AN ENTOMOLOGICAL RECONNAISSANCE OF SYNCRUDE LEASE #17 AND ITS ENVIRONS

By

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ENVIRONMENTAL RESEARCH MONOGRAPH 1975-1
PUBLISHED BY SYNCRUDE CANADA LTD.

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Foreword

With up to 20000 species of insects throughout Alberta the opportunities for entomological study are immense. An entomological reconnaissance study of the Syncrude Lease #17 area was required to gain preliminary data and to examine the potential of insects as biological monitors of environmental changes resulting from the Syncrude development.

In 1974, Syncrude Canada Ltd. commissioned Lousier, Porter and Weseloh - Ecological Services of Calgary to undertake the study. W.B. Porter[1], an insect ecologist, was the project director; J.D. Lousier[2], the co-author, is a specialist in soil biology. D.V. Weseloh[3], an avian ecologist, provided field and laboratory assistance.

The original Lousier, Porter and Weseloh report has been adapted to its present form for the monograph series.

The Management of Syncrude Ltd. feel that scientific information which results from its studies should be made available to the public. Industry has an obligation to contribute to the body of knowledge necessary for orderly and responsible development of the tar sands. It is hoped that the research information will be helpful to the scientific community and to the citizens of Alberta who are concerned with the management of resources on a sound ecological basis.

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ABSTRACT

In 1974, a three week field reconnaissance study of terrestrial insects occurring on Syncrude Lease #17 and its environs, in the Athabasca Tar Sands of Northern Alberta, was carried out. Various sampling methods were employed in disturbed and undisturbed stands of different boreal forest tree types and in an area cleared of trees for mining purposes. The results obtained suggest that further study of certain insects may give an early indication of possible environmental damage. These insects are a dung beetle, *Aphodius* sp. (Scarabaeidae : Coleoptera), two species of March flies (Bibionidae : Diptera) and several species of ground beetles (Carabidae : Coleoptera). A future sampling plan can be based on the quantitative (soil sampling) data.

KEYWORDS: Insects, Reconnaissance, Sampling, Terrestrial, Pollutants, Alteration, Environment.

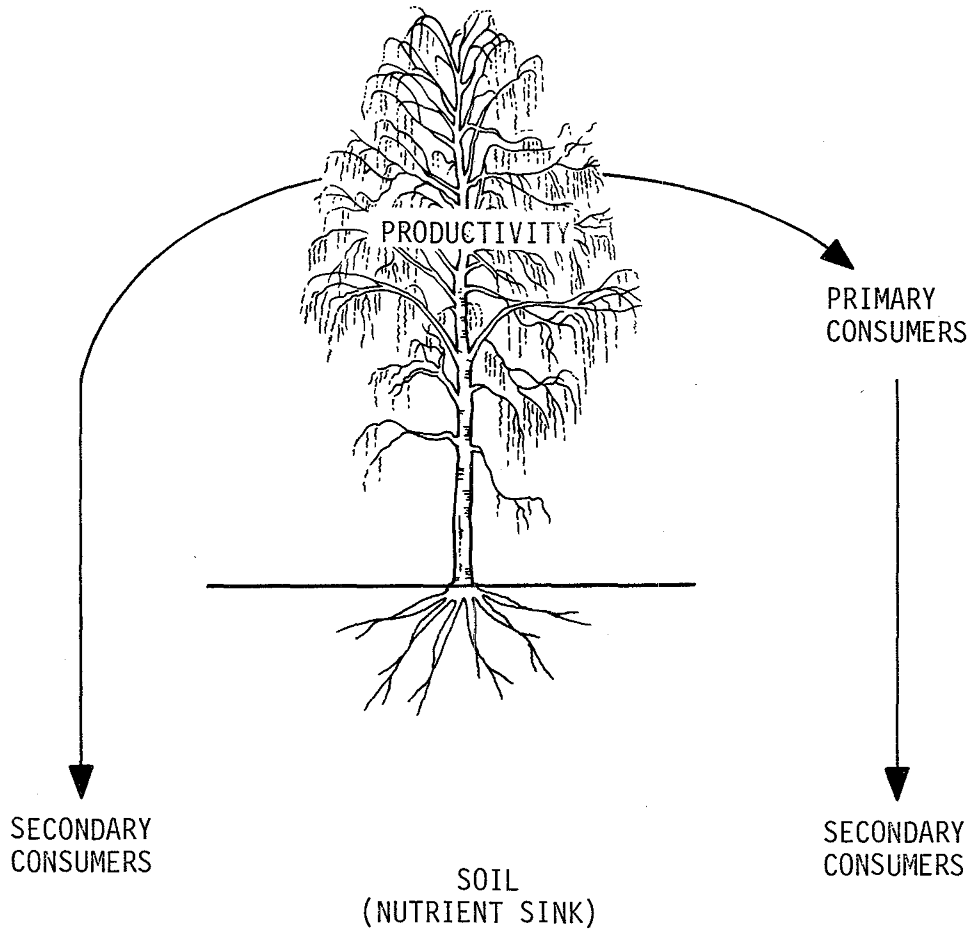
1. INTRODUCTION

1.1 General

The forest environment, its species diversity and structural complexity (ranging from coniferous to deciduous to muskeg habitats), provides many niches for exploitation by numerous undisturbed populations of insects. The ecological interactions that are involved include those reactions between insect and plant, a series of complex reactions between the many kinds of insects and physical factors in the environment, the inter- and intra- specific competitive reactions among the insects, and the trophic and other interactions between insects and the vertebrates in the forest environment. A natural forest community represents, at the least, populations and communities of organisms whose environmental requirements, or tolerances, coincide with the habitat factors of the area occupied (Lutz, 1957).

A certain synergism exists between the various components of forest ecosystems, three of which are vegetation, consumers and soils (Figure 1). The species composition and distribution of consumers, particularly insects, are determined in part by the type and amount of vegetation. Population densities of the various insect species are affected somewhat by the phenology of the area and the amount and quality of vegetative production. Primary productivity is influenced more by mineral (non-) availability in the soil, the nutrient sink, rather than by lack of energy input (Richards, 1974, Chapters 3 and 5). Adequate mineral availability is dependent upon the rate that soil organisms, of which all soil insects are a significant part, decompose and mineralize the vegetative material returning to the soil (Edwards, Reichle and Crossley, 1970).

Figure 1. A simplification of the relationships between vegetation, consumers (eg., insects) and soil.



Insects in primary and secondary consumer categories can be further divided according to feeding relationships (Figure 2). The many groups represented indicate the potential diversity of a forested system and the wide-ranging feeding habits of some groups of insects illustrate the interdependence and complexity of interacting forest ecosystem components.

Disturbing or altering any or all of a forest's components will provide a new set of environmental conditions that may rearrange and/or drastically change the community structure of the forest vegetation and fauna. The large number of insect species in Alberta (18000-20000 species, according to the Bulletin of the Entomological Society of Canada; Anon, 1974a) and their interactions with and within the habitat suggest that the study of insects may prove a useful indicator of some of the environmental changes resulting from the Syncrude development.

Appendix 1 gives the common and scientific names, and the feeding habits of the insect families collected in the tar sands area.

1.2 Objectives

The objectives of the present study were:

1. To gather baseline insect species composition and distribution data, identify possible representative and/or indicator species together with their population densities and their relation to the forest environment; and,

2. Determine the effects of tar sands development on insect populations and communities (i.e., the effects of gaseous effluents, particularly SO_2, and physical alteration of the excavation sites).

The field work was designed to examine habitats, locate study sites, check the sampling and extraction methods as applied to the study sites selected, and obtain an overview of the variety of insects present and the effects of tar sands development upon them. The data and information derived are applicable to the planning of further entomology studies and should not be regarded as a definitive documentation of the insects in the tar sands area.

1.3 Taxonomic Limitations to Study

A reconnaissance study of the scope reported here can only furnish generic and specific names of a few of the insects collected. In similar studies being conducted to examine highway and pipeline construction impacts on invertebrate communities,

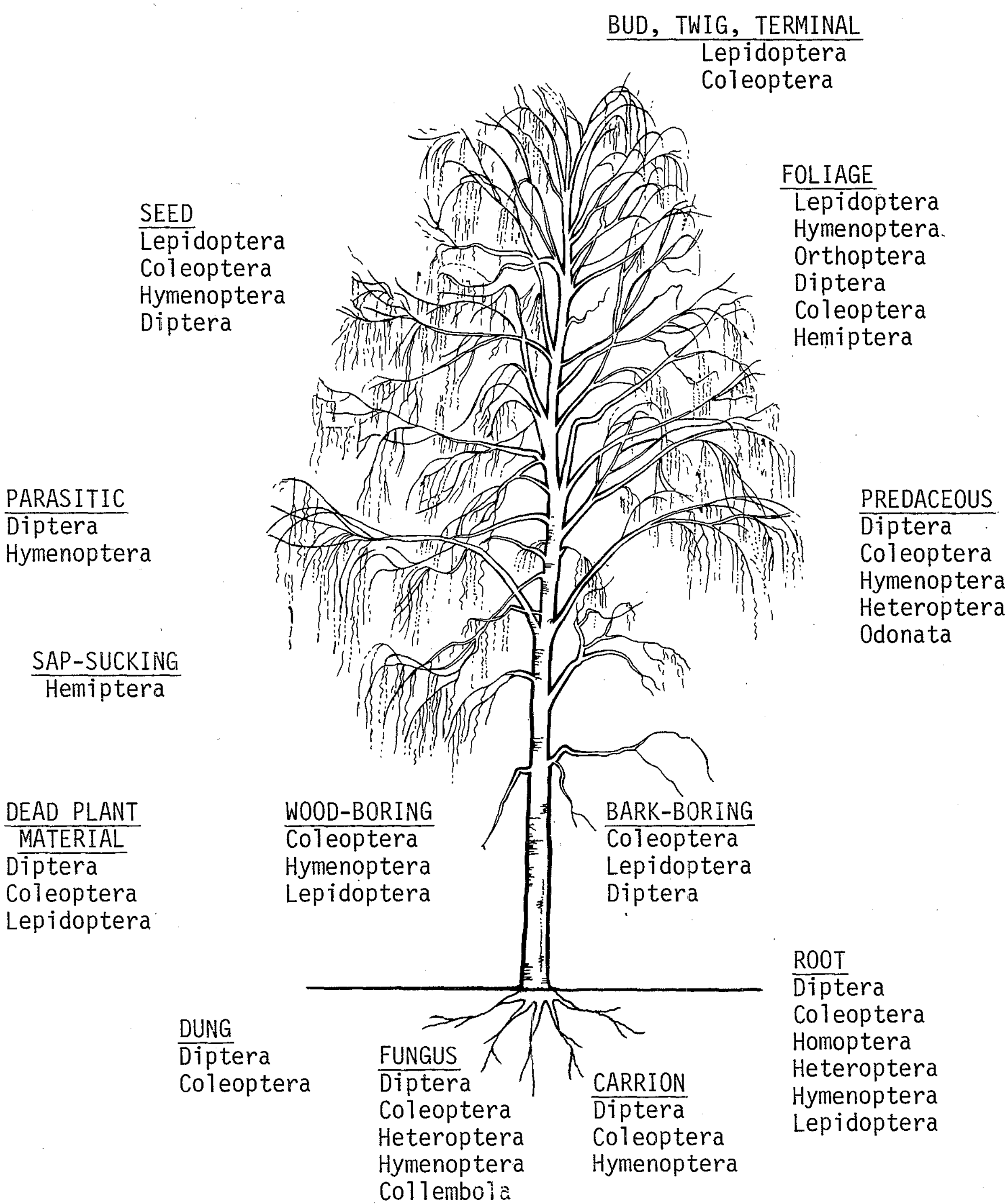


Figure 2. Categories of forest insect feeding relationships, and the main orders comprising each category (Adapted from Franklin, 1970).

results have not been encouraging despite the fact that vast amounts of time and money have been expended in tackling the problem of insect taxonomy (Anon, 1974b; page 16). The majority of work that has been done on the insects in the Athabasca tar sands area has tended to revolve around the forest pest species, generally, those that defoliate trees of economic importance. The major tree pest species in the Fort McMurray region in 1974, according to the Alberta Forest Service (F.A.S.) were *Choristoneura fumiferana* Clements (Tortricidae : Lepidoptera), the spruce budworm; and *Malacosoma disstria* Hübner (Lasiocampidae : Lepidoptera), the forest tent caterpillar.

2. DESCRIPTION OF THE STUDY AREA

The field studies were conducted in two areas of the Athabasca tar sands (Figure 3):

1. West side of the Athabasca River on Syncrude Lease No. 17, referred to in the text as "west"; and
2. East side of the Athabasca River on Petrofina Lease No. 11, referred to in the text as "east".

These areas are between 32 and 56 kilometers north of Fort McMurray, and lie in the Boreal Mixedwood forest described by Rowe (1959, 1972).

In commenting on the descriptions used for each forest region, Rowe (1972) stated that they refer to the areal distribution of "stable, climatically controlled formations characterized by the presence of certain tree species, the climax dominants". He further stated that this is not to be interpreted as "a system of purely vegetative categories based on consistently applied criteria ... For the most part, the regions are the obvious large units of forest description that all field workers recognize."

The following brief description of the Boreal Mixedwood forest is quoted directly from Rowe (1972, page 36):

> The characteristic forest association of the well-drained uplands is, as the name implies, a mixture in varying proportions of trembling aspen and balsam poplar, white and Alaska birches, white spruce and balsam fir, the last two species especially prominent in old stands. The cover type of greatest areal extent is the trembling aspen, a result of the ability of this species to regenerate readily following disturbance.

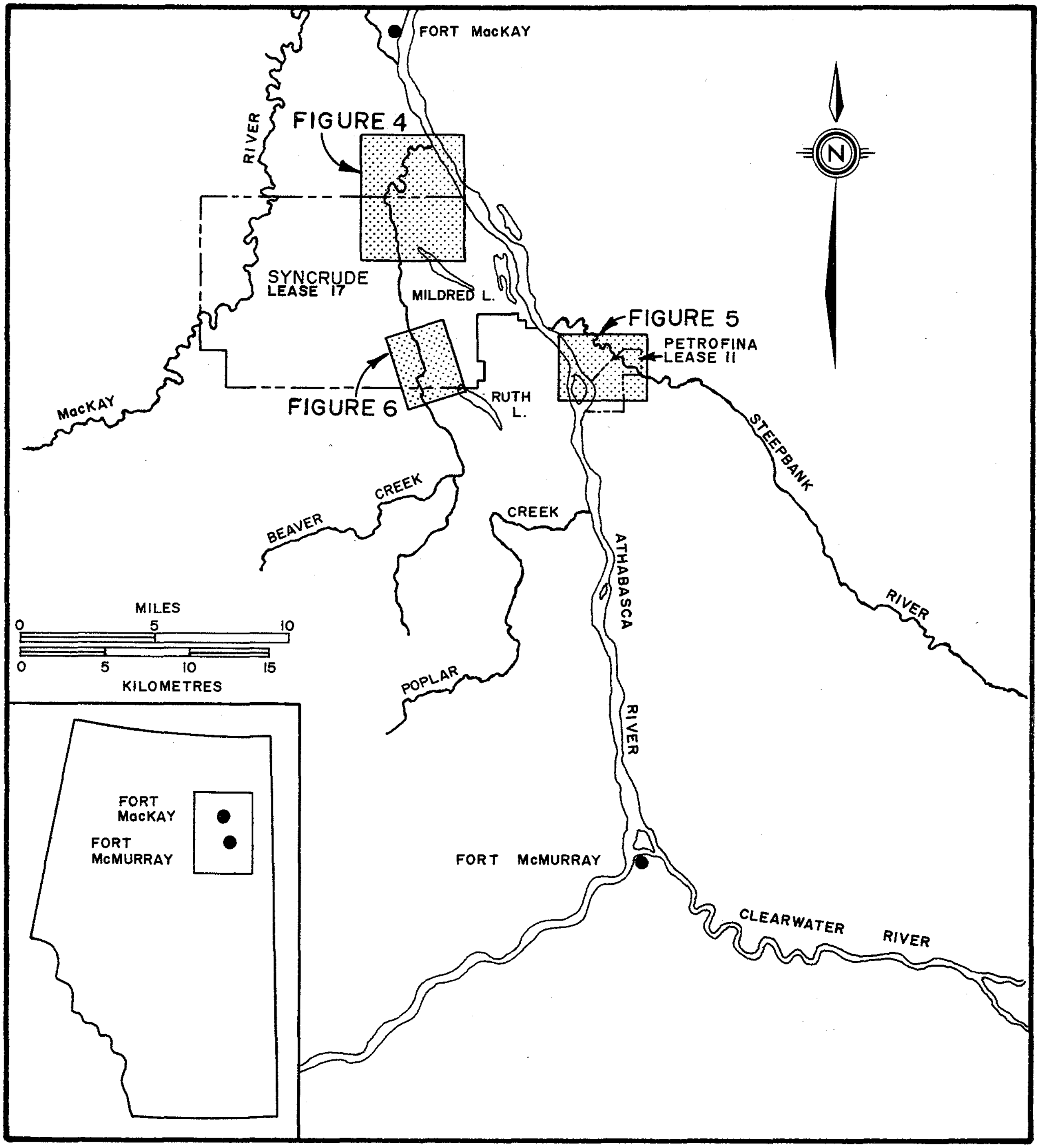


Figure 3. Map of Syncrude Lease 17 and the Surrounding Area, indicating location of Figures 4,5 and 6.

In addition to its usual dominance on sandy areas, jack pine enters into the forest composition on the drier till soils, and mixes with black spruce on the plateau-like tops of the higher hills. Lower positions and the upper water-catchment areas develop black spruce and tamarack muskeg in which, however, the accumulation of peat is not deep.

Subsequent glaciation modified the landscape, resulting in the present topography characterized by rolling morainic deposits on the uplands and smoother glacio-lacustrine deposits on the lowlands. The characteristic soil development is to the gray luvisol rather than podzolic profiles.

