MPERG Report 2006-3

Enhancing Natural Succession on Mine Tailings Sites in the Yukon Territory

By

Tom Hutchinson and Alison Clark

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MERG 2005 Interim Report

Enhancing Natural Succession on mine tailings sites in the Yukon Territory

Tom Hutchinson* and Alison Clark*

Project Objectives & Background

The overall objective of this study is to develop a low input approach for the revegetation of Yukon mine tailings sites. Low input approaches include planting directly into tailings; the use of hardy, climatically adapted species which have low nutritional requirements; and the use of plants tolerant to any metals or other potentially toxic substances which may be present. The intent is to use native plant species, which are found within the mine vicinity, or encroaching on the tailings themselves, for revegetation. To this end: 1) fewer inputs will be required as plants have already demonstrated tolerance to the harsh, if not toxic tailings conditions; 2) local genetics of native plants species could be used and therefore, genetic pools would be protected from the introduction of non-local and non-adapted genetic lines; and 3) the natural successional processes already in motion at the specific mine site will be enhanced.

To date site specific successional trajectories have been modelled for the three experimental mine sites. United Keno Hill, Mount Skukum, and Wellgreen. A number of populations of *Deschampsia caespitosa* (tufted hairgrass) from the Yukon and Ontario have been tested at each of the three experimental mine sites under different amendment treatments, as well as the metal tolerance of five populations of *Deschampsia caespitosa* from the Yukon has been screened and tested in the greenhouse at Trent University, Peterborough, Ontario. The results have been published in a previous MERG Report by Clark and Hutchinson (2005).

The modelling results demonstrated that natural succession on these tailings sites follow a trajectory of increased organic matter and litter/downed woody debris. Organic matter provides nutrients and increases the water holding capacity of the tailings. Organic matter also binds heavy metals. In turn, metals may become less available to plant roots, albeit several complex factors play a role in metals bioavailability. Downed woody debris and litter also enhance moisture retention, create shade, and eventually will decompose, providing nutrients and organic matter for plants. In addition, both organic matter (i.e. compost) and downed woody debris can capture wind blown seeds that may otherwise be blown across and off the open tailings. In summer 2005, therefore, this was field tested by placing patches of compost and downed woody debris in various non-vegetated locations throughout the tailings sites. Previously established revegetation plots were monitored and the colonization of these plots by additional plant species was also recorded as it has been in 2004 and 2005.

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Progress to Date

Field Study: Approaches

Revegetation Plots: refresher of previous methods

In June 2003, three mine sites in the Yukon Territory, Mount Skukum (MTSK), Wellgreen (WG), and United Keno Hill Mine (UKHM) were selected for experimentation from a large number of candidate sites as they provided a wide range in pH, tailings texture, latitude, and possessed various combinations and concentrations of heavy metals. Vegetation surveys were conducted on the tailings as well as at four additional abandoned mines in the Yukon (Mount Nansen, Faro, Arctic Gold and Silver, and Whitehorse Copper). Plant lists were compared and *Deschampsia caespitosa* (Tufted hairgrass) was selected for revegetation trials.

Experimental plots were established in the tailings during June 2003 at each site. Two blocks (replicates) were established for each treatment where each plot per treatment was approximately 1.5m by 1.5m in size. Plots were placed in an area with no existing vegetation at all three tailings sites. Four treatments were used at Mount Skukum and United Keno Hill Mine: 1) no amendments (untreated); 2) compost; 3) fertilizer; and 4) compost and fertilizer. Compost was acquired from the City of Whitehorse. Enough compost was added to plots to create a planting medium of at least 10cm deep around the root system of transplants. A commercial pellet 7-7-7 (NPK) slow release fertilizer was used and applied at manufacturers recommended rates: 15mL (~150kg/ha) around the rooting zone. Fertilizer was worked into the soil to a depth of 15cm. Due to the very acidic nature of the Wellgreen tailings an additional treatment of lime was used at this site only. Thus, the five treatments used at Wellgreen were: 1) no amendment; 2) lime; 3) lime and compost; 4) lime and fertilizer; and 5) lime, compost, and fertilizer. A commercial dolomite lime was used and applied at rate which in the short term corrected the pH from ~2.7 to ~5.5.

