Proceedings of the 8th Annual British Columbia Mine Reclamation Symposium in Victoria, BC, 1984.
The Technical and Research Committee on Reclamation

SOIL FAUNA RECOLONIZATION OF HIGH ELEVATION MINE SPOILS IN SOUTHEASTERN BRITISH COLUMBIA

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Introduction

The proper functioning of an ecosystem depends on the efficiency of its component parts. In a terrestrial ecosystem, the decomposer subsystem provides an important (and poorly known) link between the decomposition of dead organic matter (detritus) and the availability of essential nutrients for the production of new organic material. It is a soil community which is comprised of a complex organization of soil flora and fauna, which process detrital material and convert it into mineral soil. The process of mineralization, where decomposed material is broken down into its chemical constituents and made available for uptake by plants, is undertaken by the soil flora, or bacteria and fungi. This process of mineralization is greatly accelerated by the action of the soil fauna, who ingest and break down organic material, thus making it more available to bacteria and fungi. Soil faunal activities also stimulate fungal growth by cropping and dispersing spores, as well as improving soil aeration and water status by burrowing and opening passages occupied by decaying roots (Marshall et al, 1982).

Mine spoils initially lack such a biological community of soil flora and fauna. To compensate for this, newly reclaimed spoils are treated with annual maintenance applications of a complete fertilizer. It is therefore important to understand the functioning of these disturbed ecosystems, to determine when, if at all, a soil environment conducive to vigorous and sustained plant growth has been established, and costly fertilizer applications are no longer necessary. The incorporation of organic material back into the soil is of paramount importance, since it is essential for the development of a soil profile with such desirable characteristics as nutrient availability, soil aeration, and moisture-holding capacity.

This study was set up to investigate the role that soil fauna play in the decomposition of organic material on high elevation reclaimed land. The first and most important objective, therefore, must be to document in detail the recolonization of soil fauna on to such spoils. It is then necessary to correlate the above findings with indicators of ecosystem performance, such as site productivjty and decomposition rates. Finally, this study is investigating practical methods of ameliorating the disturbed sites, to increase the rate of soil fauna! recolonization and site quality, thereby substantially reducing further management costs.

Site Location

The reclaimed areas under investigation are located on the Westar Mining Ltd. Balmer mine site near the village of Sparwood, in southeastern British Columbia. These sites are located near the summit of Harmer Ridge, at an elevation of approximately 1,950 metres.

Four sites were chosen for study: three reclaimed sites which were two, five, and nine years of age in 1982 when sampling took place, as well as a nearby undisturbed subalpine grassland meadow. Although the natural meadow differed considerably from the reclaimed sites in slope, vegetation, soil and microhabitat conditions, it was sampled to provide an indication of how a self-sufficient natural grassland ecosystem is functioning at a similar elevation and aspect, with essentially similar parent materials.

Research Areas

This study encompasses a number of areas of research:

1. Soil cores
2. Emergence traps
3. Innoculation sources
4. Environmental parameters
5. Earthworm introduction trial

The five different areas of research will be outlined, with emphasis on work completed to date.

I. <u>Soil Cores</u>

The extraction of soil fauna from soil core samples taken from each of the study sites comprises one of the main sections of this study. Extraction techniques are described in Lawrence (1982). It is here that the majority of the important soil fauna are quantified and then identified. Major taxa extracted included:

- acari (mites)
- collembola (springtails)
- nematodes (roundworms)
- enchytraeids (potworms)
- insect larvae

Quantification and identification of the samples is still underway. Acari and collembola appear to be the major recolonizers of reclaimed land, although Diptera larvae, particularly saprophagous forms, are also abundant. Similar results have been recorded by researchers in Britain and Germany. The collembola <u>Isotoma notabilis</u> is abundant on the two-year-old site, and was also found to dominate a two-year-old reclaimed site in England (Hutson, 1980). Prostigmatic mites were the dominant acarine recolonizers on study sites in England (Hutson, I960) and are quite abundant in the study soil cores on Harmer Ridge.