A more detailed description of the area is available in Intercontinental Engineering of Alberta Limited (1973) and Syncrude Canada Ltd. (1973).

3. METHODS

The fieldwork extended from July 22 to August 10, 1974. During this period the study sites were chosen, described and sampled.

3.1 Choice of Sites

A sampling site was chosen in a stand of each major tree type that occurred in the area. A stand was considered as any area occupied and dominated by particular tree species.

On the west side five sites were selected. Four of these were in aspen, jack pine, black spruce, and white spruce (Figure 4). No birch stands were found in the immediate area, and birch was consequently not sampled on the west side of the river.

The fifth site was selected for the purpose of studying the effects of clearing: it was located at a site in the mine area (Figure 5) which had recently been cleared (April, 1974). Felled black spruce were present at the site. The cleared area was bordered to the west by an area dominated by black spruce; the plot itself was less than 100 meters from the black spruce cleared area boundary. Physical and entomological comparisons between the black spruce and cleared areas can be made but it should be borne in mind that the differences in canopy cover, light conditions, ground flora and other biological and physical factors can not be quantified since no examination of the cleared area was made prior to clearing.

Although Alberta Forest Service maps indicated that pure stands of all the major tree types were present on the east side of the river, this proved not to be the case. Three stands were selected, of aspen, birch and a mixed stand of black and white spruce (Figure 6).

Figure 4. Location of the undisturbed study sites on the west side of the Athabasca River. A. Aspen; B. Black Spruce; C. White Spruce; D. Jack Pine. (Source map used: 74E/4E Edition 2 ASE, Series A 741, Army Survey Establishment, R. C. E.)

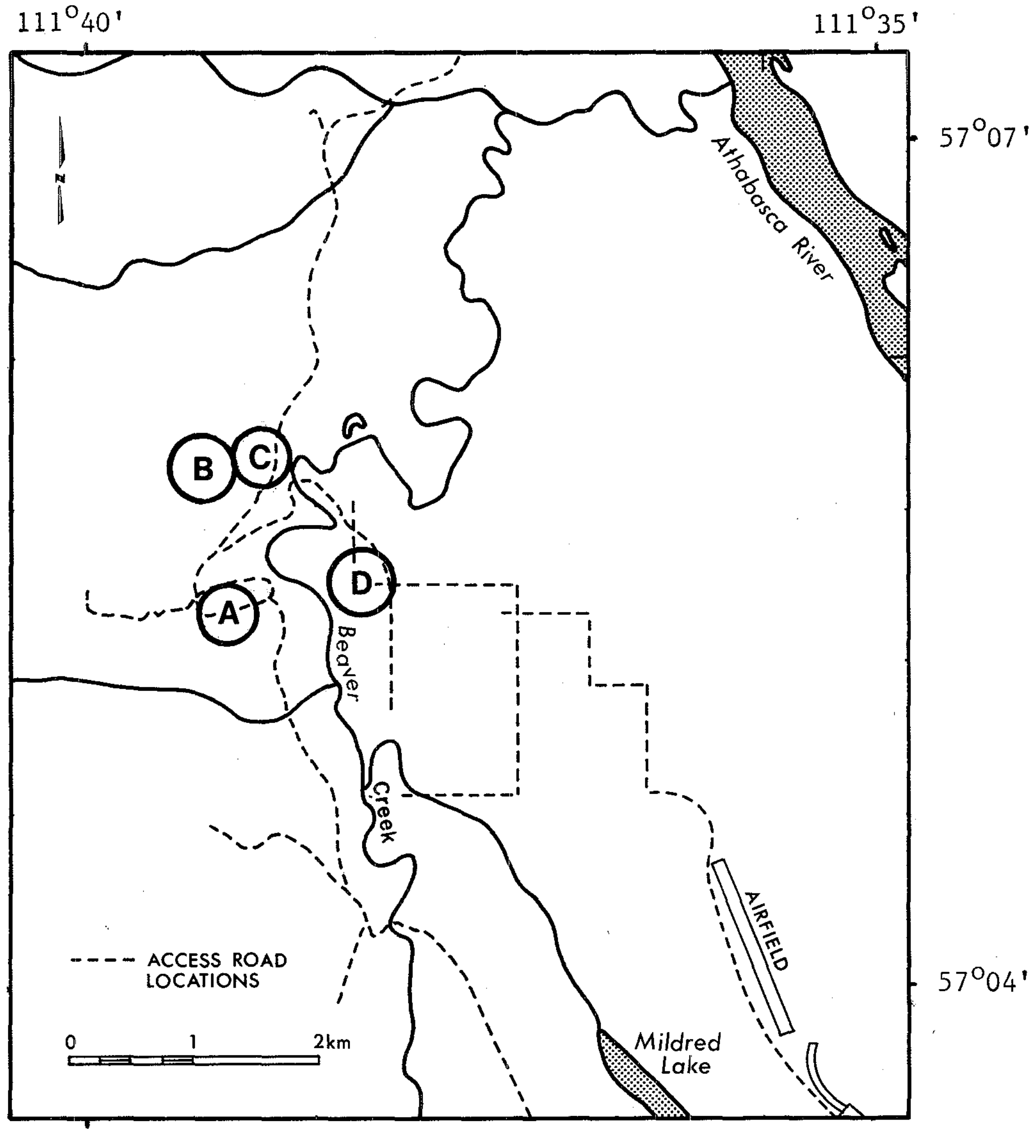


Figure 5. Location of study sites on the east side of the Athabasca River. A. Aspen; B. Birch; C. Black/White Spruce. (Source maps used: 74E/3W Edition 2 ASE, Series A 741, 74D/14W Edition 2 ASE, Series A 741, Army Survey Establishment, R. C. E.)

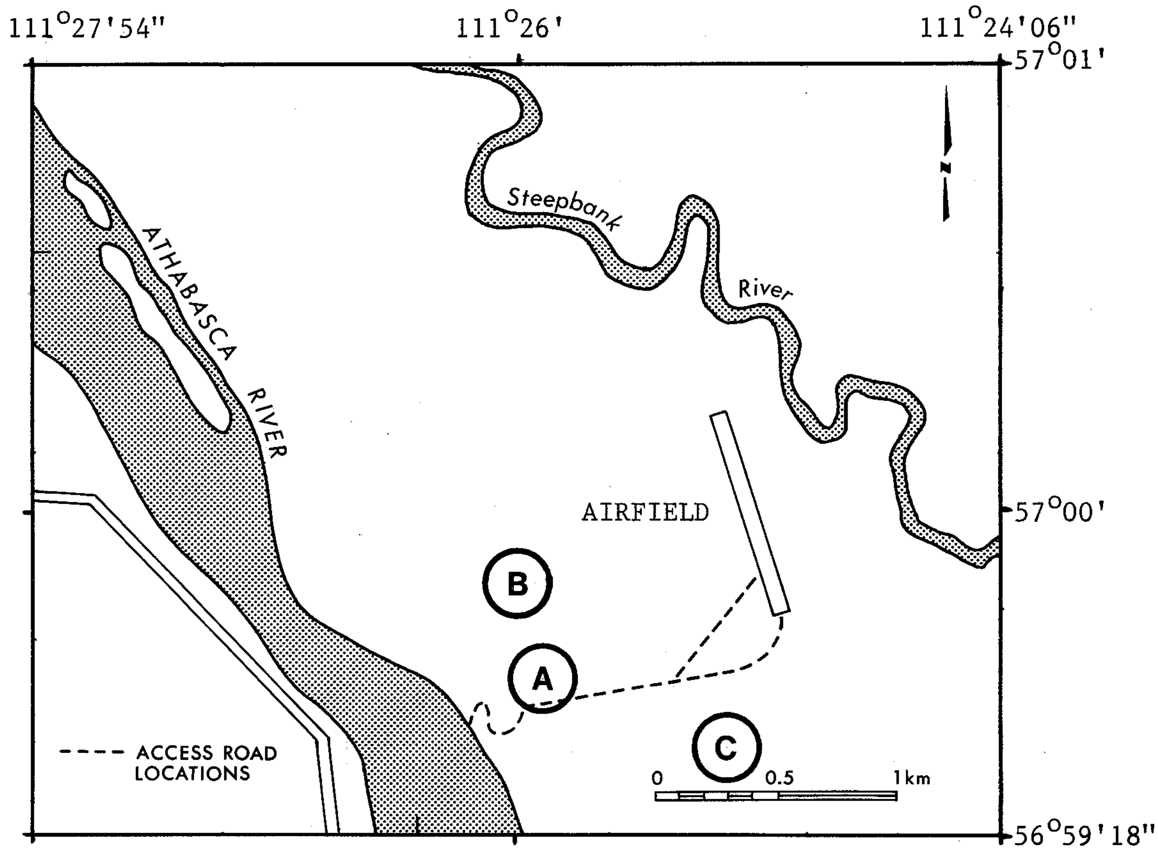
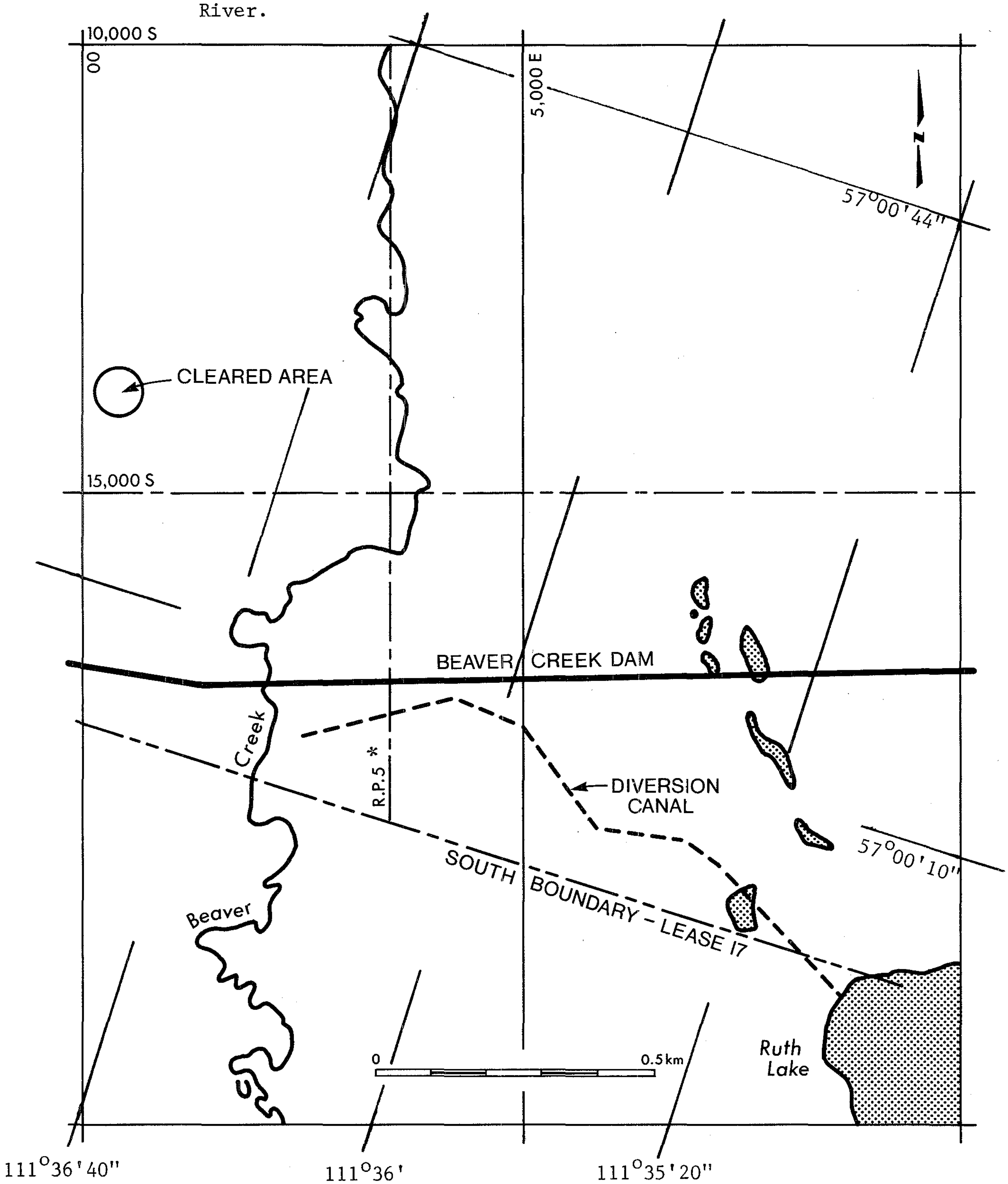


Figure 6. Location of the cleared study site, west side of Athabasca River.



Source maps used: Canadian Bechtel Ltd., Job 9776, Drawing IR-A-100B; 74E/4E Edition 2 ASE, Series A 741, Army Survey Establishment, R. C. E. Bechtel coordinate system (e. g., 10,000S, 15,000S) based on plant north (17°21'15" west of true north). *R. P. 5 - Reference Point 5, Baseline.

As all sites on the east side were near pollution indicator cylinders (set out by both the A.F.S. and Great Canadian Oil Sands Ltd. (G.C.O.S.), the only presently operating tar sands project), they were presumed to be within the area affected by G.C.O.S. atmospheric emissions. Observations of the direction in which the stack plume was blown supported this judgement.

3.2 Sampling System

In order to obtain an unbiased estimate of any given population, the quantitative sampling data should be collected at random so that every sampling unit in the universe has an equal chance of being selected. In its simplest form - the unrestricted random sample - the samples are selected by the use of random numbers from the whole universe (area) being studied. Such a method eliminates any personal choice by the worker whose bias in selecting sampling sites may lead to large errors (Handford, 1956).

For most ecological work however, the method of stratified random sampling is preferred (Yates and Finney, 1942; Healy, 1962), since it minimizes the variance. In stratified random sampling the study area is divided into a number of equal-sized subdivisions or strata and one sample is randomly selected from each stratum (using random numbers as coordinates). This eliminates the possibility of the majority of the samples being concentrated in one small area of the universe under study, and maximizes the accuracy of the results (Southwood, 1968).

The stratified random sampling method was used in this study to locate the soil and foliage samples. To avoid any biases in location of the transect line, which formed the basis for the sampling grid, it was selected randomly by throwing a stake over the shoulder. The point at which the stake landed was taken as the origin of the transect line; the direction in which the stake pointed was taken as the direction in which the transect should run.

Thus, after selection, a site was systematically treated as follows:

(a) A 50 meter transect line was selected at random.

(b) A wooden stake was driven into the ground at the origin, and the distal end of the transect line was located using a metric tape measure and a compass.

(c) Stakes were driven into the ground at 5 meter intervals.

(d) The pitfall traps were set in the ground at 5 meter intervals along lines running at 90° to the left side of the 0, 10, 20, 30, 40, and 50 meter markings on the transect (for a total of 30 pitfall traps per plot).

(e) Soil samples were removed after being located using coordinates selected from tables of random numbers.

(f) Foliage samples were removed from trees that were selected in a manner similar to that of the soil samples.

Figure 7 is a diagrammatic representation of a typical study plot.

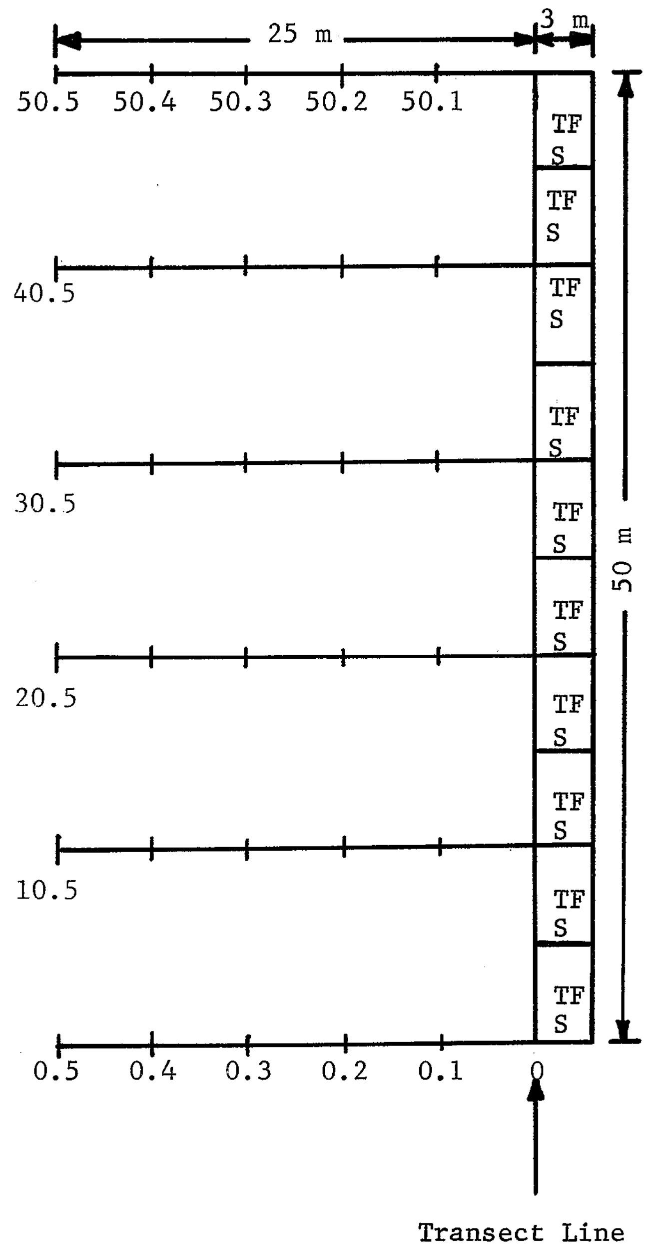
3.3 Sampling Methods

Appendix 2 presents a summary of the fieldwork activities pertaining to the sampling methods.