Healthy *D. caespitosa* transplants were collected from each mine site and planted reciprocally in each site for all treatments. Transplants were also collected from two uncontaminated sites Kluane Lake and Annie Lake Road. Each plot contained a minimum of four individual *D. caespitosa* plants from each population. In addition to the Yukon plant populations, three additional clonal populations of *Deschampsia caespitosa* from Ontario were brought to the Yukon and planted in plots (Coniston and O'Donnell Roast bed (RB), and Taylors).

A relative health scoring system for vegetative growth was created using plants with varying degrees of stress and/or necrosis as a standard. Plants were scored at the end of the first growing season (2003) and again at the end of summer 2004. The scoring system included presence and degree of chlorosis, die back, and the production of anthocyaneans. The vegetative scoring system was based on growth and visual health of the plants and is as follows: (0) dead; (1) poor growth with severe chlorosis and/or purpling and 3/4 die back; (2) better growth but with severe chlorosis and/or purpling and 1/2 die back; (3) moderate chlorosis and/or purpling, little die back; (4) new growth, healthy; (5) lush growth without visual chlorosis or anthocyanen production (purpling foliage). The number of individual flowering stalks produced was also recorded in early August.

Seed plots for *D. caespitosa* and *Shepherdia canadensis* (a nitrogen-fixing shrub) were established using the same design as the transplant plots. For untreated and fertilizer treatments, a $1m^2$ area was scarified with a trowel to create a seed bed. Two plots per treatment in separated blocks were produced, each containing 5 subplots (30cm X 30cm). For compost and mixed amendment treatments, four $1m^2$ plots were established (two plots per block) and 5cm of compost was added onto the tailings surface. In fertilizer and mixed plots, 7-7-7 (N-P-K: as available phosphoric acid and soluble potash) fertilizer was applied at a rate of 350kg/ha, a common rate for seeding practices in the north. Seeds were collected from a minimum of 30 individuals from each of the three Yukon test mine sites and from the Kluane reference site in August 2003. In each seed plot, 1g of *D. caespitosa* seed (approx. 2000 seeds) per population was planted on top of the tailings/soil surface. Thus, each population was replicated twice. In June 2004 the number of germinated seedlings in each 30cm X 30cm subplot was counted.

The presence and abundance of living voluntary colonizers, of other plant species, was documented. This assessment was done in each $1m^2$ transplant and seed plot for each treatment at all sites. Two $1m^2$ control plots where nothing was seeded and/or transplanted and no soil amendments were added, were also used to compare plant invasion. Plants were identified using Cody (2000). Because plots were placed in an area with no existing vegetation, the presence of other species can be assumed to have followed initial plot establishment. The average number of invaders per treatment (species pooled) at each site was calculated and number of colonizers and species richness was compared.

Plots of compost (obtained from the City of Whitehorse) and downed woody debris (collected from the tailings sites) were place in various non-vegetated locations at Wellgreen and United Keno Hill. The compost plots were established during the summer of 2004. Some of these plots were seeded with locally collected grass and forb seeds: others were left unseeded to assess whether wind blown seeds would be captured as well as to document the seeds contributed by the compost alone. The woody debris plots were set up in summer 2005. This is a long-term experiment and no data has been collected to date.

Field Study Results & Discussion

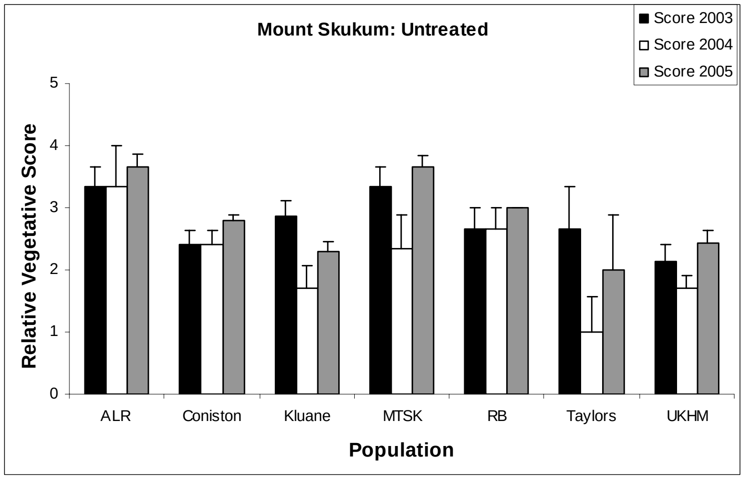
During the summer of 2004, transplanted and seeded plants suffered from the extreme heat and drought. Weather of summer 2005 was cooler and moister compared with 2004. While some plants made marked recoveries, few individuals or populations recovered to match their relative health scores of 2003. This, however, may also be due to an inability to tolerate the given climatic and/or environmental conditions presented by the mine tailings.

