

**Determining Optimum Seeding
Densities
of a Native Plant Mix
for Revegetation of Degraded Sites.**

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Objectives of this study:

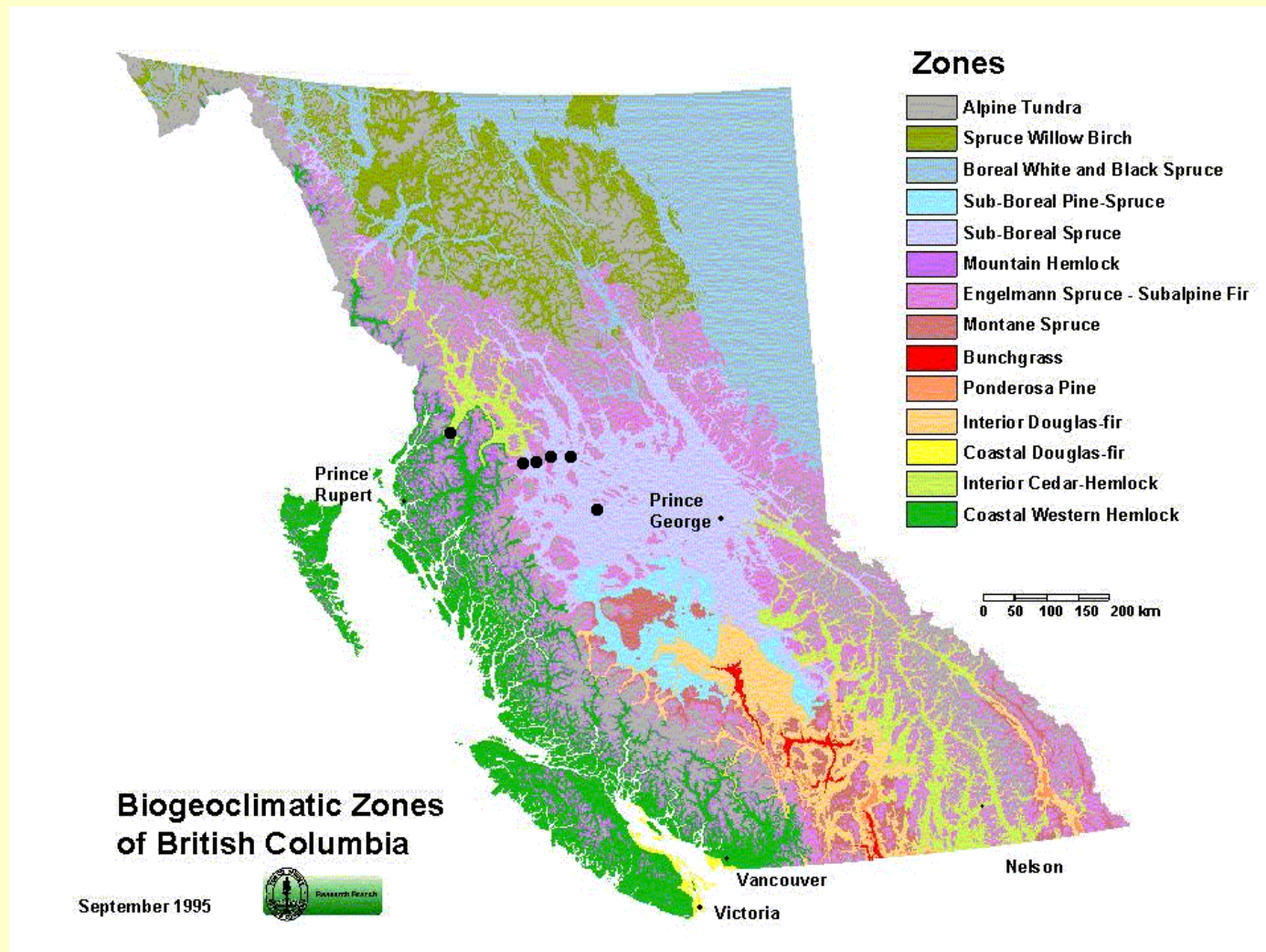
- To test different seeding densities with a standard mix of native herbaceous species.
- To test the effects of a single application of fertilizer on this mix.
- To compare the effectiveness of spring versus fall seeding on the establishment of the mix.
- To test the interaction of fertilization and the season of seeding on specific seeding densities.

Site Selection



-- Six replicate sites were chosen --

- All had little or no topsoil, & low nutrient levels.
- All were compacted by heavy machinery:
3 landings; 1 roadside; 1 log sort yard; 1 old field.



Six research sites were located in Northwestern B.C. at latitudes ranging from $54^{\circ}45'$ to $55^{\circ}12'$, at elevations ranging from 200 to 920 metres.

Plot Establishment

- At each site two 75m² sub-blocks were sown.
- One sub-block was sown in the fall and one sown in the spring.
- Each sub-block was divided into twelve 2.5 x 2.5 m plots (6.25m²) demarcated with all weather pink flagging, anchored into the ground with 20cm long metal spikes.

Plot Establishment



All sub-blocks were rototilled to a depth of 15 cm., just prior to seeding.

Species were selected based on:

- Their presence on disturbed areas in the north.
- The results of germination tests.
- The availability of seed.
- The desire to create a “balanced” seed mix consisting of:
 - fast and slow germinators,
 - plants of both small and medium stature,
 - a mixture of grasses, legumes and other herbaceous species.