3.3.1 Soil Insect Sampling

In each of the selected sites, ten 0.25 m^2 soil samples were taken. The samples were selected from within the 50 m x 3 m area to the right side of the transect line located using pairs of random numbers coordinates. The point at which the coordinates met was taken as the lower left corner of the 0.25 m^2 steel wire quadrat. The soil samples themselves were removed from inside the quadrat by means of a sharp trenching tool to the depth of the mineral soil where possible. This was generally to a depth of approximately 10 cm. In plots where the organic layer was very thick, for example in the muskeg areas, the organic layer was removed to a depth of approximately 10 cm.

Fig. 7. Outline of a typical study plot. The co-ordinates (eg., 0.1, 0.3, 50.2, 50.5) represent the location of the pitfall traps. TF - tree foliage samples taken; S - soil samples taken.



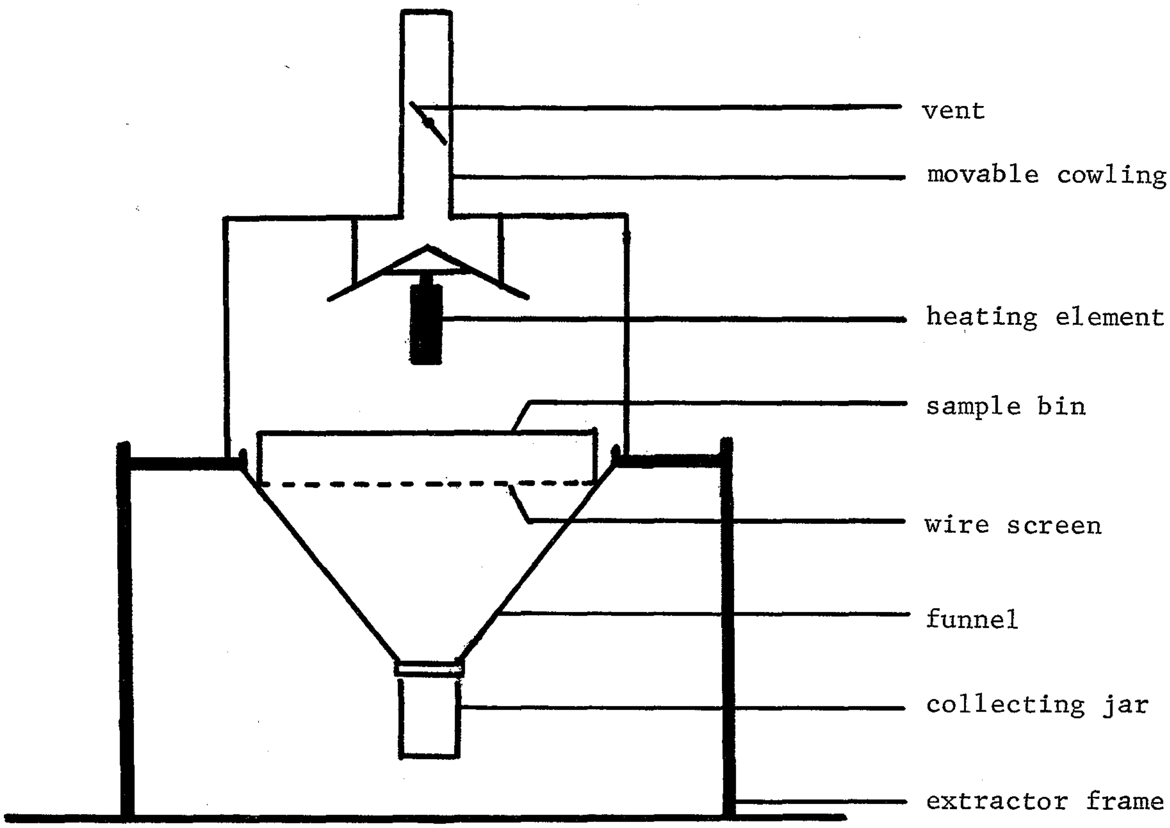
Each sample was put in a large plastic bag, labelled for later identification, and returned to the laboratory. At the laboratory insects were extracted from the samples in Macfadyen-Tullgren funnels (Figure 8).

Soil samples that were taken before extractors were available were preserved in cold storage at temperatures just above freezing. At the Syncrude Mildred Lake Lower Camp samples were stored in the "core room" and at Calgary in controlled temperature cabinets at temperatures between $1^{\circ}C$ and $5^{\circ}C$. Such temperatures restrict insect activity and maintain samples in a condition little changed from when they were first taken (Wallwork, 1970; Carter, 1975). The longest period that any sample was in cold storage was 11 days. During transportation of un-extracted samples from the Syncrude camp to the Calgary laboratory facilities, the low temperature was maintained by placing the samples in down-filled sleeping bags. Transit time was about 10 hours.

The same extractors were used throughout the study. The extraction process takes from three to six days for optimum (maximum) extraction. However, with wet muskeg samples the extraction time was as long as eight days. A temperature gradient is created in the soil sample within the Macfadyen-Tullgren funnel. The maximum temperature reached on the upper surface of the soil sample is approximately $50^{\circ}C$ in those (wetter) samples requiring eight days for extraction; in the remaining (drier) samples this maximum varied between 35 and $40^{\circ}C$. It is probable that such temperatures will be fatal to some individuals, especially those which are less mobile or less tolerant to temperatures exceeding those encountered in the soil.

All insects, including winged adults, gravitate to the bottom of the sample at the soil/air interface to avoid the heat generated by the element. From here they eventually fall through the wire mesh (holding up the soil) into the large funnel and finally into the collecting jar screwed onto the latter. The collecting jar was filled to a depth of 2 cm with water and the insects were removed every 24 hr. Extraction ceased when two criteria were fulfilled:

Fig. 8. A Macfadyen-Tullgren controlled draught extraction funnel for soil arthropods (Macfadyen, 1962). Scale 1 : 7.



(a) when the sample was dry to the touch, and

(b) when no more insects were seen to be extracted after a single period of 24 hours had elapsed.

The more mobile species (e.g., Carabidae) were extracted after a period of 48 to 72 hours (Carter, 1975).

The extraction efficiency of this method varies for different insect groups. Absolute extraction efficiency of this type of funnel has not been checked, but approaches 100% for larvae and adults of the Carabidae (Carter, 1975).

The pH of the soils was measured with an Hellige-Truog Soil Tester in the laboratory, which can read pH to the nearest 0.1 of a pH unit.

3.3.2 Litter Insect Sampling

Pitfall traps (Plate 1) comprise a plastic plantpot set into a hole in the ground. The open end diameter is approximately 15 cm, lower end diameter approximately 10 cm, and height (= depth) approximately 15 cm. The rim of the pot is left flush with the litter layer to facilitate the capture of mobile litter-dwelling insects.

No rain cover was provided but the holes in the bottom of the pots allowed rain water to escape. The holes were, however, covered with plastic screening (mesh size approximately 1.5 mm) to prevent the escape of larger organisms, especially ground beetles (Carabidae). Smaller organisms such as mites and collemboles were ignored because of the impraticability (due to their size) of their recovery in the field.

Natural litter was placed in the pitfall traps to reduce deaths among trapped specimens by predation, desiccation or starvation. No preservatives were placed in the pitfalls since these additives tend to emit odors which are detectable, and therefore avoided by, potentially trapable specimens.

Pitfall traps yield qualitative information only; the time span between collections from pitfall traps is, therefore, not critical. However, if the traps are left in place for too long they could drain an area of its more mobile litter insect fauna. None of the pitfall traps in this study was allowed to remain in place for more than eight days. On the east side of the river several traps were destroyed by bears (16 in Aspen and 8 in Birch).

3.3.3 Foliage Insect Sampling

Foliage sampling was performed in order to obtain quantitative estimates of the densities of tree canopy dwelling insects. To determine the optimum number of samples per tree (n_s) that should be taken, the within-tree sample variance (s_w^2) must be compared with the between-sample variance (s_b^2) and assessed against the time-cost of sampling within the same tree (c_w) or the time-cost of moving to, and sampling within, another tree (c_b). Thus:

$$n_s = \sqrt{\frac{s_w^2}{s_b^2} \times \frac{c_w}{c_b}} \qquad \text{(Southwood 1968).}$$

If the major source of variance is that between trees (s_b^2) and unless the cost of moving from tree to tree is very high, n_s will be of the order of one or less (i.e., one in practice) (Southwood 1968). Between-tree variance has been found to be much greater than within-tree variance in, for example, the spruce sawfly *(Gilpinnia hercyniae)* (Prebble 1943), the lodgepole pine needle miner *(Recurvia starki)* (Stark 1952), the spruce budworm *(Choristoneura fumiferana)* (Morris 1955, 1963), the winter moth *(Operophtera brumata)* (Morris and Reeks 1954) and the diamond-back moth *(Plutella maculipennis)* (Harcourt 1961). In most of these examples only one sample was taken per tree or per stratum of that tree because the within-tree variance was so small. With some aspen and apple insects the within-tree variance becomes larger, especially at certain seasons, and then as many as seven samples are required from a single tree (LeRoux and Reimer 1959; LeRoux 1961; Paradis and LeRoux 1962; Pottinger and LeRoux 1971).

In order to obtain estimates of the insect populations present in the foliage, ten trees were selected to the right side of the transect line in each plot, using coordinates selected from tables of random numbers. Where there were less than ten trees lying within the boundaries set to the right side of the transect, only the number present were sampled; that is, no other trees were selected from within the plot to increase the number sampled to ten.

Each tree crown was divided into three general levels (upper, middle, and lower crown). From each of these levels, twig samples approximately 25 centimeters in length were removed with the aid of pole pruners (maximum reach approximately 7.5 - 8m). To be consistent with the studies reported above, at least one sample was taken from each crown level and a total of seven samples was taken from each tree (n_s = 56 to 70 per plot). This sampling system is designed to yield quantitative insect population density data and such a procedure ought to furnish acceptable data upon which to base a more detailed sampling system.

Twig samples were labelled for height, aspect, tree species and plot, then placed in paper bags and returned to the laboratory for examination. Those samples which could not be examined immediately were placed in cold storage (5^{o} C maximum) (Pottinger and LeRoux 1971). Prior to examination, each twig and its bag were shaken onto paper to dislodge any insects. These, when present, were placed in a "killing jar" containing tissue paper soaked in ethyl acetate. When dead they were transferred to a vial containing glycerine alcohol and labelled for later identification. The twigs were examined under the microscope for

Plate 1.
A pitfall trap, shown in place. (Photo by Lousier, Porter and Weseloh.)

Plate 2.
A window trap. (Photo by Lousier, Porter and Weseloh.)

Plate 3.
Malaise trap. (Photo by Lousier, Porter and Weseloh.)

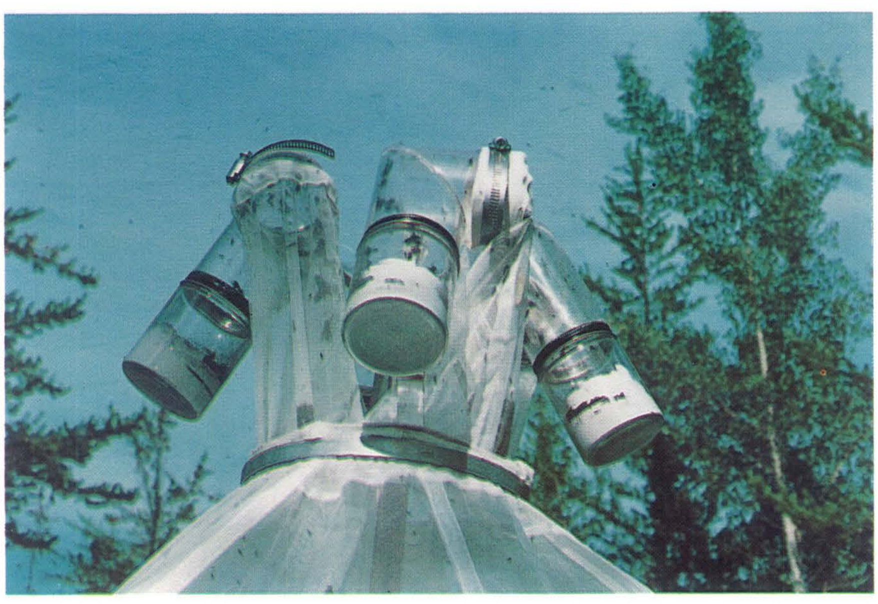


Plate 4.
Detail of Malaise trap collecting assembly. (Photo by Lousier, Porter and Weseloh.)

other evidence of insect activity (such as faeces, exuviae, eggs, partially chewed leaves) while the insects were in the "killing jar". A note was made where any evidence was found.

The insects encountered were identified with the aid of a taxonomic key (Brues, Melander and Carpenter 1954).

3.3.4 Aerial Insect Sampling

Two types of interception traps were used to sample flying insects. Flying Coleoptera and other insects which fall on hitting an obstacle during flight were sampled with window traps (Plate 2). Flying insects which tend to be directed upwards on hitting an obstacle were sampled with Malaise traps (Plates 3 and 4) (Southwood 1968). Both types of interception trap yield qualitative data only.

Window traps consist of two uprights, a "plexiglass" sheet (120 cm x 60 cm), and two metal troughs, one at the base of each side of the "plexiglass" sheet. The troughs are filled to a depth of approximately 5 cm with a dilute solution of preservative (4% formalin). The uprights are driven into the ground until the troughs are set 1 m above the ground. The window traps were oriented to intercept flying insects carried by the prevailing winds. By observation of the G.C.O.S. plume during the course of the fieldwork, the prevailing winds were seen to be primarily westerly.

Malaise traps comprise a wooden frame supporting a net "tent" with cross baffles to intercept the path of flying insects. The net mesh size was 1 mm^2, the height of the whole apparatus was approximately 2.3 m and the base was approximately 1.8 m x 1.8 m (i.e., base area about 3.25 m^2). Full details of the design and dimensions are given in Townes (1962).

Insects hitting the baffles are directed to a collecting assembly, containing a "killing agent", where they remain until the jars are emptied (every 3 to 6 days). The killing agent and preservative used was formalin. Phenol crystals were mixed with the formalin to prevent fungal growth that could destroy the trapped specimens. Plaster of Paris was placed in the collecting jars, allowed to solidify and then soaked with the formalin and phenol mixture. This procedure maintains the potency of the mixture for well over one week. The jars were left for a maximum of six days before emptying.

The window and Malaise traps were set up in areas where there was relatively little wind and where insect flightpaths were thought to occur; that is in relatively sheltered open areas (Southwood, 1968). Ground-dwelling forms will invariably enter Malaise traps. Some non-winged (nymphs) and winged (reproductive adults) specimens of ground-dwelling groups - ants and grasshoppers - were trapped. The non-winged ground-dwelling specimens were not included in the counts.

3.4 Habitat Descriptions

Brief descriptions were made of the eight sites studied. These descriptions include general features of each site; the trees, shrubs, and herbs and groundcover occurring on each site; and notes on the soil conditions and descriptions of interception and Malaise trap sites.

Subjective evaluations were made on plant abundance, i.e., "rare" (1-2 plants observed per 30 m x 50 m plot), "occassional" (3-6 plants per plot), "common" (up to 20 plants per plot), and "very common" (more than 20 plants per plot). More detailed information concerning plant species present in the tar sands area, their percentage cover and frequency, is given in Wheeler and Vaartnou (1973a, b).

The vegetation identifications were done in the laboratory facilities in Calgary with the following keys: Hosie (1969) (trees), Moss (1959) (shrubs and herbs), Schofield (1969) (feather mosses), and Hale (1969), Bird (1972), Thomson (1967), (lichens).

4. RESULTS

4.1 Habitat Descriptions

The percentage cover and relative abundance of the plant species encountered at the study sites are tabulated as follows: tree cover - Table 1; shrub cover - Table 2; herbs and ground cover - Table 3.

Appendix 3 lists the common and scientific names of the vegetation identified in the study plots.

Field observations, and frequency and cover figures provided by Wheeler and Vaartnou (1973a, b) indicate that, in terms of overall ground flora, grasses do not constitute a major component of the community. At least one of three conditions, that is, drought, habitat disturbance, and poor light conditions, that select against abundant grasses and other ground flora, characterized each of the sites chosen for this study. Laboratory identification to the species level of grasses was severely hindered as the grasses were entirely vegetative. Thus the grasses that were encountered at each site were collected but not identified; this may be justified in light of the above reasons and the reconnaissance nature of the study.

4.1.1 West Side of Athabasca River

Aspen

The area selected, a stand of aspen with some small white spruce, was quite extensive in size and uniform in age. The understory was dense and composed of a variety of shrubs varying in height from 0.5 to 2.5 m. The most sommon shurbs were wildrose and squashberry; the most common ground cover species was twin-flower. The organic layer of the forest floor was 2.5 cm deep, consisting of a thin layer of aspen litter and a well-developed fermentation layer. The underlying mineral soil exhibited considerable variability, being fine-grained, dark reddish-brown for 5 cm and underlain by pale reddish-brown soil in one area and clay-like and uniformly gray for 15 cm in another sampling area. The pH ranged from 6.9 to 7.4 (mean, 7.2; number of samples, n = 7).

Black Spruce

The plot was established in a dense stand of pure black spruce on muskeg terrain. The main transect line of the plot was oriented east-west. The common shrubs were Labrador tea and bog cranberry. The ground vegetation was dominated by feather mosses with sphagnum occurring on the hummocks. The common herbs were twin-flower, tall lungwort and coltsfoot. Conditions were very moist with the water table about 20-30 cm below the top of the mosses. The soils consisted of a spongy mass of mosses and organic matter. The live green mosses were about 5 cm deep and underlain by 12-15 cm of dead or live moss rhizoids, abundant small spruce roots and brown detritus. Below 15-20 cm, the organic matter was dark brown, fibrous, permeated by abundant small roots and very wet. Occasional large rocks were encountered at the 30 cm depth. The soil pH varied from 5.1-6.3 (mean, 5.7; n = 6).