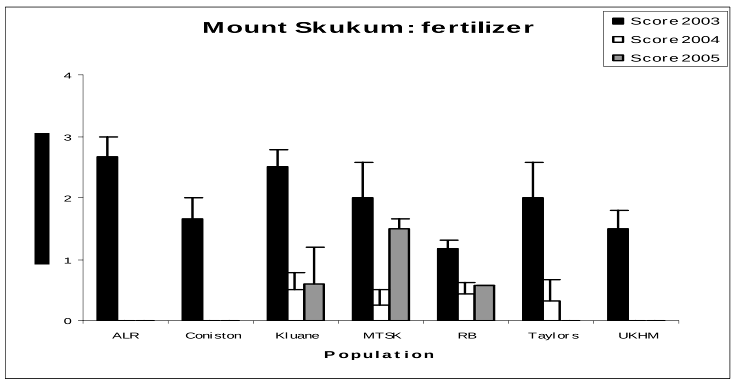
At Mount Skukum (MTSK), transplants in untreated plots performed the best, followed by the mixed amendment (compost and fertilizer) treatment. This is repeated from 2003 and 2004. The relative vegetative scores from all populations demonstrated an increase from 2004. In the fertilizer plots, plants which were still alive from the initial adverse fertilizer response also showed an increase in score, possibly due to a diminished fertilizer effect in the rooting zone.

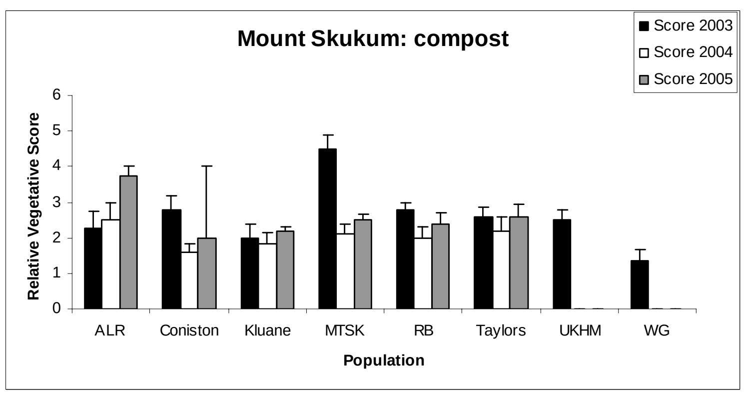
Overall, the two local populations from Annie Lake Road (ALR) and the MTSK tailings performed the best in all three years. The local nature of these populations suggest that they would be pre-adapted to the extreme dry conditions of the valley and the mineral nature of surrounding soils and tailings.

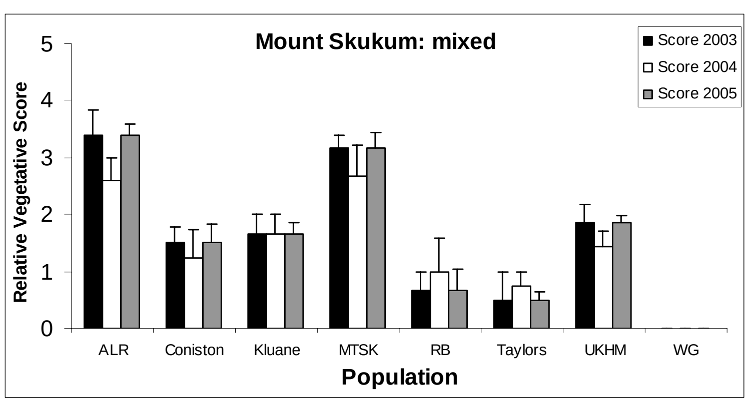
Transplants at Wellgreen (WG) have experienced many challenges. Snow melt and flooding has washed away much of the study area, including many of the plants, while heat and drought caused (or at least contributed to) severe stress. This stress was seen in the drastic reduction of scores from 2003 to 2004. Climatic stress, in addition to the great challenges presented by the tailings themselves (i.e. acidic pH, elevated nickel, copper, iron, manganese, low organic content, and iron hardpan), has been too taxing on many plants. Relative scores in 2005 were much reduced and many individuals were dead. All individuals transplanted during 2004 had died back by the end of the summer and none grew back during the 2005 growing season. Repeated from 2003 and 2004, the two local populations (Kluane and Wellgreen) as well as the two Sudbury populations (Coniston and Roast Bed (RB)) survived, produced flowers, and showed signs of improvement in 2005.

