several species in a pasture. Other reports show that management can affect biodiversity (de Vries and Kruijne 1960) and ground cover composition (Gifford and Hawkins 1976). Changes in plant associations following fertility changes (Looman 1980) or grazing strategies (Savory 1983) may have productivity implications.

In this study we measure species ground cover to detect: 1) Changes in resident vegetation of an aspen parkland pasture when fertilizer is applied and cattle management is changed from continuous to rotational or time-restricted grazing. 2) The permanence of changes in vegetation resulting from changes in fertility, grazing management, and species replacement.

Materials and Methods

Study Site

The 375 ha experimental area is part of the 5,000 ha Pathlow Community Pasture in east-central Saskatchewan (52° 41'N, 104° 58'W). Topography is undulating to varying degrees, with most soils being textural variants of luvisolic soils (Cryoboralfs, USDA-SCS 1975). By the mid-1960's, small areas totalling about 40% of the study site had been farmed for about 30 years, with the remainder in poplar (*Populus* spp.) forest. At that time, the woody growth was burned, and the entire area cultivated and seeded to a mixture of grasses and legumes, primarily smooth bromegrass, creeping red fescue, and alfalfa. In 1975, when this study began, smooth bromegrass comprised 10–30%, and creeping red fescue about 50% of the herbaceous ground cover. Kentucky bluegrass (*Poa pratensis* L.) was a minor constituent of the understory with < 5% ground cover. Alfalfa was unevenly distributed and had a ground cover < 2%. Broad-leaved, mostly native species (forbs), were present in small numbers. Season-long grazing and no additional fertilizer since seeding had led to deterioration and reduced grazing capacity.

Summaries of weather records from the Environment Canada site 3 km north of Pathlow pasture are presented in Table 1. Growing-season degree-days are summed between 1 April and 30 September: rarely are temperatures outside this period warm enough for growth. For the period from 1 September to 31 May, which supplies the water affecting growth at the time of the surveys, precipitation during the period 1975 to 1979 was average to above average from 1980 to 1983 was mostly below average, was above average in 1984 and 1985, and was below average from 1986 to 1989. Growing season degree-days tended to be the inverse of the precipitation.

Table 1. Weather summaries for 1975–1989 at a site 3 km north of the experimental area in east-central Saskatchewan (52°41'N, 104°58'W).

Year	Precipitation			Growing Season Degree-Days above 5°C
	Prev. Summer (1 Jun–31 Aug prev yr.)	Winter (1 Sept prev. yr —31 Mar)	Spring (1 Apr—31 May)	
	(mm)	(mm)	(mm)	(°C)
1975	232	132	102	1,434
1976	233	112	48	1,706
1977	235	90	153	1,627
1978	144	178	72	1,556
1979	242	227	47	1,491
1980	169	168	10	1,705
1981	210	89	44	1,720
1982	146	207	91	1,453
1983	149	100	64	1,591
1984	245	157	153	1,656
1985	139	221	104	1.305
1986	168	127	68	1,548
1987	173	130	46	1,716
1988	187	154	16	1,867
1989	131	131	66	1,676
Average	187	148	72	1,603

Treatments

The grazing systems consisted of 4-paddock, and 6-paddock rotations, each replicated 4 times, and a continuously-grazed paddock replicated twice. Each paddock in the rotations was about 8 ha (400 × 200 m), and each continuously-grazed area was about 16 ha (400 × 400 m). The 40 paddocks in the rotations were fertilized with 90 kg nitrogen, 45 kg phosphate and 10 kg sulphur ha^{-1} in fall 1975. Thereafter, half the paddocks were fertilized at the same rates in the fall in 1977, 1979, 1981, 1983, and 1985, and the other half were fertilized in fall 1978, 1980, 1982, and spring 1985. All paddocks were fertilized each fall thereafter at half the initial rate.

In 1976, 2 paddocks of the 6-paddock system in each replicate were seeded with 5.6 kg ha^{-1} 'Swift' Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski] and 19 kg ha^{-1} oats (*Avena sativa* L.). In 1979 and 1981, a paddock in each replicate was reseeded with 9 kg ha^{-1}, 'Carlton' smooth bromegrass and 2.2 kg ha^{-1} 'Rambler' alfalfa. In 1983, one paddock per replicate was seeded with 9

kg ha^{-1} 'Parkway' crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.], and in 1985, one was seeded with 9 kg ha^{-1} 'Regar' meadow bromegrass (*Bromus riparius* Rehm.) and 2.2 kg ha^{-1} 'Rambler' alfalfa. In each case, the paddocks were cultivated to destroy resident vegetation the summer prior to reseeding.