Achillea millefolium



Elymus glaucus



Festuca occidentalis



Carex aenea



Geum macrophyllum



Lupinus polyphyllus

Species used in the seed mix

Seeding Densities Selected

- 0 PLS/m²
- 375 PLS/m²
- 750 PLS/m²
- 1500 PLS/m²
- 3000 PLS/m²
- 6000 PLS/m²

Pure Live Seed (PLS) =
Number of Seeds x % germination x % purity

Fertilization Treatment

In each sub-block, immediately after sowing, 184.5 g of 18-18-18 (NPK) chemical fertilizer was applied in 1 of 2 plots of each density.

Season of Seeding Treatment

Seasonal treatments were:

fall seeding –vs spring seeding.



Sowing seed and applying fertilizer



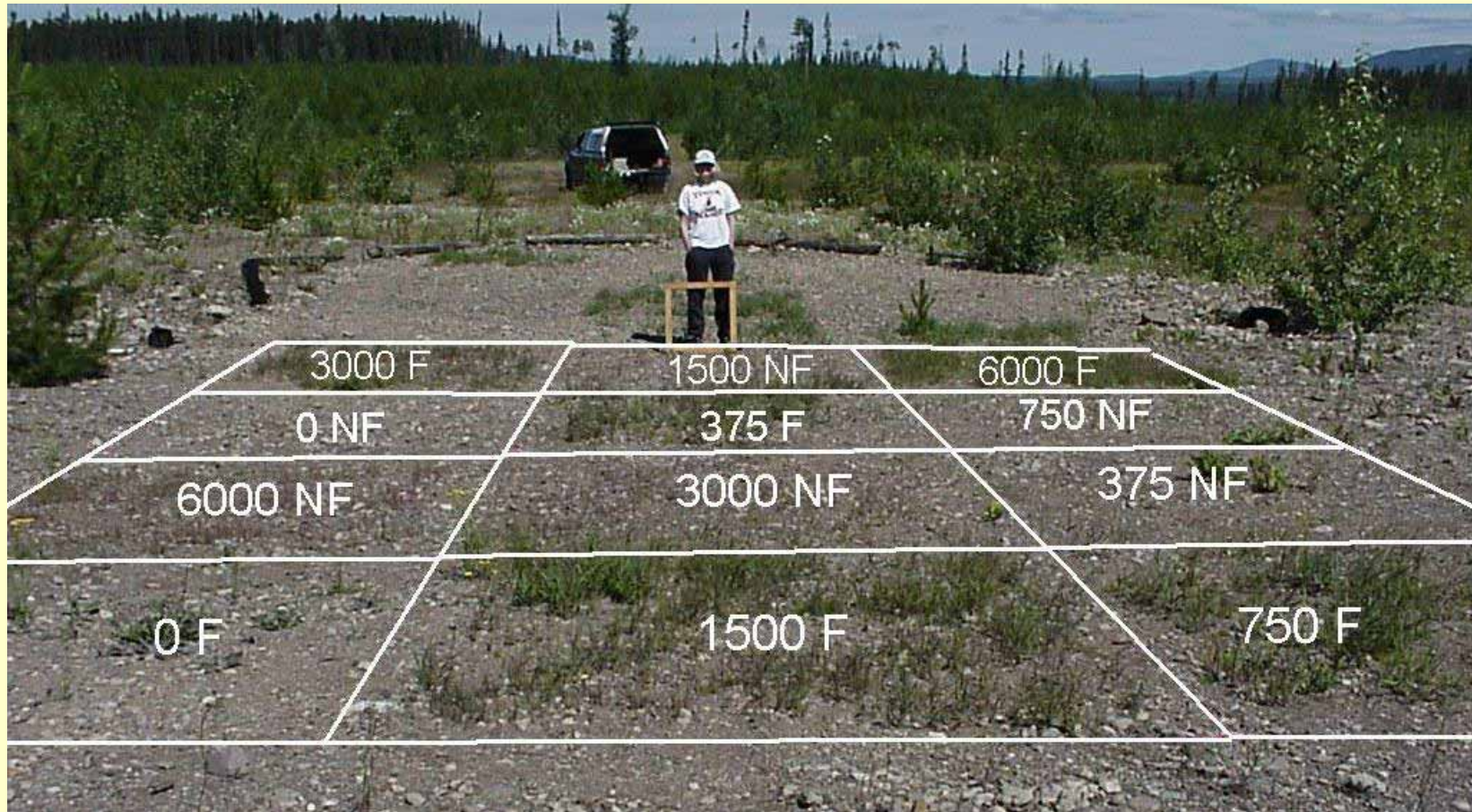
Plots were lightly raked after density treatments and fertilizer treatments were applied.

Typical site layout

Plot 1 6000 F fall	Plot 4 750 NF fall	Plot 7 375 NF fall	Plot 10 750 F fall	Plot 13 Control F spring	Plot 16 3000 NF spring	Plot 19 Control NF spring	Plot 22 1500 F spring
Plot 2 1500 NF fall	Plot 5 375 F fall	Plot 8 3000 NF fall	Plot 11 1500 F fall	Plot 14 750 NF spring	Plot 17 375 F spring	Plot 20 3000 F spring	Plot 23 750 F spring
Plot 3 3000 F fall	Plot 6 Control NF fall	Plot 9 6000 NF fall	Plot 12 Control F fall	Plot 15 6000 F spring	Plot 18 1500 NF spring	Plot 21 6000 NF spring	Plot 24 375 NF spring

↑N

2.5 m



Plot layout of one sub-block.



Each plot was monitored for plant count and cover at three randomly selected spots in each plot using a 0.25m^2 quadrat (averaged per plot prior to statistical analysis).