The Malaise trap was erected in an area west of the plot. The area was black spruce muskeg with the trees widely spaced. Occasional western larch were widely scattered throughout the area. The dominant shrub was common Labrador tea and the dominant moss was sphagnum.

White Spruce

The white spruce stand selected was about 400 m north of the Beaver Creek Provincial Campground. The area was gently sloping upwards to the west, and the plot was located in the central portion of the stand with the main transect line oriented directly east to west up the slope. A very small stream flowed through the plot area. The area was very wet with the water table only 15-25 cm beneath the tops of the feather mosses which completely covered the ground. The stand was dominated by white spruce, but some young black spruce and balsam poplar were present. The area had quite dense shrubbery, the most common of which was green alder, located in the west end. The soil was organic and covered with a dense mat of feather mosses. Live, green mosses were about 5 cm deep and beneath this was dark brown organic material of fibrous nature. Below 15 cm the material was nearly black. All layers to a depth of 25 cm were densely permeated by small roots. Soil pH ranged from 5.1 to 6.2 (mean, 5.4; n = 11).

Jack Pine

The jack pine plot was located about 50-100 m from the Fort McKay highway in a mature stand of widely spaced jack pine. The main transect line was oriented NE to SW (222^{o}). Jack pine was the only mature tree in the plot, and was infected to a large degree (more than 50%) by dwarf mistletoe. Ground cover was nearly 100%, being dominated by reindeer lichen (75%) and common bearberry (20%). Tall shrubs, including aspen saplings, were widely scattered. The soil was very sandy and excessively well-drained giving drought conditions. The forest floor, including lichens, was 2-3 cm deep, forming a poorly to well-defined organic mat with a thin fermentation layer (less than 1 cm). The mineral soil showed distinct evidence of leaching in the upper horizon, giving a podzolic appearance. The surface 3-5 cm thick layer was gray and often stained with dark organic matter. Below this, the sand was reddish-brown and the texture similar. The pH of the mineral soil was 7.5 (all four samples were 7.5).

The window trap faced east-west and was placed in the center of the plot. The Malaise trap was located outside the plot in an open area within a mixed aspen-jack pine stand with similar ground cover.

Cleared Area

The area was cleared in April 1974 of all vegetation and had a severely disturbed soil surface. An undisturbed area 100 m to the west and the presence of felled black spruce indicated that the cleared area had probably been a typical black spruce muskeg habitat. The main line of the plot was oriented WNW (290^{o}). The soil was largely disturbed and the surface was covered with considerable amounts of slash. The water table was about 10 cm below the surface. The soil was organic and composed of fibrous dead mosses and small roots, and had a pH of 4.5-8.0 (mean, 5.8; n = 7).

The window trap was placed on the main transect line at a right angle to it, i.e., approximately north-south and facing the prevailing winds. The Malaise trap was erected in the cleared area about 10 m from the undisturbed black spruce muskeg. The surrounding area was completely cleared except for the stand of aspen to the southwest. Brush species in the immediate vicinity of the trap were shrubby cinquefoil, swamp birch and Canadian buffaloberry.

4.1.2 East Side of Athabasca River

Aspen

The stand was composed of nearly pure aspen with occasional spruce and balsam poplar in the understory. The age of the aspen was estimated at 20-25 years. The elevation was highest in the SW and sloped about $2\text{-}3^{o}$. The main transect line was oriented due west. The understory was fairly dense with a variety of shrubs and herbs. The organic layer of the dry forest varied from 3-5 cm in depth with a well-developed fermentation layer. The mineral soil differed on the highest areas and on the lower area along the transect line. These differences appeared to be due to soil erosion. The surface soil on the higher areas was reddish and coarse textured with abundant gravel. This was underlain at undetermined to 25 cm depths by firm, gray clay. In the lower areas, the coarse-textured surface was absent. In these positions on the landscape the entire profile was composed of gray, hard-packed clay-like loam. The pH was 6.4-7.4 (mean, 6.7; n = 7).

Black/White Spruce

This stand was selected for study as it appeared quite comparable to the white spruce stand on the west side of the Athabasca River. However, the east stand was composed of a mixture of black and white spruce. The exact composition was not determined but the black spruce appeared to predominate. The plot was established in the center of the stand with the main transect line oriented approximately east (86°). The west end of the plot had little undergrowth whereas shrubs were quite common in the eastern end. The most common ground cover species were feather mosses, horsetails, twinflower, and one-flowered wintergreen. The soil was entirely organic in nature and quite moist. The upper 5 cm were composed of live, green mosses and spruce litter. The 5-10 cm depth was composed of brown fibrous debris and live moss rhizoids and fine roots. Below the 10 cm depth the fibrous organic matter was darker in color and moist. The pH ranged from 5.1-7.4 (mean, 6.0; n = 7).

The Malaise trap was erected in an open black spruce muskeg stand about 50 m north of the white spruce-black spruce stand. The black spruce trees were fairly widely spaced and 2-4 m tall. Occasional western larch and numerous small spruce (less than 1 m in height) were found. The most common subordinate vegetation included horsetails, small willows, common Labrador tea, Canadian buffalo-berry and the solid cover of sphagnum and feather mosses.

Birch

The white birch stand was selected for study as the site closely resembled the jack pine site on the west except for the difference in tree species. The birch site was located on a narrow, sandy ridge of glacial origin. The plot was established in the center of the birch stand and the transect ran 24° west of north along the center of the ridge. The plot sloped gently to either side of the transect. The total extent of the birch area was about 200 m long and 80-100 m wide. The birch were widely scattered and occurred in clumps of three to eight stems. Small numbers of white spruce, jack pine, balsam poplar and aspen were also present in the stand. The ground vegetation was dominated by blueberry and reindeer lichens which accounted for nearly 100% coverage. The mineral soil was of a very dry sandy texture throughout and of a uniform gray-brown color. It was overlain by a thin organic horizon and reindeer lichens. The soil was quite similar to the jack pine soil except for the absence of a leached A horizon. The pH was 4.8-7.4 (mean, 5.1; n = 8).

The window trap was erected, facing east-west, about 50 m SSE of the birch plot in the center of the sandy ridge. The area was open with widely spaced birch and occasional aspen and jack pine. A dense stand of aspen was located 25 m to the south. Dense muskeg vegetation was located to the north.

4.2 Insects Encountered in the Study Area

The following pages contain the tabulated results of the insect counts:

Table 4 outlines the densities (per m^2) of each life stage of insect taxa extracted by Macfadyen-Tullgren funnels from soil samples taken from all the study sites.

Tables 5 and 6 indicate the insects captured by pitfall traps placed in the soil in all study areas.

Table 7 lists the insect taxa encountered in the tree foliage sampling.

Table 8 presents data on the aerial insect families captured in window traps.

Table 9 indicates Malaise trap catches of aerial insect families.

Blank spaces in the above tables indicate that none of that particular taxon was observed in the sample(s).

All taxa listed in the tables are in the taxonomic order given in the keys used in the insect identification. Arnett (1968), Brues, Melander and Carpenter (1954) and Lindroth (1961-1969).

Appendix 4 lists the orders, families, genera and species, divided into stages in the life cycle, encountered in each plot and Appendix 5 the casual observations made during the study (i.e., insects observed but not present in any of the samples taken).

Table 1: Tree Species: % Canopy Cover, Distance Apart, DBH, Height

A list of tree species encountered, with data on % canopy cover in each plot.

	WEST					EAST		
TREE SPECIES	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Betula papyrifera Marsh.								20
Larix laricina (Du Roi) K. Koch								
Picea glauca (Moench) Voss			100				25-30	
Picea mariana (Mill.) BSP		100					45-50	2
Pinus banksiana Lamb.				20				2
Populus balsamifera L.							5-10	1
Populoides tremuloides Michx.	100					80		1

A list of tree species encountered, with data on distance apart of trees, in each plot.

	WEST					EAST		
TREE SPECIES	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Betula papyrifera Marsh.								5-10
Larix laricina (Du Roi) K. Koch.							12-30	
Picea glauca Moench) Voss	5-10		2-5			5-10	.7-5	12-30
Picea mariana (Mill.) BSP		.7-1	15-20				.7-5	
Pinus banksiana Lamb.				4-10				2-30
Populus balsamifera L.			10-15			30-50	1-2	12-30
Populoides tremuloides Michx.	.5-2			5-10		.5-2		12-30

Table 1 continued ....

A list of tree species encountered, with data on diameter at breast (DBH) in each plot.

TREE SPECIES	WEST					EAST		
	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Betula papyrifera Marsh.								5-20
Larix laricina (Du Roi) K. Koch								
Picea glauca (Moench) Voss	1-3		15-35			1-3	15-45	
Picea mariana (Mill.) BSP		3-12	3-7				15-30	.5-12
Pinus banksiana Lamb.				10-30				.5-18
Populus balsamifera L.		.5-1.5				0.5	2-40	.5-1
Populus tremuloides Michx.	3-12					5-10		.5-1

A list of tree species encountered, tree height, in each plot.

TREE SPECIES	WEST					EAST		
	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Betula papyrifera Marsh.								6-12
Larix laricina (Du Roi) K. Koch							0.5	
Picea glauca (Moench) Voss	1-3		25-30			1-3	20-25	
Picea mariana (Mill.) BSP		3-10	3-6				20-25	.5-6
Pinus banksiana Lamb.				6-12				.5-6
Populus balsamifera L.			1-2			.5-1.5	2-25	.5-2
Populus tremuloides Michx.	5-10			.5-1		5-10		.5-2

NOTE: DBH applies only to those trees above breast height.

Table 2: Numbers and Species of Shrubs Encountered in Each Plot

	WEST					EAST		
	Aspen	Black Spruce	White Spruce	Jack Pine	Cleared Area	Aspen	Black-White Spruce	Birch
Alnus crispa (Ait.)Pursh.	O	R	C				R	O
Amelanchier alnifolia Nutt.			R	R		C		R
Arctostaphylos rubra (Rehder & Wils.)Fern.		O		VC	C	O	O	
Betula pumila L.var. *glandulifera* Regel					O		R	
Cornus stolonifera Michx.	O	R	C			O	C	
Lendum groenlandicum Oeder.		O-C	O		O		C	O
Potentilla fruticosa L.			R		O		R	
Prunus pensylvanica L.f.				R		O		R
Ribes lacustre (Pers.)Poir.		O	C				C	
Ribes triste Pall.	C		C				C	
Rosa sp.	VC	O	O			C	C	
Salix sp.	O	R	O			O	C	
Shepherdia canadensis (L.)Nutt.	O	R	R			O	O	
Vaccinium myrtilloides Michx.				C			O	VC
Vaccinium vitis-idaea L.var *minus* Lodd.		C	C	R	C		C	O
Vibrunum edule (Michx.)Raf.	VC	O	O			C		

KEY: R = Rare = 1-2 individuals per plot

O = Occasional = 3-6 individuals per plot

C = Common = 7-20 individuals per plot

VC = Very Common = >20 individuals per plot

Blank indicates that species was not observed in that plot.

Table 3: Number and Species of Herbs and Ground Cover Encountered in Each Plot

HERBS AND GROUND COVER SPECIES	WEST					EAST		
	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Cladonia rangiferina (L.)Wigg.		R		VC	O		O	VC
Peltigera aphthosa (L.)				O			O	
Marchantia sp.						R		
Hylocomium splendens (Hedw.)B.S.C.		VC	VC				VC	
Pleurozium schreberi (Brid.)Mitt.		VC	VC				VC	
Ptilium crista-castrensis (Hedw.)De Not.		VC	VC				VC	
Sphagnum sp.		C	C				C	
Equisetum arvense L.		C-VC	VC		C		VC	
Equisetum scirpoides Michx.		VC	VC				VC	
Lycopodium complanatum L.				C				
Gymnocarpium dryopteris (L.)Newn.			R					
Carex sp.		O	O		O		O	
Achillea millifolium L.		R					R	
Anemone multifida Poir.				R				

KEY: R = Rare = 1-2 individuals per plot

O = Occasional = 3-6 individuals per plot

C = Common = 7-20 individuals per plot

VC = Very Common = >20 individuals per plot

Blank indicates that species was not observed in that plot.

Table 3 continued ....

HERBS AND GROUND COVER SPECIES	WEST					EAST		
	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Apocynum androsaemifolium L.				O				O
Aralia nudicaulis L.	O		C			C		R
Arceuthobium americanum Nutt.				C				
Aster ciliolatus Lindl.						R		
Aster conspicuus Lindl.	R					R		
Comandra pallida A. DC.				O				
Cornus canadensis L.	C	O	VC			C	C	C
Epilobium angustifolium L.	O		R		O	O	O	R
Erythronium grandiflorum Pursh.								R
Galeum boreale L.	O	O	O		O	O	C	
Geocaulon lividum (Richards)Fern.		O	R				R	R
Goodyera repens (L.)R.Br.			R					
Habenaria orbiculata (Pursh.)Torr.			R					
Lathyrus ochroleucus Hook.	O					O		
Lilium philadelphicum L.var *andinum* (Nutt.)Ker.					R			
Linnaeae borealis L.var *americana* (Foube)Rehd.	VC	C	VC	R		C	VC	
Maianthemum canadense Desf.var *interius* Fern.	C	R		VC		C		C
Melampynum lineare Desr.				C				C
Mertensia paniculata (Ait.)G.Don.	O	C	O	O			O	

Table 3 continued ....

HERBS AND GROUND COVER SPECIES	WEST					EAST		
	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Mitella nuda L.			VC				VC	
Moneses uniflora (L.) A. Gray		O	C				C	
Petasites palmatus (Ait.) A. Gray		C	C			C		
Pyrola sp.						R		
Pyrola asarifolia Michx.			O	O			R	
Pyrola secunda L.	R	R						
Rubus pubescens Raf.	C	O	C		O	C	C	
Smilacina trifolia (L.) Desf.	R							
Solidago nemoralis (Ait.) var *decemflora* (D.C.)Fern.			R					
Spiranthes romanzoffiana Cham. & Schl.			R					
Vicia americana Muhl.	O					O		

Table 4: Densities (m^{-2} ± standard error)[1] of Life Stages of Insect Taxa Extracted in MacFadyen-Tullgren Funnels from 10 Soil Samples (0.25 m^2) at Each Study Site.

			WEST					EAST		
ORDER	TAXA	LIFE CYCLE STAGE	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
HETEROPTERA	Unknown species #1	N	0.4 ± 0.38							
	Unknown species #2	N	0.8 ± 0.7							
HOMOPTERA	Aphididae	A	0.4 ± 0.38							
COLEOPTERA	Carabidae	A				2.8 ± 1.6		1.5 ± 1.08	0.4 ± 0.38	2.0 ± 0.85
		L	18.4 ± 2.84	0.44 ± 0.42	3.2 ± 0.95	1.6 ± 1.16			1.2 ± 0.81	0.4 ± 0.38
	Staphylinidae	A	13.6 ± 1.98	8.0 ± 2.95	9.6 ± 4.67	5.6 ± 1.81	8.0 ± 5.54	5.0 ± 2.42	14.4 ± 7.57	2.0 ± 1.3
		L	20.0 ± 5.48	8.89 ± 1.51	10.0 ± 1.72	3.2 ± 1.24	10.4 ± 5.5	12.0 ± 9.64	14.8 ± 3.58	4.0 ± 1.7
	Micropeplidae									
	Micropeplus sp.	A	0.8 ± 0.5							
	Cantharidae	A		0.44 ± 0.42						
	Lampyridae	L	1.6 ± 0.84		0.4 ± 0.38			0.5 ± 0.47	2.0 ± 1.52	
	Elateridae	A		2.22 ± 1.27	0.4 ± 0.38	0.4 ± 0.38				
	Byrrhidae	A		0.89 ± 0.55	0.8 ± 0.5	0.4 ± 0.38			1.6 ± 1.16	
	Cucujidae	L				0.4 ± 0.38				
	Nitidulidae									
	Brachypterus sp.	A						0.5 ± 0.47		
	Boreades sp.	A			1.2 ± 0.81		0.8 ± 0.71	2.0 ± 1.41	1.2 ± 0.58	0.4 ± 0.38
	Prometopia sp.	A						.5 ± 0.47		
	Colydiidae	A				1.6 ± 1.01				
	Anthicidae	L		0.89 ± 0.55	26.4 ± 6.45	3.2 ± 2.64		5.0 ± 1.7	3.6 ± 1.74	1.6 ± 1.52
	Pedilidae	L	16.4 ± 3.59	3.56 ± 1.71	14.8 ± 5.98	24.0 ± 8.04	1.6 ± 0.9	9.0 ± 3.45	4.0 ± 2.99	7.6 ± 4.47
	Mordellidae	A	0.8 ± 0.5			3.2 ± 1.77				
	Tenebrionidae	L	0.8 ± 0.5					8.5 ± 3.35	0.4 ± 0.38	1.2 ± 0.81
	Scarabaeidae									
	**Aphodius* sp.	A	16.7 ± 7.14							
	Curculionidae	A			0.4 ± 0.38			0.5 ± 0.47		8.0 ± 2.46
LEPIDOPTERA	Arctiidae	L		0.89 ± 0.55						
	Noctuidae	L	0.4 ± 0.38	0.44 ± 0.42						
	Pterophoridae	L		0.44 ± 0.42	0.4 ± 0.38	0.4 ± 0.38				
	Nepticulidae	L		1.78 ± 0.91						

....continued.....

Table 4 continued ......

