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ERA-NATURAL ENVIROMENT
Port Colborne Community Based Risk Assessment

Consultants Report

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Influence of Soil Chemistry on the Leaf Litter Decomposition Process in Woodlots in the Vicinity of Port Colborne, Ontario

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Executive Summary

High concentrations of metals, notably copper, nickel and cobalt, were identified as having accumulated in the terrestrial environment surrounding the City of Port Colborne. The source of the metals was identified as the nickel refinery operated by INCO Ltd. between 1918 and 1984. Concern about the situation resulted in the creation of a Public Liaison Committee in the City. Through that process, the need for an Ecological Risk Assessment (ERA) process was recognized. One of the identified components of the ERA deemed to be important was the critical ecological process generally referred to as litter decomposition. The present report is a summary of the results of the study of the litter decomposition undertaken at Port Colborne woodlots in 2001.

The study included the selection of 21 hardwood woodlots in the area. These represented woodlots growing on clay soil and organic soils in separate zones of different metal content. The distribution of the woodlots included four in each of heavy or high metal (greater than 1000 Fg/g Ni) on organic sites and on clay sites, four on intermediate levels (between 100 and 1000 Fg/g Ni) on clay soils, four on low or control (less than 100 Fg/g Ni) on organic soils, and five on low or control (less than 100 Fg/g Ni) on clay soils. Because of time constraints, a proxy method of assessing the rate of litter decomposition was made. This included collecting standing litter from 15 fixed sample points in each woodlot in late summer, 2001. The litter was separated into leafy material, twigs, and fruit. The dry weights of each component were determined and appropriate statistics prepared.

The weights of standing leafy material ranged from 63.2 to 536.9 g/m^2 which is well within the normal range identified in the scientific literature. Three of the woodlots on organic soil had the highest weights of leaf litter (430- 537 g/m^2) suggesting the slowest rate of decomposition was occurring along Reuter Road where the highest metal concentrations were present in the soil. This was especially evident where, by contrast, the smallest amounts of standing litter (211-315 g/m^2) were mostly associated with woodlots growing on organic soils with low levels of metals. On clay soils, the litter weights were intermediate to the values measured on the organic sites and showed no clear relationship between litter weight and metal concentration. Weights of twigs and fruits in the litter samples showed no statistically significant differences related to the metal level zones. Woody litter and leaf litter were typically present in nearly equal amounts averaging approximately 95% of the standing litter at the time of collection. Considerable variability existed among the amounts of litter of each type on the various woodlots, consequently, statistically significant differences were not readily detectable.

Surface soil samples collected at the woodlots were found to have metal concentration patterns that generally followed the distribution patterns mapped by the Ontario Ministry of the Environment. Concentrations of the metals of concern were highest in proximity to the refinery (i.e. along Reuter Road) and decreased with distance from the refinery. The concentrations of nickel, copper, and cobalt ranged from 18 to

4030, 8 to 436, and not detectable to 70 Fg/g respectively on the clay soil sites. On organic soils, the concentrations were greater, likely due largely to the closer proximity of some of these sites to the refinery. Concentration ranges were 98 to 22,700, 31 to 2755, and 3 to 311 Fg/g for nickel, copper, and cobalt respectively.

Among the other elements tested, arsenic, cadmium, lead, antimony, zinc, and silver were present in concentrations above some MOE guidelines. The distribution patterns of these elements were similar to the signature of nickel, copper, and cobalt but at much lower concentrations. Such a pattern suggests some possible relationship of the other elements with respect to position of the refinery but does not rule out an alternative source near the refinery, especially when the refinery is not known to have handled these in any notable quantities.

The amounts of leaf litter was correlated (statistically highly significant) with nickel, copper, and cobalt on both clay and organic soil types. Such a pattern suggests that the presence of elevated metal concentrations affects and slows the rate of litter decomposition. Statistically significant correlations were found to occur between the amounts of various standing litter components and the antimony, arsenic, cobalt, copper, lead, manganese, nickel, selenium, and zinc concentrations. A large part of the statistical relationship is due to the correlation between the secondary elements and the elements of concern, especially copper and nickel. The concentrations of cobalt, arsenic, selenium, and possibly silver and cadmium, while much elevated above background, are likely inadequate to cause any significant environmental effect by themselves. It is only nickel and copper, by virtue of their overall high concentrations, that are likely to have been responsible for the slower rates of litter decomposition observed at the Reuter Road woodlots. Even though a decomposition pattern relationship with soil metals can be demonstrated, the total amount of decomposition that occurs in any single year at any one woodlot equals the amount of litter entering the system at that site. This conclusion is based on general observations that suggested no unusual accumulations of litter on the ground. The rates of average annual fresh litter input is essentially at equilibrium with the amount decomposing each year.

A detailed analysis of the vegetation species present in each woodlot did not provide any conclusive evidence to show alterations of the plant community that might have been related to high metal concentrations. Tree and shrub health generally appeared to be normal at each woodlot. Mortality among trees and shrubs was in the normal range, especially if the endemic Dutch elm disease is taken into consideration. New foliage production did not show any relationship to soil metal levels in the 2001 growing season.

The overall conclusions reached from this study suggest that the leaf litter decomposition process might be slowed in woodlots in the zone of the highest soil concentrations of copper and nickel. While the process might be slowed in the presence of metals, the net decomposition each year is constant and there is no net accumulation of litter on the ground. A more definitive assessment would require a study period of two or three years to complete.

Influence of Soil Chemistry on the Leaf Litter Decomposition Process in Woodlots in the Vicinity of Port Colborne, Ontario

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1.0 INTRODUCTION

1.1 INTRODUCTION

A healthy forest ecosystem includes a proper functioning of each of the normal processes typical of that type of forest. The woodlot is comprised of a large number of interacting, living organisms including plants and animals, microbes, insects, etc, as well as physical features such as soil, rock and water. Each of these, through growing, surviving, hosting, reproducing, recycling and interacting with other members, has a role to play in the ecosystem. As long as these are present in moderate numbers and the system does not become unbalanced, little concern is expressed by the human population. When the system becomes upset or at least has the possibility of becoming upset, then the level of concern becomes much more important as an issue. Such was the case in Port Colborne, Ontario where the present study was undertaken. One of the general processes in an ecosystem is that of the cycling of nutrients (Figure 1) [158]. Although there are some differences between elements, the general pattern remains the same for all. Mineral elements are accumulated from soil, water, or air, and are then transferred upwards through the food chain. At any level in the food chain, they may be returned to the soil or water via the process generally referred to as decomposition (Figure 2) [158]. The decomposition process is a critical one. Without it, large amounts of organic matter would accumulate on the surface of the soil, plant nutrients would be locked up and not available for sustaining plants, and other components of the ecosystem relying on those plants could not acquire their needed sustenance.

Because of the critical nature of the decomposition process, it immediately becomes a key for consideration in any evaluations needed to complete an ecological risk assessment. In the situation at Pt. Colborne, Ontario, which is the subject of the current investigation, the woodlots there have been subjected to historic aerial deposition of metals, specifically, nickel, copper, and cobalt. It has been suggested that the levels of metals derived from aerial fallout may have reached levels that are harmful to the vegetation growing in those woodlots and that leaf litter decomposition may have been negatively impacted. It was therefore deemed necessary to conduct a field assessment of any possible impacts of the elevated metal concentrations on the leaf litter decomposition process to complete the required ecological risk assessment being undertaken at Pt. Colborne. More details about the process of litter production, the decomposition process, and available scientific evidence of any effects caused by elevated metal concentrations on that process are reviewed below.

Measurement of leaf litter decomposition rate is traditionally measured using known amounts of litter confined in mesh bags placed *in situ* under field conditions. Loss in weight of the litter over time is used to measure decomposition rate. Because the decomposition often requires over two years to complete, (woody litter will take even longer periods), time constraints imposed by the current situation would not allow for a detailed investigation using the normal procedures. Instead, a proxy method of assessing the rate of decomposition was used. That method involves the measurement of the amount of undecomposed litter remaining on the surface of the ground. Some assumptions made in employing this method are that the sites being examined are not significantly different from each other in any way other than the amount of accumulated metals in the soil. Forest species, soil moisture, soil type, etc. at the different study sites should be as similar as possible insofar as the inherent field conditions would allow. Field work to assess whether the emissions had impacted upon the litter decomposition process was undertaken in 2001 using the standing litter measurement approach. The results of that investigation are included in this report.

1.2 HISTORY OF THE SITUATION IN PORT COLBORNE

Following the outcome of the 1916 Royal Ontario Nickel Commission into the security of nickel as a strategically important metal, the International Nickel Company, now known as INCO Ltd., established a new nickel refinery at Pt. Colborne in 1918 [181]. Until 1984, a period of 66 years, the refinery was in operation, processing primarily nickel, copper, and cobalt. Over the course of those years of operation, substantial quantities of these metals were emitted into the air and were deposited in the area to the northeast of Pt. Colborne, Ontario, under the influence of the prevailing winds. The distribution of the metals of concern in surface soil (0-5 cm) is shown in Kuja *et al*. [101, 103]. Current operations on the site include processing of precious metals and because of the relatively small scale, are not considered to have any significant environmental impact.

Historically, the ambient air emissions had caused acute toxicity symptoms on sensitive species. Temple [170] reported the presence of injury to silver maple, oats, lettuce, cabbage, and sour cherry growing in the area. Bioassays showed that elevated metal concentrations in the soil collected in the area reduced the growth of lettuce, celery and onion [25]. Subsequent work by Frank [66] confirmed the impact of the soil metals. Injury symptoms have not been seen in recent years, however, uptake of the residual metals by plant roots has continued but apparently not to the levels that induce acute toxicity symptoms [130]. Although Bisessar [25] showed that some of the toxicity problems could be reduced by amelioration of the soil with lime, celery and other muck crops are no longer grown in the area and the land in question has been purchased by INCO.

In more recent times, concerns about the health and the ecological effects of the soil chemistry have been raised by the citizens of Pt. Colborne and area. Of particular relevance to the present investigation, the woodlots in the vicinity of the nickel refinery have been found to have accumulated metals at accentuated levels [102]. More specifically, and the basis for concern in the present report, is the possibility that the ecological processes represented as leaf litter decomposition may have been negatively impacted by the accumulated metals. It is this specific topic that is the subject of the current investigation. The results of this investigation will fulfill some of the data requirements for completing the required larger ecological risk assessment being undertaken in the Pt. Colborne area.

1.3 LITTER PRODUCTION

Overall change in biomass in an ecosystem is a balance between the material produced in seasonal production of vegetation (i.e. Input) and the amount lost through litter fall, decomposition, and migration or loss through leaching (i.e. Output or Loss) [117, 135, 185, 187,188]. Increase in biomass, typically seen as growth of forest trees but not exclusively so, results when the mass produced exceeds the mass lost. Perennial plants typically form the part of the ecosystem where the standing biomass accrues but organic matter may also increase in the soil, In the longer term, the perennial plants die and decay and are thus returned to the pool of materials from which new vegetation and animals are produced [46, 47].

Litter production is most conspicuously visible as autumn leaf fall in temperate forests. Somewhat less conspicuous is the woody litter fall, although this will accumulate due to slower decomposition rates of wood, and the fall of other plant parts including bud scales, flowers and fruits or seed. A large part (one half to two thirds) of the organic matter input into soil is not readily visible at all but occurs through root mortality and root exudates [151, 152]. With respect to this, Edwards *et al.* described a method for measuring short-term carbon dioxide evolution from the forest floor [60, 61]. They measured annual CO_2 evolution rates of 3.8 kg/m^2 with 48% from litter, 17% from soil and 35% from roots. Evolution of CO_2 evolved from the soil is higher than the estimates of the potential CO_2 emissions that would be released from typical organic detritus deposition. Most of the discrepancy appears to be related to release of CO_2 evolving from the breakdown of materials released from the roots and from the soil suggesting that measurements of such materials are underestimating the quantities involved. Active maple roots are known to release at lease five different sugars, twelve amino acids, and four organic acids [159]. Bradbury *et al.* studied vegetation death and decomposition in two old field communities near Guelph [29]. They found that ongoing death and subsequent decomposition of plant tissues between sampling periods could underestimate the true net aerial primary production of vegetation. This could have implications for certain types of ecological studies.

Bray and Gorham provided an overall litter production estimate of 3500 kg/ha or 350 g/m^2 in cool temperate deciduous forests [31]. In a study of forest stands in Alaska which included Balsam poplar, Sitka alder, Sitka spruce, and willow among other species, Hurd [89] found total litter fall to average 285 g/m^2 over a three-year study period. Of this, 183 g/m^2 were non-woody (mainly leaf) litter. At Brookhaven, New York, a mature oak-pine woodland had a litter fall of 275 g/m^2. Weary [182] reported 275-700 g/m^2 of standing litter in a red maple forest. Total litter production in a sugar maple-oak forest was reported to be 430 g/m^2 of which 310 g/m^2 was leaf litter [30]. Some other published litter production measurements are presented in Table 1.

By comparison, wetlands have a much higher rate of productivity. Reader *et al.* attempted to quantify the net primary production in a peatland in Manitoba. [150]. Their studies included examination of inputs and decomposition in four different forest zones including both above-ground and below-ground contributions. The results from their study demonstrated average net annual increments in peat accumulation in a bog at between 26.8 and 51.7 g/m^2 from total production rates as high as 1750 g/m^2. In their studies of wetland species, notably *Typha glauca* and *Scirpus fluviatilis*, Davis *et al*. [51] studied dry weight of standing and fallen plants as well as submerged litter using litter bags. Their measurements showed biomass measurements of 1322, 1208, and 1183 g/m2 dry weight for live plants (August 15), standing litter (April 6, and fallen litter (Apr 6) respectively. The former can be considered as an approximation of the annual productivity of the cattail marsh site [51].

1.4 THE LITTER DECOMPOSITION PROCESS

The general concept of element cycling in the natural environment is well established and is outlined in numerous texts of which a few examples are listed [28, 40, 42, 54, 158]. Although there are some differences between elements, the general pattern remains the same for all In general, mineral elements are accumulated from soil, water, and air, then transferred upwards through the food chain. At any level in the food chain, they may be returned to the soil or water via the process generally referred to as decomposition.

The decomposition process returns the elements that were incorporated into the tissues of plants and animals back to a form that can be used once again by the primary producers, generally identified as plants. In a more or less steady state, the amount of elements accrued by the organisms in the system is the same amount that is released through the decomposition process. The processes are controlled by physical factors such as temperature and moisture availability [54, 188] therefore the cycles are punctuated by daily changes (i.e. dark, light), seasonal weather conditions including day length and winter conditions, and other factors of irregular periodicity such as fire. Also certain shifts in the cycling do occur due to natural changes such as natural succession [78]. Soil pH, soil structure, shading, growing season length, and various contaminants all have roles as well. The plant species contributing to the litter are important in controlling the rate of decomposition because each has its own particular chemical composition (i.e. some have more lignins than others), and growth conditions prior to deposition onto the ground [81, 133].

The decomposition and decay process actually begins immediately after a plant tissue has formed. In some cases this is represented as attack by pathogenic organisms, colonization by a surface flora, consumption by insects, and premature litter fall [55]. These processes are typically minor in scale and the greatest proportion of the decomposition occurs after the leaves fall in the autumn in the temperate regions of the world. In tropical regions, the process is continuous or controlled largely by rainy and dry seasons.

Factors which disrupt the decomposition process, ultimately influence the natural processes that occur at a particular location. Without the decomposition process, the essential nutrients required by the plants and all other organisms that eventually depend on them would be bound up and rendered unavailable in the cycle [151]. In cases where the decomposition process is decreased, the amount of material being formed and returned to the system (i.e. leaf litter fall) is greater than the amount being broken down or decomposing. Under conditions of decreased decomposition, the amount of litter on the surface of the ground would start to accumulate and nutrients would not be available to the vegetation (i.e. forests) in that area [45, 67, 164, 165]. If the disruption continued over a much longer period, the forest trees would slow or even cease their growth and the amount of leaf and litter fall would decrease accordingly. Situations reaching this state are relatively rare.

Soils in the woodland include a complex network of organisms, each with its own role in the progressive breakdown of organic materials [80, 151]. The organisms include species as diverse as microorganisms, (bacteria, fungi, protozoa) [148], larger fungi, and fauna including mites, collembola, nematodes, earthworms [118], enchytraeid worms [118], millipedes [59], molluscs [122, 123, 124], and insects [4, 59]. Evidence is available in the literature to support different views about the relative roles of soil fauna in the decomposition process. The general view is that the presence of soil animals increases the rate of breakdown. Behan [14] noted that their presence increased the rate of breakdown by six times that of conditions where they were not present. Crossley *et al.* also found that soil arthropods increased the rate of breakdown [48]. By contrast, Malone *et al.* found that their presence decreased the decomposition rate presumably because they fed upon some of the other organisms that were responsible for the decomposition [121].

Plants and animals in the woodland derive their nutrients from two main sources: 1) litter of plants and animals falling to the ground and 2) from plant roots and their exudates. The latter is less conspicuous and difficult to measure; the former is more obvious to the casual observer. Disintegration of litter and root materials is a critical function of soil organisms. Without their actions, large amounts of plant nutrients would be locked up in the accumulating material as in the case in peat bog formation [143]. A thick accumulation of litter over a mineral soil does not mean that litter fall and decomposition are out of balance. If the two processes are in balance, the large amounts of litter on the ground tends to be relatively constant from year to year if periodic inputs (autumn leaf fall contributions) are properly taken into account. Individual twigs or leaves may take several years to completely breakdown. Conifer foliage decomposition rates are typically much slower than those for deciduous species and consequently it is normal to find a thick layer of organic matter on the ground under conifer stands [65, 96].

The breakdown of the litter usually includes a sequence of stages including physical and biochemical alteration as well as a physical mixing and redistribution in the soil profile (i.e. earthworm activity). The sequence of organisms utilizing or colonizing litter generally follows a pattern [38, 179]. In fresh materials, the soluble carbohydrates and proteins are utilized first. Cellulose and related compounds are broken down next, followed by lignins. The most important fractions of the litter, cellulose and hemicellulose, decompose much faster than the lignins which are more resistant [155].

Species rich in soluble carbohydrates and nitrogen decompose more rapidly than those with lower concentrations of these compounds or where polyphenols such as occur in beech or oak are present [94, 133, 169]. The final product includes conversion of the carbon into CO_2 [33, 34]. Nitrogen is mineralized and is either converted to new organic material by uptake by plant roots, by microorganisms or volatilization (ammonia). Other nutrient elements are eventually released for use by the various organisms in the soil. Owens *et al.* [144] reported that at least 20 volatile compounds are released by decomposing plant material stimulated microbial activity in soil. The most significant among these were aldehydes and alcohols.

Hulme buried or exposed blocks of paper birch and red pine wood to soil for three months [88]. Some of the blocks were inoculated with various known saprophytic organisms prior to exposure to known wood decay fungi. A number of saprophytic species significantly reduced the amount of decay if the wood blocks were first allowed to become colonized by these saprophytes. A number of potential mechanisms involved in the inhibition of wood decay are possible but the interactions between the different components may be quite complex. The addition of other factors including heavy metal contaminants such as in the case of the present study would make the interactions even more complex. By comparison, Sharp examined the fungal colonization of fresh wood from several tree species buried in soil over a 70-day study period. [157]. A large number of fungal species were isolated from the wood but the authors did not observe a successional change in species isolated over the study period. They assayed the wood to determine the formation of glucose, and the enzymes cellulase and amylase. Glucose was released from the wood over time but there was no clear pattern of change in the amount of enzymes present. This study did not substantiate previous work that indicated that woody litter requires a series of fungal colonizers that alter the wood substrate to make it suitable for succeeding organisms in the sequence. The nature of the experimental procedure may not have favored the natural processes but did suggest that some new wood might have had an adequate supply of nutrients to support a number of pioneering fungal species. The physical structure of the wood may have had a significant role in maintaining the numbers of organisms and the rate of colonization.

Rates of decomposition are controlled by physical environmental factors, notably available moisture and temperature [180]. Soil pH, soil structure, shading, growing season length, site disturbance, and various contaminants all have roles as well [24]. Bleak [26] examined decomposition of several herbaceous species under snow from October through May in central Utah. Grass species lost between 27 and 42% of their weight which lupine and bluebells lost between 40 and 56% in the same period. Their conclusions were that fungi and bacteria were the agents mainly responsible for the weight loss while water from melting snow would carry away soluble materials.

The species contributing to the litter are important in controlling the rate of decomposition because each has its own particular chemical composition (i.e. some have more lignins than others), and growth conditions prior to deposition onto the ground [1, 19, 20]. Different components in the litter have different degrees of resistance to breakdown. The presence of tannins, for example, slows the decomposition of litter.