Time span of study

- Fall plots were established in late September and October 1999.
- Spring plots were established in early June 2000.
- All plots were monitored for plant count and cover in September 2000.
- All plots were monitored again in late August 2001.
- All plots were monitored again in late August 2002 (data not reported here).

Dependent variables

- **Percent cover (sown, exotic, native volunteers, total)**
- **Plant count (per 0.25m² quadrat)**
- **Percent emergence (count x 4/PLS x 100)**
- **Plant vigour (cm² of cover per plant)**

Anova design

Source of Variation

Error Term

Location(="blocks", replicates), $n=6$

Main Plot Effects

density, $d=6$

fertilizer, $f=2$

density x fertilizer

Strip-plot or Sub-Block Effects

Season of seeding $s=2$

Season x density

Season x fertilizer

Season x density x fertilizer

$n \times d \times f$

$n \times d \times f$

$n \times d \times f$

$n \times s$

$n \times d \times f \times s$

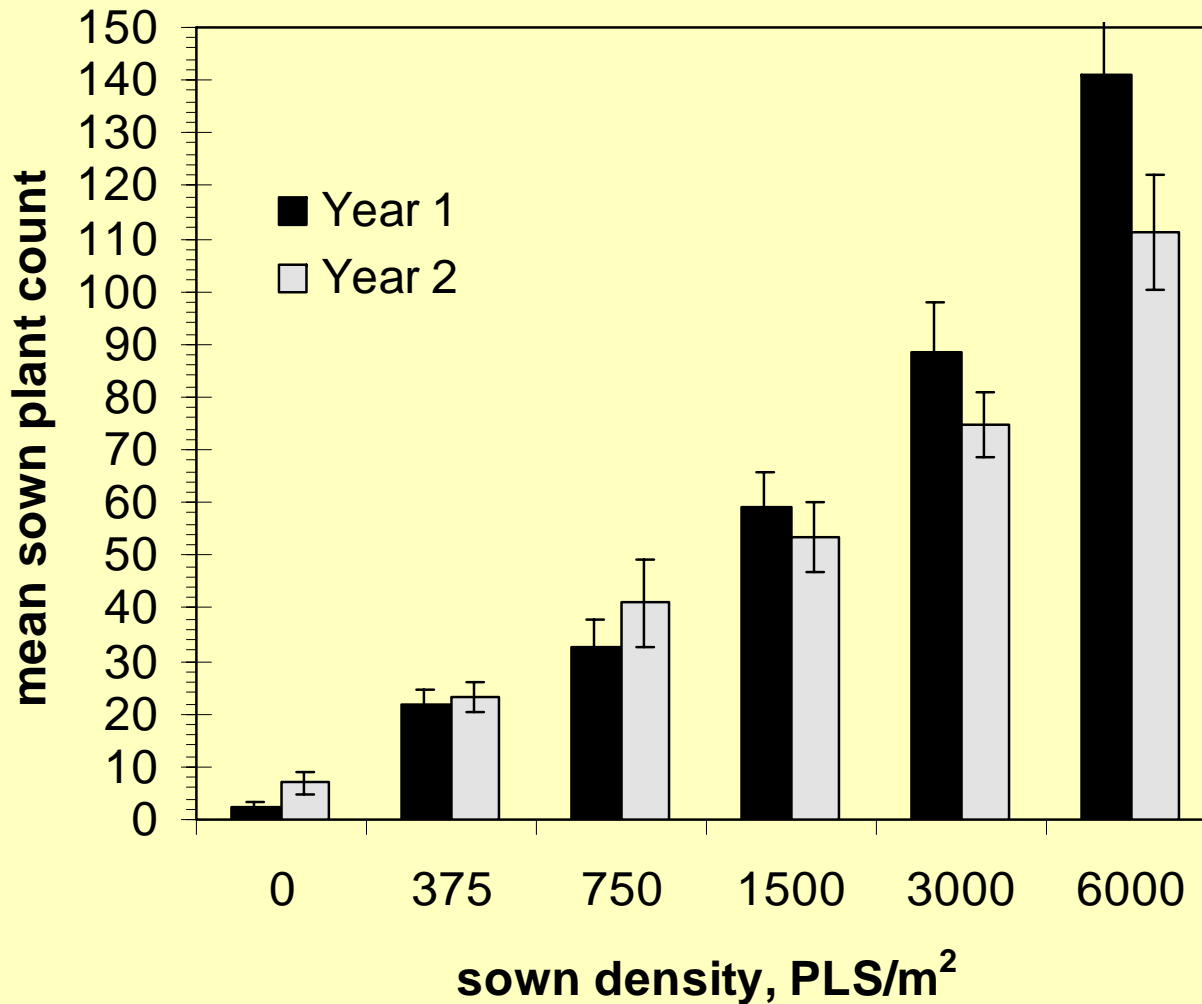
$n \times d \times f \times s$

$n \times d \times f \times s$

Seedling emergence

<i>Elymus glaucus</i>	32.7%
<i>Lupinus polyphyllus</i>	31.2%
<i>Festuca occidentalis</i>	26.4%
<i>Achillea millefolium</i>	8.5%
<i>Geum macrophyllum</i>	6.5%
<u><i>Carex aenea</i></u>	<u>0.7%</u>
Overall average:	15.9%