Nematodes were numerous on the undisturbed subalpine meadow, yet very rare on the younger reclaimed sites, particularly the two-year-old site. Stanton and Krementz (1982) found similar results on reclaimed sites in Wyoming, where disturbed areas (especially stockpiled topsoil) supported significantly fewer nematodes than undisturbed sites.

Enchytraeids <u>(ljenleq,</u> sp.) were present on the undisturbed subalpine meadow, yet absent from all reclaimed sites. This lack of a desirable earthworm population on these reclaimed sites led to the establishment of an earthworm introduction trial, which will be discussed later.

2. <u>Emergence Traps</u>

Not all soil organisms spend their complete life cycle in the soil, but may emerge as adults to breed; laying eggs back into the soil environment. Members of the Coleoptera (beetle) and Hymenoptera (wasp) orders may follow this pattern, although Dipterans (flies) are probably the most common. Larval forms are often saprophagous, feeding on dead and decaying organic matter. Insect larvae can make a significant contribution to the amount of organic matter decomposed in an ecosystem, particularly in the absence of earthworms.

Emergence traps provide a useful technique for quantifying the insect larvae present in a square metre of soil. The trap (described in Lawrence, 1982) collects any insect emerging from the soil at any time. Adult forms permit easier identification of larvae extracted from soil samples.

Study sites were monitored for eleven weeks during the summer of 1982. Samples have been identified (tentatively in some cases) to the family level. Of the 62 different insect families tallied from all sites, 28 of these belong to the order Diptera. Dipterans are well represented on all study sites, particularly on the subalpine meadow. Eighteen different Dipteran families have been recorded from the reclaimed sites alone, and although life histories are very poorly known, up to 13 of these families may include larval forms which are saprophagous, feeding on decaying organic matter. Other families may include larval forms which live as herbivores, parasites, or predators. The four most common Dipteran families on the reclaimed sites include members of the family Cecidomyiidae (gall midges), Sciaridae (fungus gnats), Phoridae (humpbacked flies), and Heleomyzidae. These families all have larval forms which feed on decaying organic matter.

Other major groups of insects are also represented in these samples. The most abundant beetle collected is a small predaceous rove beetle, belonging to the family Staphylinidae. Beetles are not well represented on the reclaimed sites, although some predaceous ground beetles (Carabidae) and ladybird beetles (Coccinellidae) were collected at certain times of the year. Members of the order Hemiptera, or "true bugs", are represented on all sites by leaf hoppers (Cicadellidae and Cercopidae) and plant bugs (Miridae). These bugs are all herbiverous, feeding on above-ground vegetation. Most of the wasps collected in these samples are parasitic on other insects. Butterflies and rnoths are not abundant on these sites. The most numerous moth collected is a member of the family Gelechiidae. This insect feeds on above-ground vegetation and seeds in the larval stage.

Figure I represents family diversity on all study sites over an eleven-week period in 1982. The Shannon-Weaver index of diversity (H') gives an indication of the distribution of individuals among categories, families in this case. The index of evenness, J, expresses this observed diversity as a proportion of the maximum possible diversity. These indices cannot be calculated when the sample consists of only one individual, as is the case on the two-year-old site in weeks 2 and 4.

This figure indicates the general trend of an increase in diversity over time as the season progressed, followed by a decrease by the end of August. Sites show a slight increase in diversity with site age, although the oldest reclaimed site is somewhat less diverse than the intermediate-aged site. This may actually reflect the more heavily compacted nature of the spoil material on this older site. Most soil animals are unable to burrow and must utilize existing pore spaces (Wallwork, 1976). The more compacted soil would be expected to have fewer pore spaces, and a lower degree of insect diversity.