Different species and even strains of plants, when living, exhibit various degrees of resistance to attack by insects and other organisms. Feeny [63, 64], for example, reported that the presence of tannins in oak leaves and the timing of their formation affected the trees susceptibility to attack. Studies of different strains of wild ginger showed that some strains were more susceptible to attack by slugs [36]. Cates also concluded that plants typically associated with early successional stages in an ecosystem were frequently more susceptible to attack by slugs than were plant species from a later stage in the ecosystem [37]. Painter [145] demonstrated that crop and other plants had a diverse means for resisting attack by insects. Some of the resistance mechanisms were physical while others were biochemical ('antibiosis' in his terminology) in nature. It is not unreasonable to expect that the mechanisms that make the plant tissues resistant to attack by various pests when the plants were alive would still be active to some degree after the leaves and twigs had fallen to the ground. Such is the case in oak leaves which take longer periods to decompose than many other species. The presence of compounds in plants (i.e. alkaloids, glycosides, oxalates, saponins, and others) [97] that inhibit attacks by pests does come at a price to the species involved. Energy that might otherwise have been directed into growth of the plant, is required to produce those compounds that confer the resistance [37]. In the case of forestry, several conferences have been held in recent years to report the results of studies of the interactions between insects and forest trees [13, 126, 131],

Meentemeyer [132] examined litter decomposition data from several studies conducted at different places in the United States and Europe. He was able to demonstrate a strong relationship between the rate of litter decomposition and the lignin content of the litter and the annual actual evaporation (AET) which is a measure of energy or temperature and moisture. From this, he was able to develop equations to predict annual loss in litter weight. The relationships show that in the absence of lignins in the tissue, the percent decomposition rate would range from approximately 26% at 300 mm AET to 85% at an AET of 900 mm. At a high lignin content of 45%, the rate of decomposition is approximately 5 and 26% respectively for the AET values noted above.

Lousier and Parkinson studied litter dynamics in an aspen woodland in the eastern Rocky Mountains of Alberta [119]. Leaf litter production in their study area input was 250 g/m^2 with an additional 66 g/m^2 of non-leaf litter. After 30 months, 40.0% of the aspen foliage and 37.4 % of balsam fir litter had disappeared from 3-mm mesh bags. Residence time for litter in a variety of woodlands is indicated in Table 1.

In their studies of wetland species, notably *Typha glauca* and *Scirpus fluviatilis*, Davis *et al.* [51] studied dry weight of standing and fallen plants as well as submerged litter using litter bags. They noted that the concentrations of iron and aluminum increased significantly over time in the submerged samples whereas calcium, magnesium, sodium, and potassium were lost. Inman *et al.* examined the decomposition of litter from three plant species in northwester Indiana. In reciprocal and source site exposures, they found that metals (cadmium, zinc, lead and copper) accumulated in the samples, notably in the urban site in Chicago [90]. Other litter decomposition studies [129] have demonstrated an ongoing accumulation of metals in the litter remaining in litter bags. In the vicinity of active sources including general urban emissions [90] or nearby refinery sources [128, 129], such increases might be understandable but the fact that increases were also noted in remote control requires that there must be an understanding that the nutritional value and toxicity factors in decomposing litter are not stable. Particularly in situations with moderate or low metal inputs, the litter could develop significantly toxic concentrations of those metals before the litter is completely decomposed.

1.5 CONTAMINATION EFFECTS ON LITTER DECOMPOSITION

1.51 Contaminant Effects on Litter Decomposition

Decreased rates of litter decomposition or lower numbers of soil-dwelling organisms have been demonstrated in the presence of pollution sources.[10, 11, 12, 15, 16, 17, 18, 21, 22, 44, 52, 56, 58, 70, 72, 73, 77, 83, 99, 105. 106. 107, 108, 109, 128, 129, 140, 141, 154, 164, 165, 175]. Freedman and Hutchinson [67, 68] found that leaf litter decomposition in the Sudbury area was reduced in the presence of the copper and nickel levels encountered in soil in proximity to smelters; however, the changes in the forest vegetation communities also occurring in their study area [69] was more likely caused by many years of sulphur dioxide fumigations and forest fires rather than through soil contamination by metals.

Giashuddin *et al.* [72] reported that nickel added to a sandy soil at rates ranging from 50 to 5000 ppm nickel reduced the breakdown of straw measured as nitrification or carbon mineralization. The effect was related to the level of nickel added and the pH of the soil being tested. The effect was greatest in the more acidic soil treatments. Nitrification was suppressed by as much as 66% at 5000 ppm Ni at pH 5.8. At higher nickel levels and higher soil pH values, the effect was less extensive. In a similar study using nickel sulphate, the authors [72] demonstrated that 1000 ppm Ni depressed nitrogen mineralization up to 68% at 1000 ppm Ni. Carbon mineralization was decreased (22%) by as little as 10 ppm Ni. CO_2 released from decomposing straw mixed in a sandy soil was studied by Bhuiya *et al.* [23]. Additions of metals (1000 ppm each of Cu, Zn, Pb as oxides and Ni as sulphate) were found to have essential no effect from the zinc addition while lead decreased CO_2 evolution by 7.1%. Copper and nickel had a much greater effect with reductions at 33.5 and 39.9% respectively. Using a similar approach, Quraishi [149] added copper as sulphate to a sandy loam soil and found that it depressed nitrogen mineralization at 1000 ppm Cu. The nitrification process was stopped at pH 5.11 and 5.9 and to some degree at pH 7.3. One conclusion from this study suggested that the toxicity of copper could be eliminated or decreased by raising the soil pH.

Inman *et al.* [90] examined the decomposition of litter from three plant species in northwestern Indiana. In reciprocal and source site exposures, they found that metals (cadmium, zinc, lead and copper) accumulated in the samples, notably in the urban site in Chicago. Litter weight loss indicated that elevated metal contaminant concentrations were associated with lower rates of decomposition

Studies of the impact of gamma radiation in a mature oak-pine woodland at Brookhaven, New York included determination of the effects on litter formation or decomposition [8]. Background sites had a litter fall of 275 g/m^2. At increasing rates of radiation, total litter production declined. The more decay-resistant woody litter formed 13% of the litter at the control sites but made up 96% near the source. This largely reflects the decreasing rates of leaf litter input with proximity to the radiation source.

The herbicide 2,4,5-Trichlorophoxyacetic acid was applied to white oak trees at two rates and the fallen leaves were studied to determine whether these treatments had any effect on the decomposition process [76]. Weight loss of natural leaf litter was similar in sprayed and non-sprayed areas. After one year, weight loss was 35% and reached 67% after two years. By comparison, foliage from trees treated with herbicide lost 59% of their weight after one year. The authors ascribed the differences between the control and herbicide treatments to a higher concentration of nitrogen in the herbicide treatment. The latter had higher densities of microarthropods in the litter, likely as a consequence of the more attractive tissues.

At Walker Branch Watershed in Tennessee, Van Hook *et al*. [177] examined the distribution of several metals in various woody plants and litter in a mixed Tulip Tree, Oak, Hickory, Pine forest. In the vegetation, most of each metal (lead, cadmium, and zinc were studied) was present in the fine plant roots with lesser amounts in foliage followed by woody tissues. Concentrations measured in plant tissues were generally much lower than in the litter. Although tree boles usually had lower metal concentrations than other tissues, they contained significant portions of the total pool of plant metals on sheer mass. Turnover of metals in the watershed was found to be three to four years but turnover in the soil involved much greater times. The watershed was retaining each of the metals (atmospheric inputs exceeded loss through streams) and these were accumulating in the soil component of the ecosystem

1.52 Metal effects in organic soils

Muck soils used for agricultural production of vegetable or other crops normally are derived through drainage of former wetlands. Under the previous condition of a high water table, the rate of production of biological material by plants on that site exceeded the rate of decomposition. Over many years, the net result of this difference is a build up of a thick layer of organic material. Once the site has been drained and the soil opened by cultivation, the organic matter begins to oxidize and disappears at moderate to slow rate in the process known as ‘subsidence’. Because the depth of the organic layer is often not great, the cultivation of the soil starts to reach into the mineral subsoil which is a less desirable soil for the production of the desired crops. Plant nutrient deficiencies with respect to copper are known to occur in organic soils and it is recommended that copper be applied in small amounts to 1) overcome the deficiency and 2) the rate of loss of organic matter through subsidence [100, 113, 114, 115, 125, 127, 147]. The copper, when added as a fertilizer, will slow down the enzymes that bring about subsidence by about 50%. Copper application rates of 14 kg/ha in each of the first three years followed by 5 kg/ha every second year thereafter are recommended for continued vegetable production.[127]

1.53 Metal Toxicity to Plants and Other Soil Organisms

Much information has been published in the scientific literature regarding the accumulation of metals in plant tissues as the result of ambient emissions of metals to the air or through uptake from metals accumulated in the soil [160]. Unfortunately, relatively few of the studies have documented the toxicological consequences of that metal contamination.

Anderson *et al. [2*] reported that oats were more sensitive to nickel than to cobalt. When grown in soil, oat plants with nickel concentrations at 88 Fg/g showed injury symptoms. In sand culture, injury was associated with tissue nickel concentrations as low as 24 Fg/g in some tissues. The authors noted the presence of nickel toxicity in plants grown in soils with nickel concentrations between 266 and 3500 Fg/g. The work conducted by Brenchley [32] using water cultures confirmed that nickel was generally more toxic than nickel or cobalt on growth of barley. Cobalt was most toxic of the three metals to broad bean. Bioassays of soil collected in the vicinity of a nickel smelter at Thompson, Manitoba showed nickel concentrations as high as 2173 Fg/g and copper at 1210 Fg/g in the soil [95]. At sites with elevated nickel and copper, seedlings of black spruce and jack pine took up the metals into the roots. Concentrations of soil copper at 300 and nickel over 1000 Fg/g reduced root growth of these two tree species.

Thurston [172] investigated the potential for direct foliar toxicity problems associated following several years application of copper and sulphur sprays in an apple crop. While the study failed to identify any spray toxicity problem with growth of the trees under the experimental conditions, it was found that the production of an apple crop greatly influenced the increase in stem diameter. The best growth was achieved in years when the apple crop failed and more resources could be diverted into tree growth rather than fruit production. No consideration was given to the possibility of accumulation of the spray materials in the soil. This should not have been a problem under the period of investigation but under longer periods this might be a concern.

Fungi

Microorganisms are responsible for between 80 and 90% of litter mineralization in northern forests [94, 151]. Horsfall [86] ranked the relative toxicities for a number of metal ions and established the following sequence in respect to fungal toxicity: Ag > Hg > Cu > Cd > Cr > Ni > Pb > Co > Zn > Fe > Ca. The same ranking generally applies to other organisms as well. Copper and nickel have been used or considered as fungicides or components of fungicides due to their toxic properties. Nickel was considered as a control of diseases of grain by treating seed grain prior tp planting [82, 85, 134]. Copper was used as a control of damping-off diseases [3,] or wheat bunt [43, 79, 138, 173].

Earthworms

Earthworms are some of the most important and largest of the soil animals in the breakdown of litter in *mull* soils (soils with organic matter well mixed into upper soil horizons) [118]. In *mor* soils (soils with a distinct layer of raw humus), their role is replaced by the smaller but related enchytraeid worms. Millipedes, isopods, and certain insects are other important agents are also important in litter decomposition in deciduous forests.

Molluscs

The role of molluscs in the litter decomposition process have been reviewed by Mason [124]. Wareborn [70] reported that molluscs can ingest between 1 and 17% of the leaf litter. Mason has suggested that slugs are more important than snails in breaking down litter [122]. Jennings *et al.* have estimated slugs to consume 8.4% of the leaf litter produced in deciduous woodlands in Great Britain [93]. In beech woods where the litter is more resistant to decomposition, the litter consumed by snails is 0.35 to 0.72% of the total [123]. The contributions of slugs and snails to the CO_2 emissions from the soil amount to only 0.05% of the total [152]. This is quite small, even if the carbon contributions of roots and root exudates are factored into the data.

Other Invertebrates

At Gusum, Sweden, the contamination of the local terrestrial environment resulted in changes in the numbers of earthworms, collembola, beetles and other types of invertebrates.[15, 16, 17, 18, 164, 174]. Hopkin, S.P., and M.H. Martin. [83] reported that isopods or wood lice *Oniscus asellus* were present in equal numbers near a zinc, cadmium, lead smelter and in the control area. By storing copper and cadmium metals in the hepatopancreas and excreting zinc and lead, the woodlice were able to tolerate the pollution. Beyer, and Anderson.[22] determined that the woodlouse *Porcellio scaber* had biological population effects at soil concentrations at 12800 ppm lead and 1600 ppm zinc. Scott-Fordsmand reported that elevated nickel concentrations in the soil were toxic to collembola [156]. Pitcher, R.S [148] studied the toxicity of silver and cupric ions to three species of plant-parasitic nematodes. In aqueous solutions, the nematodes were found to be highly sensitive to low concentrations of the two metals.

2.0 METHODOLOGY

Measurement of leaf litter decomposition rates is traditionally measured using known amounts of litter confined in mesh bags placed *in situ* under field conditions [38, 49]. Loss in weight of the litter over time is used as the indicator of decomposition rate. Because the decomposition rate is not rapid and involves sequential steps in the breakdown of the different types of material, as well as a variety of different types of microbes and small arthropods and other small animals, such studies often require over two years to complete [54, 81, 94, 96]. Woody litter will take longer periods. Because of time constraints, the current situation did not allow for a detailed investigation using the normal procedures. Instead, a proxy method of assessing the rate of decomposition was used. That method involves the measurement of the amount of relatively un-decomposed litter remaining on the surface of the ground. Some assumptions made in employing this method are that the sites being compared are not significantly different from each other in any way (other than the amount of accumulated metals in the soil). Forest species, soil moisture, soil type, etc. at the different study sites are all as similar as possible so far as the inherent field conditions will allow.

It is necessary to assess the amount and kind of leaf litter that is produced at each site to ensure that any differences being measured are not due to differences in litter production rates. Typically, the amount of litter production is measured using litter traps of fixed known area on a year-round basis [27, 38]. In addition to foliage, these traps collect flower parts, seeds or fruits, twigs, and bark, the volume of which is not insignificant. The most conspicuous part of the litter fall; however, is in the form of foliage in the autumn. A measure of leaf fall might be obtained by collecting the fresh foliage litter from the ground surface shortly after it has fallen. While less complete than using formal litter traps, this approach at least provides a rough measure of the fresh litter fall volume to demonstrate that is at least comparable at equivalent sites.

2.1 SITE SELECTION

Initial screening of sample sites considered that any woodlot within three zones of differing metal concentrations were eligible for sampling [1]. The zones were designated as Heavy (greater than 2000 Fg/g Ni), Intermediate or Moderate (between 100 and 2000 Fg/g Ni, and Low/Control (less than 100 Fg/ Ni) based on mapping produced by the Ontario Ministry of the Environment [103] (Figure 3). Secondarily, woodlots that developed separately on clay or on organic soils were considered [98] (Figure 4). Originally, a target of five woodlots in each soil type in each zone was established. Extensive searched of the area determined that there was insufficient numbers of woodlots that met the requirements in each soil type and metal class. Preliminary

[1] It should be noted that the mapped zones of elevated metal concentrations were taken as only a guide to the area of impact because mapping of metal levels is subject to a number of procedural limitations. Final interpretation was based on the levels of metals actually measured at each woodlot site as described below rather than the zones mapped by MOE

(woodlot) mapping showed a number of woodlots in each area but field inspection revealed that many of these were areas of only scrubby growth, that they had been converted to other uses (i.e. golf courses or other forms of woodland), or the owners preferred not to participate in the study. The numbers of woodlots that met the screening criteria and were selected for sampling included the following:

Numbers of sample sites expected		
Metal Zone	Soil Type	
(by MOE mapping)	Clay	Organic
Heavy - over 2000 Fg/g Ni	3	4
Moderate - 200-2000 Fg/g Ni	5	NA
Low/ Control - less than 100 Fg/g Ni	5	4

2.2 LITTER SAMPLE COLLECTION

2.2.1 Standing Litter Assessment

2.2.1.1 Sample Collection

Samples of old or standing organic litter were collected at the twenty-one selected woodlots sites throughout the later summer, 2001 as indicated in Appendix 6. Fifteen samples were obtained from each woodlot site following the protocol described below based on general procedures for quadrat studies outlined by Bonham [27] and Chapman [38].

A starting point was selected in a representative part of the woodlot as far as practical up to 100 meters away from the edge of the woodlot. This point was subsequently used as the southwest corner of a sampling grid consisting of fifteen sample points. The grid was arranged in three rows of five sample points with the longer axis oriented north-south. Spacing between sample points and rows was 5 meters (See Figure 5). A flag was placed at each target sample point to facilitate locating that point during the sample collection process.

At each sample point, samples of litter were collected from the 'open' area nearest the flag. Open areas used were of sufficient distance to avoid the immediate and direct influence trees trunks, tree roots, shrubs, large fallen branches or poison ivy. If more than one suitable and equivalent open area was present around the flag, the point nearest the north and east of the flag was selected for sample collection. In most cases, the sampled area was within 0.5 meters of the flag.

The sampling process consisted of laying a sheet of plywood 50 cm square, over the ground surface to be sampled (Figure 6). A knife was used to cut through the litter around the perimeter of the board. When twigs were too large to cut with the knife, they were severed with pruners. Litter outside the board was then scraped away so that when the board was lifted, the underlying litter was still in place. The litter comprising the LF layer soil horizon [183] was then scraped together and placed in labeled polyethylene bags. In a number of locations, the underlying soil had developed deep cracks due to drying of the soil. With practice, it was possible to minimize the amount of litter that fell into these cracks. The samples were then brought to the laboratory for sorting.

2.2.1.2 Sample Sorting

Samples of litter were sorted individually by hand. Three classes of litter were distinguished including woody litter (twigs and bark), fruits (including maple and ash samaras, acorn, hickory nuts, beech mast, etc.); and mixed leaf litter. The latter included leaf materials, stems of herbaceous plants and vines, fine woody particles and other small organic fragments, Any green plants, recently fallen litter (2001 foliage), living plant roots, or lumps of soil were removed and discarded. Notes were made of any notable organisms, including snails, present in the samples. As a standard procedure, any twigs or wood over 2 cm diameter were excluded as these could individually contributed a large portion of the total litter weight and introduced unnecessary variability into the data set. Because branches of this size were originally excluded in the field or avoided from the sampled area in a few cases, there were relatively few of these found in the samples. A single large elm at Site 8 had lost a significant portion of its current-year's foliage, in part due to the late date of sample collection (September 13). These leaves were not included in the weighed samples.

2.2.2 Fresh Litter Assessment

2.2.2.1 Litter Collection

At five of the established woodlots best representing the average tree cover for each of the five soil/contamination study zones, fresh (2001) leaf litter was collected. The plots sites included in this sampling were Plots 2, 10, 13, 17, and 21. Three sample points within the established 15-point grid area were selected (Figure 5). At each sample point, a 1 meter square frame was laid on the ground (Figure 7). A knife was used to cut through the leaf deposit at the edge of the frame. All fresh foliage within the frame was collected and placed in labeled polyethylene bags and brought to the laboratory. At the time of collection (November 2, 2001), the amount of foliage still present on the trees in the woodlot was estimated.

2.2.2.2 Sample Sorting

Samples were hand sorted and any material exclusive of the current-year foliage was discarded. The remaining leaves were sorted into any distinguishable species (see Table 6) with an additional category for species that were of uncertain identity (mainly part leaves) or were miscellaneous materials such as grass or ferns. The samples were then submitted to the laboratory for dry weight determination as described for the standing litter above.

2.2.2.3 Laboratory Analysis

Weights for each total sample were determined gravimetry in the laboratory. Samples were oven dried to constant weight at 38 degrees C. then weighed gravimetrically on a Sartorius Digital Balance to the nearest mg.

2.3 SOIL SAMPLING

2.3.1 Sample Collection

Samples of soil were collected in duplicate from the 0-5 cm depth at each sample location on September 4 and 5, 2001. Soil was sampled at one woodlot on September 13, 2001. Each sample consisted of approximately 30 cores distributed uniformly across the sample plot. The cores taken by a stainless steel Oakfield® soil corer were combined in a plastic bag, crushed and thoroughly mixed. A portion of the mixed sample was transferred to a labeled jar that was submitted for laboratory analysis.

2.3.2 Chemical Analysis

In the laboratory, determination of the moisture content the soil was determined gravimetrically as described for the litter samples above. The remainder of the sample was spread out on drying trays in a dust free environment and dried at 30-35 C to a constant weight. The sample was disaggregated with a mortar and pestle and screened through a 2 mm sieve. The fraction less than 2 mm was then ground to pass a 355 um sieve. The samples were digested using concentrated nitric acid and hydrochloric acids. The resulting digestion solution was then analyzed to determine the concentrations of aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, phosphorus, silver, titanium, vanadium, and zinc by ICP spectrographic analysis following EPA procedure 3010. Analysis for antimony, arsenic, and selenium followed EPA procedures 7061 (mod), 7042, and 7741 respectively. The analysis included a determination of the percent moisture, a scan of 17 metals, arsenic, and selenium.

Interpretation of the significance of the soil chemistry was based on MOE guidelines [142]. The level of metal actually measured in the soil at each woodlot was used to classify the various zones of metal concentrations rather than the MOE mapping used in selecting the sample sites. Differences between the MOE mapping and the concentrations of metal measured in the study woodlots are likely related to the presence of greater amounts of metals within woodlots as compared to surrounding fields [102]. The woodlots effectively form islands of elevated metals within any given zone by virtue of the ability of the trees to trap airborne metals. It would appear to be logical therefore to use the real metal concentrations measured in the woodlots in interpreting any potential biological response to the presence of elevated metals in the soil.

2.4 SITE DESCRIPTION

2.4.1 Vegetation Cover

The character of the vegetation cover on the sample plot was described under four general parameters - namely tree cover, shrub cover, herbaceous vegetation, and moss cover. The percentage of the area in a circular area within 2 meters of the sampled point covered by the specified vegetation was estimated to the nearest 5%. Tree species and shrub species overhanging the specified circular area were listed but no attempt was made to evaluate the relative amounts of each. Frequently, the canopies of individual trees over-lapped and it was difficult to distinguish between the individual trees involved, especially when the crowns were high. For herbaceous cover, species were listed individually and the cover estimated in 5% intervals or in 1% intervals when less than 5%. Mosses made only small contributions to the cover and were not evaluated further.