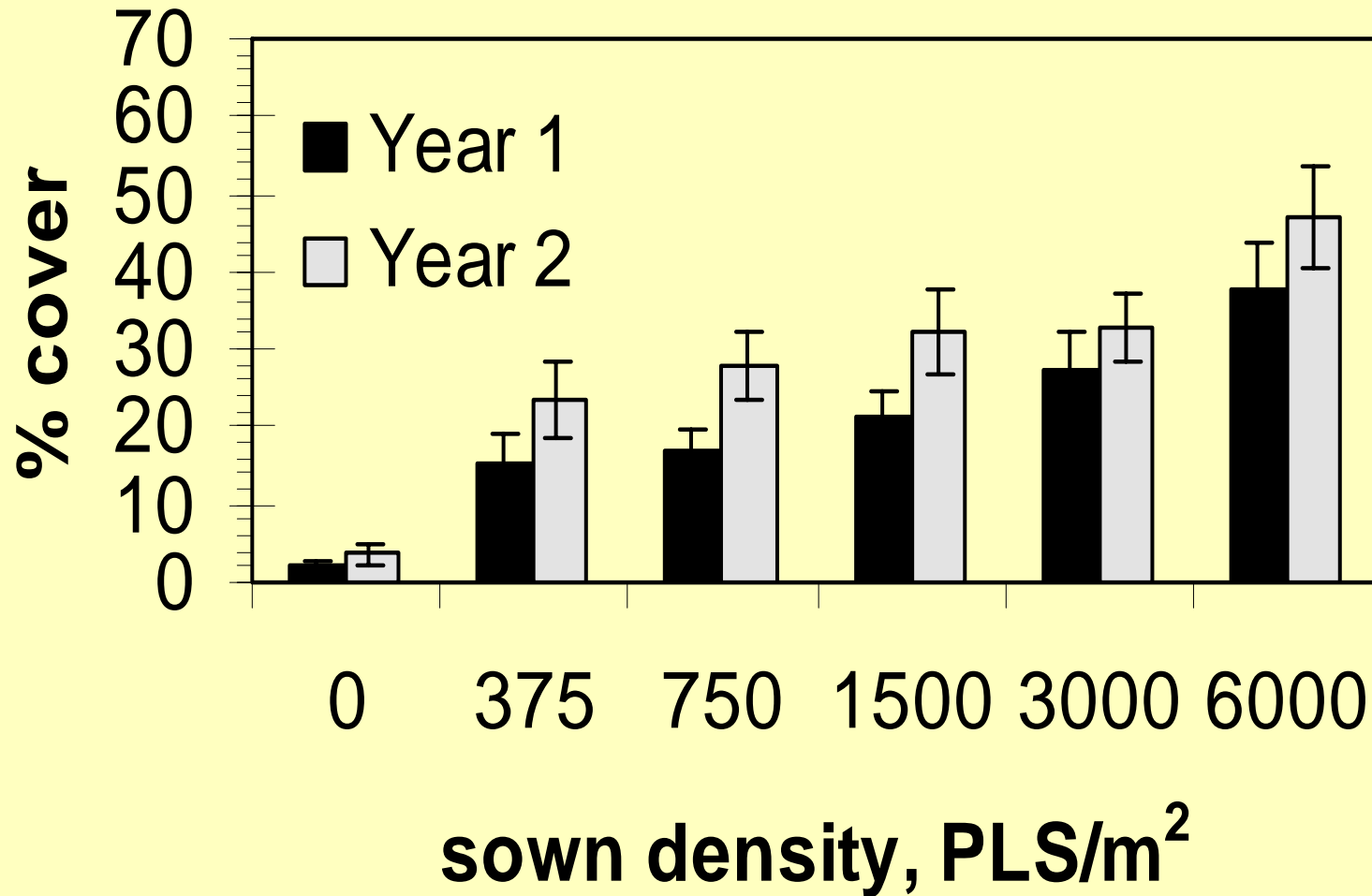
Overall effect of seed density on plant count

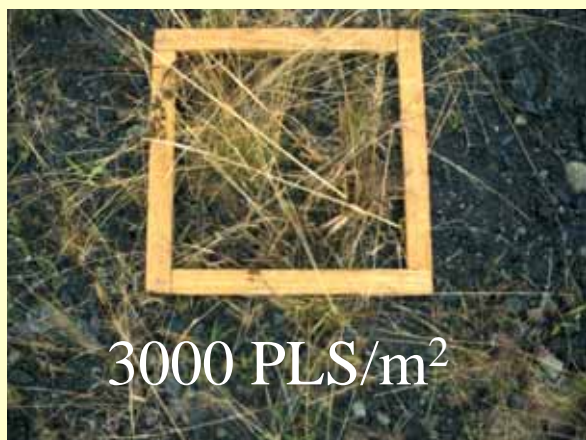
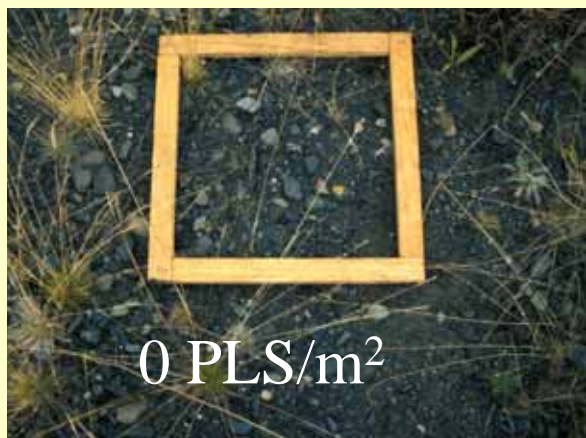


Sown plant count results

- Mean sown count was highest in the fall fertilized 6000 PLS/m² treatment in Year 1.
- By Year 2, sown count was still increasing at the lower densities but decreasing at the higher densities.
(Self-thinning??)

