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LONG-TERM MONITORING OF PERMANENT RECLAMATION PLOTS ON HIGH-ELEVATION DISTURBANCES AT THE LINE CREEK MINE

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ABSTRACT

High-elevation exploration disturbances at the Line Creek Mine were revegetated in 1980. In 1982, permanent reclamation monitoring plots were established. In 1988, the monitoring program was expanded to compare vegetation dynamics with undisturbed natural reference areas. Mean total vegetation cover increased from 1982 to 1988, decreased during the period from 1988 to 1996 and increased between 1996 and 2000. Changes in mean total cover from 1982 to 1996 are attributed to the increase and subsequent die-back of agronomic grasses while the increase in total cover in later years is attributed to colonization and expansion of native forbs. Total cover in the undisturbed reference plots remained relatively constant over the monitoring period. Species richness increased over the monitoring period although structural diversity of the reclaimed areas remains lower than that for the undisturbed "reference" plots. The most important difference between the reclaimed and the native plots is the reclaimed plots exhibit relatively high grass species cover and low woody species cover.

INTRODUCTION

The Line Creek Mine conducted exploration activities within the Dry Southern Cordilleran Engelmann Spruce Subalpine Fir Parkland (ESSFdkp) and the Dry Southern Cordilleran Alpine Tundra (AT) biogeoclimatic subzones (Braumandl and Curran 1992) on Ewin Ridge and Mount Banner. In 1980, these exploration disturbances were re-contoured, seeded and fertilized with two agronomic seed mixes. Plots Rl-1 through Rl-5b (Site 1) were seeded with a mix that included creeping red fescue *(Festuca rubra* L. cv. Boreal), alsike clover *(Trifolium hybridum* L.), meadow foxtail *{Alopecurus pratensis* L. cv. Common), red top *(Agrostis gigantea* L.), sainfoin *(Onobrychis viciaefolia* Adans. cv. Common), timothy *(Phleum pratense* L.) and sheep fescue *(Festuca ovina* L. cv. Durar). The plots R2-1 through R2-5 (Site 2) were seeded with a mixture that contained creeping red fescue, alsike clover, meadow foxtail, red top, sainfoin and Canada bluegrass *(Poa compressa* L. cv. Common). The percentage composition and rate of application were not documented. The revegetated areas were fertilized with $N_{11}P_{55}K_{22}$ fertilizer during seeding and once again in the early 1980s.

STUDY OBJECTIVES

The monitoring program was initiated in 1982 to assess revegetation of the high-elevation exploration disturbances. In 1988, the monitoring program was expanded to compare vegetation dynamics with undisturbed natural reference areas. The sampling in 2000 represented 20 years of successional progression on these subalpine and alpine disturbances.

MONITORING METHODS

Data Collection

Vegetation assessment of each of the $4m^2$ sample plots (quadrats) included species percent cover, mean species height, percent seed heads by species, species vigor and percent wildlife utilization. Other environmental data, e.g., plot number, date, latitude, longitude, elevation (metres), aspect (°), slope (percent), macro- and mesoslope position, ecological moisture and nutrient regime, successional status and structural stage, surface substrate (bedrock, rocks, mineral soil, wood, organic matter and water), exposure, flooding hazard, soil drainage and perviousness, were recorded also (Province of British Columbia 1998). Soils were classified according to the Canadian System of Soil Classification (Soil Classification Working Group 1998).

Data Analysis

Floristic and site description data for each sample plot were analyzed and graphed using SYSTAT 9.0 software (Wilkinson 1999a, 1999b).

RESULTS AND DISCUSSION

Soil Development

In 2000, the rock cover component of the surface substrate on the reclaimed sites ranged from 5.0 — 65.0 percent while humus cover ranged from 6.0 - 85.0 percent. In the undisturbed reference plots, rock cover ranged from 3.0 - 59.0 percent while humus cover ranged from 36.0 - 95.0 percent. Very little evidence of rill erosion or soil creep was observed.