2.4.2 Woody Species Inventory

All tree and shrubs 2 meters tall or greater were tallied and the DBH (Diameter at Breast Height) was measured. Some trees just outside the plot boundary but having a significant impact within the plot (i.e. at least 20% of canopy overhanging the plot) were also evaluated. Such trees were not included in the plot stand calculations but the information was available for interpretation of the results. The stem diameter measurements were made using a standard DBH tape or with electronic calipers in the case of shrubs. The health condition of each tree or shrub was also evaluated on a scale of 1 to 10 (1 = healthy, 10 = dead; See Appendix 1 for details). The percent dead branches in the crown was estimated to the nearest 5% but those branches that were considered to have died as part of the normal self pruning process were not included. Plot summaries for the kind, size, basal area, and health were prepared.

2.4.3. Ecological Land Classification

Using the information obtained from the biological inventories, soil maps and general on-site observations, each of the portions of the woodlots where the samples were collected were classified using the Ecological Land Classification (ELC) system established by the Ontario Ministry of Natural Resources [111]. Descriptions were made to the nearest closest forest type described in the ELC classification (Appendix 5).

2.4.4 Other Species

Animals including birds, amphibians, and butterflies encountered during the site visits were noted. No specific effort was made to enumerate or to prepare a complete list of all species on site. These records must be viewed as incidental observations as no attempt was made to make interpretations of this information in this report.

2.5 STATISTICAL ANALYSIS

In most cases where any information was available from replicated samples, simple arithmetic means and standard statistical deviations were calculated as appropriate. General comparisons of data from the different woodlot groupings included Analysis of Variance used in standard statistical procedures [116, 163]. Where appropriate, linear correlations between metal concentrations in soil and litter mass and between the various metals were also calculated [116, 163]. The abundance of fruit from different tree species was listed in descending order abundance at the time of sorting but no attempt was made to directly measure the weights of the different species separately. Indices to compare the co-positioning (i.e. presence of fruit and tree species at the same sample point) of a specific tree canopy with fruit of that species were calculated. Three such indices were calculated: the Whittaker & Fairbanks' [186] Index of Association of Individuals (Iai) as modified in Southwood [162]; Jaccard's Coefficient of Community (Jc) [91] and Sorensen's Quotient of Similarity (QS) [161].

3.0 RESULTS

3.1 SAMPLE COLLECTIONS MADE

In total, litter and soil collections were made in 21 woodlots. The following table summarizes the numbers of plots that were eventually selected and sampled. Zone designation is based on soil chemistry rather than the screening zones. The locations are shown in Figures 3 and 4. Details about the locations of the woodlots are included in Appendix 6.

Numbers of woodlot sites sampled

Metal Zone	Soil Type	
	Clay	Organic
Heavy - over 2000 Fg/g Ni	4	4
Moderate - 200-2000 Fg/g Ni	4	0
Low/ Control - less than 100 Fg/g Ni	5	4
Total	13	8

At each woodlot site, litter samples were obtained at 15 sample points as described in the methods section of this report. Sampling occurred between July 26 and September 13 but most samples of standing litter were obtained between August 8 and September 4, 2001. Surface soil samples were collected in duplicate at 20 sites on September 4 and 5, 2001. The final site (Woodlot 8) was sampled for soil on September 13 at the time the standing litter was collected. Fresh litter collections were made at the five selected woodlots on November 2, 2001

3.2 LITTER SAMPLING

3.2.1 Standing Litter Collections

Statistical data regarding weights of standing litter are summarized in Table 4 for individual plots. The information is also presented visually in Figures 8, 9, and 10). Averages for woodlots sharing the same soil type and metal level zone are presented in Table 5 and illustrated in Figure 11. Litter weights within individual woodlots were fairly variable as indicated by the relatively large standard deviations calculated (Table 4). The amounts of standing leafy material ranged from 63.2 to 536.9 Fg/m^2. The lowest weight was measured at Woodlot 8 which was the last site to be sampled. It might be conjectured that because of the late date, more decay might have taken place over the additional time. Countering this is the fact that virtually no rain fell over the sampling period because of the drought conditions that prevailed through July and August and this lack of moisture would have slowed any decomposition. The second lowest weight was measured at Woodlot 3. No feature of this woodlot satisfactorily explains the low weight found here as the forest components are quite as representative as any of the sites examined. Excluding these two low weight sites, the next four lowest weights found were all from the Low/Control sites on organic soils indicating that the rates of decomposition under that woodlot type was more rapid than any other. By contrast, three of the four woodlots on organic soil had the highest weights of leaf litter suggesting the slowest rates of decomposition occurred there. These high-weight sites were all located along Reuter Road and had the highest metal concentrations as described below. On clay sites, leafy litter weights were intermediate to the two extremes found on the organic sites. The range in weights on clay soils was 63.1 to 358.4 g/m^2 and showed no indication of any pattern related to the metal concentration..

The amount of standing twig litter was somewhat less variable than was the leafy litter (Figure 9). Weights ranged from a low of 110.5 g/m^2 (Woodlot 20) to a high of 510.6 g/m^2 (Woodlot 9). The means for soil type and contamination degree show very similar values at Low/Control sites (Table 5) a17.3 g/m^2 on clay sites and 190.0 g/m^2 on organic sites. Overall weights in the Heavy Zone were higher but similar to each other with 309.3 g/m^2 on clay sites and 213.0 on organic sites. Generally, the weights of leaf litter and twig litter were nearly equal (46.8% and 48.1% respectively). The remaining 5.1% was made up of the fruit litter (Figure 10).

The examination of the woodlot mean data indicated that statistically significantly more leaf litter was present in the Heavy Zone than in the Low/Control Woodlots in the case of organic soils (Table 5). This statistical significance was carried over into the total litter parameter but the twig and fruit weights were not statistically different. On clay soils, the leaf litter in the Moderate Zone woodlots was statistically significantly lower than either the Heavy or the Low/Control Zone while the Heavy and Low/Zone comparison on clay soils showed no statistical differences. The basis for such a pattern with statistical significant differences is unknown; however, it cannot be concluded that elevated metals concentrations were responsible for the litter weights measured on clay soils. No statistical differences were noted between metal zones on clay soils with respect to the amounts of twigs, fruits, or total litter.

3.2.2 Fresh Litter Collections

The woodlots sampled for fresh leaf litter production included one from each soil and metal zone. The measured dry weights of the fresh litter are shown in Table 6 together with the corrected weights based on estimates of the amounts still present on the trees at the time of collection. The average weights were all within the normal range. Despite the varied composition, the total weights are very similar at all locations. Weights of litter on the ground ranged from approximately 310 to 353 g/m^2. Corrected values show a narrower range from approximately 341 to 371 g/m^2. Statistically, there was no difference in amounts of fresh litter produced among the woodlots examined.

Freeman's Maple was the dominant species in four out of the five woodlots sampled. Despite the fact that no Freeman's Maple trees were present at Plot 2, over 14% the fresh litter was composed of this species. Other than Freeman's Maple, oak and ash generally made up significant portions of the litter on the clay sites (Figure 12). On organic sites, Red Oak was the second most abundant species (18%) at Reuter Road where there was no ash, while at the control site on Michael Road, ash made up 14.7% of the litter but no oak was present. The numbers of species represented in the fresh litter samples ranged from eight to eleven species on the clay sites and four or five on the organic soil sites. By comparison, the number tree species within these same plots were three to five on clay and two or three on organic sites. This demonstrates that considerable movement or re-arrangement of leaf litter is occurring within the woodlots. It is reasonable to assume that this is largely related to wind action. Over time, such movement of litter would have a tendency to redistribute any metals taken up by the tree roots and even out metal concentrations across the woodlot.

These results are particularly important for the study in that they demonstrate essentially equal inputs into each woodlot ecosystem. Because the inputs to the ecosystem are the same, the differences in litter decomposition rates must be considered to reflect the conditions prevailing and controlling the decomposition process at each site.

3.3 SOIL SAMPLE CHEMISTRY

The chemistry of the soil is presented in Table 7. Generally, the patterns of metal concentration were consistent with those demonstrated in the Ministry of the Environment mapping [142]. The concentrations of nickel, copper, and cobalt ranged from 18 to 4030, 8 to 436, and not detectable to 70 Fg/g respectively on the clay soil sites. On organic soils, the concentrations were greater, likely due largely to the closer proximity of these sites to the refinery. Concentration ranges were 98 to 22,700, 31 to 2755, and 3 to 311 Fg/g for nickel, copper, and cobalt respectively. The highest concentrations were found at Reuter Road while the woodlot between Lorraine and Snider Roads, being slightly somewhat further from the refinery, had correspondingly lower metal concentrations. (4745, 680, and 78 Fg/g for nickel, copper, and cobalt respectively). Woodlot 20, while considered as one of the Low/Control plots, still showed some influence of the refinery emissions due to its relative position and direction from the refinery. Here the metal concentrations were 431 Fg/g nickel, 80 Fg/g copper, and 16.5 Fg/g cobalt. The other organic soil woodlots in this zone had lower concentrations of these metals.

Elements other than nickel, copper, and cobalt were present in notable concentrations. Arsenic exceeded the MOE Table A Guideline [142] at all four woodlots on organic soils in the Heavy Zone and at Woodlot 1 (Elizabeth Street Park). Cadmium and lead at also exceeded the equivalent guideline at Woodlot 17. The elevated concentration of molybdenum at Woodlot 8 shows no relationship to the distribution of the elements of concern and must be considered a local anomalous situation unrelated to historical emissions from the refinery. Concentrations of molybdenum at Woodlots 8 and 20 only marginally exceed the Table A Guideline and are considered unrelated to historical refinery emissions. Concentrations of the metals just mentioned also exceed the less stringent Table F Guidelines at other woodlot locations (See Table 7). In addition to nickel, copper, and cobalt, the concentrations of lead, arsenic, antimony, zinc, and silver, especially evident at the woodlots in the Heavy Zone, show a signature of historical emissions from the refinery. It must be stressed that the concentrations of the latter group do not pose any significant ecological concern. Aluminum, barium, chromium, iron, manganese, phosphorus, titanium, and vanadium, were all present in normal concentrations at all sample sites. The concentrations of cadmium and selenium were found to generally exceed the soil guidelines in organic soil woodlots. This appears to be a situation where these elements are inherently present at higher concentrations on organic soils. Strictly speaking, the guidelines should be applied only to clay soils but in the absence of guidelines for organic soils, the currently available ones were applied.

Correlation coefficients among many of the pairs of chemical concentrations determined were statistically very highly significant (Table 8). For example, the concentrations of nickel were strongly correlated with the respective concentrations of copper, cobalt, antimony, arsenic, lead, silver, and selenium, all with coefficients greater than 0.90. Cadmium was slightly less correlated with the nickel values. This suggests that all of these metals may have a common origin. The relationships between nickel and iron, manganese, titanium, and zinc, all of which also had statistically significant relationships, are much more difficult to explain as these elements are typically present in fairly large concentrations in normal soil (perhaps with the exception of zinc) and were not known to have been emitted in significant amounts from the refinery.

3.4 VEGETATION INVENTORIES

3.4.1 Vegetation Cover

Vegetation cover data collected at the study sites is summarized in Table 9. Tree cover in all plots was quite extensive and most sites averaged close to 100% cover. Cover in the clay soil heavy contamination zone was slightly less than at the other site types (Figure 13). Such high cover or crown closure should be expected because the plot sites were chosen as relatively intact woodlots to be studied. Shrub and herb cover by comparison to the tree cover was substantially lower. Average shrub cover for all woodlots ranged between 4.7 and 76% while herb cover averaged between 5.5 and 60%. In the face of such variability, no statistically significant differences among woodlot site types with respect to degrees of soil contamination could be demonstrated. Despite this situation, the overall means indicate that the average cover of herbs was greater at sites with higher degrees of contamination in clay soils (Fig. 13). In organic soils, the sites in the heavy contamination zone had higher shrub cover but lower herb cover than the control sites. Despite these possible trends, the vegetation cover in each of the tree, shrub, and herb classes does not differ significantly between soil types or metal concentration.

3.4.2 Woody Vegetation

Trees

In total, seventeen tree species were found within the study plots (Table 10). The preponderance of trees across all woodlots was Freeman Maple (sometimes called Swamp Maple which is a hybrid between Red and Silver Maple; [136] (See Figure 14) with 177 out of 322 (55%) trees assessed. The other common species were American Elm (7.8%), White Ash (7.5%), American Basswood (5.9%), Red Ash (5.3%), Blue Beech (5.3%) and Red Oak (5.0%). All ash species combined made up 13.4% of the trees. Freeman Maple occurred in 20 out of 21 of the woodlots. The number of trees ranged between 6 and 30 trees (over 10 cm DBH) within the boundaries of the individual plots (Figure 15).

The mean diameter measurements for tree in the plots ranged from 14.1 (Woodlot 7) to 44 cm (Woodlot 18) (Table 11). The three plots with trees having the greatest average diameter all came from the organic soils in the zone of greatest contamination. Despite the large size of their trees, these plots did not have the highest basal area for trees in the study plots (Figure 16). The one of these three having the greatest basal area (Woodlot 19) ranked only third among all woodlots. The two plots with the highest basal area were recorded at Woodlots 23 (a Low/Control Organic site) and Woodlot 8 (Intermediate Zone Clay Soil) (Table 12).

Overall tree mortality (standing dead trees) was 7.39% (Table 13). The species with the highest mortality was American Elm with six of the 25 trees dead (24%). Half of the dead trees were located in Woodlot 20. Blue Beech had the second highest percentage of dead trees (18.75%). The third highest percent mortality was noted with Yellow Birch at 12.5%; however, it must be noted that the total population was only eight trees and the single dead tree contributed the full 12.5%. The 10.5% mortality reported for American Basswood also suffers from the same problem of small population size. Although the Ash Yellows disease is known to occur in the Niagara Peninsula area, no trees with specific symptoms of this disease were observed in the woodlots. Only two out of the 48 ash trees were recorded as dead (4.17%).

Average tree mortality per woodlot on clay soils was 1.0, 2.25., 2.00, and 0.5 dead trees per woodlot in Heavy, Intermediate, and Low/Control zones respectively. This does not suggest a trend that associates higher mortality of trees with higher levels of soil metals (Figure 17 and 18). The trend is not substantiated in organic soil sites where Heavy Zone woodlots averaged 1.0 trees per woodlot while the Low/Control averaged 1.75.

The dead trees tallied had most likely died over a period of several years.. Assuming that the standing dead trees represented deaths over a period of three to five years, the annual mortality rate would have been in the order of 1.5 to 2.5%. This rate is not particularly high, especially when the accentuated mortality due to a resurgence in activity of the Dutch Elm Disease is taken into account. Death of elm trees was noted to be fairly common in woodlots and fencerows throughout the Pt. Colborne area. A large number of elms had been recently removed from the woodlot surrounding study Woodlot 9.

Shrubs

At least 18 shrub species were recorded in the study plots (Table 15). In most cases, the plants listed as shrubs were actually immature specimens (less than 10 cm

DBH) of species which attain tree size. Only two (Black Elderberry and Spicebush) do not reach tree stature at maturity. Small Freeman Maple was the most frequently encountered shrub species representing 31% of the population. Spicebush formed 17.6% while Blue Beech made up 15.2% of the shrubs. Numbers of shrub stems measured at DBH ranged from 5 to 55 per study plot. The mean number of shrubs per study plot was 23.8 stems that had reached at least DBH height (Table 15).

Mean shrub stem diameter ranged from 2.6 to 6.5 cm (Table (16). The highest diameters reported (8.8 cm for Yellow Birch and 8.5 cm for Ash species) represent lone individuals of the species therefore these relatively high values must interpreted with caution (i.e. very small sample size). The high numbers of Freeman Maple are responsible for the high proportion (35.1%) of the total basal area contributed by shrubs (Table 17). As might be expected, the combined basal area for shrubs was much less than the amount contributed by trees (Figure 16).

Overall shrub mortality was 9.0% (Table 18) which compares with the 7.8% for trees. Of species with a total population of at least 10 individuals, the highest percent mortality was 38.9% in the case of White Ash. Freeman Maple shrubs had 13.4% mortality. At tree sizes, these species had 4.2 and 6.2% thereby suggesting that the smaller, understory trees were dying, primarily as a consequence of the natural process of competition. At clay sites, shrub mortality rates were lowest at clay sites in the Intermediate Zone (2.0 per study plot) and highest in the Low/Control (2.8 per study plot). The High Zone had 2.25 dead shrubs per woodlot. In organic soil sites, the Heavy Zone had 1.5 dead shrubs per woodlot while the Low/Control Zone had 1.75 dead shrubs per woodlot. Mortality among shrubs was therefore not correlated with elevated metals in the soil.

3.4.3 Tree Fruits

The presence of fruits in the litter can be taken as an indication that the trees had not lost the potential to reproduce themselves. The ability for the seeds and fruits to actually germinate and establish themselves was outside of the scope of the present study; however, it can be stated that at least the maple was quite capable of this based on the numerous seedlings and young trees observed in the study plots. Several tree species were well represented among the fruits that were sorted from the samples (Table 20). Oak, maple, and ash predominated by abundance with lesser amounts of hickory, basswood and beech. A few elms, cherry, and occasionally other species were also encountered.

No attempt was made to determine the relative contributions of each species by determining the mass of each type of fruit litter (i.e. weigh each species individually). The mass of an individual acorn is usually much greater that the mass of an individual maple or ash samara and it must also be noted that the fruits were in various stages of decomposition from no decay to just fragments of outer shells, husks or other fruit parts. The relative abundance of each species was noted at the time of sorting (most abundant listed first). This information was used to calculate an abundance score. The most abundant species within an individual sample was assigned a score of ‘1', the rest were assigned a value equal to the reciprocal of their rank position. By this means, the second most abundant was scored ½, the third scored 1/3, etc. The total scores an individual species for each woodlot was obtained by calculating the sum of the abundance scores over the 15 sample points. The Abundance Scores are summarized in Table 18 for the individual woodlots.. The frequency means for the various woodlots by metal zone and soil type are shown in Figure 19 (maximum possible was 15 which was the number of replicate samples collected at each plot). Figure 20 shows the mean abundance score of the tree fruits in the samples at the same locations as Figure 19. An examination of the two figures illustrates the greater abundance of oak, maple, and ash fruits. In Figure 19, there is no evidence to conclude that frequency of fruit presence in the samples is related to metal concentration in the soil. A differential between the Heavy Zone and Low/Control Zone woodlots on organic soils with respect to acorns is indicative of the presence of oak trees on the former and absence on the latter. The presence of oak trees and their fruits at the Heavy Zone woodlots is the explanation for the lower Abundance Scores for maples at those same sites.

It might be expected that fruit in the litter sample would be found in close relation to their parent tree at the sample site. The various correlations or indices (Jaccard’s Coefficient of Community, Sorensen’s Quotient of Similarity, and the Index of Association of Individuals) between the presence of fruit and nearby parent trees in the samples at each woodlot are summarized in Tables 21A to 21C. Generally, there was considerable variability between sites, species, and index values. It is very difficult to make many generalizations or interpretations of the data and the results are presented for information only. While there appeared to be some direct relationship between the trees and their fruit in some situations, there were a considerable of negative relationships. In brief, it must be accepted that in some years the trees do not produce fruit crops (a generally accepted phenomenon) and that the fruits are moved some distance by wind or animal activity.

3.4.4 Herbaceous Vegetation

Twenty-eight species of plants were identified among the herbaceous plant species. This includes small seedlings of Freeman’s Maples, Spicebush, and vines such as Poison Ivy, Thicket Creeper, and Running Strawberry. No attempt was made to distinguish the species of grass and sedge, or immature or non-flowering aster and goldenrods.

The most frequently encountered species were grass, goldenrod/aster species, and Thicket Creeper noted at 15 woodlots each. Slightly less frequent were Wood Fern, and Poison Ivy at 13 sites each. Jack-in-the-Pulpit was present in 13 plots while an Avens species was present at 11 sites. Spotted Jewelweed was abundant but present at only one location (Plot 16). Wood Nettle was found only at Plot 22.

On clay sites, the number of species ranged from 8 to 13 with no obvious relationship between metal concentration and numbers of species. By comparison, the organic sites had fewer species. In the Heavy Zone, organic soil sites had 4 to 7 species while the Low/Control Zone had 6 to 12 species. This suggests that the sites with highly elevated metal concentration may have had some influence on the composition diversity of the herbaceous flora.

The absence of certain species in relation to elevated metal concentrations is not obvious on clay soils. The absence of a species from any particular area doe not prove that toxicity factors had eliminated it. On the other hand, the presence of a sensitive species can be taken as an indication that toxicity is not a problem for that species. With these limitation considered, it might be possible that there might be some causal relationship in the case of the Solomon's Seal, False Lily-of-the-Valley, and False Solomon's Seal. These are all members of the lily family but none of the species was particularly abundant at any location. By comparison, the Twisted-stalk, another lily species was present only at Woodlots 1 and 7, both of which are in the Heavy Metal Zone. On organic soils, several species were absent from the Heavy Zone but were present in one or more of the Low/Control sites. These included Solomon's Seal and False Lily-of-the-Valley, similar to the situation on clay soils, as well as Avens sp, Running Strawberry, Enchanter's Nightshade, Tall Meadow-rue, Virginia Knotweed, Wood Nettle, and Poison Ivy. It is possible that the absence of some of these may be related to the elevated metals. Specific toxicity assessments would have to be conducted to determine if this is factually correct on a species by species basis. Other site factors (i.e. soil conditions, moisture) as well as the presence of a seed source most likely responsible for the absences noted.