Each year, starting in 1976, grazing commenced when the grass reached 10–15 cm, usually during the last week of May. Cow-calf units grazed in a paddock for 1–3 weeks and were moved to the next paddock when most of the forage had been consumed. Each paddock was grazed once or twice during the grazing season depending on forage production. Specifics on livestock numbers and grazing duration are presented in McCartney et al. (1999).

Botanical survey methodology

In fall 1974, prior to fencing, the experimental area was divided into rectangles, each 305 × 152 m. In spring 1975, basal ground cover was estimated in every second rectangle in a checkerboard pattern. In each sampled rectangle, 10 sites were selected randomly. Basal cover of all herbaceous species was estimated using an 18-pin vertical point frame with pins spaced 5 cm apart. Six frames about 2 m apart were read per site (i.e. 108 pins). Following subdivision into paddocks, 10 sites were selected at random in each paddock, and visited in 1976, 1978, 1980, 1982, 1984, 1988, and 1989 using the same procedure as in 1975, with the exception that 12 frames (i.e. 216 points) were read per site. The continuously-grazed paddocks were surveyed only in 1975, 1984, 1988, and 1989. The paddocks seeded to Russian wildrye were not included in the 1976 survey because of the recent disturbance. The sampling was started in late May and usually completed by the end of June.

Data summarization and statistical analyses

Data were analyzed: 1) For differences between grazing systems in total vegetation ground cover; and 2) For composition by species/species groups (smooth bromegrass, creeping red fescue, bluegrasses (mostly *Poa pratensis* L.), alfalfa, annual plus biennial forbs, and perennial forbs (Table 2). As paddocks were seeded, 3 species–Russian wildrye, crested wheatgrass, and meadow bromegrass, were added. These data were analyzed for effects of the various rejuvenation treatments (fertilizer, breaking and seeding) on the relative proportions of the species and species groups within grazing systems.

Ground cover data, i.e. the number of basal hits with respect to the number of pins dropped per site, and number of basal hits by species/species group with respect to total number of hits, are expected to exhibit a binomial distribution. These data were analyzed using a generalized linear model using a logit link, fitted by maximum likelihood, and summarized by an analysis of deviance. These procedures, which include the ordinary linear model and the analysis of variance for identically distributed normal data as special cases, are described in detail by McCullagh and Nelder (1989).

Because of the non-constant variance associated with the binomial distribution, terms in fitting of the generalized linear model were included sequentially according to the following rules:

Subject to the actual experimental protocol,

1. Block factors are fitted before treatments and interactions:
2. Treatment main effects and interactions having lesser importance are included before those of primary interest;

Table 2. The most frequently occuring annual, biennial, and perennial forbs found between 1975 and 1989 at the study site, Pathlow pasture, east-central Saskatchewan.

Annual and biennial Forbs	Perennial Forbs
Androsace septentrionalis L.	*Antennaria aprica* Greene
Axyris amaranthoides L.	*Antennaria neglecta* Greene
Capsella bursa-pastoris (L.) Medic.	*Antennaria rosea* Greene
Chenopodium album L.	*Aster ciliolatus* Lindl.
Crepis tectorum L.	*Erigeron philadelphicus* L.
Descurainia sophia (L.) Webb	*Fragaria virginiana* Dcne.
Draba nemorosa L.	*Galium boreale* L.
Lappula echinata Gilib.	*Maianthemum canadense* Desf.
Lepidium densiflorum Schrad.	*Plantago major* L.
Monolepis nuttalliana (R&S) Greene	*Solidago canadensis* L.
Potentilla norvegica L.	*Taraxacum officinale* Weber
Thlaspi arvense L.	*Thalictrum venulosum* Trel.
	Viola cucullata Ait.
	Viola rugulosa Greene

Table 3. Analyses of Deviance: total plant counts (basal cover) in relation to the number of sampled points, assuming binomial data distribution, Pathlow pasture, east-central Saskatchewan.