ORDER	TAXA	LIFE CYCEE STAGE	WEST ASPEN	WEST BLACK SPRUCE	WEST WHITE SPRUCE	WEST JACK PINE	WEST CLEARED AREA	EAST ASPEN	EAST BLACK-WHITE SPRUCE	EAST BIRCH
DIPTERA	Tipulidae	L	0.8 ± 0.5		1.2 ± 0.58	0.4 ± 0.38		2.0 ± 1.41	0.4 ± 0.38	
	Ceratopogonidae	L			0.4 ± 0.38	4.0 ± 2.26				
	Chironomidae	L	0.8 ± 0.5		0.4 ± 0.38	1.2 ± 1.14				
	Bibionidae									
	*Unknown species #9	L	28.8 ± 13.82			216.0 ± 79.8				
	*Unknown species#10	L	174.0 ± 51.1							
	Mycetophilidae	L	49.2 ± 10.6	1.78 ± 1.68	8.0 ± 3.71	0.8 ± 0.76	4.0 ± 2.26	2.0 ± 1.87		0.8 ± 0.76
		P	2.4 ± 1.52			0.4 ± 0.38				
		A	4.4 ± 1.99			1.6 ± 0.62	0.8 ± 0.71			
	Cecidomyiidae	L	9.2 ± 3.05		2.4 ± 1.52	2.0 ± 0.85	1.6 ± 0.88	1.5 ± 1.4	4.8 ± 3.04	
		A	2.0 ± 1.29			0.8 ± 0.51				
	Stratiomyidae	L	9.2 ± 3.8		1.6 ± 0.84	2.8 ± 1.5	9.6 ± 6.94			1.2 ± 0.81
	Tabanidae	L	4.0 ± 1.26	1.33 ± 0.63	6.4 ± 2.05		2.4 ± 2.15	1.0 ± 0.61	4.0 ± 1.88	
	Therevidae	L				1.2 ± 0.81				
	Empididae	L	0.4 ± 0.38							
	Phoridae	L					0.8 ± 0.71			
	Syrphidae	L	1.2 ± 0.81	0.44 ± 0.42	2.4 ± 0.62					
	Anthomyidae	L	0.8 ± 0.7							
	Tachinidae	A				0.4 ± 0.38				
HYMENOPTERA	Ichneumonidae	A				0.4 ± 0.38				
	Pteromalidae	A		1.33 ± 0.89						
	Eulophidae	A				0.4 ± 0.38				
	Diapriidae	A		0.44 ± 0.42	0.4 ± 0.38	0.4 ± 0.38				
	Formicidae	A & I	8.4 ± 7.14	12.44 ± 7.31	8.4 ± 4.43	54.4 ± 26.38	8.8 ± 4.14	13.0 ± 9.58	8.0 ± 7.18	35.2 ± 14.63

LIFE CYCLE STAGES:
L - Larvae
P - Pupa
I - Immature
A - Adult
N - Nymph

*Possible indicator species

1. Densities were calculated using program no. FS2L30/SC95 from the Lousier, Porter and Weseloh program library.

Table 5: Occurrence and Life Stages of Insect Taxa Captured by Pitfall Traps in Each of the Study Sites. Data derived from 30 pitfall traps per plot on west side of river; 14, 30 and 22 traps respectively in ASPEN, BLACK/WHITE SPRUCE and BIRCH on east side of river. Presence indicated by +.

ORDER	TAXA	LIFE CYCLE STAGE	WEST					EAST		
			ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
ORTHOPTERA	Tetrigidae	A					+			
HETEROPTERA	Miridae	A				+	+			
	Tingidae	A							+	
	Aradidae	A					+			
	Scuterellidae	A					+			
	Podopidae	A								+
HOMOPTERA	Cercopidae	A								+
	Cicadellidae	A							+	
	Cixiidae	A			+					
	Aphididae	A				+	+			
COLEOPTERA	Carabidae	A	+	+		+	+	+	+	+
		L	+	+						+
	Histeridae	A				+				
	Staphylinidae	A	+	+	+	+	+	+	+	+
		L	+		+			+		
	Helodidae	L					+			
	Chrysomelidae	A	+							
	Curculionidae	A			+		+			+
		L	+		+					
TRICOPTERA	Limnephilidae	L			+					
LEPIDOPTERA		L	+					+		

.... continued .....

Table 5 continued ....

ORDER	TAXA	LIFE CYCLE STAGE	WEST: ASPEN	WEST: BLACK SPRUCE	WEST: WHITE SPRUCE	WEST: JACK PINE	WEST: CLEARED AREA	EAST: ASPEN	EAST: BLACK-WHITE SPRUCE	EAST: BIRCH
DIPTERA	Tipulidae	L					+	+		
	Chironomidae	L					+			
	Bibionidae	L	+							
	Mycetophilidae	L			+					
	Cecidomyiidae	L			+					
	Tabanidae	A			+			+		
		L			+					
	Asilidae	L	+							
HYMENOPTERA	Tenthredinidae	L	+							
	Braconidae	A			+					
	Diapriidae	A	+		+					
	Formicidae	A	+	+	+	+	+	+	+	+

LIFE CYCLE STAGES: A - Adult
L - Larva

Table 6: Carabidae Observed in Pitfall Catches. Data derived from 30 pitfall traps per plot on west side of river, 14, 30, and 22 respectively in ASPEN, BLACK/WHITE SPRUCE on east side of river. Presence indicated by +.

TAXA	LIFE CYCLE STAGE	WEST					EAST		
		ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	CLEARED AREA	ASPEN	BLACK-WHITE SPRUCE	BIRCH
Agonum retractum Leconte	L	+							
	A	+							
Amara sp.	A				+				+
Carabus taedatus Fabr.	A								+
Calathus ingratus Dejean	A				+	+			+
Cymindis sp.	A								+
Harpalus sp.	A						+		
Notiophilus sp.	A				+				+
Pterostichus haematopus Dejean	A		+						
Pterostichus sp.	A	+				+	+	+	+
	L								+
Synuchus impunctatus Say	A	+			+	+	+		+
Trechus sp.	A								
Unidentified apecies #5	A		+						

LIFE CYCLE STAGES: A - Adult

L - Larva

Table 7: Results of Foliage Insect Sampling. Absolute numbers of each species encountered on the sample twigs.

			WEST				EAST		
ORDER	TAXA	LIFE CYCLE STAGE	ASPEN	BLACK SPRUCE	WHITE SPRUCE	JACK PINE	ASPEN	BLACK-WHITE SPRUCE	BIRCH
HETEROPTERA	Unknown species #3	N				2			
HOMOPTERA	Unknown species #4 *	N	35						
LEPIDOPTERA	Geometridae **	L	18						
	Gracillariidae *Phyllocnistis populiella******	L	3						

* 1 Mass found on 1 leaf cluster (petioles).

** All 18 found on the laminae of 1 twig.

*** Each larva was found on a different twig, i.e., 3 different twigs had 1 larvae present on 1 leaf.

In jack pine plot there was evidence of needle miner activity (hole + faeces) on less than 1% of the needles on the twigs examined (N = 56).

LIFE CYCLE STAGES: N - Nymph

L - Larva

Table 8: Aerial Insects Captured in Window Traps in Selected Study Sites. All individuals trapped were adults. Presence indicated by +.

ORDER	TAXA	WEST JACK PINE	WEST CLEARED AREA	EAST BIRCH
EPHEMEROPTERA	Baetidae	+		+
PSOCOPTERA	Psocidae	+		
HETEROPTERA	Miridae	+		
HOMOPTERA	Aphididae	+	+	+
COLEOPTERA	Staphylinidae	+		+
	Lycidae			+
	Elateridae			+
	Eucnemidae	+		+
	Mordellidae	+		+
	Scarabaeidae			+
LEPIDOPTERA	Microlepidoptera	+	+	+
DIPTERA	Chironomidae	+		
	Simuliidae			+
	Mycetophilidae	+	+	
	Stratiomyidae			+
	Tabanidae			+
	Asilidae	+		
	Phoridae		+	
	Syrphidae	+		+
	Tachinidae	+		
HYMENOPTERA	Ichneumonidae			+
	Formicidae	+		+
	Sphecidae			+
	Halictidae	+		
	Apidae	+		

Table 9: Insect Taxa Captured in the Selected Sites by the Malaise Traps. All individuals captured were adults. Presence indicated by +.

ORDER	TAXA	WEST JACK PINE	WEST BLACK SPRUCE	WEST CLEARED AREA	EAST BIRCH
ODONATA	Aeshnidae		+		
ORTHOPTERA	Acrididae				+
PLECOPTERA	Nemouridae				+
PSOCOPTERA	Psocidae			+	+
HETEROPTERA	Miridae	+	+	+	+
	Tingidae			+	
HOMOPTERA	Cercopidae			+	
	Cicadellidae	+	+	+	+
	Cixiidae		+	+	+
	Psyllidae	+		+	
	Aphididae	+	+	+	+
NEUROPTERA	Hemerobiidae		+	+	
COLEOPTERA	Staphylinidae	+		+	+
	Elateridae		+		+
	Buprestidae			+	+
	Helodidae			+	+
	Cucujidae			+	
	Nitidulidae			+	
	Coccinellidae			+	+
	Mordellidae				+
	Cerambycidae		+	+	
	Chrysomelidae	+	+		+
	Cleridae			+	
	Curculionidae			+	+
LEPIDOPTERA	Pterophoridae			+	
	Noctuidae			+	+
	Hepialidae				+

.... continued .....

Table 9 ...... continued ....

ORDER	TAXA	WEST JACK PINE-ASPEN	WEST BLACK SPRUCE	WEST CLEARED AREA	EAST BLACK-WHITE SPRUCE
DIPTERA	Tipulidae	+	+	+	+
	Psychodidae		+	+	
	Dixidae	+			
	Chaoboridae		+		
	Culicidae	+	+	+	+
	Ceratopogonidae	+	+	+	
	Chironomidae		+	+	+
	Simuliidae	+	+	+	+
	Anisopodidae				+
	Mycetophilidae	+	+	+	+
	Sciaridae	+	+	+	+
	Cecidomyiidae	+	+	+	+
	Stratiomyidae	+	+	+	+
	Tabanidae	+	+	+	+
	Threevidae	+			
	Asilidae	+	+	+	+
	Bombyliidae	+	+	+	+
	Empididae	+	+	+	+
	Dolichopodidae	+	+	+	+
	Phoridae	+	+	+	+
	Pipunculidae	+	+	+	+
	Syrphidae	+	+	+	+
	Conopidae				+
	Sepsidae		+		+
	Sciomyzidae	+	+	+	+
	Chloropidae	+	+	+	+
	Anthomyiidae	+	+	+	+
	Muscidae	+	+	+	+
	Tachinidae	+	+	+	+
HYMENOPTERA	Tenthredinidae	+	+	+	+
	Argidae				+
	Braconidae	+	+	+	+
	Ichneumonidae	+	+	+	+
	Eulophidae	+			+
	Eucharitidae	+			+
	Chalcididae			+	+
	Torymidae	+	+		
	Pteromalidae				+
	Perilampidae	+	+	+	+
	Proctotrupidae	+	+	+	+

.... continued ......

Table 9 ... continued ....

ORDER	TAXA	WEST: JACK PINE-ASPEN	WEST: BLACK SPRUCE	WEST: CLEARED AREA	EAST: BLACK-WHITE SPRUCE
HYMENOPTERA continued	Diapriidae	+	+	+	+
	Scelionidae				+
	Chrysididae	+	+		+
	Formicidae	+		+	+
	Pompilidae	+	+	+	+
	Vespidae	+	+	+	+
	Sphecidae	+	+	+	+
	Colletidae	+			
	Halictidae	+	+	+	+
	Megachilidae	+	+	+	+
	Apidae	+	+	+	+

Plate 5.

Coleoptera : Carabidae *Carabus taedatus*, a ground beetle. Ground beetles were most often caught in the pitfall traps. (Photo by Allan Carter, Department of Botany, University of Calgary, Alberta.)

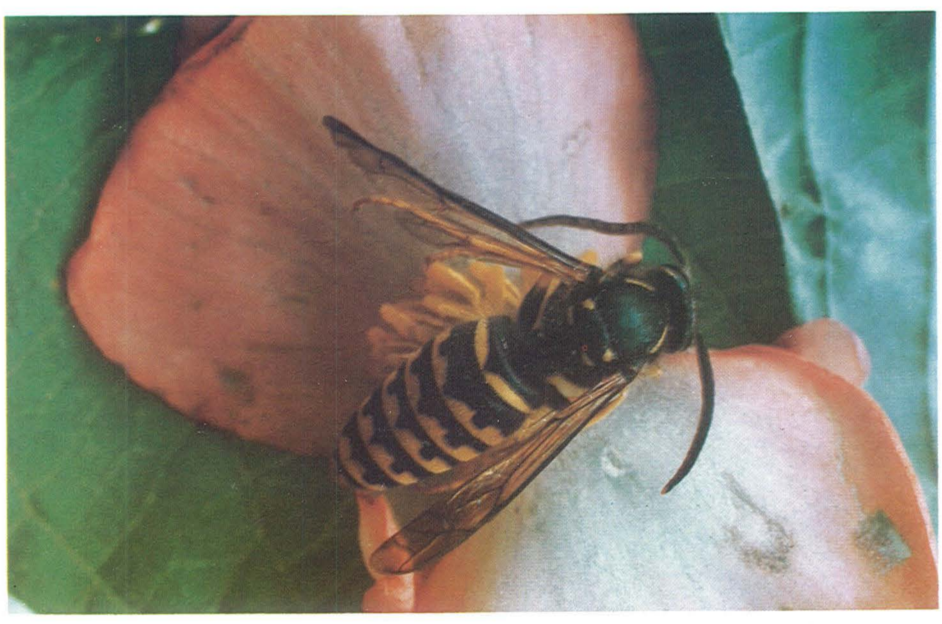


Plate 6.

Hymenoptera : Vespidae or vespid wasp. (Photo by Jack Scott, Courtesy of The Department of Entomology, University of Alberta, Edmonton, Alberta.)

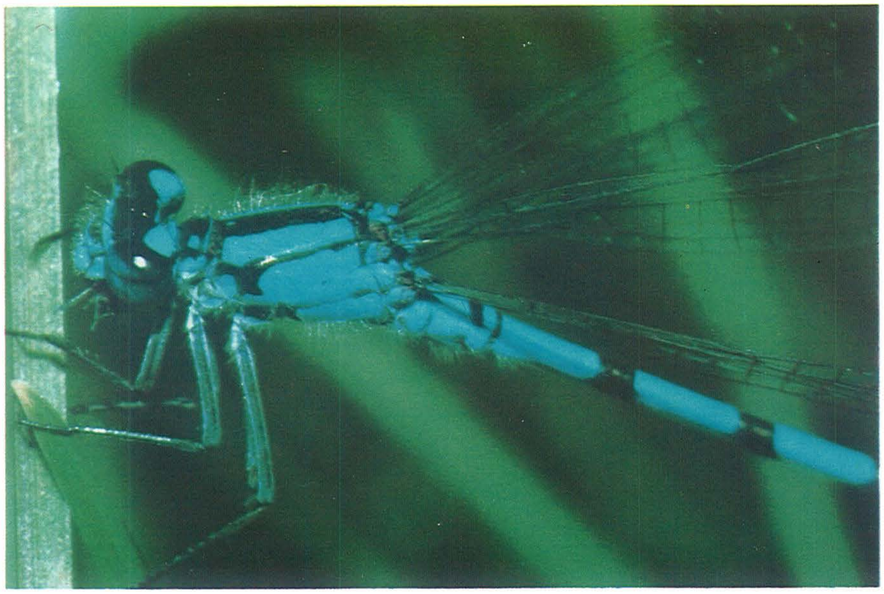


Plate 7.
Odonata : Coenagrionidae or damsefly. (Photo by Jack Scott, Courtesy of The Department of Entomology, University of Alberta, Edmonton, Alberta.)

Plate 8.
Hymenoptera : Sphecidae or sphecid wasp. Members of this family were quite common in the samples, being present in samples from 5 of the 8 sites. (Photo by Jack Scott, Courtesy of The Department of Entomology, University of Alberta, Edmonton, Alberta.)

Plate 9.

Homoptera : Cicadellidae or leafhopper. (Photo by Jack Scott, Courtesy of The Department of Entomology, University of Alberta, Edmonton, Alberta.)

5. DISCUSSION

5.1 Discussion of Sampling Methods

It should be noted that the sampling success of the different methods will vary, since each method has intrinsic properties which affect catch efficiency from habitat to habitat, family to family, and species to species (Carter, 1975; Southwood, 1968). Some insect density information has been derived but, based on the length of the sampling period and the small number of samples taken, the data are not as reliable as those that would be obtained from longer and more intensive study. However, a future sampling plan can be based on these data.

Macfadyen-Tullgren funnels appeared to have been adequate for the extraction of larger soil and litter organisms. However, the very low numbers of collembola and mites (micro-arthropods generally less than 1-2 mm long) extracted in this study may indicate the inefficiency of this method for sampling these organisms. In some soils the efficiency of the Macfadyen-Tullgren funnels has been found to be adequate for the extraction of particularly small species (Pande and Berthet, 1973), including collembola and mites. It appears, however, that the soils examined in the present study do not yield satisfactory results with this extraction method. One of the purposes of this study was to examine the study area, test sampling and extraction methods and make recommendations for future studies. In order to obtain acceptable samples of both mites and collembola for the soil types encountered, much more refined techniques would be required, e.g., high gradient extractors (Kempson, Lloyd and Ghelardi, 1963; Macfadyen, 1961, 1962). More accurate density estimates may be obtained as well for soil-dwelling larvae with wet funnel extractors (O'Connor, 1955).

Pitfall trapping was successful for its limited objective, which was to provide qualitative information on litter dwelling insects. In quantitative entomological studies, however, this method of trapping would be unnecessary.

The foliage sampling as planned proved to be unsuccessful and perhaps would require considerably more samples per tree. Although intensive sampling would yield more reliable quantitative data, the information obtained would be of little benefit with such low densities, since any fluctuations in density may be so small as to be undetectable or not attributable to a specific factor such as airborne pollutants. Thus, it appears that in the sites selected, tree canopy insects would be poor choices for indicator species.