The percent ground cover of each herbaceous species is summarized in Table 23. Coverage values of 5% or greater are highlighted in the table for visual purposes only and have no statistical significance. Garlic mustard covered 46.7% of the ground at Woodlot 19 while Spotted Jewelweed covered 36% of the ground at Woodlot 16. Grass cover exceeded 5% at six sites, Avens sp covered over 5% at five woodlots and Thicket Creeper exceeded 5% at four woodlots. The higher average rates of coverage by these species generally follow their respective higher frequencies of occurrence.

3.5 INCIDENTAL OBSERVATIONS

Species mentioned in the body of this report are listed in Appendix 2. Notes were also made on the presence of various animals encountered during the course of the field work. These sightings are included in Appendix 3. No formal methods were in place as this was not an integral part of the project, however, the information might prove useful in other related studies. Because of the incidental nature of the observation, the time of the year and the time of day, the records should not be expected to provide high numbers of birds (i.e. birds sing most readily in the morning during the breeding season while much of the field work included late morning and afternoon site visits)

Birds

The breeding season for birds was largely past before the litter collection project commenced therefore there was little opportunity to observe breeding evidence. Species such as Easter Wood-Pewee continue calling long after the breeding season and were noted at a number of locations. In total, 27 bird species were noted including some fall migrants.

Mammals

Only three mammal species were seen including Gray and Red Squirrels, and a raccoon.

Amphibians and Reptiles

The amphibian list included six different frog species. Wood frogs were especially numerous at Woodlot 15, probably at densities approaching one per square meter. Spring Peepers were heard calling late into October in the prolonged mild fall weather conditions, including all of the woodlots along Reuter Road. A small Red-backed Salamander (Lead-back Phase) was accidentally included in the litter sample collected at Plot 16 on Reuter Road on August 16. It was returned to the same site on a subsequent trip to the Pt. Colborne area.

Two snakes were noted, both Brown Snakes. One was noted at Woodlot 15 on August 31. The other was seen on the former railroad right-of-way near Woodlot 2 on November 2, 2001, a rather late date for snakes not to be in hibernation.

Butterflies

Fourteen different butterfly species and one moth species were noted during the study period. As was the case for birds, the peak flight periods for butterflies had passed before the field work was initiated. The species seen were generally fairly common types. The sides of the abandoned railway was particularly productive for butterflies.

Other Insects

Three species of Lady Beetles (Seven-spotted, Southern, and Fourteen-spotted) were recorded. All of these are introduced species and the two former were particularly common throughout southern Ontario throughout the fall of 2001. The latter was found in different litter samples. Other insect records were only scattered sightings.

Invertebrates

The woodlots in the Pt. Colborne area were found to have numerous spiders with conspicuous webs throughout the woodlots. These were mostly of the orb weaver (subfamily Araneidnae) and garden spider (subfamily Argiopinae) types. Harvestmen, also know as Phalangids or Opiliones, were also very common. It is worthy of mention that the metal contaminated areas at Gusum, Sweden, had higher numbers of these organisms than did the uncontaminated areas [175]. Whether the more-contaminated woodlots at Pt. Colborne had more of these organisms is uncertain, due in part to the differences in available shrubs to support the webs. It is reasonably possible that this indeed was the case. Spiders were frequently encountered in the litter samples. Chimneys of Meadow Crayfish were noted near Woodlot 23.

Molluscs

No specific effort was made to include molluscs in the standing litter samples; however, a number were found during the sorting of the samples. Appendix 4 includes a list of the mollusc species noted in the litter samples. The numbers found are tabulated in Table 24. At least three species of aquatic types and seven terrestrial types were identified. The presence of Physa and Stagnicola at Woodlot 9 is an indicator of long periods of standing water. *Physa gyrina gryrina* Say "occurs in all perennial water habitats and in temporarily flooded pools and swamps" [39]. *Stagnicola elodes* (Say) is listed as "ubiquitous and found in all kinds of aquatic habitats [39]. The Fingernail Clams were not identified definitively but appear to best fit the description of *Sphaerium occidentale* (Prime) (Herrington's Fingernail Clam). It is restricted to water bodies that dry up for a part of each year including ditches and swamps and among damp leaves [39]. The clams were found at five of the woodlots on clay soils including Woodlots 6, 9, 10, 11, and 14. *Gyraulis circumstriatus* (Tryon) is characteristic of small vernal habitats [39]. Interestingly, no aquatic molluscs were noted in samples from any of the organic soil sites despite the fact that they were usually the ones with the highest moisture content (Table 7).

The slug (*Arion circumscriptus*) was found in samples from 5 different woodlots. *Succinea* species were found at a total of eight woodlots. Small numbers of other terrestrial molluscs were found at various Woodlots (Table 24). The available information did not identify any sort of trend in occurrence that could be related to metal distribution patterns. It would seem highly probable that a more systematic search would provide a much better picture of the numbers and distribution of molluscs in the Port Colborne area. Whether such an effort would show any influence of elevated metals can only conjectured and such an investigation would likely fare better under conditions with higher moisture than was present in 2001.

Fungi

Eight species of fungi were noted, mostly those which occur in decaying wood. This list is a poor representation of the numbers of species that would be expected throughout the area. It is stressed that the numbers of fungi to be found was also likely greatly reduced due to the drought situation present in 2001.

4.0 SUMMARY AND DISCUSSION

4.1. Soil Chemistry

Nickel, copper, and cobalt are the dominant elements of concern in soil. On the clay soil sites, the concentrations of ranged from 18 to 4030, 8 to 436, and not detectable to 70 Fg/g respectively. The distribution patterns of metal concentration were consistent with those demonstrated in the Ministry of the Environment mapping [103]. On organic soils, the concentrations were much greater, likely due largely to the closer proximity of these sites to the refinery. Concentration ranges were 98 to 22,700, 31 to 2755, and 3 to 311 Fg/g for nickel, copper, and cobalt respectively. The highest concentrations were found along Reuter Road while the woodlot between Lorraine and Snider Roads, being slightly somewhat further from the refinery, had correspondingly lower metal concentrations. (4745, 680, and 78 Fg/g for nickel, copper, and cobalt. Other elements including lead, arsenic, antimony, zinc, and silver, showed a pattern that suggested some relationship with distance and direction from the refinery, even though some of these elements were not handled by that facility. Possibly some of these had a different source closely positioned to the refinery. Lead, for example, may have a general area origin in the urban area of Port Colborne.

A number of elements exceeded soil contaminant guidelines established by the Ministry of the Environment, particularly at those sites nearest the refinery. The guidelines were developed for clay and loam soils [142]. No comparable guidelines have been developed for organic soils or for sandy soils therefore, strictly speaking, they are not directly applicable to the soils in the woodlots along Reuter Road. In the absence of any other guidelines, the only ones available were used in the interpretation of the soil chemistry data obtained from this study.

4.2. Fresh Litter Input

The weights of litter on the ground in the late autumn of 2001 was measured in the range from approximately 310 to 353 g/m^2. Making allowance for the foliage that had not fallen by the date of litter collection, the corrected litter weights ranged from approximately 341 to 371 g/m^2. These weights do not include any new woody litter (i.e. twigs and bark) or fruits that fell in 2001. Some of these non-foliar materials would have been included in the standing litter collections; however, no accounting for any of the new material fallen and decayed in 2001 can be made. This was a potential problem identified by Bradbury et al. [29]. Despite the shortcomings created by the few methods available due to time constraints imposed on the present investigation, it is possible to conclude that the amounts of fresh leafy litter produced across the study area was quite uniform. Any discrepancy between the measured weights and the true total litter production is likely to be relatively small.

The amount of leaf litter produced at the Pt. Colborne woodlots is well within the range of values published in the scientific literature. The mean production rate for a variety of hardwood forests included in Table 1 was calculated to be in the range of 259 to 301 g/m^2 of soil surface, therefore the production of leafy material at Port Colborne is actually above published average values. The Port Colborne values are still well below the maximum of 639 g/m^2. Leaf litter production was unaffected by elevated metal concentration in the soils, even at forest sites nearest the refinery.

The samples of fresh litter included leaves of species not growing in the immediate area of the sample location. This demonstrates that considerable mixing of leaves is occurring due to wind action. Through this action, any materials taken up from the soil by the tree roots or airborne materials trapped by foliage are distributed evenly through the woodlot over time.

4.3 Standing Litter

The measurements of weights of different types of standing litter showed considerable variability among sites. The amounts of standing leafy material ranged from 63.2 to 536.9 $g/m^{2.}$ The amount of standing twig litter was somewhat less variable than was the leafy litter and weights ranged from a low of 110.5 g/m^2 to a high of 510.6 g/m^2. Twig litter and leaf litter were found to be present in approximately equal amounts. Fruit litter made up only about 5% of the weight of the litter in most locations. Total weights of standing litter found at the Pt. Colborne woodlots ranged widely from 60 to 898 g/m^2. By comparison, the mean weights of standing litter reported in the scientific literature averaged 1046 to 1099 g/m^2 (Table 1). The standing litter values reported here underestimate the true value in that large wood pieces (tree trunks, large branches) were not considered. Efforts to include such material would require very much larger sample areas and a corresponding effort beyond the scope of the present project. In part this may explain the large difference noted between the Pt. Colborne woodlots and woodlots elsewhere; however, the data obtained from this study suggests that decomposition in general proceeds fairly rapidly in the vicinity of Pt. Colborne (also see predicted rates below). On clay soils in particular, bare mineral soil often was found in direct contact with leafy and woody litter without any notable amounts of decomposed material (i.e most new litter either decomposes within a year or is incorporated into the soil by organisms such as earthworms). Notwithstanding the relatively rapid decomposition rate, it was demonstrated that significantly higher amounts of standing leaf litter (386 g/m^2) were present in woodlots with high metal concentrations compared with control sites on organic soils (138 g/m^2). The amounts of leaf litter was correlated (statistically highly significant) with nickel, copper, and cobalt on both soil types. Such a pattern suggests that the presence of elevated metal concentrations affects and slows the rate of litter decomposition. Even though this decomposition pattern relationship with soil metals can be demonstrated, the total amount of decomposition that occurs in any single year at any one woodlot equals the amount of litter entering the system at that site. This conclusion is based on general observations that suggested no unusual accumulations of litter on the ground. The rates of average annual fresh litter input is essentially at equilibrium with the amount decomposing each year. The conceptual litter decomposition processes under the two levels of soil metal loadings are shown in Figures 21 and 22.

4.4. Relationships Between Soil Chemistry and Litter Weights

The soil chemistry results are presented in Table 7 and the weights of standing litter are shown in Table 4. Statistical correlations between the various litter components and the soil chemistry were calculated and are presented in Table 25. It must be stressed that positive correlations are not indicators of causal relationships between factors but they are only a indication that some connection might exist between the two factors. Many of the correlation coefficients in the data obtained in this study were found to be statistically highly significant. Weights of leafy material and twigs were significantly correlated with total litter weights. This would be expected because these were found to contribute more or less equally to approximately 95% of the total litter. Other litter components were also correlated including leaf litter and fruit weights and total and fruit weights.

Correlations between litter weights and chemical concentrations offer a more complex relationship. Barium, chromium, phosphorus, and vanadium showed no correlation with amounts of standing litter. Beryllium and aluminum indicated a slight but negative relationship with leaf weights. Cadmium, iron and titanium concentrations showed a significant correlation with fruit weight. Twig weights had only two significant correlations with soil chemistry; molybdenum and silver. In the first, the correlation (P = 0.8421) between twig weight and molybdenum has the highest coefficient. The relationship between molybdenum concentration and leaf and fruit weight is not significant and negative. In any case, the majority of soil samples do not have measurable concentrations of molybdenum. Iron, and titanium are not environmental concerns and there is no reason to consider the relationships to have any relevance to the refinery. By contrast, silver has more biologically toxic properties but whether the highest concentrations measured at the Reuter Road woodlots are great enough to affect the decomposition is not known. The highest concentrations are still less that the MOE Table A Guidelines. In addition to the significant correlation with twig weight, the silver concentrations are correlated with leaf and total litter weight.

Antimony, arsenic, cobalt, copper, lead, manganese, nickel, selenium, and zinc, all show highly significant relationships with leaf and fruit litter weights. A significant correlation of these elements with total litter weights extends only in the case of arsenic, cobalt, manganese, silver and zinc. For lead, nickel, and selenium, the correlation with total litter is significant only at the P=0.05 level. While the list of elements shows considerable positive correlations amongst themselves (Table 8), the only elements considered to be present in concentrations great enough to have a potentially significant environmental impact are copper, and nickel. The concentrations of cobalt, arsenic, selenium, and possibly silver and cadmium, while much elevated above background, are likely inadequate to pose significant environmental risk by themselves. In combination with each other and especially with the copper and nickel, there is a greater probability that they are contributing to the high metal problem rather than mitigating the effect. In general, the effect of single metals on litter decomposition has not received a great of attention. In situations where a number of different elements are involved at the same time, interpretation of any environmental impacts is extremely difficult.

4.5. Predicting Decomposition Rates

In order to determine whether the rates of decomposition observed in the study woodlots was near normal, an estimate of the expected rates was calculated using the relationship with lignin content of foliage and potential evaporation rates as described by Meentemeyer [132] Using Thornthwaite's [171] method for computing potential evaporation and the temperature and precipitation data reported at Pt Colborne for the period 1951-1980 [62], a potential evaporation rate was calculated to be 472 mm of rainfall. While the precipitation pattern experienced in 2001 may not be typical for the long term, the use of the indicated weather records can be justified on the basis that they would cover the period when maximum inputs or accumulations of metals in the soil were present. If the high metal concentrations were responsible for reducing rates of decomposition, then this is the period when excessive litter would be expected to accumulate. The potential evaporation computed was then used in the Meentemeyer equation predicting the annual decomposition rate. Using the lignin content measurements provided by Lawrey [110], the calculated annual decomposition rates for beech, silver maple, sugar maple, and ash were predicted to be 40.9, 41.0, 36.1 , and 35.9 percent respectively. At these rates, leaf litter would require approximately 2.5 or more years to break down.

At all sites, except the three on Reuter Road, the amount of standing leafy litter was less than the weights of fresh litter in the respective corrected weights for the different metal zones. Excluding the Reuter Road sites, the average difference or weight lost is 43.3% assuming that the weight of leaves that fell in the year 2000 was the same as in 2001 and that there was no litter older than one year. The weight differences were quite variable and ranged from 3.2% to 81.5%. The latter value was found at Woodlot 8 which was the last one sampled and therefore had the longest time over which the decomposition process could occur. The average however is quite close to the value that was predicted from the Meentemeyer relationship. It is more difficult to determine the annual amount of decomposition in the Reuter Road woodlots because the amount of standing leaf litter was equivalent to over one year's input (range 1.16 to 1.56 years). Regardless of the annual rate of decomposition measured or predicted, the total amount decomposed each year is the sum of the amount decomposed from each of the cohort year's foliage on the ground. Because there is no evidence of accumulation of litter at any site, the total amount of leaf litter decomposed equals the amount of fresh litter entering the system on an annual basis.

The presence of constant and available soil moisture increases the rate of litter decomposition. On clay sites at Port Colborne, there is normally an abundance of water early in the growing season as indicated by the presence of aquatic molluscs. Later in the summer, these sites dry considerably as was the case in 2001. Such a pattern would cause rapid decomposition of any fresh litter in the late autumn and in the spring into the early summer provided that temperatures were adequate. In mid to late summer, the drier conditions would be expected to slow the decomposition process. By comparison, the organic soils were much more moist and over a longer period. The presence of moisture over a longer period is likely responsible for the lower weights of standing leafy litter on organic sites (mean 138 g/m^2) versus clay site (mean 259 g/m^2).

4.6 Effects of Metals on Decomposition

The maximum concentrations of nickel and copper in silver maple foliage at Port Colborne reported by Temple [170] were 235 and 32 Fg/g respectively. These concentrations were used in an equation derived from data obtained in a study by Freedman [67] in which he added various combinations of copper and nickel to leaf litter. The mixtures were incubated for a period of 60 days in a growth chamber and the amount of decomposition measured. At the concentrations reported by Temple, the decomposition rate would only be reduced by approximately 7%. At the lower current concentrations of the metals in foliage, the direct effect of the metals in the foliage would have a much lower impact. Current high concentrations on the metals in tree foliage are much lower than those reported by Temple (O. Curran, Pers. Comm.) therefore, the metal content of the current foliage is not expected to affect the decomposition process. The Freedman relationship requires a combined copper and nickel concentration of 1985 Fg/g to reduce litter decomposition by 10%. Much higher concentrations of metals are required for more significant reductions in litter decomposition rates. In view of the field situation encountered in the present study and interpretations of the literature, it must be concluded that the slower decomposition rates seen at the Reuter Road sites are not due to the metal concentrations in the fresh foliage being added to the soil. Instead, some other agent or agents involved in the decomposition process must have been affected by the elevated metals concentrations either directly (i.e. soil organisms such as mites, springtails, or fungi, are reduced in number or in their functioning rates) or metals in the soil are being transferred into the foliage as it lies on the soil surface.

4.7 Suggestions for Further Studies

Interpretation of the information obtained in the present study has been taken any as far as possible in this report. Should further data or investigations be required, those investigations will require procedures using more controlled conditions and substantially greater times for completion. The following suggestions are offered but it not necessarily recommended that they be completed in the context of the greater environmental study. The suggestions are: 1) collection of fresh litter fall over at least one full year using formal litter collection devices; 2) exposing leaf litter in mesh bags at selected study sites over a two year period; 3) exposing leaf litter to known concentrations of metals under a controlled environmental situation but under more realistic conditions than were used by Freedman; and 4) taking large soil cores from different woodlot locations and placing them together in other woodlots topped by selected fresh litter. Using these procedures, information that can better define the impact of the historical emissions from the Pt. Colborne refinery can be obtained. The main drawback for most of these investigations is the long time frame for completion (approximately 3 years).

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7.0. ATTACHMENTS

Figures, Tables and Appendices

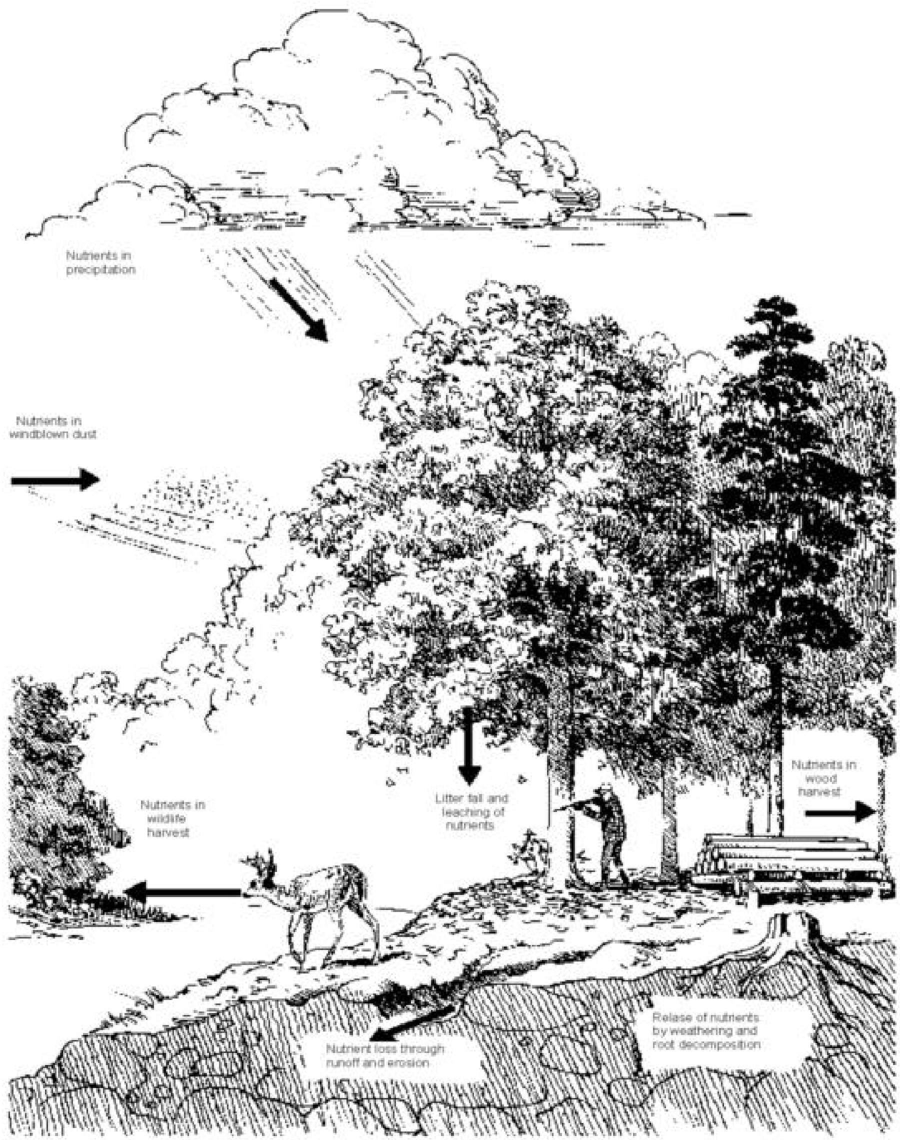


Figure 1. Generalized nutrient budget in a forested ecosystem showing major processes (after R.L. Smith, 1986)

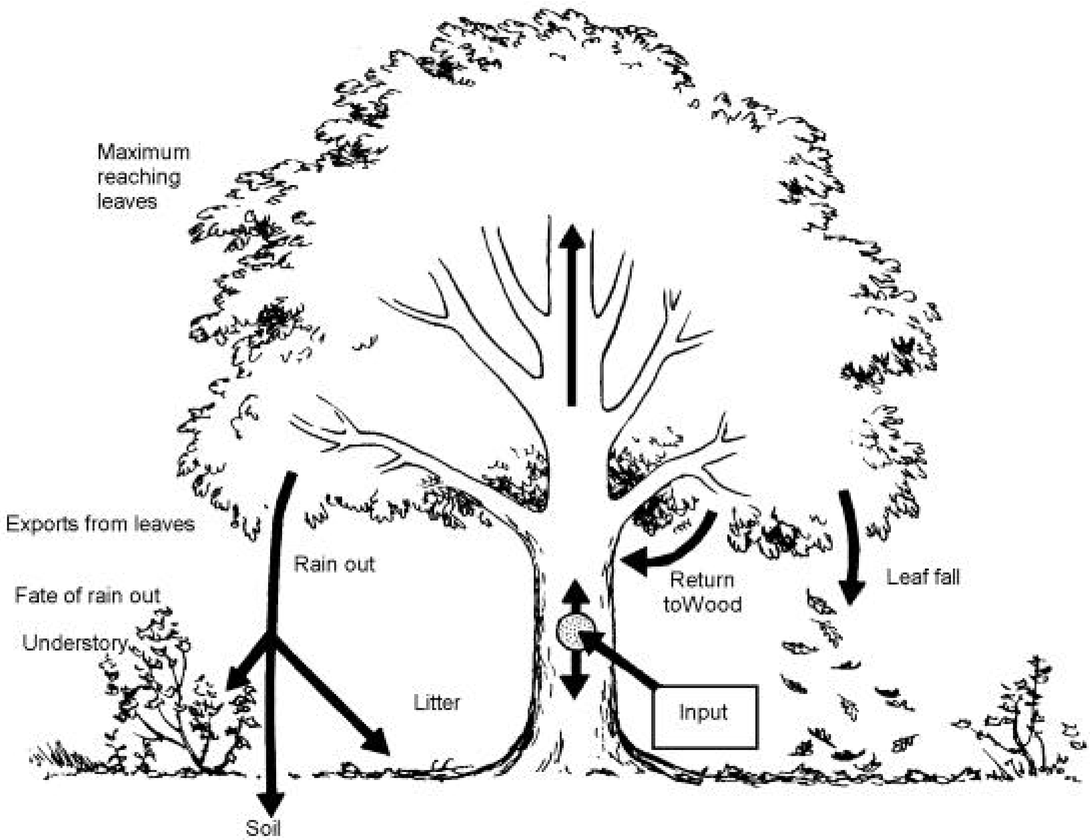


Figure 2. General scheme for cycling of chemical elements through vegetation (after R.L.Smith, 1986).