Year	Source of Deviance						
	Replicates (R)	Grazing System (GS)	R x GS	Fertility (F)	GS x F	Paddocks within R x GS x F	Residual Degrees of Freedom
1975	23.9	3.4	19.0	0.5	0.4	49.4	254
1976	147.2	0.6	21.9	0.3	0.0	46.2	289
1978	35.2	6.2	15.9	49.6	0.5	99.2	363
1980	25.3	10.4	9.1	27.1	7.9	123.4	361
1982	11.0	4.3	3.2	76.9	0.1	200.2	362
1984	28.1	14.3	2.1	0.0	7.4	298.9	363
1988	2.8	15.6	5.4	0.8	9.4	97.4	366
1989	9.9	6.9	15.0	1.3	1.0	57.6	363
D.F.	3	1	3	1	1	27^{+}	
Chi^2 5%	7.8	3.8	7.8	3.8	3.8	40.1^{+}	

Degrees of freedom 18 in 1975, 19 in 1976, Chi^2 28.9 in 1975, 30.1 in 1976.

Table 4. Mean basal ground cover % (standard error) by grazing system between 1975 and 1989, Pathlow pasture, east-central Saskatchewan.

Year	4-Field rotation fertilizer		6-Field rotation fertilizer reseeding		Continuously grazed		Significance Level
	(%)						
1975	20	(0.3)	22	(0.4)	21	(0.7)	NS
1976	28	(0.2)	27	(0.2)	-	-	NS
1978	20	(0.2)	19	(0.2)	-	-	5%
1980	14	(0.2)	12	(0.1)	-	-	1%
1982	21	(0.2)	19	(0.2)	-	-	5%
1984	27	(0.2)	24	(0.2)	35	(0.7)	1%
1988	13	(0.2)	15	(0.2)	27	(0.7)	1%
1989	30	(0.3)	28	(0.2)	34	(0.7)	1%

NS, 5%, 1%: not significantly different, different for $P < 0.05$, $P < 0.01$

3. Marginality constraints are obeyed, i.e. higher-order interactions are not included before those of lower order included in (marginal to) them.

The sequential fitting allows estimates of the changes in deviance (interpretable as goodness of fit) to be determined as each term is included. Changes in deviance are referred to the chi-squared distribution for testing significance; a probability of less than 5% is considered to be significant. From the fitted model, estimates of expected values, which in the ordinary analysis of variance are called "least square means", and approximate standard errors are obtained. Further details on theory and applications can be found in McCullagh and Nelder (1989). Genstat 5, Release 2.1, (Lawes Agricultural Trust 1987) was used for all statistical computations.

Results

Total vegetation cover

Interaction among paddocks, replicates, grazing systems, and fertility was significant in 1975 before treatments were applied, demonstrating the variability of the vegetation in the pasture (Table 3). Adding fertilizer to half the paddocks in alternate years had significant effects on vegetation cover between 1978 and 1982, but not in 1984. The analyses reflect the uniform fertilizer additions across the pasture in 1988 and 1989.

Imposition of rotational grazing systems also caused significant differences in vegetation cover (Table 3). By 1984, the continuously-grazed paddocks had greater vegetation cover than the rotationally-grazed paddocks, and the 4-field paddocks had more cover than the 6-field paddocks (Table 4). With rotational grazing, the cover varied by 100% between the years with greatest (1989) and least (1980) cover. The increase between 1975 and 1976 was probably in response to the fertilizer application in fall 1975. In later years, changes appeared to be in response to spring moisture. Year-to-year cover changes were much less in continuously-grazed paddocks.

Species responses to continuous grazing

The proportion of smooth bromegrass in the vegetation changed little between 1975 and 1989, remaining at about 11% (Table 5). Creeping red fescue declined significantly from 49% to 19% in the same period and Kentucky bluegrass increased slightly from 2% to 8%. Alfalfa and annual-biennial forbs almost disappeared. There was a major increase in perennial forbs from 7% in 1975 to over 50% in 1989, caused mainly by the spread of mat-forming *Antennaria* species.

Species responses in the 4-field rotation

For most of the 13-year period of the surveys, there was significantly more bromegrass and creeping red fescue cover in paddocks fertilized the fall before each survey than in the paddocks fertilized 18 months previously (Table 6). During this time the proportion of bromegrass cover in the paddocks increased by about 50%, and that of the fescue declined about 5-fold. There was no consistent effect of fertilizer application timing on Kentucky bluegrass cover although it increased in proportion from < 3% to 40% of the ground cover between 1976 and 1989. The proportion of alfalfa in the vegetation cover quadrupled between 1975 and 1982, and then declined to its original level by 1989 with no significant differences due to the differential fertilizer application times. Cover of annual and biennial forbs was consistently < 1% after 1975. Perennial forbs also varied little among years, averaging about 3% cover the year after fertilizing and about 5% the second year after fertilizing.