The undisturbed soils of the study area were classified previously as Orthic Regosols or Orthic Eutric Brunisols (Lacelle 1990). After 20 years, the reclaimed soils have the profile development of Orthic Regosols. The organic horizons on the reclaimed sites range from 0.0 to 2.0 cm whereas litter depths

range from 0.1 to 1.0 cm on the undisturbed sites. Litter and fibric (partially-decomposed) material dominate the organic horizons on the reclaimed sites whereas humified material is dominant on the undisturbed sites. Mycorrhizae were observed on both the reclaimed and undisturbed sites.

Weathering of the large rock fragments was observed at all of the reclaimed sites. The percentage of large fragments was much greater in the soil profiles of the reclaimed sites in comparison to the undisturbed sites where weathering has taken place over a much longer period of time. A prominent feature of the reclaimed soils was the "random" orientation of the large fragments.

The texture (<2.0 mm) of the reclaimed soils ranged between sand and sandy loam whereas the soil textures of the undisturbed soils textures ranged between sand (Regosols) and silt loams (Brunisols). The reclaimed soils had a fragmental rooting zone particle size class while the native soils were either sandy-skeletal or coarse-loamy-skeletal.

Humification is occurring in the reclaimed sites. Evidence for this is derived from the observed differences in the hue, value and chroma between the subsurface parent materials (C horizon) and the overlying A and B horizons. The presence of a relatively thin litter layer may be diagnostic as well.

Root abundance was plentiful in both the reclaimed and undisturbed sites. Rooting depth varied with the species present but generally ranged between 15.0 and 20.0 cm on both disturbed and undisturbed sites. The root systems in the reclaimed soils were dominated by fine (1.0 - 2.0 mm) roots while the undisturbed sites were dominated by fine and medium (3.0 — 5.0 mm) roots.

Vegetation

A total of 160 plant species were recorded within the reclaimed and undisturbed sample plots, i.e., 5 trees, 10 shrubs, 3 rush, 8 sedges, 24 grasses, 90 forbs, 2 fern allies, 6 mosses, 1 leafy liverwort and 11 lichens. All but 4 grasses and 2 forbs were natives.

Several trees within the subalpine forests on Ewin Ridge and Mount Banner were cored and aged. The objective was to determine the stand initiation point for the surrounding natural vegetation and to obtain a reference point for the reclamation of the exploration disturbances, particularly forested stands. The age of the trees ranged from 120 years for subalpine larch *(Larix lyallii* Parl.), 47 years for whitebark pine *(Pinus albicaulis* Engelm.) to 30 years for subalpine fir *(Abies lasiocarpa* [Hook.] Nutt).

In the reclaimed plots, mean total cover increased from 1982 to 1992, declined in 1996 and increased in 1998 and 2000. Vegetation cover on the undisturbed plots remained relatively constant until 1998 when distinct increases were recorded (Figure 1).

Mean total cover in Site 1 plots increased from 54.0 percent in 1982 to 67.8 percent in 1992, declined in 1996 and 1998 but increased to 68.5 percent in 2000. The reduction in cover recorded in 1998 is attributed to a decrease in the cover of creeping red fescue and common timothy while the increase in cover in 2000 is attributed to increased native forb cover.

Mean total cover values for Site 2 plots were lower than Site 1 plots in 1982, 1988, 1990 and 1992 but higher in all other years. Total cover in the Site 2 treatment has increased consistently since 1992. The decrease in cover between 1985 and 1992 is attributed to the decline in agronomic grass and legume cover whereas the increase in cover in recent years is considered to be the result of native species ingress.