Figure 3 Location of woodlots and sample sites in the Pt Colborne Area. Dashed and solid contour lines indicate concentrations of 100 and 2000 Fg/g nickel in soil respectively based on MOE mapping. Sites 1-10 on clay soil, 16 to 20 on organic soils

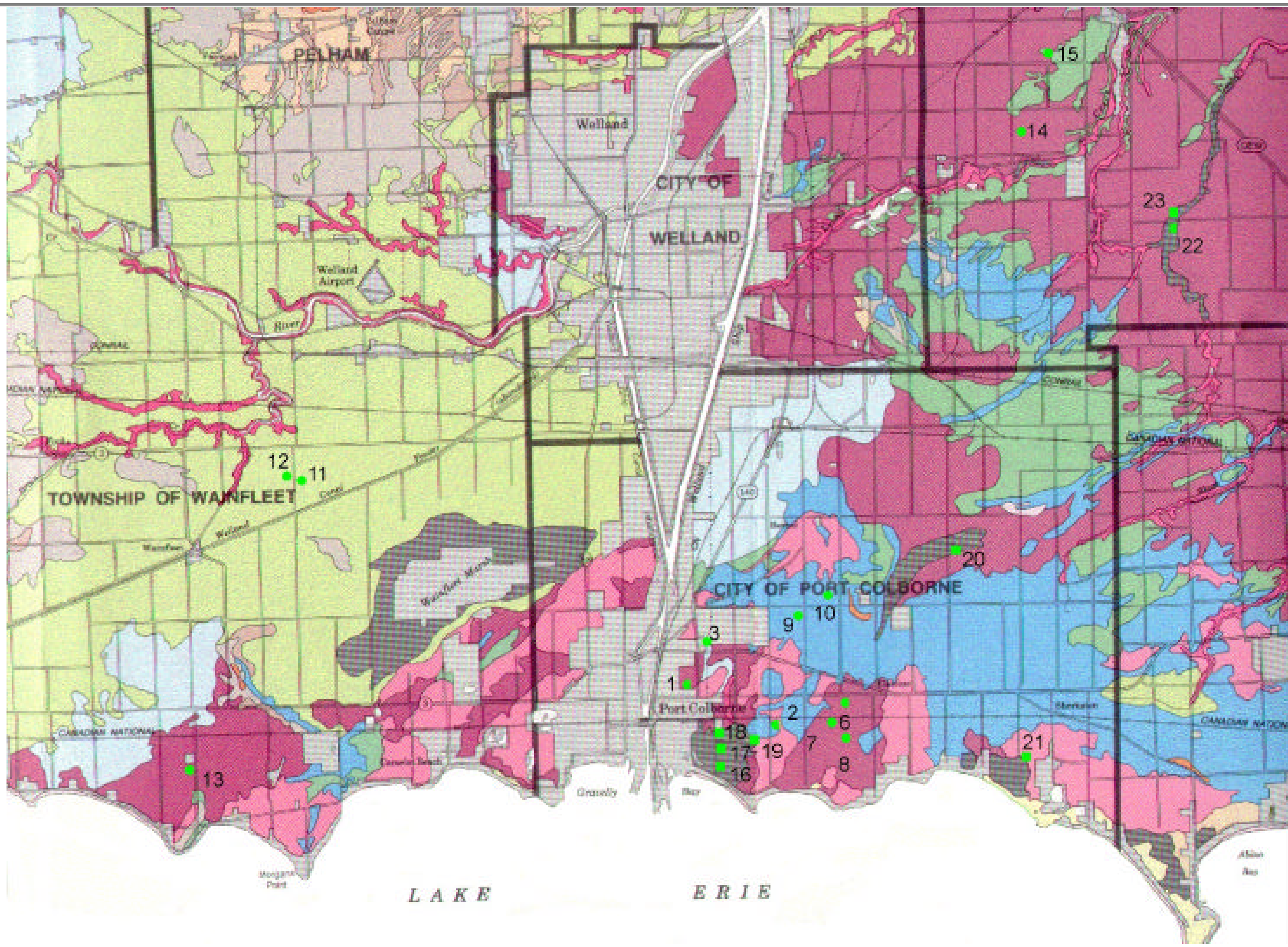


Figure 4. Location of woodlots and sample sites in the greater Pt Colborne area by soil type. Site shown with square symbols are on organic soils (dark gray); sites shown as circles are on clay soils (various colours)

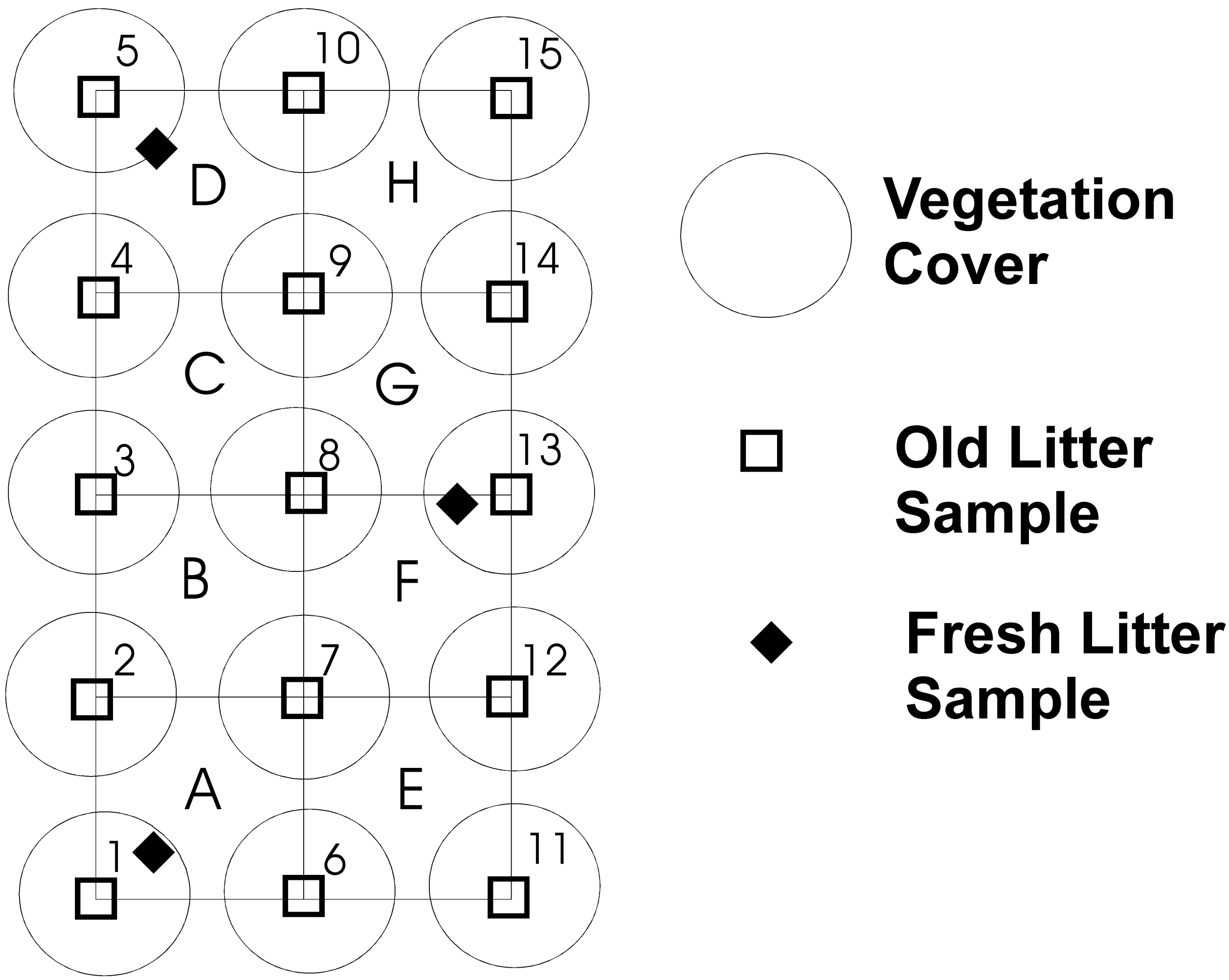


Figure 5. Layout of sampling points utilized for leaf litter assessment at woodlots in the Port Colborne, Ontario, 2001


A. B.


C. D.

Figure 6 Stages in collection of litter samples A.. Undisturbed litter. B. Board placed on surface and cut made around perimeter, litter removed. C. Board is removed revealing area to be sampled. D. Litter is collected and placed in sample bag.

A.

B.

Figure 7. Steps in the process for the collection of fresh leaf litter **A.**. Litter from within frame collected and bagged. **B**. Appearance of sampled area after litter was removed.

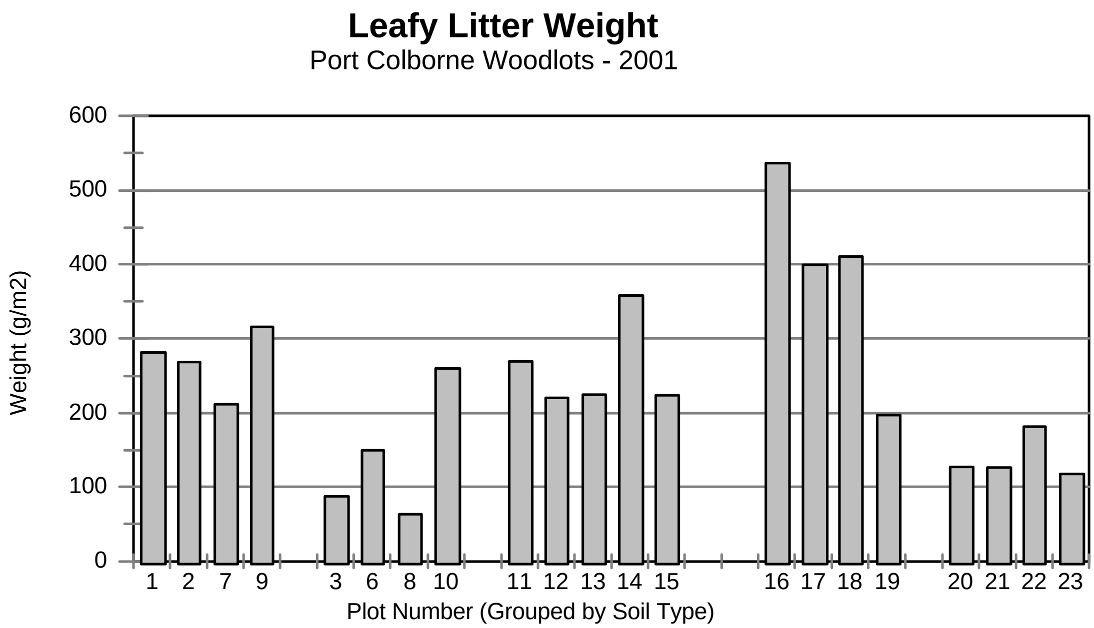


Figure 8. Weight of standing leafy litter at individual woodlots in the Port Colborne, Ontario, 2001

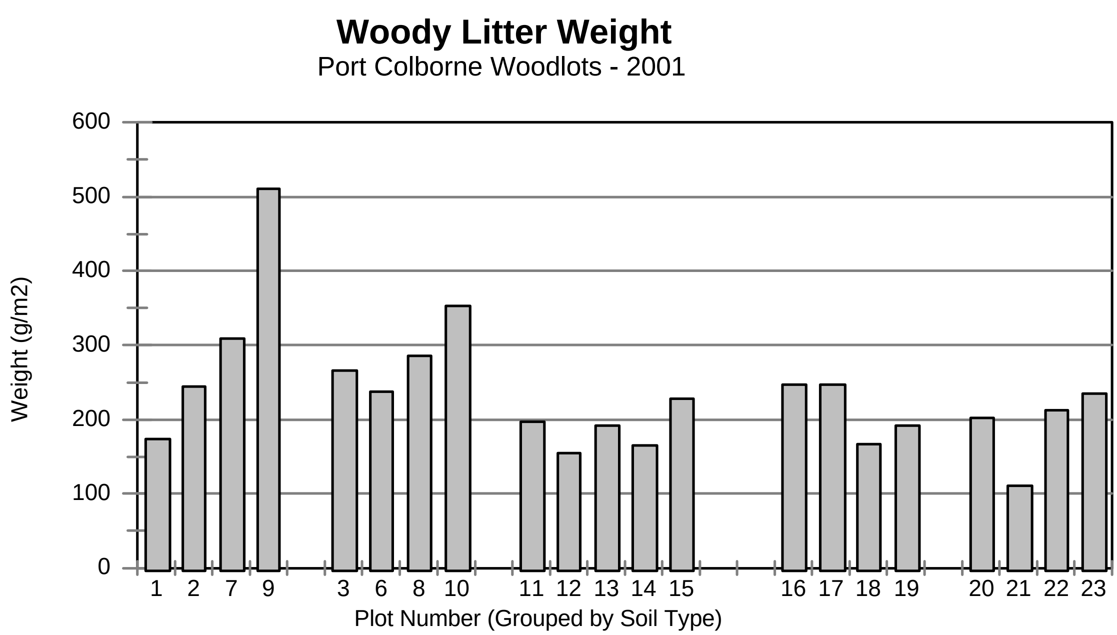
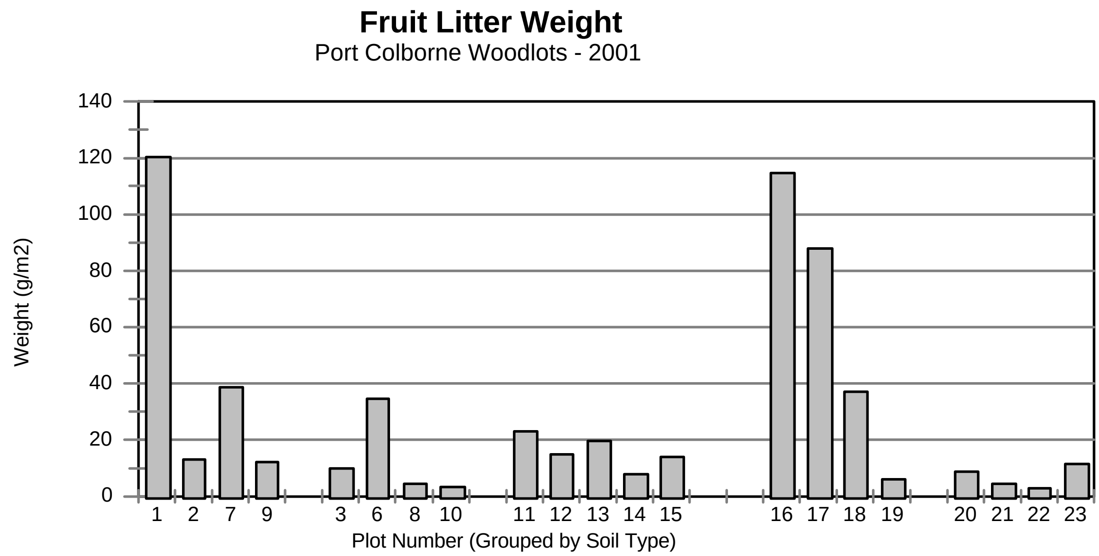


Figure 9. Weight of standing woody litter at individual woodlots in the Port Colborne, Ontario, 2001



Fgure 10. Weight of standing fruit litter at individual woodlots in the Port Colborne, ntario, 2001

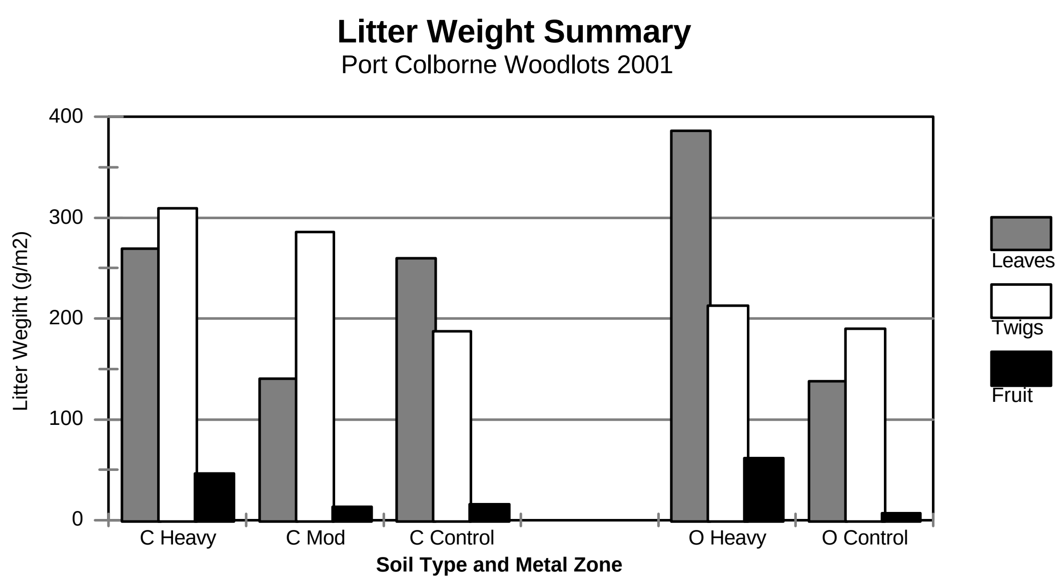


Figure 11. Mean weight of standing litter on different soil types and metal levels at woodlots in the Port Colborne, Ontario, 2001.