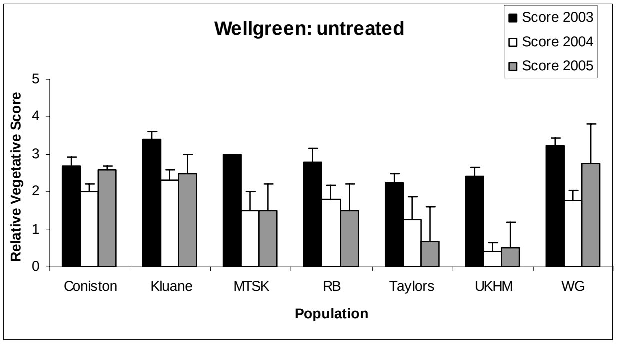
The transplant plots at United Keno Hill Mine (UKHM) have, overall, performed well and have produced many flowers. In 2005, transplants in the mixed amendment treatment had the highest performances. Population scores from 2005 demonstrated an increase from 2004. The local population, UKHM, as well as Mount Skukum and Annie Lake Road performed the best each year. Plants grown in the mixed amendment treatment performed the best. In 2004, plants in compost plots had a significantly greater vegetative score relative to those growing in untreated plots. In 2005, however, this was not the case.

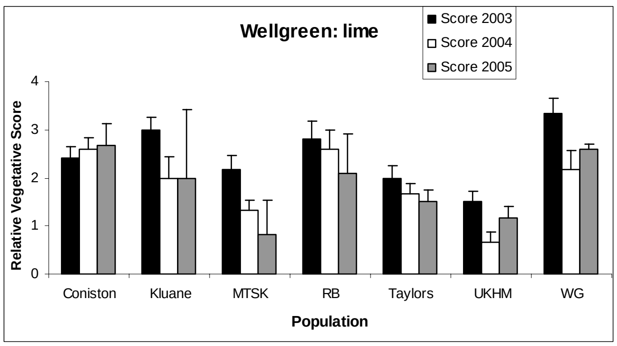

Mount Skukum: Untreated
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
0
1
2
3
4
5
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
Population

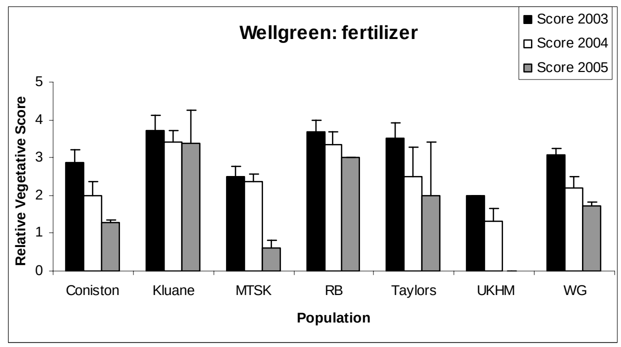

Mount Skukum: fertilizer
Score 2003
Score 2004
Score 2005
0
1
2
3
4
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
Population

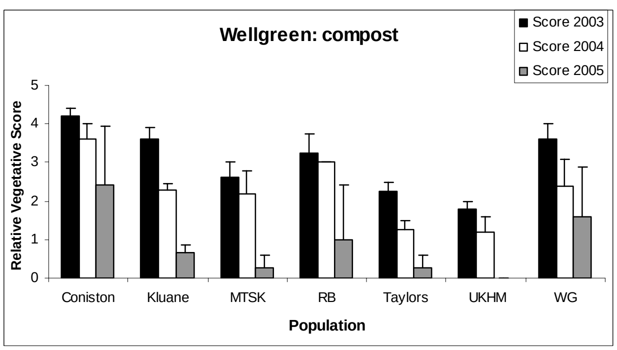

Mount Skukum: compost
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
0
1
2
3
4
5
6
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