The flight traps used (window and Malaise) were successful for their qualitative objectives. The restricted use of Malaise traps was appropriate on the scale employed in this study - at this scale they were readily managed. Their larger-scale use, however, would provide an unwieldly number of specimens to sort and identify.

5.2 Discussion of Results

5.2.1 Sampling Programs

Soil Insect Sampling

The soil sampling was designed as a preliminary program and yielded the only quantitative data in this study. The diversity of soil insects can also be determined and this is summarized below. The quantitative data derived can be used to predict the number of samples that are required to obtain more accurate estimates of population densities of those insects under study.

The small number of collembola and mites extracted from the soil samples may have indicated the inefficiency of the extraction method. It may also have indicated that only small numbers of these organisms existed in the soils. However, as indicated in Appendix 6, densities in the 10,000-70,000 per m^2 range could have been expected for collembola in the study area. Because the densities of those extracted from the soil samples were so low (less than 10% expected results), the collembola were only cursorily treated in this report.

The cleared area had a very low diversity of soil insects (9 families) in comparison to other sites on the west side: aspen - 22 families; black spruce - 23 families; white spruce - 20 families; and jack pine - 23 families (Table 4). Similarly, it is evident that lower diversity of soil insects occurs in all sites on the east side than those on the west: aspen - 13 families; black/white spruce mixture - 12 families; and birch - 10 families (Table 4). A comparison can also be made of the cleared area with the three spruce sites since the cleared area was probably somewhat similar to one or more of the spruce plots prior to clearing.

The results of the soil sampling could, therefore, indicate that physical alteration of the environment and airborne pollutants (H_2S and SO_2) may affect soil insect diversity adversely.

An estimate of population density of pest species with a standard error of 25% of the mean will enable a doubling or halving of the population to be detected; this is sufficiently accurate for damage assessment and control studies on each species (Church and Strickland, 1954). For life table studies of natural populations, a higher level of accuracy is necessary and the level is frequently set at 10% (Southwood, 1968). However, in studies of soil insects, the estimates frequently have very high standard errors due to sampling difficulties and to date the better density estimates for soil insects have standard errors in the region of 25% to 30% (Phillipson, 1971; Carter, 1975). Data derived from a preliminary sampling program such as this can be used to predict the number of samples required to obtain values of the mean density which have an acceptable standard error. Example calculations are given below.

Example Calculations:

Ten (n) soil samples of 0.25 m^2 each were taken; the mean density ± standard error of carabid larvae in Aspen West was 18.40 ± 2.84/0.25 m^2 (Table 4, p. 38). The number of samples (N) required which will give a standard error with a 95% probability of being within a given percentage range (D) of the true mean is given by the formula:

$$N = \left(\frac{ts}{Dx}\right)^2 \qquad \text{(Southwood, 1968)},$$

where s = standard deviation ($=\sqrt{n}$ x standard error = 2.84 x 3.61), D = the required level of accuracy expressed as a decimal (i.e., ideally 0.1 (= 10%), and t is a quantity, depending on the number of samples (n), and is obtained from tables (Southwood, 1968). In this instance, 10 samples were taken, and for n = 10, t = 2.262 at p = 0.05. Thus, substituting in the formula:

$$N = \left(\frac{2.262 \times 2.84 \times 3.61}{0.1 \times 18.40}\right)^2 = 122,$$

which is a cumbersone number of samples to process.

By reducing the level of accuracy to 20% (i.e., D = 0.2), the value for N becomes:

$$\left(\frac{2.262 \times 2.84 \times 3.61}{0.2 \times 18.40}\right)^2 = 30.$$

This is a threefold increase over the initial sampling but gives acceptable estimates and ought to pose little problem to field-workers and laboratory technicians studying this one group of insects. Sampling in each study plot should be performed regularly, usually every 2-3 weeks, in order not to miss any stages in the life cycle. This would require 10-15 sets of 30 samples per plot over one six month field season.

Litter Insect Sampling

Table 5 lists the occurrence and life stages of insect families captured by pitfall traps; Table 6 details the Carabidae genera and species captured by these traps. From the pitfall trapping it appears that the cleared area has the greatest diversity of litter insects, viz. west aspen - 9 families, black spruce - 3 families, white spruce - 10 families, jack pine - 6 families, cleared area - 13 families; east aspen - 4 families, black/white spruce mixture - 5 families and birch - 6 families. Figures for the east side plots do, however, appear to be generally somewhat lower than those for the west side. The higher number of families found in the cleared area may simply reflect transient individuals. Examination of Table 5 shows that of the 13 families encountered, 6 of them are the adult (winged) stages of insects which are not litter or soil dwellers: a grasshopper (Tetrigidae), four bugs (Miridae, Aradidae, Scutelleridae and Aphididae) and a fly (Tabanidae).

However, the Tetrigidae, Aradidae, and Scutelleridae were found only in the cleared area and may be consumers of plants characteristic of open or revegetating areas; that is, they may indicate the onset of community succession. The Tabanidae caught in pitfall traps were found elsewhere only in the white spruce plot and may be present for one of two reasons: (1) egg laying, or (2) emerging from the pupa (Tabanid immatures are found in moist areas such as white spruce (Table 4)).

Foliage Insect Sampling

The results of the foliage sampling are in Table 7. Although the design for the sampling system appeared adequate insufficient specimens were collected from the foliage sampling to show any relationships whatsoever. However, it should be noted that two outbreaks of pest species occurred in the general area outside the study plots. The pest species were *Choristoneura fumiferana* (Clem.)(spruce budworm) and *Malacosoma disstria* Hbn. (forest tent caterpillar)(Glanfield and Ward, 1974).

Aerial Insect Sampling

The window trap catches indicate that the cleared area has a low aerial insect diversity, especially with regard to the beetles. Table 8 indicates that jack pine plot traps contained representatives of 15 families, cleared area, 3 families, and the birch, 15 families. These traps were meant to augment Malaise trap catches but caught only four families that were not captured by the Malaise; these were Baetidae, Lycidae, Eucnemidae and Scarabaeidae, the latter 3 families being beetles.

The Malaise trap catches suggest that the aerial insect diversity is of a similar order in all areas samled, viz. jack pine - 47 families, black spruce - 48 families, cleared area - 57 families, and black/white spruce mixtures - 61 families (see Table 7).

5.2.2 Comparison of the East and West Plots

By subdividing each taxon encountered into stages in the life cycle, we obtain 156 subdivisions of which 43 were found only on the west side of the Athabasca River; that is, outside the G.C.O.S. plume impingement area. These data are summarized in Table 10 and are derived from data obtained by all sampling methods and personal observations; that is, they were extracted from Tables 4, 5, 6, 7, 8, and 9, and Appendix 4.

It should be noted that the larvae of 3 families (Nepticulidae, Gracillariidae and Diprionidae) were found only on the west side. In a fourth family (Tenthredinidae) the larvae were found only on the west side but adults were present on both sides of the river. This could reflect the egg laying preferences of these insects. It is possible that the adults may be able to withstand the sulfur gas effluents at present levels but their eggs and larvae may not be able to survive as well. It could also indicate that eggs laid in the G.C.O.S. impingement area are unable to develop in numbers that can be detected by the usual sampling procedures. They may be laid there and die, causing a loss of energy and vital elements from the populations of the species concerned. This could eventually lead to extinction for some species, which could in turn upset the natural balance of the environment.

Table 10: A List of Insect Families, Genera and Species (subdivided into stages in the life cycle) Found only on the West Side of the Athabasca River. Data extracted from Tables 4, 5, 6, 7, 8, 9, and Appendix 4.

ORDER	TAXA	GENUS &/OR SPECIES	LIFE CYCLE STAGE
COLEOPTERA	Carabidae	*Agonum retractum*	A
			L
		Pterostichus haematopus	A
	Micropeplidae	*Micropeplus* sp.	A
	Cantharidae		A
	Cucijidae		A
			L
	Coldiidae		A
	Scarbaeidae	*Aphodius* sp.	A
	Histeridae		A
	Cerambycidae		A
	Cleridae		A
DIPTERA	Ceratopogonidae		A
			L
	Bibionidae	Unidentified species #9	L
		Unidentified species #10	L
	Mycetophyllidae		P
	Therevidae		A
			L
	Psychodidae		A
	Dixidae		A
	Chaoboridae		A
LEPIDOPTERA	Arctiidae		L
	Pterophoridae		A
			L
	Nepticulidae		L
	Gracillariidae	*Phyllocnistis populiella*	L
	Lycaenidae		A
ORTHOPTERA	Tetrigidae		A
HETEROPTERA	Tingidae		A
	Aradidae		A
	Cycadidae		A
	Scutelleridae		A
HOMOPTERA	Cercopidae		A
	Psyllidae		A

.... continued .....

Table 10. .... continued ...

ORDER	TAXA	GENUS &/OR SPECIES	LIFE CYCLE STAGE
HYMENOPTERA	Torymidae		A
	Colletidae		A
	Diprionidae		L
	Tenthredinidae*		L
NEUROPTERA	Hemerobiidae		A
EPHEMEROPTERA	Baetidae		A
TRICHOPTERA	Limnephilidae		L
ODONATA	Aeshnidae		A

LIFE CYCLE STAGES: A - Adult
L - Larva
P - Pupa

* Indicates larval stages encountered on the west side of the river only, whilst their adult stages were encountered on the east side.

Habitat preferences of soil and litter insects can be seen by studying the data in Tables 4, 5, and 6. Some families were noted to be restricted to particular habitats (e.g., Therevidae in the jack pine plot only) whereas others were found to be somewhat more ubiquitous (e.g., Carabidae). However, defining habitat preferences by insects based on presence or absence data or preliminary quantitative sampling data should be avoided, since there are too many within-habitat variables (e.g., specific host-phytophagous insect relationships, differences in tree density, ground flora and soil type).

Examination of the numbers of insect families observed at each plot (Table 11) indicates that the numbers of soil insect families are lower on the east side of the river, but that the numbers of families of aerial insects are similar.

Table 11. Summarized Count of Insect Families Encountered By Soil, Pitfall, Window and Malaise Trapping at all Sites Derived from Tables 4, 5, 8, and 9 and Appendicies 1 and 4.

	NUMBERS OF INSECT FAMILIES ENCOUNTERED			
Habitat	Soil	Pitfalls	Window	Malaise
West Aspen	22	9	--	--
Black Spruce	17	3	--	48
White Spruce	20	10	--	--
Jack Pine	23	6	15	47
Cleared Area	9	13	3	57
East Apen	13	4	--	--
Black/White Spruce	12	5	--	61
Birch	10	6	15	--

The number of families of aerial insects in those areas affected by sulfur gases could remain relatively high because sulfur gas levels are not constantly at peak values. Cumulative effects of these gases on insects are not known, however.

Unfortunately, comparisons such as these that have been made between different sites cannot be fully justified because of their many varied differences in, for example, ground vegetation cover, per cent canopy cover (which in turn affects light, temperature and water regimes), age of trees and tree density. Such factors can greatly influence the species composition of the insects inhabiting an area.

The data are not as reliable as those that would be obtained from a longer and more intensive study; a future sampling plan can, however, be based on the quantitative data.

Potential Indicator Species

Insects that might be of possible use as indicator species in the tar sands area may be divided into two groups:

(1) Those occurring in both polluted and non-polluted areas. Here, a comparison of factors such as fecundity, egg-laying site selection, natality and mortality would be advantageous. For example, families that were encountered in the soil and pitfall samples of all plots are Carabidae, Staphylinidae, Pedilidae, and Formicidae. Studies such as those mentioned above could be performed on selected species of Carabidae (e.g., *Pterostichus* sp. and *Synuchus impunctatus* both occur in the two aspen plots).

(2) Those occurring in non-polluted areas only. Here, experiments performed to determine to what degree H_2S and SO_2 pollutants affect the same factors mentioned for those insects in group 1 would be advantageous; for example, determining the levels at which egg mortality will occur. Test species here could possibly include *Aphodius* sp. (Coleoptera : Scarabaeidae) and two species of Bibionidae (Diptera). All three were encountered on the west side of the river in aspen and aspen/jack pine respectively.

5.3 Discussion of Impact of Industrial Development on Insects

Two major impacts on insect ecology created by the Syncrude project are habitat disruption and the release of gaseous effluents. Depending on type and severity, habitat disruption will have several effects. Clearing the vegetation from an area obviously removes a food source, a shelter and a habitat for immature stages of some terrestrial insects - 16% of those families encountered in this study. (A close examination of Appendix 1 reveals that the approximate percentages of families observed which have their immature stages in the soil were 57%, in water 11%, as parasites 16% and in foliage 16%). Draining wet areas removes a habitat for all the aquatic insects and also for those aquatic immature stages of terrestrial insects (11% of those families encountered in this study). Disturbing and/or removing the litter and soil severely disrupts a major habitat for the immature stages of many (57% of those families encountered in this study) of the terrestrial insects and for some adult forms. Clearing the vegetation will result in densities of some insects being reduced, and altering the soil surface will also reduce soil and litter insect densities even further. However, diversity and some population levels may remain high, indicating an influx of wide-ranging aerial insects, or rapid reinvasion by some species and little or reduced effects of the treatments on others (Vlug and Borden, 1973). Careful consideration must be given to the type and extent of reclamation planned. Cleared areas in the process of revegetation must not be allowed to become reservoirs of pest insect species. The revegetation of barren areas with several plant species (as suggested in Wheeler and Vaartnou, 1973a, 1973b) will increase the possibilities of the development of more diverse and stable consumer communities.

Gaseous effluents, particularly the sulfur gases, can affect insects through various pathways (Figure 9). Each of these pathways is itself affected by many interacting environmental factors. Little, if any, research has been done on the transfer of sulfur along each particular pathway and the effects of the environmental variables. However, certain observations of such gaseous effluent impacts on insects can be made.

Air pollution concentration data indicated that the recent ground level concentration standards set by Alberta Environment (Environment Conservation Authority, 1973) were exceeded on several occassions and levels of 1.0 ppm per hour were occassionally exceeded. A ground level concentration of 1.0 ppm per hour would be injurious (if not lethal) to all Alberta forest tree species and lethal to lichens and bryophytes (Loman, Blauel, and Hocking, 1972).

Figure 9 Pathways through which sulfur gases can affect forest insects.

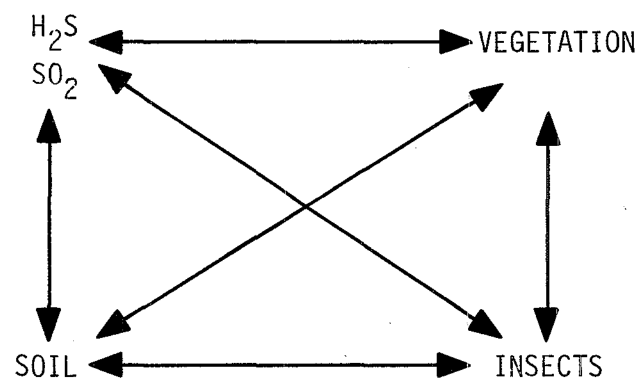
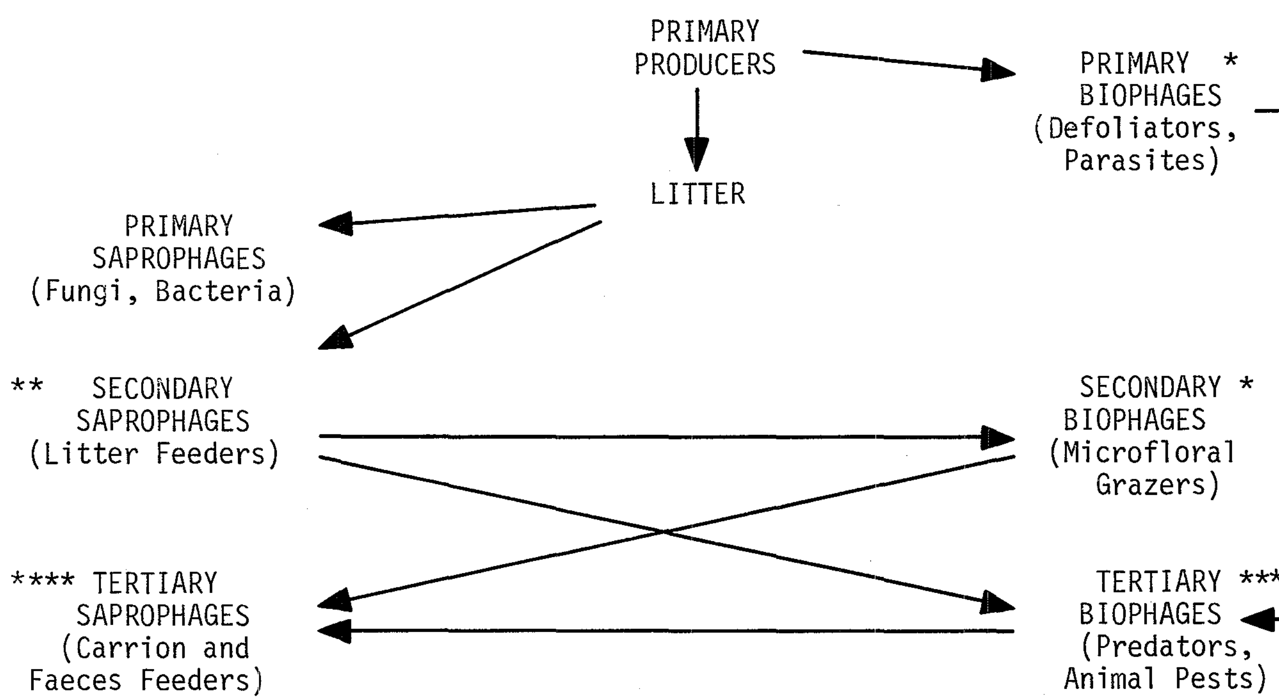


Figure 10 A generalized forest insect food web.