Species responses in the 6-field rotation

Paddocks seeded to Russian wildrye with an oat companion in 1976 By 1978, Russian wildrye contributed

Table 5. Mean ground cover % (standard error) of major species in continuously grazed unfertilized pastures, Pathlow, east-central Saskatchewan.

Year	Smooth Bromegrass		Creeping Red Fescue		Kentucky Bluegrass		Alfala		Annual + Biennial Forbs		Perennial Forbs	
	(%)											
1975	10.3	(1.2)	48.9	(1.9)	2.4	(0.6)	1.1	(0.4)	3.2	(0.7)	6.7	(1.0)
1984	10.8	(0.9)	35.1	(1.3)	7.6	(0.7)	0.6	(0.2)	0.1	(0.1)	35.2	(1.1)
1988	12.7	(1.0)	28.3	(1.3)	8.0	(0.8)	0.1	(0.1)	0.1	(0.1)	41.6	(1.4)
1989	11.5	(0.8)	18.6	(1.0)	7.4	(0.7)	0.1	(0.1)	0.1	(0.1)	51.8	(1.3)

Table 6. Mean ground cover % (standard error) of major species in fertilized 4-field rotational grazing system, Pathlow pasture, east-central Saskatchewan.

Year	Smooth Bromegrass		Creeping Red Fescue		Kentucky Bluegrass		Alfala		Annual+ Biennial Forbs		Perennial Forbs	
	(%)											
Paddock fertilized fall previous to the year of survey[1]												
1975	20.6	(1.1)	55.6	(1.3)	0.6	(0.2)	0.7	(0.2)	0.9	(0.3)	1.4	(0.3)
1976	17.4	(0.5)	62.0	(0.7)	3.0	(0.3)	0.3	(0.1)	0.1	(0.0)	3.5	(0.3)
1978	15.3	(0.6)	60.3	(0.7)	5.1	(0.4)	1.7	(0.2)	0.1	(0.1)	3.3	(0.3)
1980	22.5	(0.8)	52.8	(1.0)	7.4	(0.5)	2.8	(0.3)	0.0	(0.0)	2.9	(0.3)
1982	29.6	(0.7)	29.7	(0.7)	15.7	(0.5)	2.8	(0.2)	0.4	(0.1)	2.9	(0.3)
1984	24.3	(0.6)	29.1	(0.6)	16.4	(0.5)	1.2	(0.2)	0.2	(0.1)	4.4	(0.3)
1988	31.8	(1.0)	9.8	(0.6)	35.7	(1.0)	1.4	(0.2)	0.0	(0.0)	3.3	(0.4)
1989	31.5	(0.6)	11.2	(0.4)	40.0	(0.6)	0.5	(0.1)	0.1	(0.0)	3.7	(0.3)
Paddocks fertilized in fall 18 mos. previous to the survey[1]												
1975	19.4	(1.1)	44.8	(1.4)	1.4	(0.3)	0.6	(0.2)	1.6	(0.4)	4.0	(0.6)
1976	14.8	(0.5)	53.6	(0.7)	2.7	(0.2)	0.3	(0.1)	0.1	(0.0)	6.8	(0.4)
1978	16.8	(0.7)	49.1	(0.9)	5.0	(0.4)	1.2	(0.2)	0.1	(0.1)	5.0	(0.4)
1980	18.7	(0.8)	40.8	(1.0)	5.6	(0.5)	2.0	(0.3)	0.0	(0.0)	5.3	(0.5)
1982	29.6	(0.7)	31.4	(0.8)	12.8	(0.6)	1.9	(0.2)	0.2	(0.1)	5.3	(0.4)
1984	21.1	(0.6)	7.5	(0.7)	19.3	(0.6)	0.9	(0.1)	0.2	(0.1)	3.9	(0.3)
1988	27.1	(0.9)	4.7	(0.4)	36.1	(0.9)	1.7	(0.3)	0.0	(0.0)	6.3	(0.5)
1989	26.9	(0.6)	9.2	(0.4)	41.5	(0.7)	0.4	(0.1)	0.1	(0.0)	5.3	(0.3)

[1]Paddocks fertilized each fall, 1988–1989.