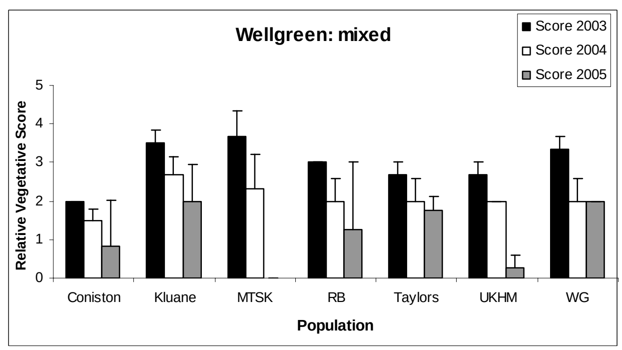

Mount Skukum: mixed
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
0
1
2
3
4
5
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

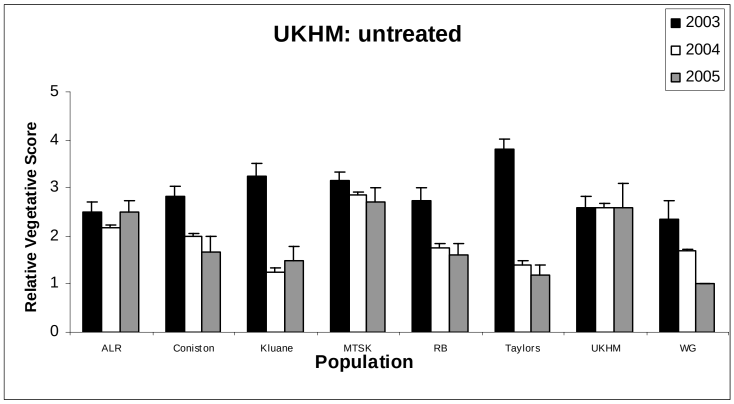

Wellgreen: untreated
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

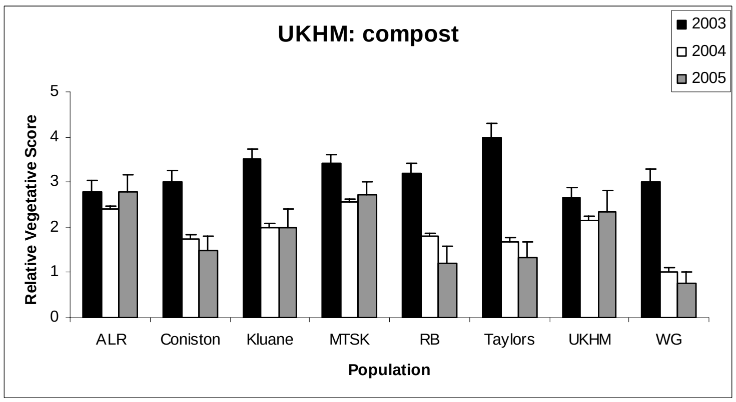

Wellgreen: lime
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

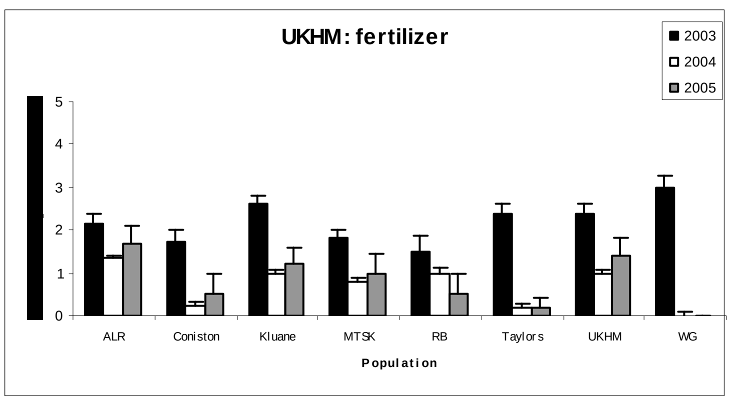

Wellgreen: fertilizer
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

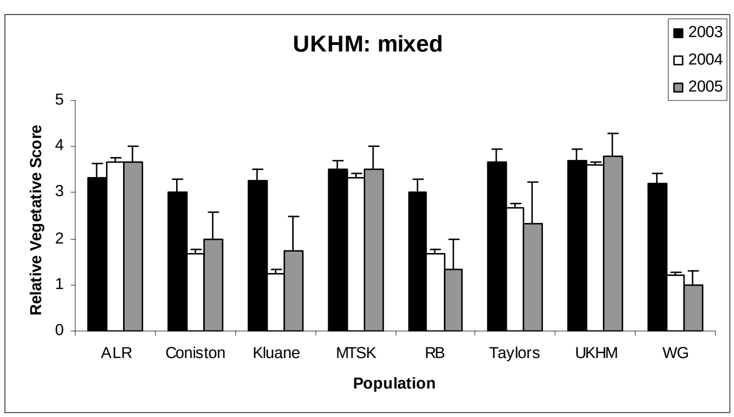

Wellgreen: compost
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population