3. Innoculation Sources

On sites which lack a dominant earthworm population, collembola and mites assume the role of the important decomposer group. The major means of dispersal for soil animals such as mites and collembola is that of wind or water; either in snowmelt or rainwater (Christiansen, 1964; Fjellberg pers. comm.). It is likely that on Harmer Ridge, the organisms travel downslope with the snowmelt. Since the study sites are located very near the ridge summit, it is believed that sources of recolonizers might be limited. The probable sources of innoculation are likely to be the subalpine fir/whitebark pine forest patches which have been left undisturbed on and near the ridge summit.

A number of soil samples were taken along a transect run through the largest patch of forest in June, 1983. Organisms extracted will be compared to those found on the reclaimed sites, to investigate the possibility of the forest acting as an innoculation source.

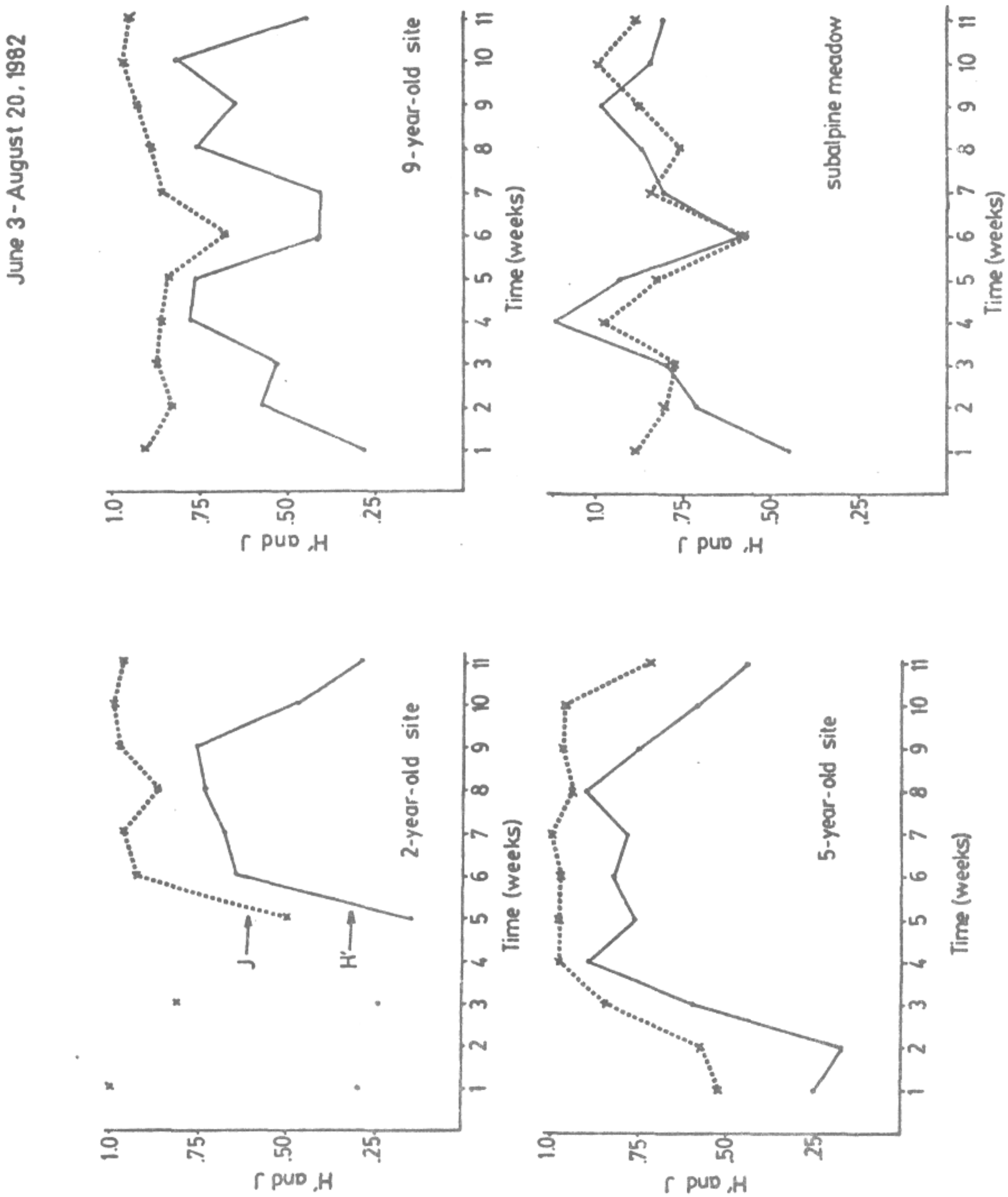
Without such a source, the rate of recolonization by soil organisms and subsequent litter decomposition would be considerably slower than that already seen. Large disturbances on ridgetops may face such a situation in the future. If mine plans do not permit leaving small patches of undisturbed ground, an alternate plan may be to dump a number a truckloads of fresh (not stockpiled) topsoil in strategic locations on the newly reclaimed spoil, which should be revegetated as soon as possible after resloping. Some of this "innoculation source" should be placed near the highest point in the reclaimed spoil, to allow for downslope movement of organisms. Placement of topsoil in moist microsite conditions (favorable to mites and collembola) such as those found in small topographic depressions, or behind rock berms or dumps, etc., is also desirable. These microsites may be easily created during the resloping process.