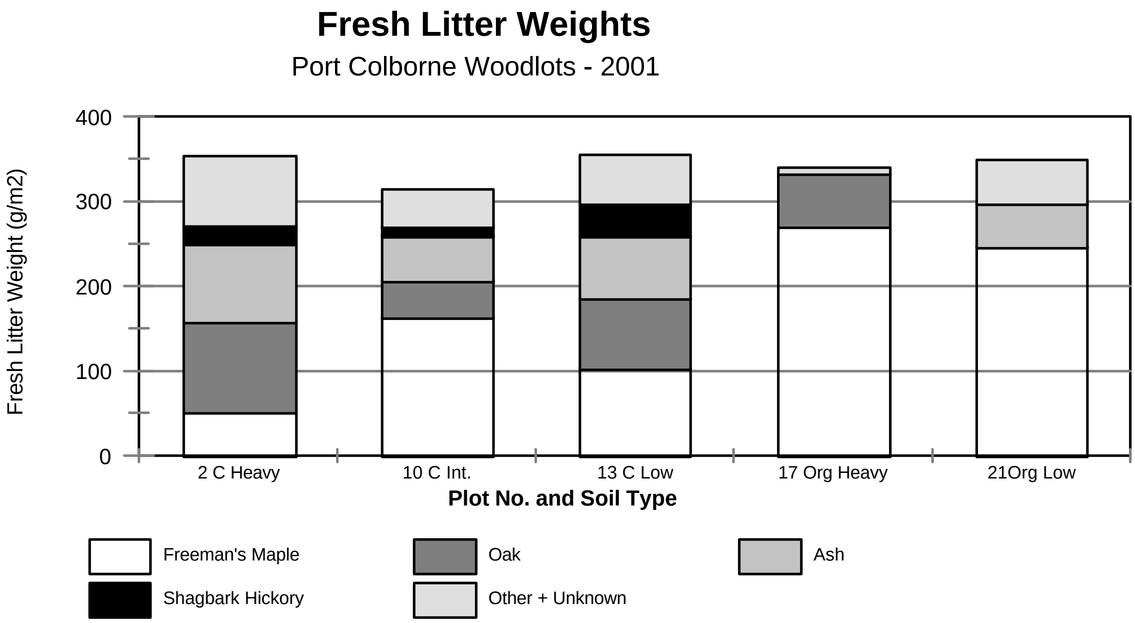


Figure 12. Mean weight and composition of fresh litter on different soil types and metal levels at selected woodlots in the Port Colborne area, Ontario, 2001.

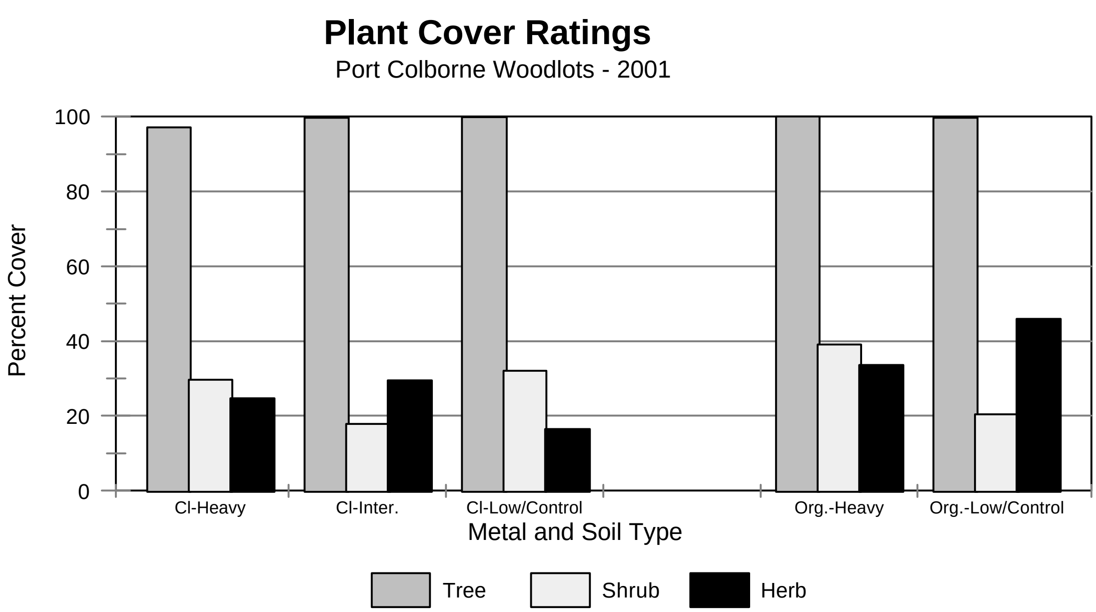


Figure 13. Summary of vegetation cover evaluations at woodlots in the Port Colborne, Ontario, 2001

Typical Red Maple   Hybrid= Freeman's Maple   Typical Silver Maple

Typical Port Colborne Area Maple foliage

Figure 14. Illustration showing most common maple type found in Pt Colborne area woodlots. Species illustrations redrawn from Moore [136]

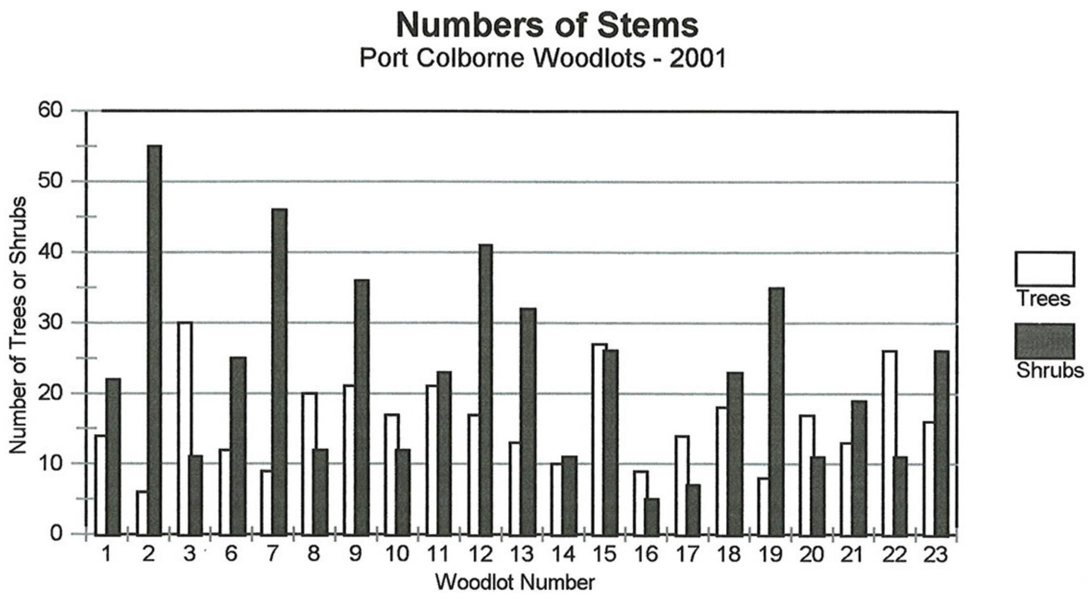


Figure 15. Numbers of woody stems within study plots established in woodlots in the Pt. Colborne area, 2001.

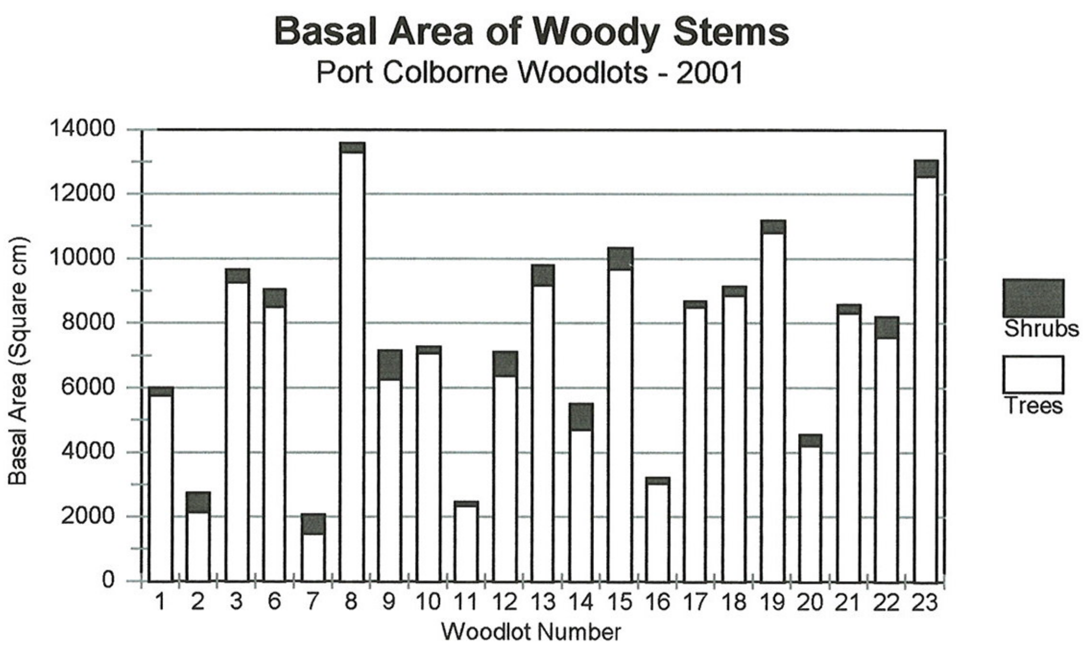


Figure 16 Contributions of trees and shrubs to total basal area of woody stems within study plots established in woodlots in the Pt. Colborne area, 2001.

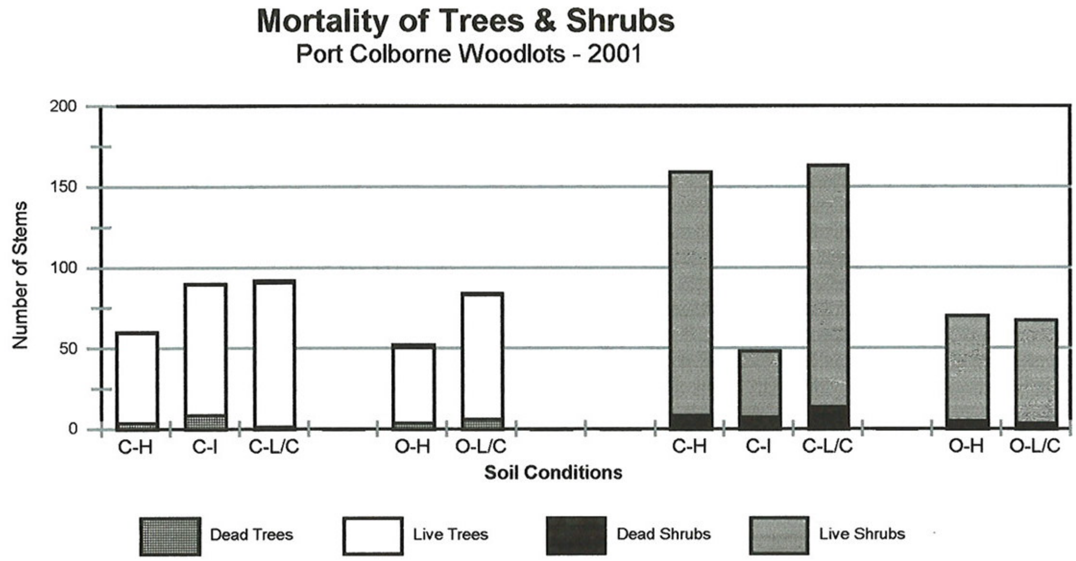


Figure 17 Mortality totals among trees and shrubs within study plots established in woodlots in the Pt. Colborne area, 2001. (C=Clay, O = Organic; H, I & L/C = Heavy, Intermediate and Low/Control)

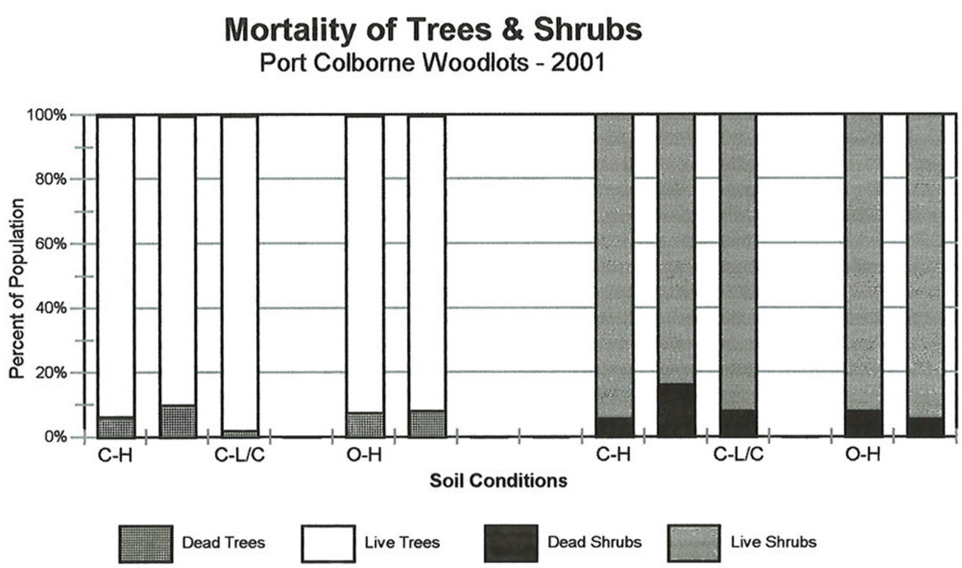


Figure 18 Percent mortality among trees and shrubs within study plots established in woodlots in the Pt. Colborne area, 2001.(C=Clay, O = Organic; H, I & L/C = Heavy, Intermediate and Low/Control)

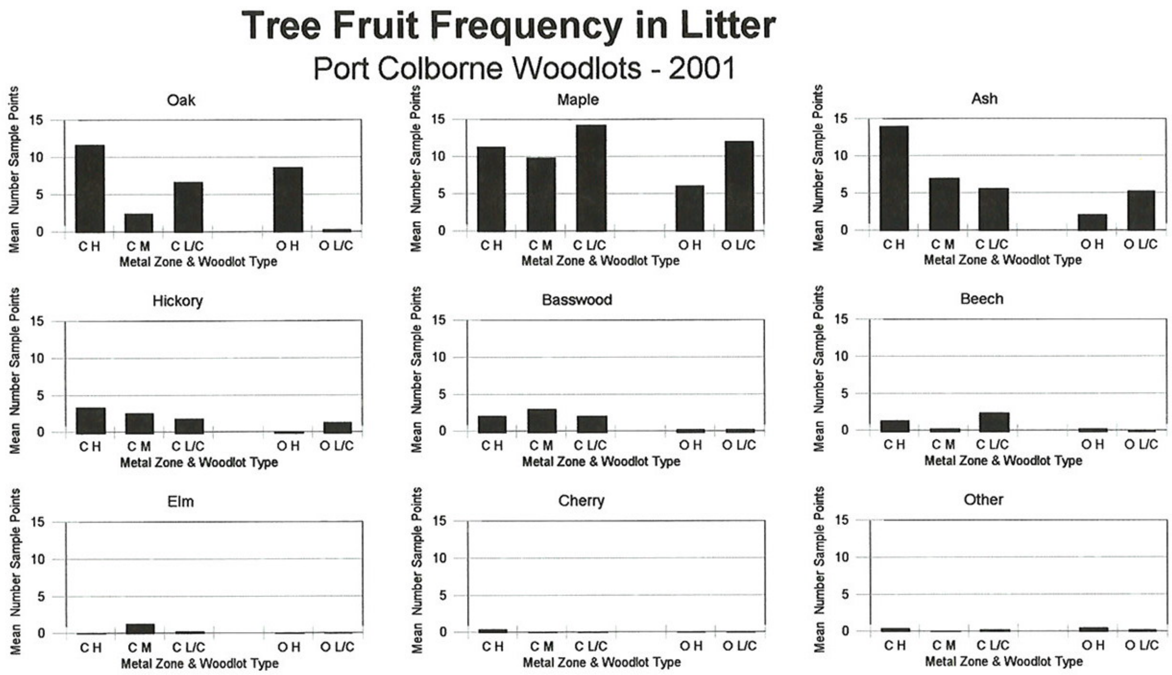


Figure 19. Frequency of occurrence various tree fruits in litter in woodlots in the Port Colborne Area, 2001.

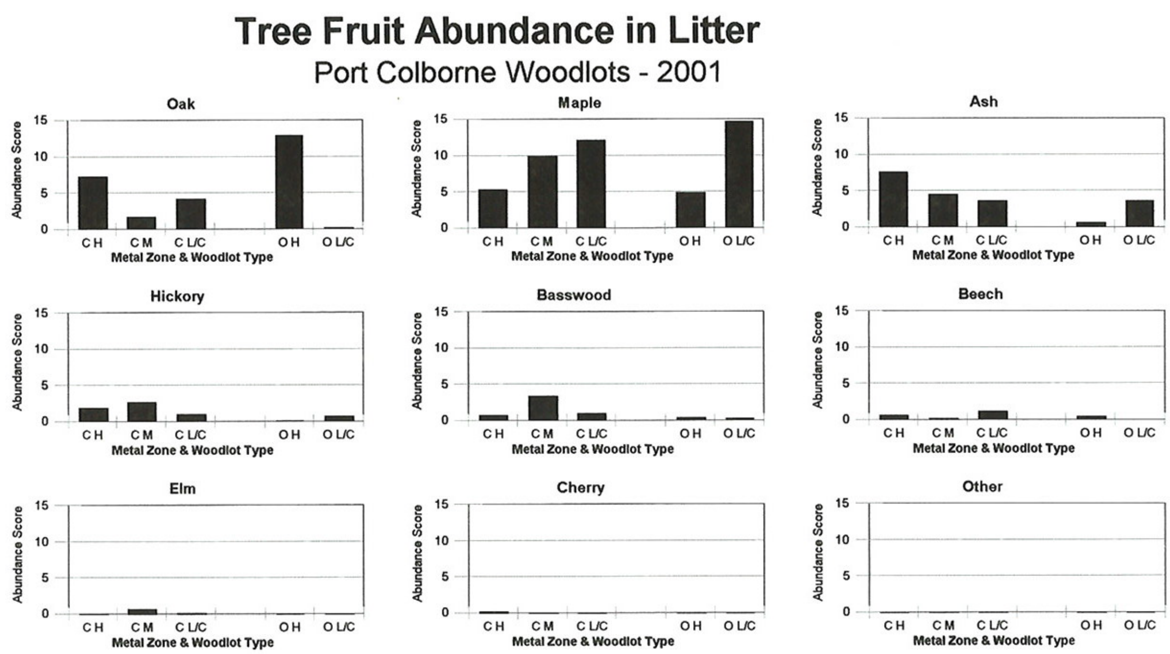


Figure 20. Abundance of various tree fruits in litter in woodlots in the Port Colborne Area, 2001. (See text for explanation

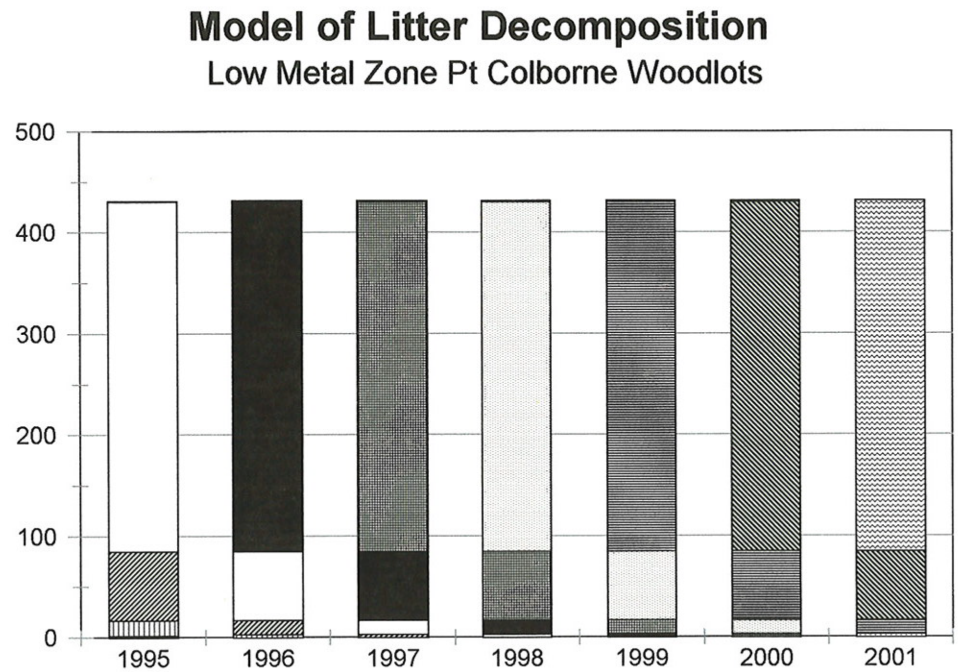


Figure 21. Conceptual decomposition process at woodlots on organic soils in the Low/Control Zone, Port Colborne

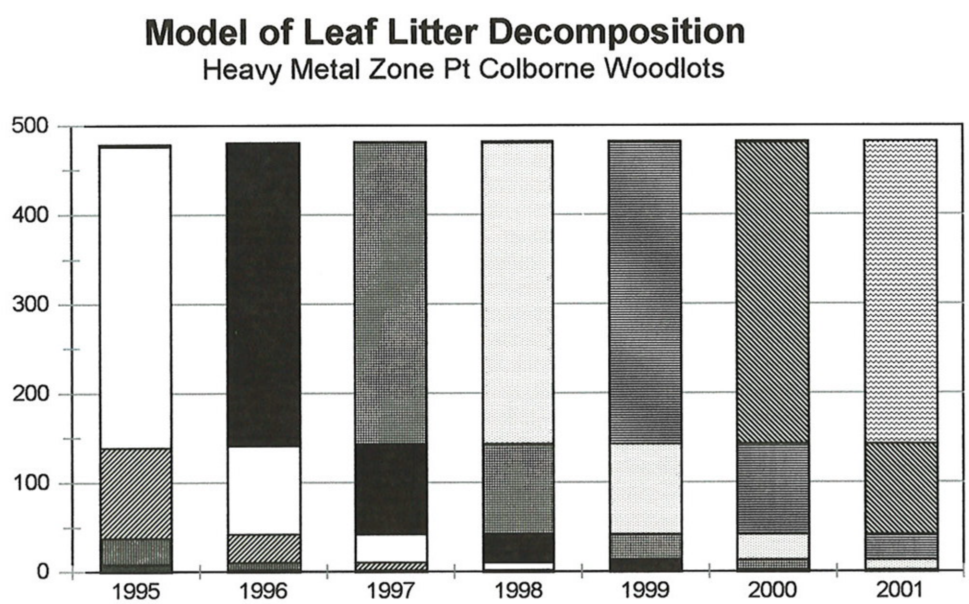


Figure 22. Conceptual decomposition process at woodlots on organic soils in the Heavy Metal Zone, Port Colborne (Compare with Figure 21)