Table 7. Mean ground cover % (standard error) of major species before and after seeding Russian wildrye in 1976, Pathlow pasture, east-central Saskatchewan.

Year	Smooth Bromegrass		Creeping Red Fescue		Kentucky Bluegrass		Russian wildrye		Annual+ Biennial Forbs		Perennial Forbs	
	(%)											
Paddock fertilized fall previous to the year of survey[1]												
1975	29.3	(6.0)	58.6	(6.5)	0.0	(0.1)	-	-	0.0	(0.0)	1.7	(1.7)
1978	12.3	(0.8)	12.4	(0.8)	19.3	(1.0)	25.1	(1.0)	0.1	(0.1)	13.9	(0.8)
1980	15.1	(1.07)	12.5	(0.9)	27.5	(1.2)	21.4	(1.1)	0.7	(0.2)	7.7	(0.7)
1982	18.8	(0.8)	6.9	(0.5)	28.7	(1.0)	16.3	(0.8)	0.7	(0.2)	7.3	(0.6)
1984	17.5	(0.7)	10.2	(0.6)	37.5	(0.9)	4.8	(0.4)	0.0	(0.0)	6.7	(0.5)
1988	23.0	(1.2)	3.9	(0.6)	47.3	(1.4)	2.3	(0.4)	0.0	(0.0)	4.1	(0.6)
1989	20.4	(0.8)	1.7	(0.3)	46.6	(1.0)	4.6	(0.4)	0.0	(0.0)	0.9	(0.2)
Paddocks fertilized 18 mos. prior to the survey[1]												
1975	14.8	(4.5)	50.8	(6.4)	0.0	(0.1)	-	-	0.0	(0.0)	0.0	(0.1)
1978	8.7	(0.7)	17.5	(0.9)	17.2	(0.9)	23.7	(1.0)	0.2	(0.1)	19.9	(1.0)
1980	11.5	(1.0)	17.8	(1.1)	27.1	(1.3)	21.3	(1.2)	0.1	(0.1)	7.6	(0.8)
1982	13.3	(0.7)	9.0	(0.6)	35.8	(1.1)	15.5	(0.8)	0.1	(0.1)	3.2	(0.4)
1984	11.7	(0.6)	9.3	(0.6)	41.0	(1.0)	5.7	(0.4)	0.2	(0.0)	8.0	(0.5)
1988	15.7	(1.0)	1.8	(0.4)	53.9	(1.3)	5.6	(0.6)	0.2	(0.1)	4.1	(0.5)
1989	15.5	(0.7)	4.4	(0.4)	57.2	(1.0)	3.1	(0.3)	0.0	(0.0)	2.1	(0.3)

[1]Paddocks fertilized each fall, 1988-1989.

only 25% to the total ground cover, and continually declined thereafter (Table 7). Bromegrass re-established after cultivation, and increased to 15–20% of the ground cover by 1989. Paddocks fertilized the fall previous to the surveys had more bromegrass cover than paddocks fertilized earlier, and this difference was significant after 1980. Creeping red fescue did not recover fully after cultivation, with significantly poorer recovery where fertilized the fall previous to the surveys. Its cover declined further over time. Kentucky bluegrass cover increased from near zero in 1975 to over 46% by 1989. Alfalfa was absent from these paddocks.

Paddocks seeded to Bromegrass-Alfalfa in 1979 Reseeding tripled bromegrass ground cover in the vegetation (Table 8), and it remained significantly above its initial level. Creeping red fescue declined slowly in the period before reseeding, and dropped to a low level as bromegrass re-established. Kentucky bluegrass cover increased rapidly after 1984. Reseeding increased the proportion of alfalfa in the ground cover from 3% in 1978 to 11% by 1982. Thereafter, alfalfa steadily declined to its pre-rejuvenation level. Forbs were a major component of the ground cover the year after seeding, but had declined to low levels by 1984.

Paddocks seeded to bromegrass-alfalfa in 1981 Reseeding increased bromegrass ground cover 50% above

Table 8. Mean ground cover % (standard error) of major species before and after reseeding with smooth bromegrass-alfalfa, paddocks fertilized in fall 18 mos prior to survey[1], Pathlow pasture, east-central Saskatchewan.