Wellgreen: mixed
Score 2003
Score 2004
Score 2005
Relative Vegetative Score
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

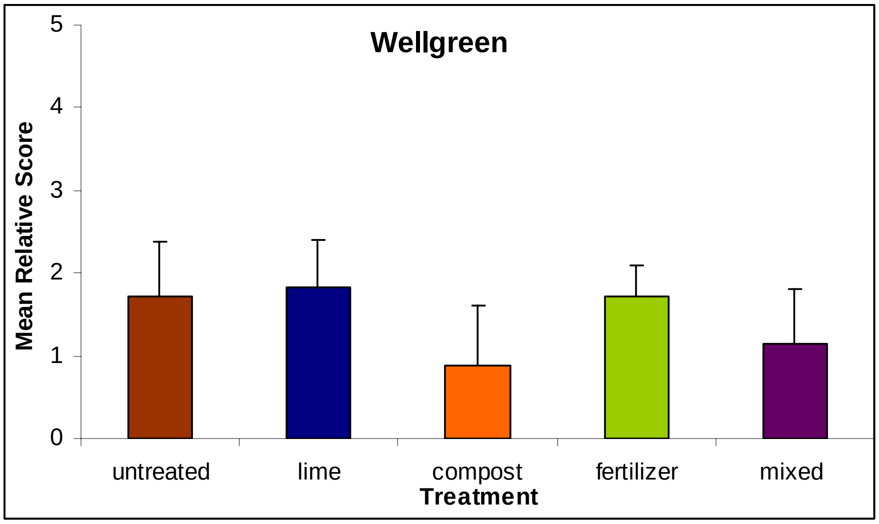

UKHM: untreated
2003
2004
2005
Relative Vegetative Score
0
1
2
3
4
5
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

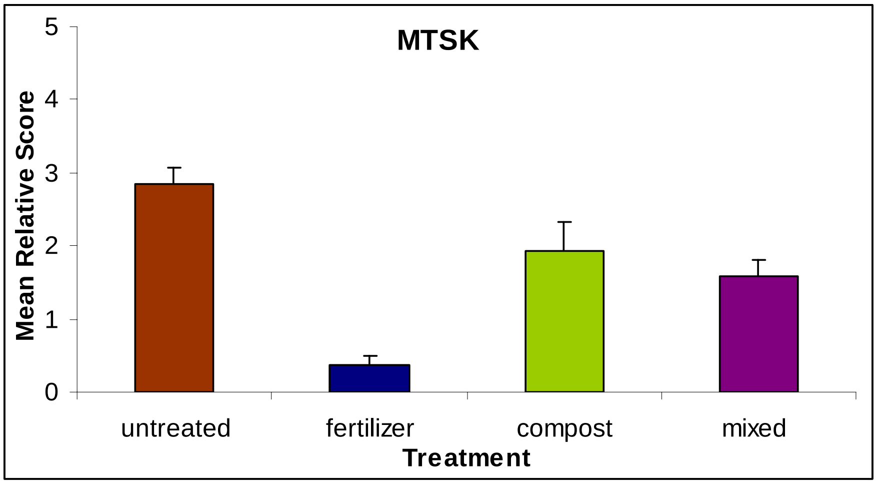

UKHM: compost
2003
2004
2005
Relative Vegetative Score
0
1
2
3
4
5
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