* Phytophagous Insects
** Saprophagous Insects
*** Carnivorous Insects
**** Necrophagous and Coprophagous Insects

Most Alberta soils are sulfur deficient (Environment Conservation Authority, 1973). The addition of sulfur to the soil or the absorption of sulfur by the plant (as sulfate in the water-filled mesophyll tissues of the leaf) could provide conditions favoring plant growth. This increased the capacity of the plant to assimilate SO_2 but reduces its tolerance to SO_2 (Loman, Blauel, and Hocking, 1972). Plants less tolerant to gaseous effluents may disappear from localized habitats. The addition of sulfur compounds to the soil could, after a certain accummulation, begin to lower the soil pH to levels intolerable to various plants ($SO_2 + H_2o = H_2SO_3 \rightarrow$ oxidation $= H_2SO_4$)(Westman, 1974).

Any subsequent changes in the composition of the plant community will influence insect community composition.

Westman (1974), in a recent paper on the effects of SO_2 on the growth of spruce and pine, found that the SO_2 emissions caused significant growth reduction of the trees up to a distance of at least 10 km from the source of emissions. Westman also found a significant reduction (from 3.4-3.8 to less than 2.5) in the pH of pine bark. If a decrease in pH in plant tissues can be caused by SO_2 emissions, the palatability of these tissues may be affected adversely or beneficially to the insects and other consumers. If the effects were adverse, species extinction could occur and community structure would subsequently change; if the effects were beneficial, outbreaks of known and potential insect pest species could occur.

Gaseous effluents can have a direct effect on tree-insect associations. Stark *et al* (1968) and Wong *et al* (1973) found that atmospheric pollutants increased the susceptibility of trees to bark and wood inhabiting insects. These infestations can lead to tree death. Toxicant levels do not have to be high enough to kill the entire tree - an affected branch or tree region can provide adequate opportunity for infestation by insects. The cumulative effects of gaseous effluents on plant-insect relationships are not known.

The soil and its organisms act as a nutrient sink and concentrate certain elements which have been released through decomposition of organic matter. These elements are concentrated by colloidal adsorption, molecular complexing and biological activity. Unfortunately, very little is known concerning the metabolism of sulfur in the soil, despite it being an essential element for structural components (e.g., proteins and some amino acids) of organisms. Food chains (Figure 10) tend to concentrate nutrients and pollutants (e.g., pesticides). The main decomposers, the bacteria and the fungi, mineralize organic compounds (e.g., organic sulfur to highly soluble sulfates) and thus influence the availability of nutrients to organisms. Thus, the efficient mineralization of nutrients depends on a physiologically healthy microflora (uninhibited by toxicants and pH). The sulfur available to soil insects may, therefore, be high (no references or data are available) and may affect the insect (a) as an atmospheric pollutant - affecting respiratory gas exchange mechanisms, (b) as a physical pollutant of their habitat, disrupting mechano- and chemo-receptor organs, and (c) as a concentrated toxicant in the food supply; this will affect those insects in the higher trophic levels of the food chain most (i.e., tertiary biophages and saprophages).

The interrelationships illustrated in Figures 9 and 10 illustrate the necessity of integrated studies of forest ecosystems. For example, some of the interrelationships between gaseous effluents, vegetation and insects can be defined by examining the arthropod-lichen associations described by Gerson (1973). Lichens are perhaps the most useful biological indicators of sulfur gas pollution (Gilbert, 1970; Hawksworth and Rose, 1970; Leblanc and Rao, 1966; Leblanc *et al*, 1972) and could be used to monitor ground levels of SO_2. Gerson (1973) on page 441 described an interesting phenomenon as follows:

> "Representatives of several insect and mite orders feed on and burrow in lichens, such feeding at times inducing the formation of galls. The resistance of lichens to invertebrate grazers is attributed to specific lichen compounds, to the gelatinous covering of certain lichens, and the presence of

> chelating agents in these plants. Some arthropods shelter in lichens, the animals at times mimicking the plants. Lichen propagules are disseminated by certain arthropods. Lichen populations - and their dependent arthropods - are undergoing changes in abundance and distribution as a result of nuclear fall-out and air pollution."

This association provides a unique opportunity for comparing areas under the influence of SO_2 and H_2S for gradient effects, and comparing these with non-affected areas.

Revegetation programs are an integral part of reclamation planning for disturbed areas. While the grasses found in the sites in this study appeared to be a minor component of the herbaceous communities, Wheeler and Vaartnou (1973a, 1973b) suggested that these grasses may, given adequate conditions, become more significant in terms of the revegetation of disturbed areas. Various faunal influences can be expected in areas undergoing revegetation, however, and it should be noted that grasshoppers and other phytophagous insects can severely hamper the early growth of herbaceous plants (Andrezejewska and Wojcik, 1970, 1971). The high number of insect families found in the cleared area in the present study suggests that colonization of disturbed areas by insects is quite rapid, indicating the need for a better understanding of insect - vegetation interrelationships before large scale revegetation studies begin.

GLOSSARY

arthropod -- jointed-limbed invertebrates; includes crabs, scorpions, spiders and insects

biophage -- organism feeding on living animal and/or plant material

coprophagous -- feeding on dung

entomology -- the study of insects

insect -- six-legged arthropod; single pair of antennae; body divided into head, thorax, and abdomen

litter -- the upper layer of the soil organic horizon; composed of undecomposed leaves, stems and woody fragments

necrophagous -- feeding on animal carcasses

phytophagous -- feeding on living plant tissues

saprophage -- organism obtaining its nutrition from decaying, dead or dying animal or plant material

stand -- any area occupied and dominated by a particular tree species

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Appendix 1: Key to common names and general feeding habits of insect families collected in this study.
(Where several types of feeding habits are listed, these refer to different groups within the family.)
(References: Arnett, 1968; Borror and White, 1970; Chu, 1949; Lindroth, 1961-1969; Wigglesworth, 1968)

Order	Family	Common Name	Feeding Habits: Larvae or Immatures	Feeding Habits: Adults
Ephemeroptera	Baetidae	Mayflies	Herbivorous (aquatic plants)	Do not feed
Odonata	Libellulidae	Red skimmers	Predatory (aquatic organisms)	Predatory (aerial insects)
	Coenagrionidae	Damselflies	Predatory (aquatic organisms)	Predatory (aerial insects)
	Aeshnidae	Darners or dragonflies	Predatory (aquatic orgamisms)	Predatory (aerial insects)
Orthoptera	Tetrigidae	Pygmy grasshoppers	Herbivorous (grasses)	
	Acrididae	Short-horned grasshoppers	Herbivorous (grasses)	
Plecoptera	Nemouridae	Spring stoneflies	Herbivorous (aquatic plants)	Do not feed
Psocoptera	Psocidae	Common barklice	Decaying animal and plant material; molds and fungi	
Heteroptera	Miridae	Leaf or plant bugs	Sap feeders (various plants)	sap feeders
	Tingidae	Lace bugs	Sap feeders (foliage of trees and shrubs)	sap feeders
	Aradidae	Flat or fungus bugs	Sap feeders (tree stems and fungi)	sap feeders
	Scutelleridae	Shield-backed bugs	Sap feeders (various plants)	sap feeders
	Podopidae	Terrestrial turtle bugs	Sap feeders (various plants)	sap feeders
Homoptera	Cercopidae	Froghoppers or spittle-bugs	Sap feeders (various plants)	sap feeders
	Cicadidae	Cicadas	Sap feeders (various plants)	sap feeders
	Cicadellidae	Leafhoppers	Sap feeders (various plants)	sap feeders
	Cixiidae	Cixiid planthoppers	Sap feeders (various plants	sap feeders
	Psyllidae	Psyllids	Sap feeders (some gall-makers)(various plants)	sap feeders
	Aphididae	Aphids	Sap feeders (various plants)	sap feeders
	Adelgidae	Spruce gall aphids	Sap feeders (gall-makers)(various spruce)	sap feeders
Neuroptera	Hemerobiidae	Brown lacewings	Predatory (aquatic orgamisms)	Predatory

Appendix 1. continued ....

Order	Family	Common Name	Feeding Habits: Larvae or Immatures	Feeding Habits: Adult
Coleoptera	Carabidae	Ground beetles	Predatory; scavenging	
	Histeridae	Hister beetles	Predatory (insected attracted to dung, carrion, decaying plants, and oozing sap)	
	Staphylinidae	Rove beetles	Predatory; scavenging; parasitic	
	Micropeplidae	Micropeplid beetles	Predatory; scavenging	
	Cantharidae	Soldier beetles	Predatory	Pollen and nectar
	Lampyridae	Lightningbugs	Predatory (snails, earthworms, crustaceans)	Do not feed
	Lycidae	Netwinged beetles	Predatory	Plant juices; predatory
	Elateridae	Click beetles	Herbivorous (roots, seeds); predatory	Most apparently do not feed
	Eucnemidae	False click beetles	Scavenging (rotting wood)	Carnivorous (rotting wood)
	Cleridae	Checkered beetles	Predatory (larvae of wood boring insects); pollen feeders	
	Buprestidae	Metallic wood boring beetles	Herbivorous (living, dying or dead plants)	Herbivorous (foliage, bark, flower products)
	Helodidae	Marsh beetles	Biology in need of investigation	
	Byrrhidae	Pill beetles	Herbivorous	
	Cucujidae	Flat bark beetles	Herbivorous (various plants); predatory (wood boring insects and mites)	
	Nitidulidae	Sap beetles	Saprophagous	Predatory (aphids; scale insects)
	Coccinellidae	Ladybird beeltes	Predatory (aphids, scale insects, mites and other injurious forms)	
	Colydiidae	Cylindrical bark beetles	Predatory (wood boring insects); herbivorous	
	Anthicidae	Ant-like flower beetles	Herbivorous (detritus); predatory	Possibly flower products
	Pedilidae	Pedilid beetles	Herbivorous (detritus); predatory	Possibly flower products
	Mordellidae	Tumbling flower beetles	Herbivorous (leaf and stem miners); predatory	Possibly flower products
	Tenebrionidae	Darkling beetles	Scavenging	
	Scarabaeidae	Scarab beetles	Herbivorous; dung feeders	
	Cerambycidae	Long horned beetles	Herbivorous (borers of libing and dead tissue)	Possibly flower products
	Chrysomelidae	Leaf beetles	Herbivorous (foliage and roots)	Herbivorous (foliage and flower products)
	Curculionidae	Snout beetles	Herbivorous (nuts, fruits and other parts of plants)	

Appendix 1 continued ....

Order	Family	Common Name	Feeding Habits: Larvae or Immatures	Feeding Habits: Adults
Tricoptera	Limnephilidae	Northern caddis flies	Herbivorous (aquatic plants)	Do not feed
Lepidoptera	Gracillariidae	Aspen leaf miner	Herbivorous (aspen leaves)	
	Geometridae	Geometer moths or inchworms	Herbivorous (various plants)	If lepidopterm adults feed at all, their diet consists of liquids, including nectar
	Arctiidae	Tiger moths	Herbivorous (grasses, trees, shrubs)	
	Noctuidae	Noctuid moths	Herbivorous (roots, shoots, stems, fruits)	
	Pterophoridae	Plume moths	Herbivorous (leaf rollers, stems)	
	Nepticulidae	Nepticulid moths	Herbivorous (leaf miners,galls)	
	Hepialidae	Ghost moths or swifts	Herbivorous (tree root borers)	
	Olethreutidae	Jack pine cone moth	Herbivorous (cone borer)	
	Pteridae	Christina sulfur	Herbivorous (eg, vetch)	
	Lycaenidae	Coppers	Herbivorous (various plants)	
Diptera	Tipulidae	Craneflies	Herbivorous (detritus, algae, fungi)	Do not feed
	Psychodiadae	Moth and sand flies	Herbivorous (detritus)	Probably omnivorous
	Dixidae	Dixid midges	Predatory (water surface organisms)	Probably omnivorous
	Chaoboridae	Phantom midges	Predatory	Probably omnivorous
	Culicidae	Mosquitos	Organic debris	( ) vertebrate blood; ( ) plant liquids
	Ceratopogonidae	Punkies or biting midges	Organic debris	Mammalian blood; insect ectoparasites
	Chironomidae	Midges	Organic debris	Probably do not feed
	Simuliidae	Black flies	Organic debris	Mammalian blood
	Anisopodidae	Wood gnats	Organic debris	Sap feeders
	Bibionidae	March flies	Herbivorous (roots, detritus)	Possibly flower products
	Mycetophilidae	Fungus gnats	Herbivorous (detritus, fungi)	Possibly flower products
	Sciaridae	Dark-winged fungus gnats	Herbivorous (detritus, fungi)	Possibly flower products
	Cecidomyiidae	Gall gnats	Herbivorous (galls, living and decaying vegetation); predators; parasites	Possibly flower products

Appendix 1 continued ......

Order	Family	Common Name	Feeding Habits: Larvae or Immature	Feeding Habits: Adults
Diptera continued	Stratiomyidae	Soldier flies	Detritus	Possibly flower products
	Tabanidae	Horse and deer flies	Predatory (various insects)	(f) mammalian blood; (m) flower products
	Therevidae	Stiletto flies	Predatory (various insects)	Probably predatory
	Asilidae	Robber flies	Predatory (various insects)	Predatory (various insects)
	Bombyliidae	Bee flies	Parasitic (various insects)	Possibly flower products
	Empididae	Dance flies	Organic debris	Predatory; herbivorous (flower products)
	Dolichopodidae	Long-legged flies	Organic debris	Predatory
	Phoridae	Hump-backed flies	Detritus; fungi; parasitic	Possibly flower products, detritus
	Pipunculidae	Big-headed flies	Parasitic (on HOMOPTERA only)	Possibly flower products
	Syrphidae	Hover flies	Predatory (aphids); scavenging	Herbivorous (flower products)
	Conopidae	Thick-headed flies	Parasitic (adult bees and wasps)	Herbivorous (flower products)
	Sepsidae	Black scavenger flies	Dung	Possibly dung and plant liquids
	Sciomyzidae	Marsh flies	Predatory (aquatic snails)	Possibly plant liquids
	Chloropidae	Frit flies	Herbivorous (grass); detritus	Possibly flower products
	Anthomyiidae	Anthomyiid flies	Herbivorous; scavenging	Possibly flower products
	Muscidae	Muscid flies	Scavenging	Nectar, etc; blood
	Tachinidae	Tachina flies	Parasitic	Possibly flower products
Hymenoptera	Tenthredinidae	Common sawflies	Herbivorous (foliage, galls)	Herbivorous (flower products)
	Argidae	Argid	Herbivorous (foliage)	Possibly flower products
	Diprionidae	Conifer sawflies	Herbivorous (conifer needles)	Herbivorous; predatory
	Braconidae	Braconids	Parasitic (wide variety insects)	Possibly flower products
	Ichneumonidae	Ichneumon flies	Parasitic (wide variety insects)	Possibly flower products
	Eulophidae	Eulophids	Parasitic (wide variety insects)	Possibly flower products
	Eucharitidae	Eucharitids	Parasitic (ant pupae)	Possibly flower products
	Chalcididae	Chalcidids	Parasitic (wide variety insects)	Possibly flower products
	Torymidae	Torymids	Parasitic (many insects); seeds	Possibly flower products
	Pteromalidae	Pteromalids	Parasitic (wide variety insects)	Possibly flower products
	Perilampidae	Perilampids	Mostly hyperparasites	Possibly flower products
	Proctotrupidae	Proctotrupids	Parasitic (beetles)	Possibly flower products
	Diapriidae	Diapriids	Parasitic (fungus, gnats, other DIPTERA)	Possibly flower products

Appendix 1 continued ....

Order	Family	Common Name	Feeding Habits: Larvae or Immatures	Feeding Habits: Adults
Hymenoptera continued	Scelionidae	Scelionids	Parasitic (eggs of various insects)	Possibly flower products
	Chrysididae	Cuckoo wasps	Parasitic (COLEOPTERA, LEPIDOPTERA)	Possibly flower products
	Formicidae	Ants	Carnivorous; herbivorous; scavenging	
	Pompilidae	Spider wasps	Carnivorous (supplied by adult)	Possibly flower products
	Vespidae	Vespid wasps	Carnivorous (supplied by adult)	Omnivorous: fruits, nectar, and insects given to larvae
	Sphecidae	Schecid wasps	Carnivorous (supplied by adult)	Possibly flower products
	Colletidae	Plasterer bees	Provisioned in nest	Possible flower products
	Halictidae	Halictid bees	Provisioned in nest	Herbivorous (flower products)
	Megachilidae	Leaf cutting bees	Provisioned in nest	Herbivorous (flower products)
	Apidae	Digger, carpenter and bubble bees	Provisioned in nest	Herbivorous (flower products)

Appendix 2. Summary of Fieldwork.

A. Soil Insect Sampling

Side of River	Plot	Soil Samples Removed	Number of Days Stored At CA. $5^{o}C$.	Soil Samples Placed In Extractors	Soil Samples Removed From Extractors	Number of Days Stored At CA. $5^{o}C$.
East	Black/White Spruce*	5 August	9	14 August	14 August	3
	Birch*	6 August	8	14 August	14 August	3
		6 August	11	17 August	17 August	3
	Aspen	6 August	11	17 August	17 August	3
West	Jack Pine	25 July	0	25 July	25 July	3
	Aspen	27 July	1	28 July	28 July	3
	White Spruce	29 July	2	31 July	31 July	8
	Black Spruce*	2 August	0	2 August	2 August	6
		2 August	8	10 August	10 August	4
	Cleared Area	3 August	7	10 August	10 August	4

* Samples divided into two sets of five each in order to make full use of the available extractors.

Appendix 2 continued ......