4. Environmental Parameters

The development of an ecosystem may be monitored through the production of vegetative biomass and the decomposition rate of detritus, or organic matter. The soil fauna! community influences these processes through its various feeding activities, and subsequent effects on soil structure and

Figure I

Diversity (H') and Evenness (J) Versus Time



chemistry.

A number of environmental parameters will influence the species composition and abundance of the soil community itself. Such factors include soil temperature and moisture levels, as well as particle size distributions.

The species distribution and abundance of the soil organisms sample will be correlated with the above-mentioned parameters, using a multivariate statistical technique. Data for a number of different environmental factors have been collected, although a summary at this point is beyond the scope of this paper.

5. Earthworm Introduction Trial

As mentioned previously, earthworms, particularly enchytraeids, were absent from soil cores taken from all reclaimed sites, yet present in the undisturbed subalpine meadow. Since the dispersal rate of earthworms is very low, it is expected that enchytraeids would recolonize these reclaimed sites extremely slowly.

The lack of earthworms on the sites is significant because the earthworm is probably the most important soil animal, and its beneficial effects on the soil are numerous. Up to 15 tons of dry earth per acre may pass through an earthworm's body annually (Brady, 1974). Ingested organic matter and mineral soil are subjected to digestive enzymes and a grinding action within the animal. Earthworm casts, compared to the mineral soil, are higher in bacteria and organic matter, available phosphorus and potassium, pH and percent base saturation, and cation exchange capacity. Holes left by earthworm burrows serve to increase soil aeration and drainage. The soil is mixed and granulated through the transportation of lower soil to the surface, and undecomposed organic matter such as leaves and grass down into the burrows (Edwards and Lofty, 1972).

A number of factors affect earthworm activity. An optimum habitat is a moist, reasonably well-aerated soil, with an available organic matter food source. Most earthworms thrive best where the soil is not too acid. A high level of exchangeable calcium is necessary for optimum activity. The abundance and distribution of earthworms is affected by soil temperature and moisture, a temperature of 10°C being optimum for Lumbricus terrestris. Cold weather or dry upper soil conditions will drive earthworms deeper in the soil profile, occasionally down to a depth of 2 metres. In barren soils, a sudden heavy frost in the fall may skill the organisms before they are able to move deeper, and a good insulating soil cover is important in these circumstances (Edwards and Lofty, 1972).

Workers in Ohio have been able to successfully introduce L. terrestris onto forested acid shale spoil banks, where these organisms buried or consumed the equivalent of 5 metric tons of leaf litter per hectare over a five-year period. The levels of exchangeable cations and available P in the mineral spoil were also increased (Vimmerstedt and Finney, 1973). German investigators concluded that on sites reclaimed for IO years, earthworms were the sole important decomposers, removing over 70 percent of the litterfall (Hutson, 1980).