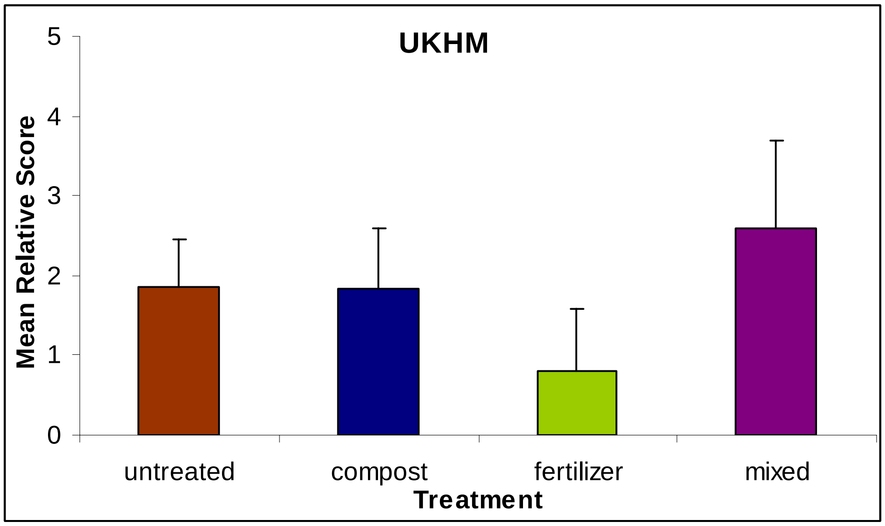

UKHM: fertilizer
2003
2004
2005
0
1
2
3
4
5
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population


UKHM: mixed
2003
2004
2005
Relative Vegetative Score
0
1
2
3
4
5
ALR
Coniston
Kluane
MTSK
RB
Taylors
UKHM
WG
Population