Table 1. Published data for plant litter production and decomposition rates

Area	Species	Leaf Litter Fall (gm/m^2)	Total Litter (gm/m^2)	Standing Litter (gm/m^2)	Residence Time (years)	*k* rate	Half Life (years)	Reference
Canada	*Populus*	100-204						41
	Betula populifolia	103-234						41
	Fagus grandifolia	169-210						41
	Populus		210	1495				179
	Acer saccharum	217-362						120
	Acer saccharum - Quercus	310	430					30
	Alnus rugosa		550					50
	Bog forest		488	345	3.39 yr			150
	Muskeg		846	638	4.07 yr			150
	Bog		1750	1428	5.44 yr			150
	Acer rubrum			275-700	1.21-2.09			182
Kananaskis	*Populus tremuloides*		316			0.113-0.486	1.4-6.3	119
	Populus balsamifera		316			0.121-0.485	1.5-6.1	119
United States	*Alnus rubra*	346-639	449-990					189
	Alnus rubra	422	491-559					71
	Alnus crispa - Salix	182-184	226-295					89
	Populus balsamifera	149	239-345					89
	Alnus incana		163-214					176
	Quercus alba, Q. borealis, Q. velutina (250 years)	440	615.9	3230	5.24			104
United States	*Quercus alba, Q. coccinea, Pinus rigida*	259	275	1875	6.82			8
	Pinus palustris	520	526					184
Alaska	*Betula papyrifera*					0.456	1.5	176
	Populus tremuloides					0.389	1.8	176
	Alnus crispa in B. papyrifera					0.408	1.7	176
	Alnus crispa in P. tremuloides					0.423	1.6	176
Hubbard Brook	*Acer saccharum*					0.510	1.4	75
	Fagus grandifolia					0.370	1.9	75
	Betula allegheniensis					0.850	0.8	75

Table 1. Published data for plant litter production and decomposition rates

Area	Species	Leaf Litter Fall (gm/m^2)	Total Litter (gm/m^2)	Standing Litter (gm/m^2)	Residence Time (years)	*k* rate	Half Life (years)	Reference
	Acer saccharum, F. grandifolia, Betula allegheniensis	280	570.2					75
	Beech fruit litter	0.14						75
	Maple fruit litter	1.97						75
	Yellow birch fruit litter	0.87						75
Tennessee	*Liriodendron tulipifera*					0.852	0.8	9
	Fraxinus pennsylvanica					0.768	0.9	9
	Carya tomentosa					0.788	0.88	9
	Quercus spp.					0.707	0.98	9
	Acer rubrum					0.883	0.78	9
Tennessee	*Cornus florida*					1.152	0.6	9
	Liriodendron, Carya, Quercus Pinus			230				177
Ohio	*Platanus occidentalis*					0.29	2.39	110
	Pinus resinosa					0.37	1.87	110
	Populus grandidentata					0.38	1.82	110
	Robinia pseudoacacia					0.41	1.69	110
	Fagus grandifolia					0.44	1.58	110
	Acer saccharinum					0.59	1.17	110
	Acer saccharum					0.72	0.96	110
	Fraxinus americana					0.78	0.88	110
	Liriodendron tulipifera					0.87	0.79	110
	Ailanthus altissima					1.44	0.48	110
Minnesota	*Pinus resinosa*		329	1581	5.0			168
	Pinus resinosa, Corlyus cornuta		410	1282	3.2			168
	Pinus resinosa, Herb, low shrub		380	1534	4.1			168
	Betula papyrifera, Corlyus cornuta		280	623	1.7			168
	Betula papyrifera, Herb, low shrub		246	603	2.3			168
Northern Hemisphere	*General northern temperate forest*	250	410					31

Table 1. Published data for plant litter production and decomposition rates

Area	Species	Leaf Litter Fall (gm/m^2)	Total Litter (gm/m^2)	Standing Litter (gm/m^2)	Residence Time (years)	*k* rate	Half Life (years)	Reference
U.S.S.R.	*Populus*		460-600					166
	Populus tremula		390-490					153
Hungary	*Populus alba*		350-460					92
	Populus nigra		400					92
	Populus sp.		440					92
	Alnus glutinosa		330					92
England	*Quercus petraea*	213	386					35
	Fagus sylvatica, Castanea sativa	358	425					5
	Castaneae					0.406-0.623	1.1-1.7	5
	Fagus sylvatica					0.218-0.327	2.1-3.2	5
	Alnus glutinosa, Betula pendula	185	263-273					87
	Quercus petraea, Q. robur, Fraxinus excelsior	323	513					167
	Pinus nigra			216				143
	Picea abies			255				143
	Quercus petracea			37				143
	Betula sp.	94-127	150-180					178
England	*Fagus sylvatica*	357	570					139
	Quercus robur	326	528					6
	Populus tremula	190	394					7
	Fagus sylvatica		240-500					53
	Fagus sylvatica		440					137
	Fagus sylvatica		420-440					57
France	*Fagus sylvatica*	214-254	299-401					74
	Fagus sylvatica					0.520-0.230	1.3-3.0	112
	Quercus petraea					0.533	1.3	112
	Carpinus betulus					0.910	0.8	112

Table 2. Summary of soil classifications at woodlots sampled in the Pt. Colborne area, 2001 - Clay sites*

Woodlot	Soil	Description	Drainage	Classification	OM	pH	Size fraction (%)					Texture
							Gravel	Sand	Very Fine Sand	Silt	Clay	
1	Welland	Mainly reddish-hued lacustrine heavy clay	Poor	Orthic Humic Gleysol	5.9	6.0	1	12	3	40	48	Silty Clay
2	Jeddo	Mainly reddish-hued lacustrine heavy clay loam till	Poor	Humic Luvic Gleysol	4.3	6.1	2	22	10	46	32	Clay loam
3	Haldimand	Mainly lacustrine heavy clay	Imperfect	Gleyed Brunisolic Gray Brown Luvisol	4.1	6.2	1	11	2	44	45	Silty Clay
6	Welland	Mainly reddish-hued lacustrine heavy clay	Poor	Orthic Humic Gleysol	5.9	6.0	1	12	3	40	48	Silty Clay
7	Welland	Mainly reddish-hued lacustrine heavy clay	Poor	Orthic Humic Gleysol	5.9	6.0	1	12	3	40	48	Silty Clay
8	Welland	Mainly reddish-hued lacustrine heavy clay	Poor	Orthic Humic Gleysol	5.9	6.0	1	12	3	40	48	Silty Clay
9	Jeddo	Mainly reddish-hued lacustrine heavy clay loam till	Poor	Humic Luvic Gleysol	4.3	6.1	2	22	10	46	32	Clay loam
10	Jeddo	Mainly reddish-hued lacustrine heavy clay loam till	Poor	Humic Luvic Gleysol	4.3	6.1	2	22	10	46	32	Clay loam
11	Toledo	15-40 cm loamy textures over lacustrine silty clay	Poor	Orthic Humic Gleysol	4.8	6.2	0	13	5	49	38	Silty Clay Loam
12	Toledo	15-40 cm loamy textures over lacustrine silty clay	Poor	Orthic Humic Gleysol	4.8	6.2	0	13	5	49	38	Silty Clay Loam
13	Welland	Mainly reddish-hued lacustrine heavy clay	Poor	Orthic Humic Gleysol	5.9	6.0	1	12	3	40	48	Silty Clay
14	Niagara	Mainly reddish-hued lacustrine heavy clay	Imperfect	Gleyed Brunisolic Gray Brown Luvisol	3.8	6.1	1	14	5	46	40	Silty Clay Loam
15	Welland	Mainly reddish-hued lacustrine heavy clay	Poor	Orthic Humic Gleysol	5.9	6.0	1	12	3	40	48	Silty Clay

Table 3. Summary of soil classifications at woodlots sampled in the Pt. Colborne area, 2001 - Organic Soil Sites*

Woodlot	Soil	Description	Drainage	Classification	OM	pH	Size fraction (%)					Texture
							Gravel	Sand	Very Fine Sand	Silt	Clay	
16	Quarry	Organic soil, swamp associated,40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	74.0	5.6	NR	NR	NR	NR	NR	Organic
17	Quarry	Organic soil, swamp associated,40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	74.0	5.6	NR	NR	NR	NR	NR	Organic
18	Quarry	Organic soil, swamp associated,40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	74.0	5.6	NR	NR	NR	NR	NR	Organic
19	Quarry	Organic soil, swamp associated,40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	74.0	5.6	NR	NR	NR	NR	NR	Organic
20	Lorraine	Organic soil 40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	73.3	5.0	NR	NR	NR	NR	NR	Organic
21	Sherkston	Organic soil, fen associated greater than 160 cm deep	Very poor	Typic Fibrisol	79.1	5.7	NR	NR	NR	NR	NR	Organic
22	Quarry	Organic soil, swamp associated,40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	74.0	5.6	NR	NR	NR	NR	NR	Organic
23	Quarry	Organic soil, swamp associated,40-160 cm deep over clayey mineral soil	Very poor	Terric Mesisol	74.0	5.6	NR	NR	NR	NR	NR	Organic

* Data published in Kingston and Presant, 1989, The soils of the Regional Municipality of Niagara [98]
NR - Not reported

Table 4. Statistical summary of weights of litter samples collected in individual woodlots in the Port Colborne, 2001

Woodlot			Leaves				Twigs				Fruit			
Number	Soil	Zone	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
1	Clay	Heavy	281.4	668.3	108.8	135.4	173.2	475.5	91.5	99.3	120.4	473.0	1.3	145.7
2	Clay	Heavy	268.5	533.9	128.8	132.9	244.4	543.9	75.9	125.1	13.0	83.1	0.1	20.7
3	Clay	Moderate	87.2	240.5	33.1	57.2	265.5	896.9	89.7	198.9	10.0	62.7	0.7	15.7
6	Clay	Moderate	149.5	357.5	53.2	90.4	237.3	618.2	60.4	135.2	34.5	99.1	0.4	33.3
7	Clay	Heavy	212.1	394.9	101.3	75.0	308.9	562.8	140.2	125.5	38.7	132.6	2.3	41.1
8	Clay	Moderate	63.1	129.0	31.6	32.0	285.7	554.0	43.7	157.9	4.5	6.8	1.1	1.8
9	Clay	Heavy	316.3	463.1	200.3	81.7	510.6	935.3	268.7	193.9	12.3	50.1	2.7	11.0
10	Clay	Moderate	259.7	860.2	95.1	244.7	353.0	639.4	123.7	162.9	3.2	13.9	0.5	3.4
11	Clay	Low	269.2	566.8	81.9	128.4	196.5	494.1	35.0	130.1	22.9	63.9	1.7	19.3
12	Clay	Low	220.0	313.4	131.8	47.1	155.1	386.6	50.1	103.4	14.8	37.2	4.7	9.7
13	Clay	Low	225.0	525.4	104.7	102.4	191.9	604.0	33.5	153.8	19.7	102.0	1.4	27.6
14	Clay	Low	358.4	794.7	142.0	193.6	165.2	370.7	52.1	95.3	7.9	80.2	0.7	20.2
15	Clay	Low	224.1	372.0	128.5	69.2	227.8	453.4	89.0	107.8	14.1	67.2	2.8	16.6
16	Organic	Heavy	536.9	965.6	222.4	207.5	246.6	520.5	29.0	126.7	114.6	481.1	26.3	114.5
17	Organic	Heavy	399.9	835.4	199.7	176.9	247.3	499.6	103.8	102.4	88.0	271.1	2.4	101.3
18	Organic	Heavy	410.5	725.1	215.5	181.8	166.3	504.9	68.9	105.7	37.0	113.2	0.0	38.3
19	Organic	Heavy	197.1	343.7	93.4	67.6	191.6	341.8	40.7	90.0	6.1	20.3	0.7	6.5
20	Organic	Low	127.2	211.0	42.9	48.8	202.0	343.3	80.8	80.2	8.8	18.3	3.8	4.2
21	Organic	Low	126.0	315.3	48.5	65.3	110.5	197.2	49.3	44.5	4.5	12.9	1.2	3.5
22	Organic	Low	181.3	233.6	80.2	44.3	212.8	377.5	88.3	80.7	2.9	6.0	1.2	1.3
23	Organic	Low	117.3	211.3	76.3	42.8	234.6	469.4	71.3	136.0	11.5	23.4	2.4	6.9

Values reported are means based on 15 sample points, each 0.25 m^2

Table 5. Statistical summary of weights of standing litter samples collected in woodlots in the Port Colborne, 2001.

Soil	Soil Metal Zone	Leaves		Twigs		Fruit		Total	Mean Nickel Conc (Fg/g)
		Weight	% *	Weight	%	Weight	%		
Clay	Heavy	269.58 a	43.14	309.27 a	49.49	46.09 a	7.37	487.83 a	2183
	Intermediate	139.86 b	31.91	285.37 a	65.11	13.04 a	2.98	557.87 a	581
	Low/Control	259.35 a	56.07	187.26 a	40.49	15.90 a	3.44	462.50 a	30
Organic	Heavy	386.10 x	58.46	212.95 x	32.24	61.40 x	9.30	660.45 x	14649
	Low/Control	137.95 y	41.20	189.97 x	56.74	6.92 x	2.07	334.83 y	206

Values reported are means for four or five woodlots per soil and metal level class, grams per square meter oven dry weight. Compare with Figure 9
Values followed by the same letter in each soil type are not significantly different at P=0.05 based on Analysis of Variance testing of woodlot means.

Table 6 Weight* of fresh litter at selected woodlots in the Pt Colborne area, 2001

Species	Dry Weight					% of Total				
	Woodlot 2	Woodlot 10	Woodlot 13	Woodlot 17	Woodlot 21	Woodlot 2	Woodlot 10	Woodlot 13	Woodlot 17	Woodlot 21
Freeman's Maple	50.98	163.77	103.18	271.29	246.57	14.4%	52.9%	29.3%	80.4%	71.4%
Red Maple	-	-	3.50	-	-	-	-	1.0%	-	-
Sugar Maple	-	-	4.86	-	-	-	-	1.4%	-	-
Red Oak	22.18	39.81	38.90	60.63	-	6.3%	12.9%	11.0%	18.0%	-
Bur Oak	84.62	3.15	42.97	1.06	-	24.0%	1.0%	12.2%	0.3%	-
American Elm	32.81	6.51	4.82	2.57	7.98	9.3%	2.1%	1.4%	0.8%	2.3%
American Basswood	19.85	3.73	6.09	-	-	5.6%	1.2%	1.7%	-	-
Ash	91.77	52.80	74.03	-	50.60	26.0%	17.0%	21.0%	-	14.7%
Shagbark Hickory	23.49	11.67	38.18	-	-	6.7%	3.8%	10.8%	-	-
Blue Beech	10.82	0.55	14.57	-	0.83	3.1%	0.2%	4.1%	-	0.2%
American Beech	-	13.72	16.39	-	-	-	4.4%	4.7%	-	-
Ironwood	-	-	-	-	7.60	-	-	-	-	2.2%
Unknown	16.36	17.90	7.25	4.20	34.86	4.6%	5.8%	2.1%	1.2%	10.1%
Total	352.86	309.71	352.42	337.33	345.35					
Standard Deviation	17.5	4.0	15.3	45.9	17.7					
Corrected Total**	370.50	340.68	370.04	344.08	348.80					
% Leaves retained	5%	10%	5%	2%	1%					

* Values reported represent means of triplicate samples, oven dry weight
** Corrected totals calculated by adding estimated % leaves still on trees to weights of leaves on ground.
Woodlots represent one from each of the metal zones and soil types.

Table 7 Part A. Chemical element concentrations in soil collected in woodlots in the Pt. Colborne area, 2001

Station No.	Moisture	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper
1	29.3	11050	0.8	**29.9**	86	0.55	**1.15**	20	**70.0**	**436**
2	35.8	13650	0.9	14.0	130	0.70	**1.30**	21	**40.0**	**252**
3	31.2	19200	0.6	8.2	121	0.90	0.85	25	17.0	**106**
6	36.8	22150	0.6	6.9	130	0.95	**1.20**	25	17.5	**95**
7	29.0	16400	0.8	**15.4**	117	0.75	**1.15**	23	**28.0**	**125**
8	38.0	16825	0.5	8.2	157	**1.25**	**2.33**	21	11.8	**125**
9	35.7	18700	0.6	7.4	136	1.00	**1.50**	25	**23.0**	**176**
10	24.6	13000	0.5	7.7	82	0.60	0.65	19	16.0	**73**
11	18.2	4235	0.2	0.9	29	ND	ND	7	ND	8
12	16.3	4248	0.1	1.8	31	ND	0.45	8	ND	8
13	28.7	16200	0.5	4.6	85	0.60	0.35	20	5.5	17
14	32.6	12100	0.3	3.5	91	0.65	0.40	18	3.5	20
15	25.0	10195	0.4	6.3	75	0.55	0.25	16	6.0	33
16	66.6	4080	**1.5**	**92.5**	122	0.40	**2.80**	21	**211.3**	**1453**
17	70.7	4375	**2.0**	**127.5**	127	0.35	**5.85**	27	**311.0**	**2755**
18	64.3	5780	**1.7**	**99.8**	121	0.60	**3.05**	29	**247.5**	**2270**
19	56.9	8650	**1.4**	**45.1**	102	0.95	**2.50**	23	**78.0**	**680**
20	31.9	27875	0.4	5.4	151	**1.30**	**1.63**	32	16.5	**80**
21	53.7	12100	0.5	7.4	104	0.65	**1.20**	17	7.0	55
22	39.4	14550	0.4	2.8	112	1.10	**1.05**	18	6.5	40
23	59.6	4655	0.6	3.4	44	0.20	ND	12	3.0	31

Means	Moisture	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper
Clay Soil - Heavy Zone	32.1	14633	0.7	**17.3**	112	0.72	**1.10**	22	**42.3**	**264**
Clay Soil - Intermediate Zone	32.8	17415	0.6	9.1	124	0.91	**1.37**	23	**19.3**	**118**
Clay Soil - Low/Control Zone	24.2	9396	0.3	3.4	62	0.36	0.29	14	3.0	17
Organic Soil - Heavy Zone	64.6	5721	**1.6**	**91.2**	118	0.58	**3.55**	25	**211.9**	**1789**
Organic Soil - Low/Control Zone	46.2	14795	0.5	4.7	103	0.81	0.97	20	8.3	51
Guidelines										
Table A			13.0	25	1000	1.2	4.00	1000	50	200
Table F			1.0	14	190	1.2	1.00	67	19	56

Values reported represent means for duplicate samples, ug/g air dry weight
Values shown in shaded cells exceed Table A Guidelines, Bold values exceed Table F Guidelines
ND = Not detectable

Table 7 Part B. Chemical element concentrations in soil collected in woodlots in the Pt. Colborne area, 2001

Station No.	Iron	Lead	Manganese	Molybdenum	Nickel	Phosphorus	Selenium	Silver	Titanium	Vanadium	Zinc
1	18450	**83**	535	ND	**4130**	865	**6.95**	**2.00**	100	30	**187**
2	14200	**76**	286	ND	**2025**	1485	**7.65**	ND	65	21	145
3	21200	41	206	ND	**780**	1060	**2.15**	ND	96	33	114
6	14450	47	239	ND	**709**	1625	**2.60**	ND	57	28	124
7	23650	55	605	ND	**1070**	1090	**3.40**	ND	110	36	135
8	14825	48	246	**5.8**	**288**	1813	**2.65**	ND	61	30	144
9	11850	**67**	85	ND	**1505**	1570	**4.65**	ND	65	30	143
10	16850	35	310	ND	**550**	943	**1.75**	ND	83	28	123
11	2580	25	50	ND	16	419	0.30	ND	53	6	28
12	3353	19	72	ND	18	370	0.30	ND	49	7	33
13	18750	41	271	ND	39	1320	0.75	ND	46	36	98
14	10120	40	103	ND	39	1025	0.75	ND	36	16	58
15	12100	30	467	ND	41	905	0.65	ND	30	21	61
16	34200	**189**	650	ND	**12900**	1113	**32.65**	**5.50**	118	23	**296**
17	33900	**209**	707	ND	**22700**	1165	**50.30**	**9.00**	128	24	**280**
18	30500	**179**	519	2.0	**18250**	1255	**37.50**	**6.50**	125	29	**319**
19	19900	**101**	378	2.0	**4745**	1870	**13.95**	**2.50**	103	30	149
20	26250	37	347	1.5	**431**	1665	**1.80**	**1.75**	81	45	136
21	18000	42	118	ND	167	1155	**2.95**	ND	107	40	98
22	8975	53	44	ND	98	1650	**1.50**	ND	57	24	59
23	7325	74	36	ND	128	1135	**2.05**	ND	54	11	47

Means	Iron	Lead	Manganese	Molybdenum	Nickel	Phosphorus	Selenium	Silver	Titanium	Vanadium	Zinc
Clay Soil - Heavy Zone	17950	67	342	ND	**2312**	1137	**5.58**	**0.67**	87	28	149
Clay Soil - Intermediate Zone	16325	50	297	1.2	**824**	1408	**3.01**	0.00	75	30	134
Clay Soil - Low/Control Zone	9381	31	192	ND	30	808	0.55	0.00	43	17	55
Organic Soil - Heavy Zone	29625	169	564	1.0	**14649**	1351	**33.60**	**5.88**	118	26	**261**
Organic Soil - Low/Control Zone	15138	51	136	0.4	**206**	1401	**2.08**	**0.44**	74	30	85
Guidelines											
Table A		200		5.0	200		2.00	25		250	800
Table F		55		2.5	43		1.40	0.35		91	150

Values reported represent means for duplicate samples, ug/g air dry weight

Values shown in shaded cells exceed Table A Guidelines, Bold values exceed Table F Guidelines

Table 8. Summary of correlations (*r* values) between various element concentrations measured in soil samples from woodlots in the vicinity of Pt. Colborne, 2001.