Year	Smooth Bromegrass		Creeping Red Fescue		Kentucky Bluegrass		Alfala		Annual+ Biennial Forbs		Perennial Forbs	
	(%)											
Reseeding in 1979												
1975	12.4	(1.2)	57.2	(1.8)	0.6	(0.3)	1.1	(0.4)	0.7	(0.3)	3.2	(0.6)
1976	14.0	(0.7)	51.5	(1.0)	4.1	(0.4)	0.8	(0.2)	0.1	(0.1)	4.6	(0.5)
1978	14.4	(1.0)	48.3	(1.3)	4.5	(0.6)	2.8	(0.5)	0.3	(0.1)	9.1	(0.8)
1980	23.2	(1.9)	19.7	(1.5)	3.2	(0.8)	8.7	(1.3)	14.0	(1.4)	11.8	(1.5)
1982	47.8	(1.5)	2.6	(0.5)	7.3	(0.8)	10.6	(1.0)	8.5	(0.9)	6.9	(0.7)
1984	38.7	(1.1)	6.3	(0.6)	8.3	(0.7)	9.5	(0.7)	0.2	(0.1)	2.9	(0.4)
1988	34.4	(1.4)	1.1	(0.3)	30.1	(1.4)	6.9	(0.8)	0.0	(0.0)	3.2	(0.5)
1989	36.3	(1.0)	7.9	(0.6)	35.3	(1.0)	2.3	(0.3)	0.1	(0.1)	2.7	(0.3)
Reseeding in 1981												
1975	13.4	(1.2)	54.5	(1.8)	2.3	(0.6)	0.6	(0.3)	1.1	(0.4)	2.6	(0.6)
1976	18.3	(0.8)	54.7	(1.0)	8.3	(0.6)	0.7	(0.2)	0.1	(0.1)	2.9	(0.4)
1978	12.2	(0.8)	46.7	(1.3)	8.7	(0.7)	2.0	(0.4)	0.0	(0.0)	5.9	(0.6)
1980	22.2	(1.5)	22.8	(1.4)	15.5	(1.3)	3.6	(0.7)	1.7	(0.6)	4.0	(0.7)
1982	34.4	(1.3)	2.4	(0.5)	5.1	(0.7)	3.7	(0.5)	14.1	(0.9)	12.0	(1.0)
1984	37.7	(1.1)	7.3	(0.6)	12.5	(0.7)	3.7	(0.4)	0.9	(0.2)	4.1	(0.5)
1988	32.1	(1.3)	4.5	(0.6)	33.9	(1.3)	4.3	(0.6)	0.2	(0.1)	7.1	(0.8)
1989	30.7	(1.0)	2.7	(0.3)	37.3	(1.0)	1.7	(0.3)	0.2	(0.1)	3.0	(0.4)

[1]Paddocks fertilized each fall, 1988-1989.

its pre-seeding values and reduced creeping red fescue cover to a minor constituent, where it remained with some fluctuations through 1989 (Table 8). Kentucky bluegrass cover was increasing prior to reseeding, and after a reduction in response to cultivation, increased steadily to 37% by 1989. Reseeding alfalfa in 1981 did not result in increased cover, but apparently delayed the decline that occurred in other treatments. Forbs were a major component of the ground cover the year after seeding, but had declined to low levels 2 years later.

Paddocks seeded to crested wheatgrass in 1983 Crested wheatgrass established well and was 62% of the total ground cover in 1984 (Table 9). Its cover declined to 41% by 1989. Cultivation reduced bromegrass cover to 4% and creeping red fescue and alfalfa to very low levels. Kentucky bluegrass increased between 1975 and 1989 from 1% to 34% of total ground cover, and was not noticeably affected by the establishment of the crested wheatgrass. Forbs cover increased significantly the year after seeding, but had declined to their previous levels by 1988.

Paddocks seeded to meadow bromegrass-alfalfa in 1985 Meadow bromegrass established poorly, and formed only 27% of ground cover in 1989 (Table 10). Smooth bromegrass remained a major constituent through the reseeding period and Kentucky bluegrass increased its cover. Creeping red fescue cover was reduced to 8%. Seeding alfalfa increased its cover to 4% in 1988, but this was followed by a decline to 1% in 1989. Forbs showed no response to reseeding.