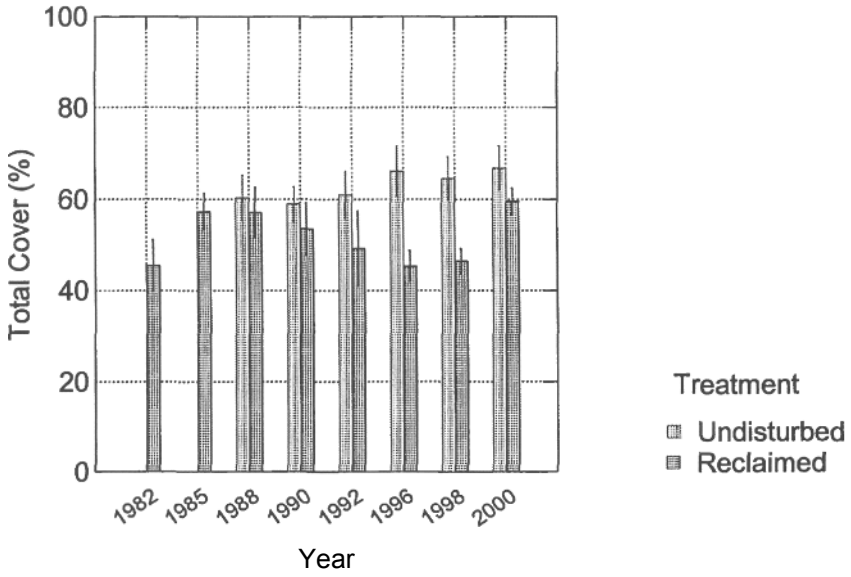
Mean percent cover of agronomic grasses declined from a high of 25.9 percent in 1985 to a low of 13.4 percent in 1998 (Figure 2). A slight increase was observed in 2000. Mean percent cover of the agronomic forbs (legumes) has been low (1.2-3.4 percent) throughout the monitoring period. Currently, only small percentages of alsike clover and sainfoin are present. Over the years, creeping red fescue, meadow foxtail and common timothy have provided erosion control and initiated nutrient cycling, but their percent cover has declined in recent years.

Colonization by native species has increased in the reclaimed plots over the 20 years since revegetation (Figure 3). In 2000, the ingress of native species increased slightly, but, more importantly, their percent cover increased significantly. Although usually comprising less than 5.0 percent cover individually, the ingress of herbaceous species such as cushion buckwheat *(Eriogonum umbellatum* Nutt.), fireweed *(Epilobium angustifolium* L.), pale agoseris *(Agoseris glauca* [Pursh] Raf.), yarrow *(Achillea millefolium* L.), wild strawberry *(Fragaria virginiana* Duchesne), silky phacelia *(Phacelia sericea* Graham A. Gray), silky locoweed *(Oxytropis sericea* Nutt.), subalpine daisy *(Erigeron peregrinus* Pursh), umber pussytoes *(Antennaria umbrinella* Rydb.), alpine fescue *(Festuca brachyphylla* Schult), rough fescue *(Festuca scabrella* Torr.), spike trisetum *(Trisetum spicatum* [L.] Richt), three-leaved sandwort *(Arenaria capillaris* Poir.) is significant. Agronomic ingress into the undisturbed reference stands is very low. The lack of outward migration of the agronomic species is important in that it indicates that the ecological integrity of the undisturbed ecosystems has not been severely compromised.

Most of the reclaimed areas had a grass-dominated structural stage whereas the undisturbed sites had a low shrub or young forest structural stage. However, differences in structural stages between disturbed and undisturbed areas are often imperceptible where the exploration roads occur in subalpine or alpine grasslands.

Shrub cover at the undisturbed plots increased slightly between 1988 and 1992 but declined in 1996 and 1998. In 2000, shrub cover in the undisturbed plots increased slightly from that recorded in 1998 while shrub cover increased marginally on the disturbed plots. The low woody plant cover in the reclaimed plots indicates the slow rate of colonization by species with this growth habit. The results support similar observations reported by Chambers (1997).

Figure 1. Comparison of total cover of undisturbed and reclaimed plots.



Species richness on the reclaimed sites was relatively constant between 1985 and 1990. However, a dramatic increase in species richness was recorded in 1996 and 1998, and the increasing trend continued in 2000 (Figure 4). In 2000, a cumulative total of 2 agronomic forbs (legumes), 4 agronomic grasses, 48 native forbs, 18 native grasses, 7 mosses and 8 lichens were recorded in the reclaimed treatment plots.

Native species ingress appears to be increasing as "biological space" (Urbanska 1995) is being vacated by the seeded agronomic species.

Figure 2. Graph of plant group cover versus year.