Success of transplants irrespective of population 2005

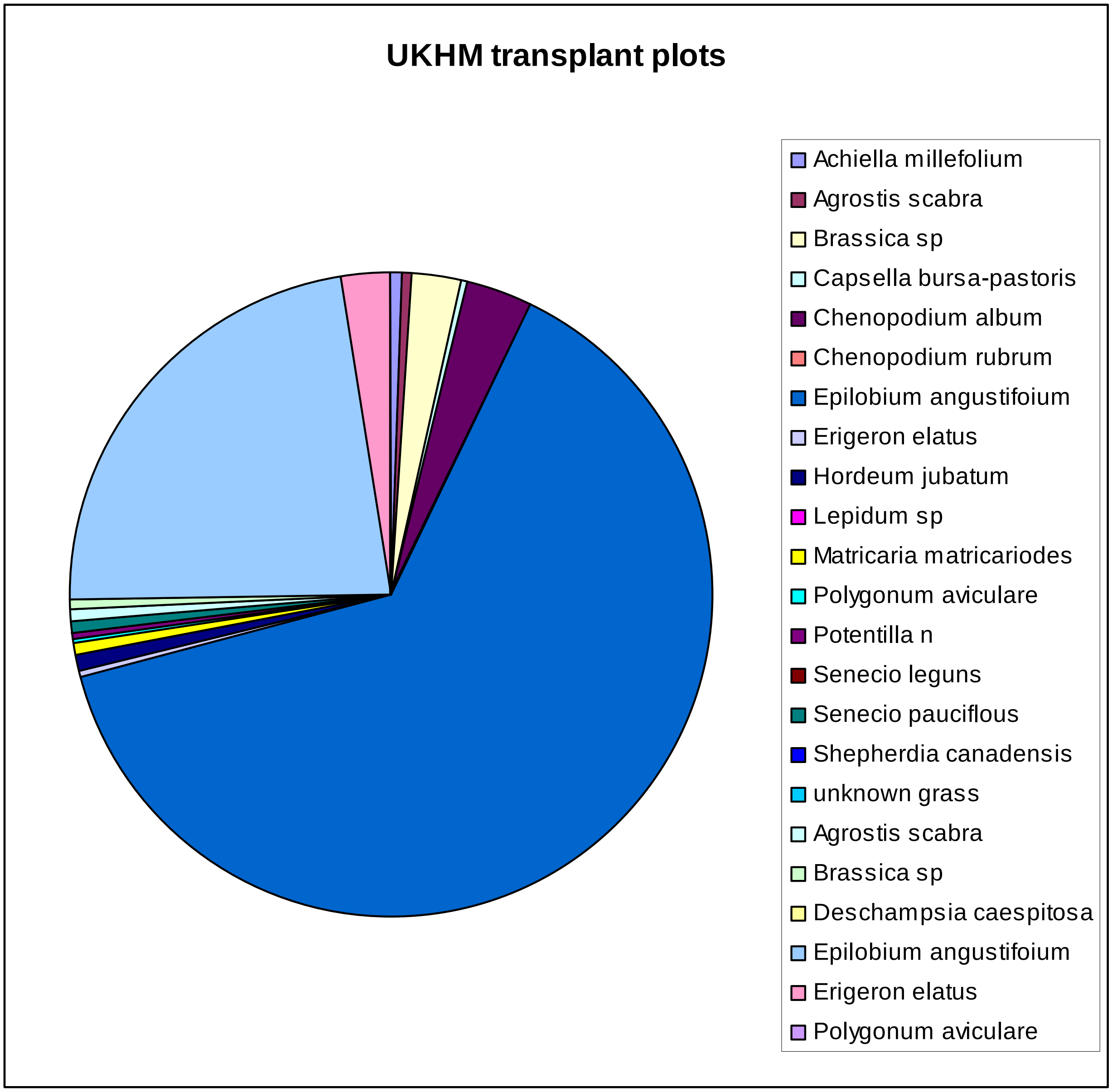






Colonization of Plots by Additional Plant species

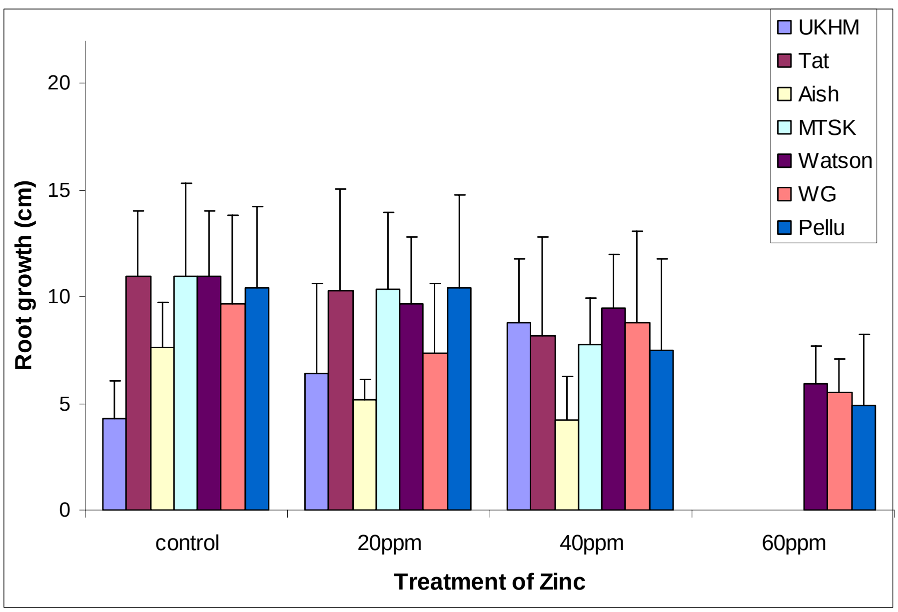
Analysis of colonization has not been completed to date. Below is a figure outlining colonization of transplant plots which were established in summer 2003 for example. What is evident at all three experimental mine sites is that annual ‘weedy’ species which were present in 2003 and 2004 (presumed to be contributed by the compost itself) have declined while native species which are located within the mine vicinity and some on the tailings have increased. In 2005, Common Fireweed was the most prevalent colonizing species in all plots containing compost. Indeed, the presence of compost increases the number of colonizing plants relative to untreated and fertilizer treatments.



Laboratory Study

We are currently investigating 11 populations of *Deschampsia caespitosa* collected from the Yukon and northern British Columbia for their metal tolerance to Ni, Zn, and Cd. We are also testing four populations from the Sudbury area and one from Tobermory, Ontario (alvar environment near Georgian Bay). Methods are similar to that of the previous study, but we have expanded the number of concentrations used and certainly the number of populations. These experiments are ongoing and analyse of results is expected by October 2006. Below, however, are some results for zinc trials. What is most interesting here, is that UKHM plants, a zinc enriched environment, has increased root growth at higher concentrations. This may suggest some need for zinc, although the metal requirement hypothesis has not had much support in the literature and this question has not been tested directly as of yet.

1) United Keno Hill Mine, YT
2) Mount Skukum, YT
3) Wellgreen, YT
4) Pelly, YT
5) Tagish Road, YT
6) Atlin, BC
7) Haines Road, BC
8) Wheaton River, YT
9) Watson River, YT
10) Aishihik Lake, YT
11) Kluane, YT
12) Coniston, Sudbury area
13) Falconbridge, Sudbury area
14) Roast Bed, Sudbury area
15) Copper Cliff, Subury area
16) Tobermory, ON



Near Future

The greenhouse experiments will be completed by October 2006. Data analysis is ongoing and a number of manuscripts are currently underway. The 2006 field season in the Yukon is currently undetermined. The remaining questions and *in situ* studies require long-term monitoring. Thus, data collected from the field this summer, albeit fortuitous, is not imperative to determining the overall success of the project.