Discussion

There are 4 basic influences on the relative proportions of species in pasture: weather patterns and trends, the timing and intensity of grazing, the application of fertilizer, and reseeding. The latter 3 are aspects of pasture management, and in the order given, represent an increasing degree of intervention in the ecosystem. Of the species originally present, smooth bromegrass and alfalfa are considered desirable components from an animal productivity viewpoint. Creeping red fescue and Kentucky bluegrass are usually considered less desirable because of low productivity, although red fescue was included in the original seeding because it can produce higher quality forage late in the growing season (Elliott and Baenziger) 1977).

Table 9. Mean ground cover % (standard error) of major species before and after seeding crested wheatgrass in 1983, and fertilizing in fall previous to measurement, Pathlow pasture, east-central Saskatchewan.

Year	Smooth Bromegrass		Creeping Red Fescue		Kentucky Bluegrass		Crested Wheatgrass		Annual+ Biennial Forbs		Perennial Forbs	
	(%)											
1982	40.6	(1.2)	17.3	(0.9)	13.0	(0.8)	-	-	0.0	(0.0)	2.8	(0.4)
1984	4.0	(0.5)	0.3	(0.1)	12.3	(0.9)	62.2	(1.3)	2.8	(0.5)	6.8	(0.7)
1988	14.2	(0.9)	0.2	(0.1)	24.2	(1.1)	40.2	(1.2)	0.4	(0.2)	1.2	(0.3)
1989	12.2	(0.6)	0.1	(0.1)	33.9	(0.9)	41.7	(1.0)	0.1	(0.1)	1.6	(0.2)

Table 10 Mean ground cover % (standard error) of major species before and after seeding meadow bromegrass in 1985 and fertilizing in fall previous to measurement, Pathlow pasture, east-central Saskatchewan.

Species	Year					
	1984		1988		1989	
	(%)					
Smooth bromegrass	33.9	(1.1)	27.9	(1.4)	22.4	(0.8)
Creeping red fescue	21.0	(0.9)	7.7	(0.8)	7.1	(0.5)
Kentucky bluegrass	14.7	(0.8)	19.4	(1.2)	25.5	(0.9)
Alfalfa	2.6	(0.4)	3.6	(0.6)	1.2	(0.2)
Meadow bromegrass	—	—	20.0	(1.1)	26.7	(0.9)
Annual + biennial forbs	0.1	(0.1)	1.0	(0.3)	0.2	(0.1)
Perennial forbs	4.3	(0.5)	3.8	(0.6)	2.8	(0.3)

Species responses to continuous grazing

The greatest change in these paddocks was the major increase in perennials, mainly low-growing *Antennaria* spp. Perhaps the vegetation was on the edge of a "threshold" to a lower stability point as alluded to by Looman (1980). Although bromegrass ground cover remained the same as at the start, decline of creeping red fescue and alfalfa, and increase in unproductive perennials suggests that the areas were overgrazed (Looman 1976). However, McCartney et al. (1999) reported that dry matter yields in the continuously grazed paddocks averaged over the 13-year period, were comparable to those in an adjacent field in the community pasture, grazed in some years only in late summer.

Species responses in the fertilized 4-field rotation

The increase of smooth bromegrass ground cover was probably a result of improved fertility more than rotational grazing. Fertilizing smooth bromegrass increases both the proportion of leafy tillers and their size (Waddington 1968).

Alfalfa ground cover increased during a period of average to above average precipitation. Its later reduction shows that rotational grazing does not guarantee its continued presence, contrary to the report of Walton et al. (1981). Perhaps competitive success of alfalfa depends on a water supply at depth which is replenished at intervals by higher than normal precipitation or by ground water infiltration from elsewhere, similar to many rangeland shrubs (Looman 1983). Also, previous work in the same climate zone (Cooke et al. 1965, Walton et al. 1981) was conducted on better-quality soils. The apparent response of alfalfa to weather- or soil- related factors rather than management changes suggests that problems in retaining it in pastures lie as much in its characteristics as in the treatments applied.

The most striking feature of change was the replacement of creeping red fescue by Kentucky bluegrass as the principal understory grass. This replacement was likely caused by the improved fertility conditions which are more favourable to Kentucky bluegrass than to creeping red fescue (Elliott and Baenziger 1977). Kentucky bluegrass is a major component of many pastures in the central and northern parts of the prairie provinces (Looman 1976). Its minor status initially in the present case is probably due to the inclusion of creeping red fescue when seeded in the mid-1960s, followed by a rapid decline in fertility. It has also been observed that creeping red fescue growth is poorer with low light levels (Dobb and Elliott 1964) which it would have received after 1975 because of the increased vigour of bromegrass.