Effect of density on sown cover

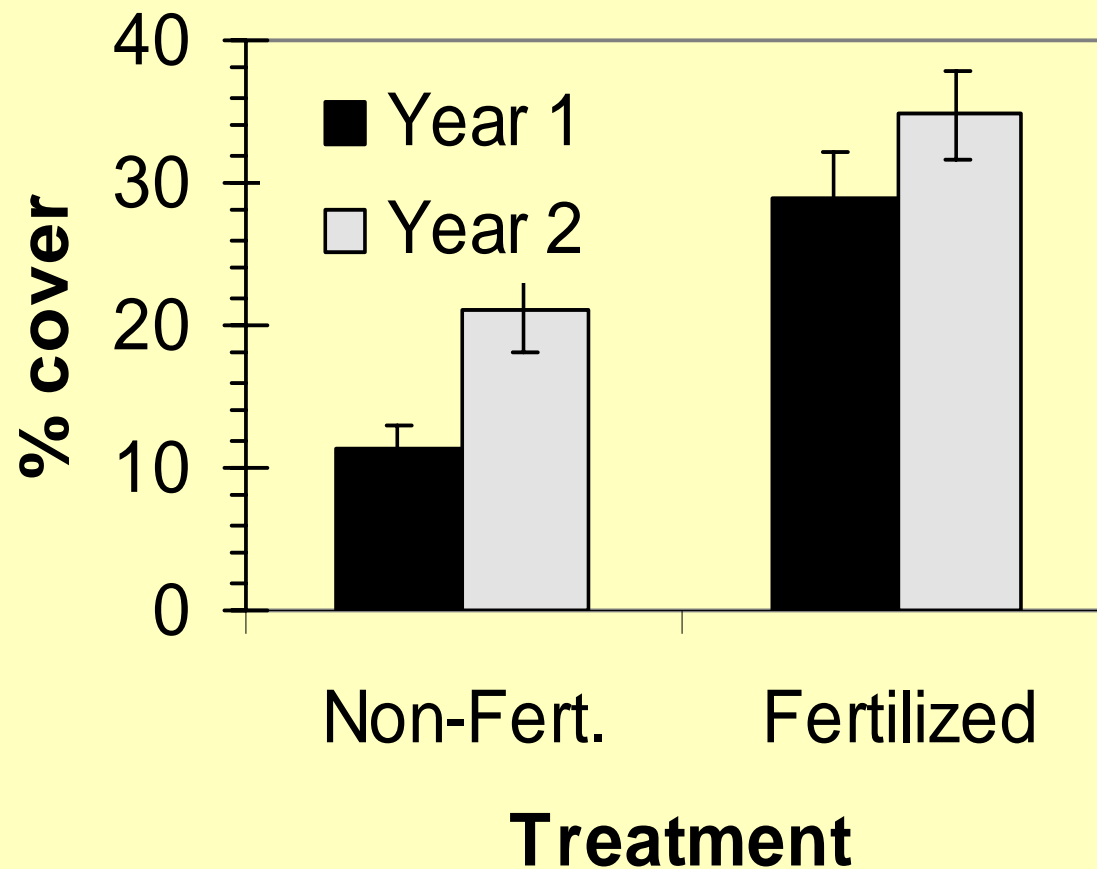




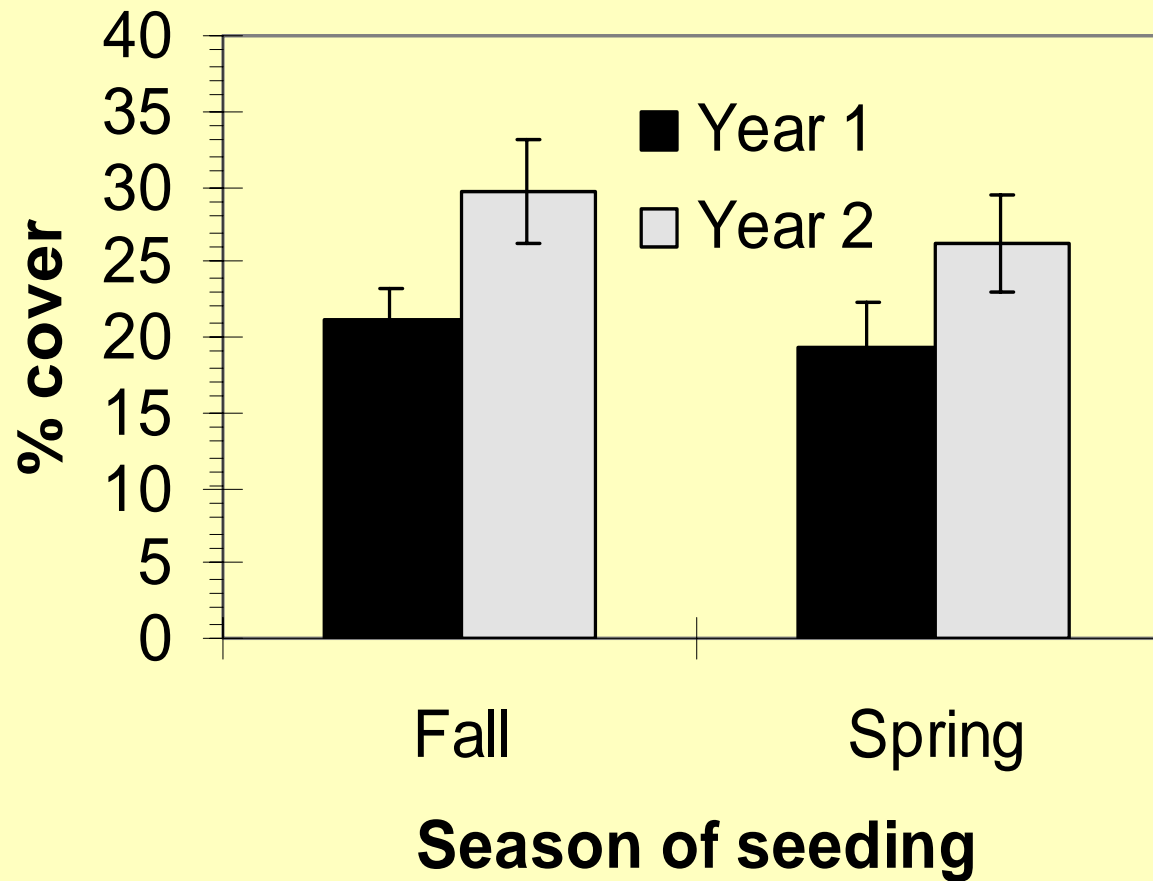
Year 2
Nass
fertilized

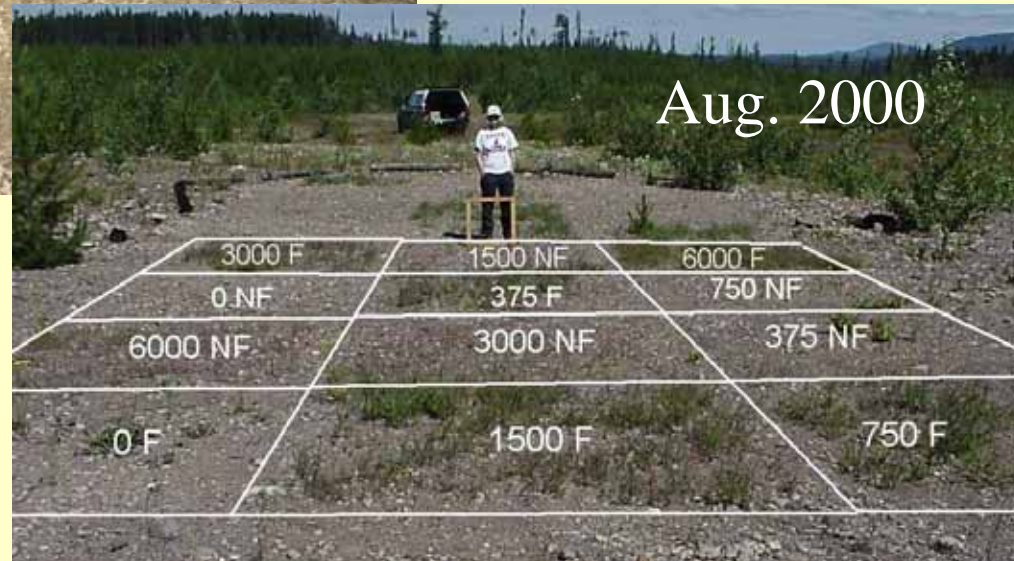


Effect of fertilizer on sown cover



Effect of season of seeding on sown cover

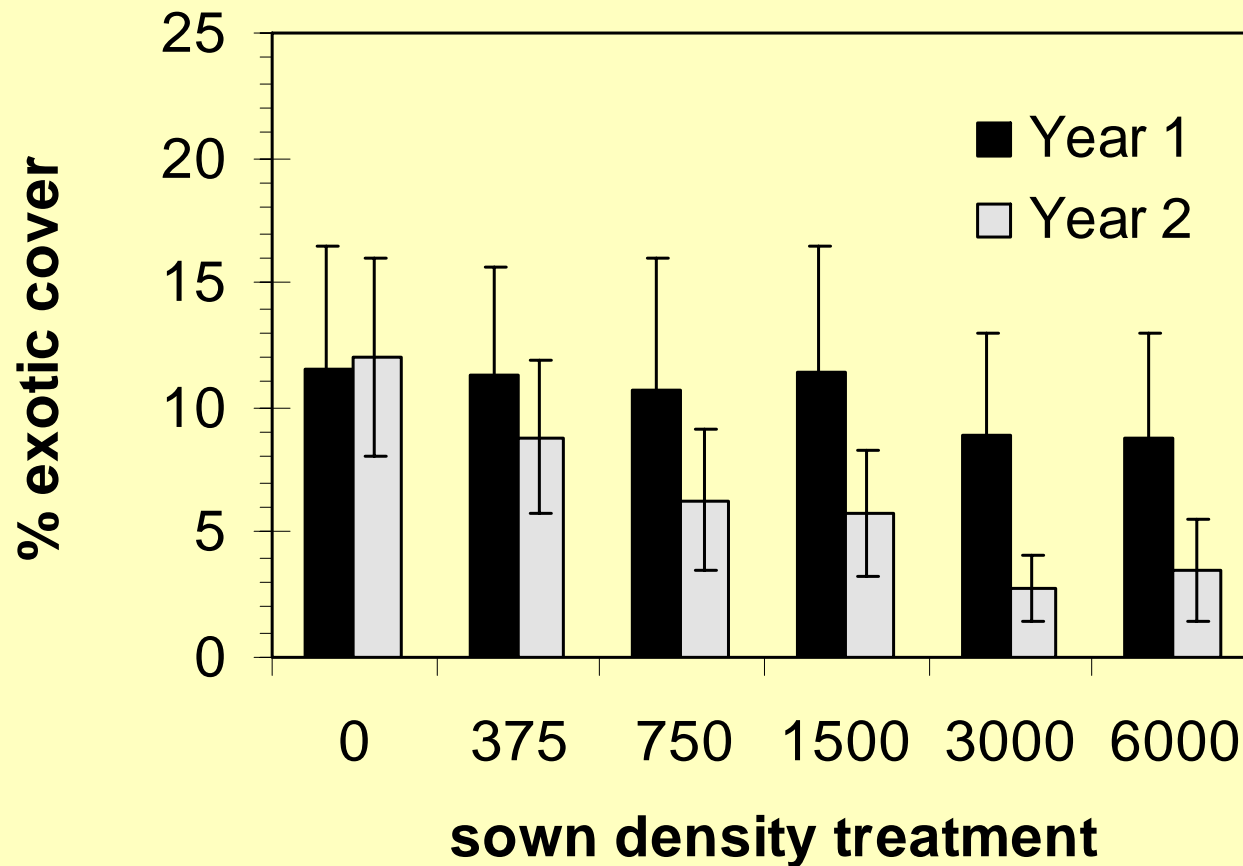




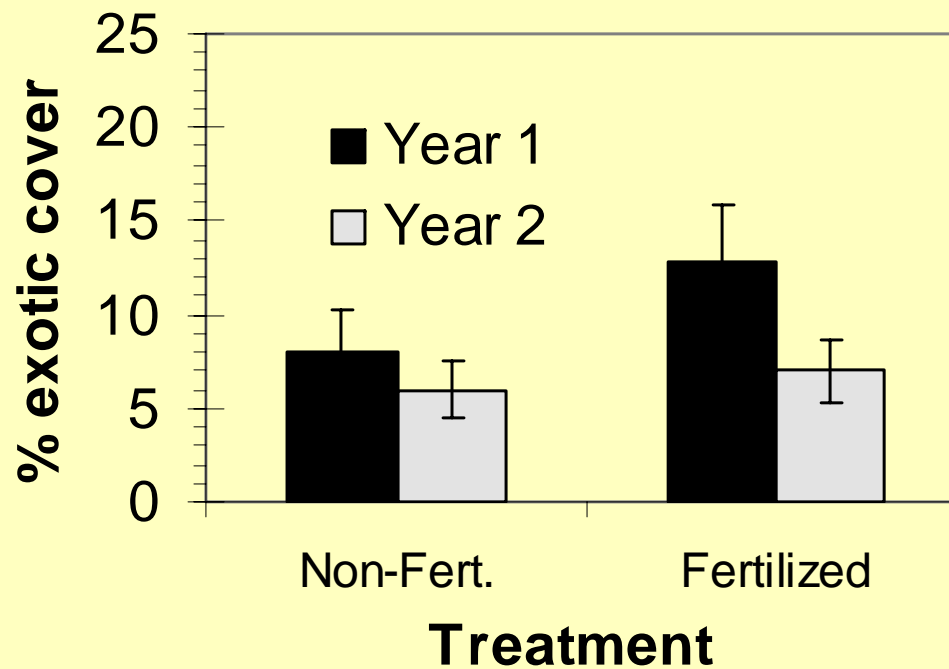
Pictorial
progression of
cover
establishment



Effect of density treatments on exotic cover



Effect of fertilizer treatments on exotic cover



Conclusions and Recommendations

- With fertilizer, adequate cover is achievable with 3000 PLS/m² in the first year, but if you can wait (e.g. level ground), densities as low as 375 PLS/m² can provide adequate cover.
- Fertilizer should be used when establishing native plants from seed on degraded sites; a single application when sowing can be beneficial for at least two years.
- Season of seeding does not affect cover establishment.
- There were no significant treatment interactions.