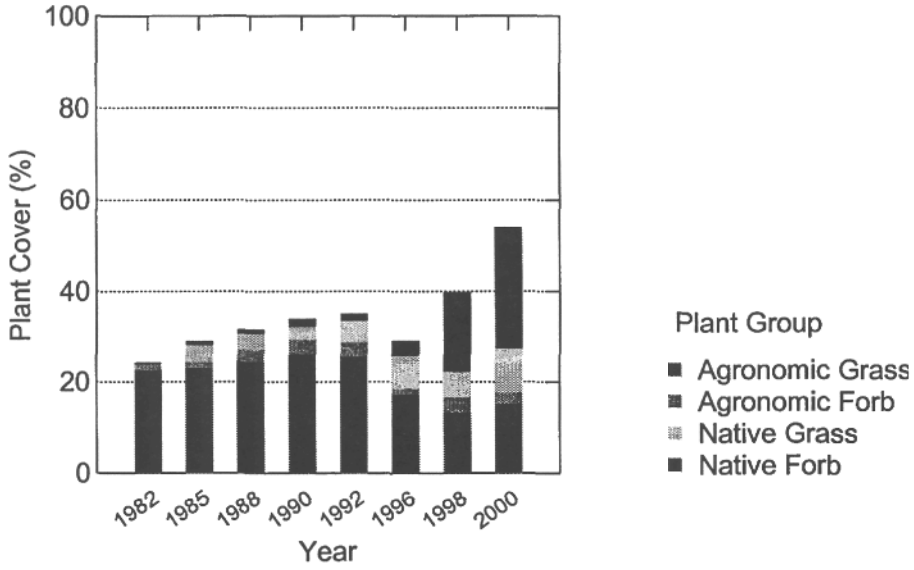


Figure 3. Native species colonization of reclaimed plots.

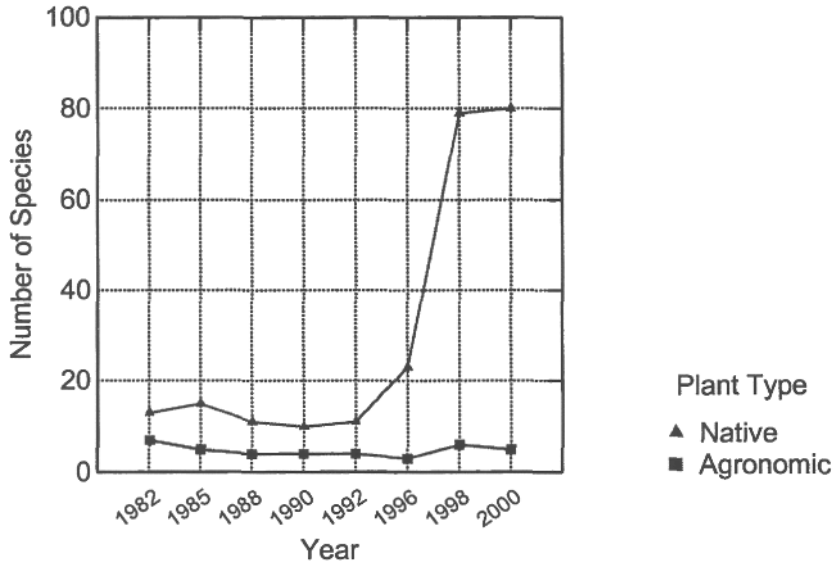
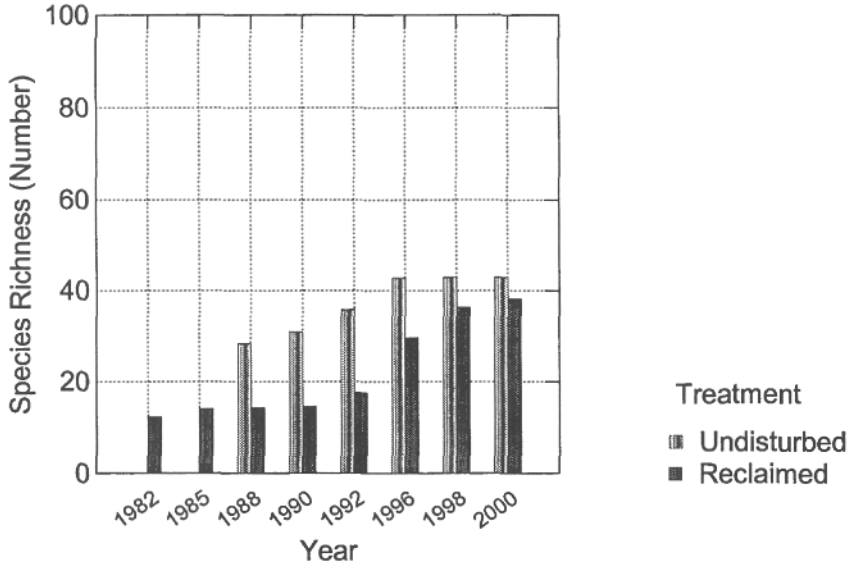