Due to the absence of large invertebrate decomposer fauna on these high elevation reclaimed sites, this section of the soil fauna study was designed to experimentally introduce two species of lumbricid earthworms, Lumbricus terrestris and L. rubellus onto a reclaimed site, to investigate both survival and effects on decomposition rates and certain soil characteristics. Their beneficial activities will enable establishment of a "self-sustaining" reclaimed site at an earlier age than previously expected, thereby reducing further management costs.

This introduction trial was separated into two different experiments. The first trial, or "species trial" is simply investigating earthworm survival on an 8-year-old reclaimed site. Two different species of earthworms were used, Lumbricus terrestris and L. rubeilus. A number of sexually mature worms of each species were placed at 10 innoculation points along a transect on the reclaimed site. Surrounding litter was placed over the worms to protect them from excessive ultraviolet radiation and drying conditions. The introduction was made in early June, 1983, and all innoculation points still showed evidence of earthworm survival by September of 1983. Here survival is indicated by the presence of established burrows near the innoculation points, and/or the presence of earthworm casts on the soil surface. These points will be checked again in 1984 to determine whether or not these particular earthworm species have survived the winter.

The second introduction trial was designed to test the effects of Lumbricus terrestris on the decomposition rate of detritus, as well as certain soil characteristics. In this case, five 1-metre innoculation plots were established on a 7-year-old reclaimed site in mid-June, 1983, and 100 mature L. terrestris were placed in each of the five plots. None of the detrital material was disturbed. In September the detritus levels were checked, and although the treated plots had slightly lower detritus levels than the control plots, this difference was not significant. Detritus levels will be determined again in 1984, along with certain soil characteristics.

It is expected that the major limiting factor influencing earthworm survival on these sites will be soil temperature. The worms must be able to migrate below the freezing level of the ground to overwinter, and they must be able to survive at sufficient depths to avoid extreme summer temperatures and dessication.

In order to obtain a rough estimate of the depth to which the soil may freeze on these sites, a 1.8 m test hole was drilled on the 8-year-old site, and a plastic pipe containing small vials of water, spaced at regular intervals, was inserted. The pipes will be lifted in May 1984, and the depth to which the water-filled vials froze and broke should give a rough indication of freezing depth.

Food supply should not pose a problem, as these sites have roughly 260 g/m^2 of above-ground detritus which would also serve as insulating protection against desication and ultraviolet radiation.

The soil pH of these particular sites is approximately 7.2 (Fyles, 1980), which is optimum for most earthworm species (Edwards and Lofty, 1972).

If earthworms are indeed able to survive on these high elevation sites, they may well prove to be a viable means of encouraging the incorporation of detritus on the soil surface down into the spoil material. The rate of nutrient availability will be increased, and maintenance fertilization may be stopped at an earlier age, thus resulting in both a reduction in further fertilizer costs, and possible future site amendments.

Summary

Although a great deal of work is still to be done in this study, research may be summarized in a number of points.

1. Acari and Collembola are abundant on all study sites, including the youngest reclaimed area.
2. Enchytraeids are present in the subalpine meadow, and absent from all reclaimed study sites.
3. Nematodes are very rare on the younger reclaimed study sites.
4. Dipterans (flies) are diverse and abundant on all sites.
5. Inoculation sources of soil organisms are likely found in small patches of undisturbed subalpine forest.
6. A trial introduction of earthworms successfully survived the summer of 1983.

It is likely that this study will indicate that a desirable decomposer population of soil fauna is developing soon after the spoils have been reclaimed. The development of these spoils may be further enhanced by establishing favorable microsite conditions, providing an inoculation source, and possible inoculating reclaimed spoils with larger decomposer fauna such as earthworms. Attention to a number of details at the time of reclamation may ultimately enhance the decomposition/nutrient cycling processes, encourage self-sufficiency at an early age, and thus reduce fertilizer and other management costs.

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