Conclusions and Recommendations

- There may be a thinning effect on plants at densities of 1500 to 6000 PLS/m² after two growing seasons.
- Sowing native seed at high densities may inhibit the growth of exotic species by the second growing season.
- The impact of fertilizer on exotic species may be short-lived since fertilizer increased the growth of exotic species in Year 1, but by Year 2 exotic cover began to decline.

Further Work

- Density dependent studies, following analysis of third year of monitoring.
- Long term trends in community composition.
- Refining the mixture of native species to be used for revegetation.
- The need for new trials to test a range of fertilization rates.

Thanks to :

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- **My advisors Nancy Turner, Richard Hebda, and Paul West, who allowed me to explore my ideas relatively freely.**
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- **Harvard Forest, for access to their library, office space and use of computer equipment.**
- **Friends here who offered valuable suggestions.**

Soil analysis of six replicate sites

Table 7: Summary of soil analysis						
Attribute	Location					
	Viewmount	Francois	Ptarmigan	Chapman	McKendrick	Nass
Texture (determined by hand)	loam	clay loam	loam	sandy loam	sandy loam	gravelly sandy loam
Nitrogen, ppm	3.00 ^d	<1 ^d	3.50 ^d	<1 ^d	<1 ^d	<1 ^d
Phosphorus, ppm	13.50 ^m	>60 ^o	5.75 ^d	38.00 ^o	2.50 ^d	59.00 ^o
Potassium, ppm	72.00 ^d	163.5 ^m	63.50 ^d	71.00 ^d	39.50 ^d	52.50 ^d
Sulphate	10.00 ^o	4,50 ^o	4.00 ^m	4.00 ^m	5.00 ^m	2.00 ^m
pH	6.4 ⁿ	6.4 ⁿ	5.9 ^a	5.9 ^a	6.7 ⁿ	5.6 ^a
Electrical conductivity	0.21 ^g	0.09 ^g	0.15 ^g	0.09 ^g	0.12 ^g	0.10 ^g
Organic Matter %	7.90 ^{hn}	1.82 [*]	2.55 ^{ln}	8.50 ^{hn}	4.80 ⁿ	8.80 ^h
d = deficient m = marginal o = optimum						
n = neutral a = acidic						
g = good h = high hn = high normal ln = low normal						
*Francois spring low /normal, Francois fall - deficient averaged to low						