Species responses in the 6-field rotation

The choice of Russian wildrye to extend the grazing season in both spring and fall was based on the success of Cooke et al (1973). Russian wildrye seedlings are small, slow-growing, and difficult to establish (Smoliak et al 1970). Shading by the oat companion crop during the establishment year probably increased the difficulty. All the species previously present except for alfalfa re-established along with the wildrye, and the progression to dominance by smooth bromegrass with a Kentucky bluegrass understory proceeded perhaps slightly faster than in the other paddocks. Russian wildrye survived only on the dry knolls, probably because of greater drought tolerance than bromegrass and bluegrass. It was also observed to be growing successfully in paddocks where it was not seeded, on soil heaps formed from the remnants of trees, roots, and soil piled and burned during pasture establishment in the mid-sixties. It was able to establish when these heaps of rich, relatively dry topsoil had bare patches due to the activities of bulls. It appears that Russian wildrye is not adapted to low-fertility soils in the parkland zone, in contrast to its success in the same region on a fertile deep black soil after establishment on fallow (Cooke et al. 1973).

The use of cultivation and reseeding of smooth bromegrass and alfalfa to increase their contribution to the vegetation worked well in 1979, but less so in 1981 following a winter of low precipitation. In general, the effects merely accelerated or accentuated changes in the grasses that were already taking place, and delayed the decline in alfalfa that was evident in other paddocks.

Crested wheatgrass is a competitive caespitose grass that is easily established (Smoliak et al. 1970) and can be grazed earlier in spring than smooth bromegrass (Cooke et al. 1973). Although in the year following seeding it dominated the vegetation in our study, by 1989, the pre-seeding vegetation had re-established dominance in ground cover. This suggests that crested wheatgrass pastures in northeastern Saskatchewan are unlikely to be as stable as those observed by Looman and Heinrichs (1973) in the southwest of the province.

Meadow bromegrass has better regrowth potential than smooth brome (Beacom 1991), and was intended to replace creeping red fescue for late

summer grazing. It did not establish well in 1985, nor did the alfalfa seeded with it, in spite of precipitation during the establishment period being well above the long-term average. Competition from inadequately-controlled resident vegetation is the probable reason.

Cultivating in summer did not rid a paddock of all resident vegetation prior to seeding new species the following spring. Although alfalfa and creeping red fescue were effectively removed, bromegrass was not. The concurrent invasion by Kentucky bluegrass has parallels in the invasions of crested wheatgrass into Russian wildrye and meadow bromegrass pastures in a semi-arid location at Swift Current (Holt, pers. commun.), about 500 km southwest of the experimental site.

Differences between paddocks in proportions of the various plant species remained throughout the experimental period and are considered a result of the uniqueness of each paddock. The rapid response to changes in management, particularly of the rhizomatous grasses, suggests that changes in the relative proportions of pasture species are permanent only so long as the management changes are permanent. Pastures used for extensive grazing, and intended to be truly permanent, not part of a rotation with annual crops, should be managed by considering ecological principles rather than agronomic practices, even though the desired species are introduced rather than native. In particular, it seems unnecessary to cultivate and reseed to improve the proportion of smooth brome and alfalfa, because there was little benefit beyond that achieved by applying fertilizer and grazing rotationally. It seems probable that the use of caespitose grasses such as crested wheatgrass and Russian wildrye, and even of less aggressively-spreading rhizomatous grasses such as meadow bromegrass will require their reseeding from time to time if they are to be used to lengthen the grazing season in the parkland area of western Canada.

Conclusions

1) Increasing pasture fertility and changing from continuous to rotational grazing increased smooth bromegrass ground cover, replaced creeping red fescue with Kentucky bluegrass as the principal understory grass, and had little effect on the minor components alfalfa and other broadleaved species.

2) Cutlivation in summer and seeding with different species the following spring did not allow enough time to fully control all species in the resident vegetation. Smooth bromegrass and Kentucky bluegrass reestablished and sometimes replaced the seeded species within a few years. Forbs in quantity were ephemeral, and declined to low levels without specific control measures.

3) The rapid responses of the pasture components to changes in management and weather demonstrate the dynamic nature of their interrelationships. Permanent changes in vegetation require permanent changes in management and the use of species which are adapted to soil, climate and the pasture management used.

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