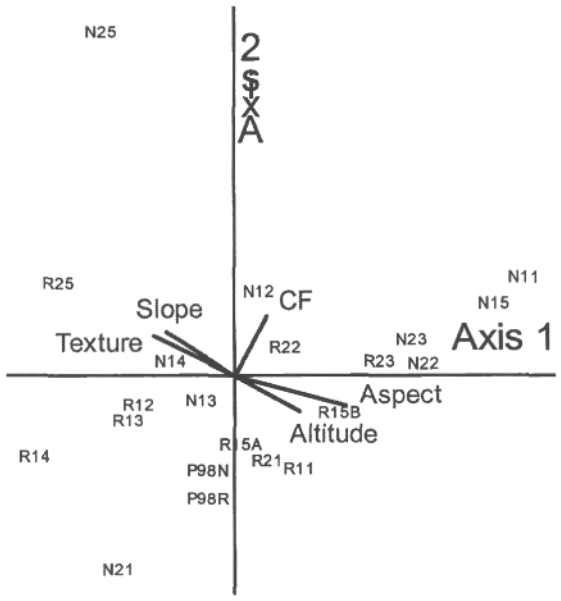
Figure 4. Graph of species richness versus year.



Floristic composition of the reclaimed and native plots was also compared by calculating community coefficients. Proportional similarity ranged between 4.6 - 48.7 percent and indicates that the reclaimed plots are still dissimilar to their paired undisturbed 'reference' plots in terms of floristics and species abundance. The similarity between paired reclaimed and undisturbed plots has increased between 1996 and 2000, and this indicates a continual progression towards naturally-functioning systems. The interpretation of the results presented here suggests that there is still a long recovery period required before these disturbed ecosystems can be considered fully restored to pre-disturbance species composition.

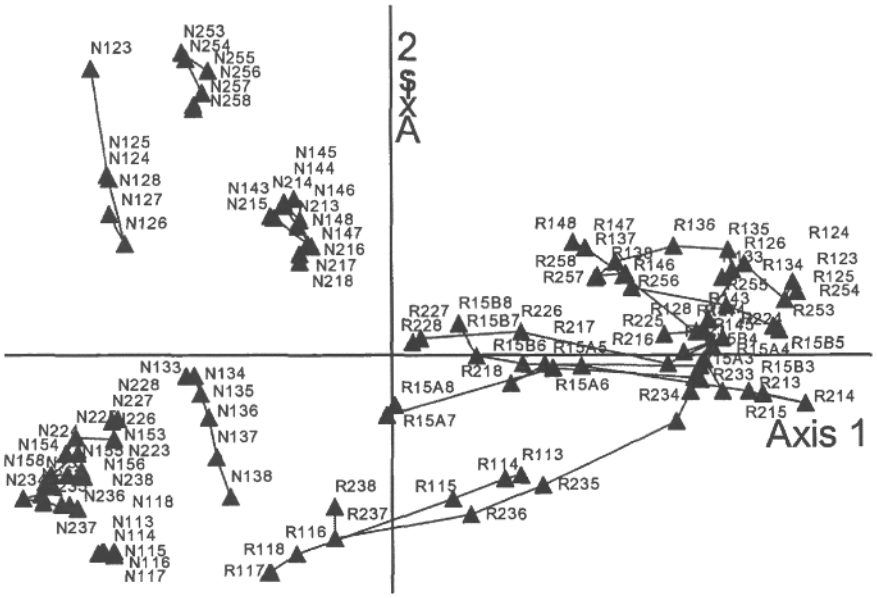
The vegetation within the study area is controlled by three dominant parameters as determined by Detrended Correspondence Analysis and Canonical Correlation Analysis (CANOCO) (ter Braak 1988). Intra-set correlations of vegetation and environmental variables showed that aspect *(R* = 0.84 on axis 1), coarse fragments *(R* = 0.77 on axis 2) and mesoslope position *(R* = 0.75 on axis 3) were the main determinants of the environmental variables sampled (Figure 5).