Weather table

Table 10. Comparison of annual weather conditions with 30 year normals for Environment Canada weather stations closest to the study sites.												
Climatic Attribute	Nass				Smithers				Wisteria			
	30yr	1999	2000	2001	30yr	1999	2000	2001	30yr	1999	2000	2001
Spring (Apr-May)												
Maximum Temp.	12	11.7	13.7	12.2	12.8	11.5	12.3	11.6	10.0	9.1	10.1	9.0
Minimum Tem.	0.3	1.6	1.9	0.8	0.2	-0.2	0.1	-0.3	-1.4	-2.4	-2.1	-2.1
Mean Temp.	6.2	6.7	7.8	6.5	6.5	5.6	6.2	5.7	2.9	3.3	4.0	3.5
Precipitation (mm)	95	141.8	88.0	82.5	52.0	84.6	48.2	71.6	51.0	43.2	57.8	45.4
Summer (Jun-Aug)												
Maximum Temp.	19.2	20.0	¹ 19.7	18.9	20.4	19.5	20.2	18.8	18.0	17.4	18.1	18.0
Minimum Tem.	7.3	9.0	¹ 9.6	8.9	6.9	7.5	7.7	7.2	5.8	6.6	6.0	5.6
Mean Temp.	13.3	14.5	¹ 14.5	13.9	13.7	13.5	13.9	13.0	11.9	11.7	12.4	11.8
Precipitation (mm)	195	233.6	¹ 76	173.2	133.0	210.4	118.0	175.4	133.0	184.4	119.6	121.4
Yearly (Jan-Dec)												
Maximum Temp.	8.5	² 10.1	³ 10.1	⁴ 10.4	9.0	9.3	8.9	8.6	7.2	8.5	⁵ 8.8	⁶ 9.4
Minimum Tem.	-0.9	² 1.5	³ 0.7	⁴ 1.6	-1.8	-0.8	-1.2	-1.2	-3.0	-1.7	⁵ -1.8	⁶ -1.4
Mean Temp.	3.8	² 5.8	³ 5.4	⁴ 6.0	3.6	4.2	3.9	3.7	2.1	3.4	⁵ 3.5	⁶ 4.0
Precipitation (mm)	1156	² 899.2	³ 734.9	⁴ 615.0	516.0	501.4	419.6	526.8	511.0	476.5	⁵ 338.4	⁶ 267.8
¹ =Data missing for Aug				⁴ =Data missing for Dec								
² =Data missing for Oct				⁵ =Data missing for Dec								
³ =Data missing for Aug, Oct, Dec				⁶ =Data mssing for Nov, Dec								

Total plant cover after two growing seasons

Table 11. Total plant cover after two growing seasons under all treatment combinations.

		Plant Cover, %								
Season		Sown	Sown Sp.		Exotic Sp.		Native Volunteer		All Spp.	
Sown	Fertilization	Density	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Fall	Fertilized	0	9.7	10.5	14.5	28.7	6.2	6.3	30.4	25.0
		375	30.0	35.8	15.6	20.6	9.2	14.2	54.8	44.7
		750	36.8	17.1	7.2	15.9	3.3	3.0	47.3	26.9
		1500	41.7	27.2	4.3	9.9	2.3	2.7	48.3	28.5
		3000	41.9	17.5	2.8	4.5	1.1	1.5	45.9	20.0
		6000	57.2	22.4	7.8	19.0	1.3	1.3	66.3	32.9
	Non-Fert.	0	4.6	5.7	9.8	20.9	13.2	24.0	27.6	32.1
		375	25.7	24.7	7.2	15.3	9.6	19.3	42.4	45.4
		750	28.9	30.8	7.8	18.9	2.7	4.3	39.4	43.6
		1500	27.0	26.4	5.6	12.0	3.7	4.3	36.4	31.3
		3000	20.3	23.4	4.6	11.1	0.8	0.5	25.6	33.7
		6000	32.6	32.9	2.0	3.9	2.0	3.2	36.6	36.5
Spring	Fertilized	0	0.2	0.3	13.2	16.8	7.6	7.8	21.0	14.4
		375	23.2	15.7	6.4	9.3	1.7	2.1	31.3	16.0
		750	32.6	17.9	3.4	5.6	2.4	2.3	38.5	18.6
		1500	37.6	30.7	5.6	11.9	1.9	1.5	45.1	30.9
		3000	45.1	18.6	1.1	2.2	1.2	2.1	47.1	19.8
		6000	62.3	25.0	2.5	5.8	1.2	2.3	66.0	24.8
	Non-Fert.	0	0.2	0.2	10.7	14.8	6.9	8.7	17.7	14.2
		375	15.8	18.8	6.1	14.4	1.5	2.1	23.4	24.3
		750	13.7	14.0	6.7	15.7	1.6	2.4	22.0	24.2
		1500	22.6	27.9	7.6	17.7	1.3	1.6	31.6	36.3
		3000	24.4	21.6	2.4	5.7	0.7	0.5	27.6	25.8
		6000	36.0	42.1	1.7	3.4	0.7	1.0	38.3	43.2