B. Litter Insect Sampling

Side of River	Plot	Pitfall Traps Placed	Pitfall Traps Emptied	Number of Collecting Days
West	Cleared area	25 July	28 July	3
	Jack Pine	25 July	29 July	4
	Aspen	26 July	3 August	8
	White Spruce	27 July	3 August	7
	Black Spruce	27 July	2 August	6
East	Black/White Spruce	30 July	5 August	6
	Birch	1 August	6 August	5
	Aspen	1 August	6 August	5

C. Aerial Insect Sampling

Side of River	Plot	Malaise Traps Placed	Malaise Traps Emptied	Number of Collecting Days
East	Black/White Spruce	1 August	7 August	6
West	Jack Pine/Aspen	25 July	28 July	3
	Black Spruce	28 July	3 August	6
	Cleared Area	3 August	8 August	5

Side of River	Plot	Window Traps Placed	Window Traps Empited	Number of Collecting Days
East	Birch	1 August	6 August	5
West	Cleared Area	25 July	28 July	3
	Hack Pine	25 July	3 August	9

Appendix 2 continued ....

D. Foliage Insect Sampling

Side of River	Plot	Foliage Samples Taken	Foliage Samples Examined	Number Of Days Stored At CA. $5^{o}C$.
East	Black/White Spruce	5 August	5 August	0
	Birch	6 August	11 August	5
	Aspen	6 August	11 August	5
West	Jack Pine	25 July	31 July	6
	Aspen	1 August	1 August	0
	Black Spruce	2 August	2 August	0
	White Spruce	3 August	4 August	1

Appendix 3. A List of Vegetation (including common names) Identified in the Eight Area Study Plots.

SCIENTIFIC NAME	COMMON NAME
TREES	
Betula papyrifera Marsh.	White birch
Larix laricina (Du Roi) K. Koch	Tamarack
Picea glauca (Moench) Voss	White spruce
Picea mariana (Mill.) BSP	Black spruce
Pinus banksiana Lamb.	Jack pine
Populus balsamifera L.	Balsam poplar
Populus tremuloides Michx.	Trembling aspen
SHRUBS	
Alnus crispa (Ait.) Pursh	Green alder
Amelanchier alnifolia Nutt.	Saskatoon berry
Arctostaphylos rubra (Rehder & Wils.) Fern.	Alpine bearberry
Betula pumila L. var. *glandulifera* Regel	Swamp birch
Cornus stolonifera Michx.	Red-osier dogwood
Ledum groenlandicum Oeder.	Common Labrador tea
Potentilla fruticosa L.	Shrubby cinguefoil
Prunus pensylvanica L. f.	Pincherry
Ribes lacustre (pers.) Poir.	Swamp gooseberry
Ribes triste Pall.	Wild red currant
Rosa sp.	Wild rose
Salix sp.	Willow
Shepherdia canadensis (L.) Nutt.	Canadian buffalo-berry
Vaccinium myrtilloides Michx.	Canada blueberry
Vaccinium vitis-idaea L. var. *minus* Lodd.	Bog cranberry
Viburnum edule (Michx.) Raf.	Squashberry
LICHENS	
Cladonia rangeferina (L.) Wigg.	Reindeer lichen
Peltigera aphthosa (L.)	Dog lichen
LIVERWORTS	
Marchantia sp.	Common liverwort
MOSSES	
Hylocomium splendens (Hedw.) B. S. G.	Feather moss
Pleurozium schreberi (Brid.) Mitt.	Feather moss
Ptilium crista-castrensis (Hedw.) De Not.	Feather moss
Sphagnum sp.	Sphagnum

Appendix 3. continued ....

SCIENTIFIC NAME	COMMON NAME
HORSETAILS	
Equisetum arvense L.	Common horsetail
Equisetum scirpoides Michx.	Dwarf scouring horsetail
CLUB MOSSES	
Lycopodium complanatum L.	Ground cedar
FERNS	
Gymnocarpium dryopteris (L.) Newn.	Oak fern
SEDGES	
Carex sp.	Carex sedge
HERBS	
Achillea millifolium L.	Common yarrow
Anemone multifida Poir.	Cut-leaved anemone
Apocynum androsaemifolium L.	Spreading dogband
Aralia nudicaulis L.	Wild sarsaparilla
Arceuthobium americanum Nutt.	Dwarf misteltoe
Aster ciliolatus Lindl.	Lindley's aster
Aster conspicuus Lindl.	Showy aster
Comandra pallida A. DC.	Pale comandra
Cornus canadensis L.	Bunchberry
Epilobium angustifolium L.	Fireweed
Erythronium grandiflorum Pursh.	Glacier lily
Galeum boreale L.	Northern bedstraw
Geocaulon lividum (Richards) Fern.	Bastard toad flax
Goodyera repens (L.) R. Br.	Rattlesnake plantain
Habenaria orbiculata (Pursh.) Torr.	Round-leafed orchid
Lathyrus ochroleucus Hook.	Sweat pea
Lilium philadelphicum L. var. *andinum* (Nutt.) Ker.	Western wood lily
Linnaea borealis L. var. *americana* (Foube) Rehd.	Twin-flower
Maianthemum canadense Desf. var. *interius* Fern.	Wild-lily-of-the-valley
Melampyrum lineare Desr.	Cow wheat
Mertensia paniculata (Ait.) G. Don.	Tall lungwort
Mitella nuda L.	Mitrewort
Moneses uniflora (L.) A. Gray	One-flowered wintergreen
Pentasites palmatus (Ait.) A. Gray	Palmate-leaved colts-foot
Pyrola sp.	Wintergreen
Pyrola ascarifolia Michx.	Pink wintergreen
Pyrola secunda L.	One-sided wintergreen
Rubus pubescens Raf.	Dewberry
Smilacina trifolia (L.) Desf.	Three-leaved Solomon's seal
Solidago nemoralis (Ait.) var. *decemflora* (D.C.) Fern.	Goldenrod
Spiranthes romanzoffina Cham. & Schl.	Ladies' tresses
Vicia americana Muhl.	American vetch

Appendix 4: A List of Orders, Families, Genera and Species, Divided into Stages in the Life Cycle, Encountered in Each Plot. Presence indicated by +.

Order	Family	Genus &/or Species	Life Cycle Stage	WEST Aspen	WEST Black Spruce	WEST White Spruce	WEST Jack Pine	WEST Cleared Area	EAST Aspen	EAST Black-White Spruce	EAST Birch
Ephemeroptera	Baetidae		A				+				
Odonata	Libellulidae		A	+	+	+				+	
	Coenagrionidae		A			+				+	
	Aeshindae		A		+					+	
Orthoptera	Tetrigidae		A					+			
	Aerididae		A							+	
Plecoptera	Nemouridae		A							+	
Psocoptera	Psocidae		A				+	+		+	+
Heteroptera	Miridae		A		+		+	+		+	
	Tingidae		A					+		+	
	Aradidae		A					+			
	Scutelleridae		A					+			
	Podopidae		A								+
	*	Unidentified species #1	N	+							
	*	Unidentified species #2	N	+							
	*	Unidentified species #3	N				+				
Homoptera	*	Unidentified species #4	N	+							
	Cicadidae		A				+				
	Cercopidae		A					+			+
	Cicadellidae		A		+		+	+		+	
	Cixiidae		A		+	+		+		+	
	Psyllidae		A				+	+			
	Aphididae		A	+	+		+	+		+	+
		Pterocomma sp.	A				+				+
			N				+				+
	Adelgidae	*Adelges* sp.	A		+	+					
			N		+	+					

Appendix 4. continued ....

Order	Family	Genus and/or Species	Life Cycle Stage	WEST Aspen	WEST Black Spruce	WEST White Spruce	WEST Jack Pine	WEST Cleared Area	EAST Aspen	EAST Black-White Spruce	EAST Birch
Diptera continued	Culicidae		A		+		+	+		+	
	Ceratopogonidae		A		+		+	+			
			L			+	+				
	Chironomidae		A		+		+	+		+	
			L	+		+	+	+			
	Simuliidae		A		+		+	+		+	+
	Anisopodidae		A							+	
	Bibionidae	Unidentified species #9	L	+			+				
		Unidentified species #10	L	+							
	Mycetophyllidae		A	+	+		+	+		+	
			P	+			+				
			L	+	+	+	+	+	+		+
	Sciaridae		A		+		+	+		+	
	Cecidomyiidae		A	+	+	+	+	+	+	+	
			L	+		+	+				
	Stratiomyidae		A		+		+	+		+	+
			L	+		+	+	+			
	Tabanidae		A		+	+	+	+		+	+
			L	+	+	+		+	+	+	
	Therevidae		A				+				
			L				+				
	Asilidae		A		+		+	+		+	
			L	+							
	Bombyliidae		A		+		+	+		+	
	Empididae		A		+		+	+		+	
			L	+							
	Dolichopodidae		A		+		+	+		+	
	Phoridae		A		+		+	+		+	
			L					+			
	Pipunculidae		A		+		+	+		+	
	Syrphidae		A		+		+	+		+	+
			L	+	+	+					
	Conopidae		A							+	
	Sepsidae		A		+					+	

Appendix 4 continued ....

Order	Family	Genus &/or Species	Life Cycle Stage	WEST Aspen	WEST Black Spruce	WEST White Spruce	WEST Jack Pine	WEST Cleared Area	EAST Aspen	EAST Black-White Spruce	EAST Birch
Neuroptera	Hemerobiidae		A		+			+			
Coleoptera	Carabidae	*Agonum retractum* Leconte	L	+		+					
			A	+							
		Amara spp.	A				+				+
		Carabus taedatus Fabr.	A								+
		Carabus ingratus Dejean	A				+	+			+
		Cymindis sp.	A								+
		Harpalus sp.	A						+		
		Notiophilus sp.	A				+				+
		Pterostichus haematopus Dejean	A		+						
		Pterostichus sp.	A	+				+	+	+	+
			L								+
		Synuchus impunctatus Say.	A	+			+	+	+		+
		Unidentified species #5	A		+						
	Histeridae		A					+			
	Staphylinidae		A	+	+	+	+	+	+	+	+
			L	+	+	+	+	+	+	+	+
	Micropeplidae	*Micropeplus* sp.	A	+							
	Cantharidae		A		+						
	Lampyridae		L	+		+			+	+	
	Lycidae		A								+
	Elateridae		A		+	+	+			+	+
	Eucnemidae		A				+				+
	Cleridae		A					+			
	Buprestidae		A					+		+	
	Helodidae		A					+		+	
			L					+			
	Byrrhidae		A		+	+	+			+	
	Cucujidae		A					+			
			L				+				
	Nitidulidae	*Brachypterus* sp.	A			+		+	+	+	+
		Boreades sp.	A			+		+	+	+	+
		Prometopia	A			+		+	+	+	+

Appendix 4. continued ....

Order	Family	Genus and/or Species	Life Cycle Stage	WEST Aspen	WEST Black Spruce	WEST White Spruce	WEST Jack Pine	WEST Cleared Area	EAST Aspen	EAST Black-White Spruce	EAST Birch
Coleoptera continued	Coccinellidae		A					+		+	
	Colydiidae		A				+				
	Anthicidae		L		+	+	+		+	+	+
	Pedilidae		L	+	+	+	+	+	+	+	+
	Mordellidae		A	+			+				+
	Tenebrionidae		L	+					+	+	+
	Scarabaeidae	*Aphodius* sp.	A	+							
		Unidentified species #6	A								+
	Cerambycidae		A		+			+			
	Chrysomelidae		A	+	+		+			+	
		Unidentified species #7	A						+		
	Cucurlionidae		A			+		+	+	+	+
			L	+		+					
Trichoptera	Limnephilidae		L			+					
Lepidoptera	Gracillariidae	*Phyllocnistis populiella* Cham.	L	+							
	Geometridae	Unidentified species #8	L	+							
	Arctiidae		L		+						
	Noctiudae		A					+		+	
			L	+	+						
	Pterophoridae		A					+			
			A		+	+	+				
	Nepticulidae		L		+						
	Hepialidae		A		+						
	Olethreutidae	*Laspeyresia* sp.	L				+				
	Pieridae	*Colias alexandra christina*[1]	A	+	+	+	+	+	+	+	+
	Lycaenidae		A		+						
Diptera	Tipulidae		A		+		+	+		+	
			L	+		+	+	+	+	+	
	Psychodidae		A		+			+			
	Dixidae		A				+				
	Chaoboridae		A		+						

Appendix 4. continued .....

Order	Family	Genus and/or Species	Life Cycle Stage	WEST Aspen	WEST Black Spruce	WEST White Spruce	WEST Jack Pine	WEST Cleared Area	EAST Aspen	EAST Black-White Spruce	EAST Birch
Diptera continued	Sciomyzidae		A		+		+	+		+	
	Chloropidae		A		+		+	+		+	
	Anthomyiidae		A		+		+	+		+	
			L	+							
	Muscidae		A		+		+	+		+	
	Tachinidae		A		+		+	+		+	
Hymenoptera	Tenthredinidae		A		+		+	+		+	
			L	+							
	Argidae		A							+	
	Diprionidae		L			+					
	Braconidae		A		+	+	+	+		+	
	Ichneumonidae		A		+		+	+			+
	Eulophidae		A				+			+	
	Eucharitidae		A				+			+	
	Chalcididae		A					+		+	
	Torymidae		A		+		+				
	Pteromalidae		A		+					+	
	Perilampidae		A		+		+	+		+	
	Proctotrupidae		A		+		+	+		+	
	Diapriidae		A		+	+	+	+		+	
	Scelionidae		A							+	
	Chrysididae		A		+		+			+	
	Formicidae		A	+	+	+	+	+	+	+	+
			I	+	+	+	+	+	+	+	+
	Pompilidae		A		+		+	+		+	
	Vespidae		A		+		+	+		+	
	Sphecidae		A		+		+	+		+	
	Colletidae		A				+				
	Halictidae		A		+		+	+		+	
	Megachilidae		A		+		+	+		+	
	Apidae		A		+		+	+		+	
Totals	110 Families Identified		156	41	72**	36	81**	76**	21	76**	39

Appendix 4. continued..........

Life Cycle Stages: A - Adult
L - Larvae
P - Pupa
N - Nymph
I - Immature

* Family unidentified because only nymphs found
** These totals include Malaise trap catches

1 Identified by Dr. C.D. Bird, Department of Biology, University of Calgary.

Appendix 5. Insects Observed but Not Present in any of the Samples Taken.*

Order	Family	Common Name	Life Cycle Stage	East	West
Odonata	Libelluidae	Red skimmers	A	+	+
	Coenagrionidae	Damselflies	A	+	+
Homoptera	Cicadidae	Cicadas	A		+
	Aphididae	Black willow aphids[1]	A & N	+	+
	Adelgidae	Spruce gall aphids[2]	A & N		+
Coleoptera	Chrysomelidae	Willow leaf beetles	A	+	
Lepidoptera	Pieridae	Christina sulfur[3]	A	+	+
	Lycaenidae	Coppers	A		+
	Olethreutidae	Jack pine cone moth[4]	L		+
Hymenoptera	Diprionidae	Conifer sawflies	L		+

LIFE CYCLE STAGES: A - adult
N - nymph
L - larvae

1. *Pterocomma* sp.
2. *Adelges* sp.
3. *Colias alexandra christina*
4. *Laspeyresia* sp.

*These are included in Appendix 4.

Appendix 6. Soil Insect Sampling - A Discussion of the Collembola Results.

The densities of Collembola extracted from soils in this study ranged from 1300 to 2300 m^{-2}. These extractions were considered very inefficient because the densities are low compared to those listed in the literature.

DENSITY (M^{-2})	REFERENCE	HABITAT
22000	Gwenydd Adams (1971)	New Zealand pasture soils
35000-95000	Niijima (1971)	Japanese warm temperature region
26000-43000	Price (1973)	Ponderosa pine - California
12000	Takeda (1973)	Japanese red pine
71000	Mitchell (1974)	Rocky Mountain aspen woodland
10000-20000	J. Sharp (1975)	High Arctic tundra (Devon Is.)

The densities of Collembola encountered in the tar sands area ranged from 1.4 to about 10% of the literature figures. Collembola were found in all habitats but the following table lists the Collembola identified and counted from only three habitats sampled. The data simply reflect the proportions of species found in the samples.

	% TOTAL COLLEMBOLA		
ORDER COLLEMBOLA	WHITE SPRUCE	EAST ASPEN	EAST BIRCH
Sub-order Arthropleona			
Family Poduridae			
Willemia sp.	-	-	1.9
Frisea sp.	-	0.5	-
Odontella armata (Axelson)	-	-	12.0
Pseudachorutes subcrassus (Tullberg)	0.5	-	-
Anurida pygmaea (Börner)	-	-	0.9
Family Onychiuridae			
Onychiurus sibiricus (Tullberg)	2.4	0.5	-
Onychiurus sp. nr. *absoloni* (Börner)	23.0	11.5	9.2
Tullbergia sp.	-	-	0.9
Family Isotomidae			
Anurophorus laricis (Nicolet)	-	2.4	11.1
Anurophorus sp.	2.9	-	-
Folsomia quadrioculata (Tullberg)	1.9	-	-
Folsomia sp. nr. *duodecimsetosa* (Hammer)	67.0	81.0	62.0
Isotoma violacea (Tullberg)	1.8	0.5	-
Isotoma viridis (Bourlet)	0.5	-	-
Isotoma sp.	-	3.5	-
Sub-order Symphypleona			
Family Sminthuridae			
Arrhopalites sp.	-	-	1.9

Appendix 6. continued ....

The data in the preceding table are dominated by more primitive Collembola (i.e., Poduridae, Onychiuridae, Isotomidae). No Entomobryidae and only two specimens of Sminthuridae, more advanced Collembola, were found. Hammer (1953) described the primitive Collembola as becoming more prevalent in northern habitats in Canada; these Collembola are strictly soil dwellers as opposed to the more advanced which venture up into some vegetation.

It is conceivable that if the Collembola are as abundant as should be expected an entire entomology study should be devoted to them alone.