Figure 5. CANOCO graph – axis 1 versus axis 2.



In addition to the above analysis, vector overlays were superimposed on detrended correspondence analysis output to examine the temporal patterns or successional trajectories (Figure 6). While the natural or undisturbed and reclaimed plots were separated spatially on the graph, there was overlap in the temporal vectors of some of the plots. This figure illustrates graphically that a dynamic system has been created, and, in some situations, the reclaimed sites may be approximating adjacent undisturbed areas. The results of Indicator Species Analysis were used to generate species groups that might be diagnostic for successional progression. Creeping red fescue *(Festuca rubra* L.) and meadow foxtail *(Alopecurus pratensis* L) are diagnostic of the early stages of revegetation while the presence of common yarrow *(Achillea millefolium* L.) and Holboell's Rock Cress *(Arabis holboellii* Homem.) are diagnostic of later stages. Grouseberry *(Vaccinium scoparium* Leiberg), silky phacelia *(Phacelia sericea* [Graham] A. Gray) and Wyoming Besseya *(Besseya wyomingensis Rydb.)* were indicator species for the undisturbed sites.

Figure 6. Successional trend analysis – axis 1 versus axis 2.



CONCLUSION

The results of the reclamation performance-monitoring program of high-elevation exploration disturbances on Ewin Ridge and Mount Banner are very favorable. Ingress or colonization of these disturbances by native plant species has continued, and their cover increased greatly in 2000. Although agronomic species cover has declined, persistence of several agronomic grasses continues. No evidence of erosion has been observed.

Soil profile development is progressing on the reclaimed exploration disturbances. Evidence of weathering of large fragments and the presence of fine-textured materials are important indicators. Humification of the uppermost portion of the profile was observed at most plots indicating that decomposition and comminution of organic material has occurred. The observed soil profile development indicates that nutrient cycling processes are operating and that the system is probably self-sustaining.

REFERENCES

Braumandl, T. and M.E. Curran. 1992. A Field Guide for Site Identification and Interpretation for the Nelson Forest Region. (1996 Reprint). Ministry of Forests Research Program. Victoria. Slip.

British Columbia Ministry of Environment. 1996. Field Manual for Describing Terrestrial Ecosystems. (Draft). British Columbia Ministry of Environment and British Columbia Ministry of Forests, Victoria. 108 p.

Chambers, J.C. 1997. Restoring alpine ecosystems in the western United States: environmental constraints, disturbance characteristics and restoration success. Restoration Ecology and Sustainable Development. (K. Urbanska and N. Webb, Editors). Cambridge University Press, Cambridge, pp. 161-187.

Lacelle, L.E.H. 1990. Biophysical Resources of the East Kootenay Area: Soils. Wildlife Technical Monograph TM-1. Report No. 20. British Columbia Soil Survey. British Columbia Soil Survey. Habitat Inventory Section, Wildlife Branch, British Columbia Ministry of Environment, Victoria. 359 p.

Province of British Columbia. 1998. Field Manual for Describing Terrestrial Ecosystems. Land Management Handbook Number 25. British Columbia Ministry of Lands, Parks and Housing and the British Columbia Ministry of Forests, Victoria. 240 p.

Soil Classification Working Group. 1998. The Canadian System of Soil Classification. Third Edition. Research Branch, Agriculture and Agri-Food Canada Publication 1646. NRC Research Press, Ottawa. 187 p.

ter Braak, CJ.F. 1988. CANOCO - an extension of DECORANA to analyze species-environment relationships. Vegetatio 75: 159-160.

Urbanska, K.M. 1995. Biodiversity assessment in ecological restoration above timberline. Biodiversity and Conservation 4: 679-695.

Wilkinson, L.E. 1999a. SYSTAT 9.0. Statistics I. SPSS Incorporated, Chicago. 660 p.

Wilkinson, L.E. 1999b. SYSTAT 9.0. Graphics. SPSS Incorporated, Chicago. 485 p.