Element	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper
Antimony	-0.381								
Arsenic	-0.482	**0.948**							
Barium	**0.608**	0.386	0.279						
Beryllium	**0.821**	-0.050	-0.195	0.812					
Cadmium	-0.186	**0.869**	**0.880**	**0.559**	0.134				
Chromium	**0.559**	0.520	0.431	**0.873**	**0.689**	**0.598**			
Cobalt	-0.457	**0.935**	**0.996**	0.295	-0.193	**0.879**	0.449		
Copper	-0.462	**0.922**	**0.985**	0.278	-0.190	**0.885**	0.442	**0.992**	
Iron	0.045	**0.794**	**0.781**	**0.603**	0.214	**0.754**	**0.764**	**0.775**	**0.737**
Lead	-0.467	**0.959**	**0.969**	0.319	-0.154	**0.844**	0.433	**0.967**	**0.947**
Manganese	-0.147	**0.745**	**0.742**	0.360	-0.007	**0.649**	0.527	**0.728**	**0.681**
Molybdenum	0.019	-0.380	-0.386	**0.538**	0.370	0.054	-0.701	-0.386	-0.352
Nickel	-0.468	**0.921**	**0.988**	0.269	-0.211	**0.876**	0.434	**0.996**	**0.998**
Phosphorus	**0.553**	0.244	0.051	**0.774**	**0.846**	0.343	0.657	0.042	0.051
Selenium	-0.472	**0.939**	**0.993**	0.297	-0.194	**0.894**	0.432	**0.995**	**0.992**
Silver	-0.672	**0.879**	**0.971**	0.220	-0.718	**0.918**	0.152	**0.985**	**0.983**
Titanium	-0.171	**0.790**	**0.743**	0.394	0.040	**0.707**	0.527	**0.730**	**0.704**
Vanadium	**0.696**	0.156	0.039	**0.703**	**0.724**	0.237	**0.762**	0.035	0.021
Zinc	-0.158	**0.895**	**0.889**	**0.560**	0.101	**0.824**	**0.671**	**0.896**	**0.864**

Element	Iron	Lead	Manganese	Molybdenum	Nickel	Phosphorus	Selenium	Silver	Titanium	Vanadium
Lead	0.749									
Manganese	0.830	0.681								
Molybdenum	-0.779	-0.350	-0.692							
Nickel	0.743	0.954	0.693	-0.367						
Phosphorus	0.281	0.152	0.043	0.365	0.025					
Selenium	0.755	0.969	0.690	-0.370	0.994	0.071				
Silver	0.823	0.932	0.806	0.622	0.988	-0.354	0.989			
Titanium	0.824	0.715	0.669	-0.683	0.708	0.102	0.714	0.906		
Vanadium	0.582	0.022	0.329	-0.416	0.013	0.569	0.014	-0.670	0.446	
Zinc	0.881	0.892	0.782	-0.259	0.871	0.255	0.874	0.848	0.799	0.341

Values shown in bold typeface indicate highly significant positive correlation between the elements indicated in the respective columns and rows
Shaded cells indicate values greater than P=0.9

Table 9 Summary of vegetation cover in woodlots in the Port Colborne area, 2000

	Tree Cover			Shrub Cover			Herb Cover		
Woodlot	Mean	Std Dev	St. Error	Mean	Std Dev	St. Error	Mean	Std Dev	St. Error
1	91.67	17.29	4.46	43.00	30.81	7.96	32.33	18.70	4.83
2	97.00	8.41	2.17	43.33	29.44	7.60	18.47	14.67	3.79
3	100.00	0.00	0.00	27.00	21.11	5.45	43.00	27.18	7.02
6	99.33	2.58	0.67	10.00	4.63	1.20	47.33	18.21	4.70
7	100.00	0.00	0.00	21.33	11.09	2.86	21.27	27.43	7.08
8	100.00	0.00	0.00	28.40	24.37	6.29	8.93	6.27	1.62
9	100.00	0.00	0.00	10.80	7.81	2.02	27.00	21.36	5.52
10	99.33	2.58	0.67	5.80	2.31	0.60	18.60	12.08	3.12
11	100.00	0.00	0.00	24.67	20.48	5.29	7.53	6.20	1.60
12	100.00	0.00	0.00	74.33	21.87	5.65	5.53	8.51	2.20
13	100.00	0.00	0.00	30.33	27.93	7.21	23.80	23.89	6.17
14	99.00	2.80	0.72	7.60	11.47	2.96	17.93	16.06	4.15
15	100.00	0.00	0.00	23.33	14.23	3.67	28.00	25.60	6.61
16	100.00	0.00	0.00	4.67	5.16	1.33	49.67	27.09	6.99
17	100.00	0.00	0.00	14.13	11.52	2.97	8.87	6.41	1.66
18	100.00	0.00	0.00	61.67	34.83	8.99	16.80	14.32	3.70
19	100.00	0.00	0.00	76.00	24.51	6.33	59.33	13.35	3.45
20	100.00	0.00	0.00	6.33	7.43	1.92	32.67	24.27	6.27
21	100.00	0.00	0.00	29.00	25.09	6.48	47.00	23.74	6.13
22	100.00	0.00	0.00	30.00	20.00	5.16	60.00	19.09	4.93
23	98.67	3.52	0.91	16.47	12.14	3.13	44.00	22.30	5.76
Means									
Clay - Heavy	97.17	3.40	0.96	29.62	14.05	8.11	24.77	5.34	3.08
Clay - Intermediate	99.67	0.33	0.19	17.80	10.02	5.79	29.47	16.14	9.32
Clay - Low/Control	99.80	0.40	0.20	32.05	22.45	11.22	16.56	8.81	4.41
Organic - High	100.00	0.00	0.00	39.12	30.33	17.51	33.67	21.30	12.30
Organic - Low/Control	99.67	0.58	0.33	20.45	9.74	5.62	45.92	9.73	5.62

Values based on ratings made at 15 possible sample points in each woodlot

Table 10. Numbers* of trees within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	Ash sp	Red Ash	White Ash	American Beech	Bur Oak	Red Oak	Freeman Maple	Red Maple	Sugar Maple	Blue Beech	Yellow Birch	Butternut	Shagbark Hickory	American Elm	Basswood	Hawthorn sp.	Peach-L. Willow	Total
1	1	1		1		1	4			4			1			1		14
2	1													4	1			6
3		6				6	12								6			30
6		3				1	2						3					9
7							6			2								8
8			1				15							4				20
9			15				6											21
10		1				1	11	2								2		17
11			1			2	8			5				5				21
12			1	5			11											17
13		5					1		1				3		3			13
14					1		7							2				10
15							12		5					1	9			27
16						1	8											9
17						2	12											14
18		1				1	6										1	9
19							3			6		1						10
20			3				8							6				17
21			3				9							1				13
22						1	17				8			2				28
23							19											19
Total	2	17	24	6	1	16	177	2	6	17	8	1	7	25	19	3	1	322
Woodlots	2	6	6	2	1	9	20	1	2	4	1	1	3	8	4	2	1	73

* Numbers are for plot 20 m x 10 m. See text.

Table 11. Mean diameter* of tree species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	Ash sp.	Red Ash	White Ash	American Beech	Bur Oak	Red Oak	Freeman Maple	Red Maple	Sugar Maple	Blue Beech	Yellow Birch	Butternut	Shagbark Hickory	American Elm	Basswood	Hawthorn sp.	Peach-L. Willow	Mean
1	20.2	17.6		18.5		11.0	48.0			12.8			18.3			20.5		20.9
2	12.2													20.2	28.3			20.2
3		23.4				17.5	21.4								14.4			19.2
6		12.1				25.7	49.6						23.4					27.2
7							17.6			10.5								14.1
8			21.5				21.6							29.7				24.2
9			17.4				20.8											19.1
10		41.0				14.3	19.5	22.8								22.5		24.0
11			11.2			42.3	20.5			16.1				18.3				21.7
12			25.3	20.5			20.0											21.9
13		35.3					16.5		47.5				21.7		18.4			27.9
14					25.7		18.7							33.3				25.9
15							20.7		25.9					30.0	18.0			23.7
16						30.6	18.2											24.4
17						50.5	19.4											34.9
18		46.7				61.5	20.1										48.8	44.3
19							61.2			18.0		28.2						35.8
20			26.0				17.4							14.1				19.1
21			30.1				26.3							16.2				24.2
22						12.1	20.2				16.4			24.1				18.2
23							30.6											30.6
Mean	16.2	29.4	21.9	19.5	25.7	29.5	25.4	22.8	36.7	14.3	16.4	28.2	21.1	23.2	19.8	21.5	48.8	24.9

*Diameters equals arithmetic means for all stems over 10 cm for measurements made at DBH level in centimeters, See text.

Table 12. Total basal areas* of tree species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	Ash sp.	Red Ash	White Ash	American Beech	Bur Oak	Red Oak	Freeman Maple	Red Maple	Sugar Maple	Blue Beech	Yellow Birch	Butternut	Shagbark Hickory	American Elm	Basswood	Hawthorn sp.	Peach-L. Willow	Total
1	321	974		311		380	1902			522			1047			330		5787
2	117													1462	629			2208
3		2766				513	4964								1042			9284
6		36				519	5983						1852					8390
7							1540			174								1714
8			363				7383							5574				13320
9			4091				2189											6279
10		1321				161	3730	856								1029		7097
11			99			1404	354			229				271				2356
12			503	1816			4105											6423
13		5118					214		1773				1254		857			9216
14					519		2464							1780				4763
15							3566		3024					707	2461			9758
16						736	2355											3091
17						4125	4406											8531
18		1714				2972	2352										1871	8908
19							9778			1754		625						12157
20			1658				1607							984				4249
21			2184				5983							206				8373
22						115	6032				1709			939				8794
23							15779											15779
Total	438	11926	8898	2127	519	10927	86683	856	4797	2680	1709	625	4153	11924	4988	1360	1871	156480

* Basal area reported as square centimeters equals sum of cross sectional area measured at DBH

Table 13. Mortality* of tree species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	Ash sp.	Red Ash	White Ash	American Beech	Bur Oak	Red Oak	Freeman Maple	Red Maple	Sugar Maple	Blue Beech	Yellow Birch	Butternut	Shagbark Hickory	American Elm	Basswood	Hawthorn sp.	Peach-L. Willow	Total
1	0	0		0		0	0			3			0			0		3
2	0													0	0			0
3		1				1	0								2			4
6		0				0	0						0					0
7							0			0								0
8			0				5							0				5
9			1				0											1
10		0				0	0	0								0		0
11			0			0	0			0				1				1
12			0	0			0											0
13		0					0		0				0		0			0
14					0		0							0				0
15							0		0					1	0			1
16						0	1											1
17						0	3											3
18		0				0	0										0	0
19							0			0		0						0
20			0				0							3				3
21			0				0							0				0
22						0	1				1			1				3
23							1											1
Total	0	1	1	0	0	1	11	0	0	3	1	0	0	6	2	0	0	26
Trees	2	18	28	7	2	19	187	2	6	16	8	1	8	25	19	3	1	352
%	0.0%	5.65%	3.57%	0.0%	0.0%	5.26%	5.88%	0.0%	0.0%	18.75%	12.5%	0.0%	0.0%	24.0%	10.53%	0.0%	0.0%	7.39%

* Mortality measured as numbers of recently dead standing trees. Percentages computed from number of all trees of the given species in Table 10

Table 14. Mean of crown ratings* for tree species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	Ash sp.	Red Ash	White Ash	American Beech	Bur Oak	Red Oak	Freeman Maple	Red Maple	Sugar Maple	Blue Beech	Yellow Birch	Butternut	Shagbark Hickory	American Elm	Basswood	Hawthorn sp.	Peach-L. Willow	Weighted Mean
1	2.0	5.0		3.0		3.0	2.0			8.0			3.0			2.0		4.14
2	3.0													2.8	2.0			2.67
3		4.7				4.5	2.6								4.3			3.73
6		3.0				3.0	2.0			4.5			3.0					3.78
7							2.7											2.00
8			4.0				5.4							3.5				4.98
9			3.8				2.4											3.37
10		3.0				3.0	2.6	2.5								5.0		2.94
11			3.0			4.0	2.4			3.2				4.2				3.19
12			5.0	3.8			3.2											3.47
13		2.0					2.3		2.0				2.7		2.0			2.18
14					6.0		2.9							3.0				3.20
15							2.9							10.0	3.0			2.66
16						2.5	3.8											3.61
17						2.0	4.5											4.14
18		3.0				2.0	2.1										3.0	2.32
19							2.3			2.8		4.0						2.80
20			4.3				2.0							6.5				4.00
21			4.7				3.3							4.0				3.69
22						3.0	3.3				4.3			6.5				3.79
23							3.9											3.95

Scoring based on range 0 (perfect tree) to 10 (recently dead) Values of 4 or less are considered healthy, 5 to 7 have healthy problems, 8 to 10 very serious health problem

Table 15. Numbers* of shrubs within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	American Elm	Ash sp.	Red Ash	White Ash	Basswood	American Beech	Red Oak	Shagbark Hickory	Ironwood	Blue Beech	Yellow Birch	Choke Cherry	Service Berry	Black Elder	European Buckthorn	Freeman Maple	Sugar Maple	Spicebush	Total
1			1		2		1	3		10		2				3			22
2	3	1	3		1					18		29							55
3			1		2				4	1						3			11
6	2		2		1		1	2		14		2				1		4	29
7				2	3	2	8					4				23		3	45
8	7															2			9
9				5												31		4	40
10						1						5		1		1			8
11				7						2						14			23
12						12				4			1			22		2	41
13			3		1			1		15		3				4	5		32
14			1						1			1				4	4		11
15					6	6				5						5	4		26
16												1				4			5
17																5		2	7
18																		33	33
19										7		4						24	35
20	6															5			11
21				4							1					2		13	20
22	1						1					2				6			10
23	8		6												2	7		3	26
Total	27	1	17	18	16	21	11	6	5	76	1	49	1	1	2	139	13	88	499
Woodlot	6	1	7	4	7	4	4	3	2	9	1	10	1	1	1	18	3	9	

* Numbers are for plot 20 m x 10 m. See text.

Table 16. Mean diameter* of shrub species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	American Elm	Ash sp.	Red Ash	White Ash	Basswood	American Beech	Red Oak	Shagbark Hickory	Ironwood	Blue Beech	Yellow Birch	Choke Cherry	Service Berry	Black Elder	European Buckthorn	Freeman Maple	Sugar Maple	Spicebush	Mean
1			1.8		3.8		2.9	2.5		3.3		3.9				2.9			3.0
2	6.6	8.5	6.8		2.5					2.8		1.2							4.7
3			8.0		8.0				2.2	5.7						8.7			6.5
6	2.0		9.5		1.2		5.0	8.5		3.5		1.3				1.4		2.1	3.8
7				2.4	4.3	7.6	3.6					1.6				3.2		0.7	3.3
8	5.2															4.3			4.7
9				8.1												4.4		3.3	5.3
10						6.3						3.0		5.2		8.8			5.8
11				3.8						9.0						6.0			6.3
12						3.8				4.0			3.5			4.5		1.5	3.5
13			5.0		3.9			6.8		4.1		1.5				4.3	5.1		4.4
14			0.6						0.9			0.4				2.2	9.0		2.6
15					5.6	4.8				2.8						7.3	3.8		4.8
16												3.2				5.9			4.5
17																5.2		1.5	3.3
18																		2.8	2.8
19										3.9		4.1						2.8	3.6
20	4.9															6.7			5.8
21				5.7							8.8					5.9		2.1	5.6
22	3.2						8.3					1.7				6.6			4.9
23	4.6		2.8												2.5	5.7		3.4	3.8
Mean	4.4	8.5	4.9	5.0	4.2	5.6	4.9	5.9	1.5	4.3	8.8	2.0	3.5	5.2	2.5	5.2	5.9	2.2	4.7

Diameters equals arithmetic means for all stems under 10 cm for measurements made at DBH level in centimeters, See text.

Table 17. Total basal areas* of shrub species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	American Elm	Ash sp.	Red Ash	White Ash	Basswood	American Beech	Red Oak	Shagbark Hickory	Ironwood	Blue Beech	Yellow Birch	Choke Cherry	Service Berry	Black Elder	European Buckthorn	Freeman Maple	Sugar Maple	Spicebush	Total
1			2.4		24.4		6.8	14.7		122.2		29.5				21.0			221.0
2	129.2	56.8	117.1		5.0					179.7		38.4							526.1
3			50.3		104.1				14.8	25.5						178.9			373.6
6	6.6		140.7		1.1		19.3	112.3		185.7		2.7				1.6		15.7	485.7
7				8.7	55.7	90.8	84.6					8.6				256.0		1.3	505.7
8	195.7															72.1			267.8
9				267.1												607.7		34.2	909.1
10						31.2						37.9		21.2		60.8			151.2
11				16.4						63.0						31.4			110.7
12						179.7				47.7			9.6			450.9		3.3	691.2
13			67.5		12.0			36.3		241.6		5.1				82.0	131.3		575.7
14			0.3						0.6			0.6				16.7	711.5		729.6
15					160.1	112.9				33.2						227.0	52.1		585.4
16												8.0				115.0			123.0
17																149.9		3.3	153.2
18																		224.3	224.3
19										131.3		70.5						163.5	435.8
20	122.0															179.5			301.5
21				107.3							60.8					59.6		46.0	273.7
22	8.0						54.1					4.8				226.1			293.1
23	186.9		40.1												9.9	217.5		26.9	481.3
Total	648.5	56.8	418.3	399.5	362.4	292.6	164.9	163.3	15.3	1029.9	60.8	206.1	9.6	21.2	9.9	2953.6	894.9	158.4	8418.6

* Basal area reported as square centimeters equals sum of cross sectional area measured at DBH

Table 18. Mortality* of shrub species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	American Elm	Ash sp.	Red Ash	White Ash	Basswood	American Beech	Red Oak	Shagbark Hickory	Ironwood	Blue Beech	Yellow Birch	Choke Cherry	Service Berry	Black Elder	European Buckthorn	Freeman Maple	Sugar Maple	Spicebush	Total
1			0		0		0	0		0		0				0			0
2	0	0	0		0					0		1							1
3			1		0				1	0						1			3
6	0		0		0		0	1		2		0				0		1	4
7				0	0	1	0					0				2		0	3
8	1															1			1
9				2												2		0	4
10						0						0		0		0			0
11				5						0						0			5
12						0				0			0			2		0	2
13			0		0			0		3		0				0	0		3
14			0						0			0				1	0		1
15					0	0				0						4	0		4
16												0				3			3
17																0		0	0
18																		2	2
19										0		0						1	1
20	0															0			0
21				0							1					0		0	1
22	0						1					0				1			2
23	0		0												0	2		2	4
Total	1	0	1	7	0	1	1	1	1	5	1	1	0	0	0	19	0	6	44
Shrubs	27	1	17	18	16	21	11	6	5	76	1	53	1	1	2	142	13	88	499
%	3.7%	0.0%	5.9	38.9%	0.0%	4.8%	9.1%	33.3%	16.7	6.6%	100.0%	1.9%	0.0%	0.0%	0.0%	13.4%	0.0%	6.8%	9.0%

* Mortality measured as numbers of recently dead standing trees. Percentages computed from number of all trees of the given species in Table 15

Table 19. Mean of crown ratings* for shrub species within study areas in woodlots in the vicinity of Pt. Colborne, 2001

Woodlot No.	American Elm	Ash sp.	Red Ash	White Ash	Basswood	American Beech	Red Oak	Shagbark Hickory	Ironwood	Blue Beech	Yellow Birch	Choke Cherry	Service Berry	Black Elder	European Buckthorn	Freeman Maple	Sugar Maple	Spicebush	Mean
1			4.0		3.5		4.0	2.0		2.3		3.5				2.0			2.59
2	3.3	4.0	3.7		2.0					2.6		3.9							3.38
3			10.0		2.0				4.8	3.0						5.7			4.82
6	2.0		3.5		4.0		2.0	6.0		3.7		3.0				3.0			3.10
7				2.5	2.7	7.0	3.9					3.5				3.9		4.3	3.88
8	4.3															3.8		2.7	4.18
9				6.4												3.8			3.78
10						7.0						2.6		4.0		3.0		2.0	3.38
11				8.0						3.0						3.8			5.00
12						3.2				3.4			3.0			3.9		3.0	3.55
13			4.3		3.0			2.0		4.4		3.0				2.5	3.2		3.72
14			2.0						2.0			2.0				5.0	2.8		3.38
15					2.8	3.0				2.6						8.6	3.0		3.96
16												4.0				8.3			7.40
17																3.2		3.0	3.14
18																		3.5	3.45
19										2.4		3.0				2.6		2.7	2.31
20	3.0																		1.64
21				3.0												3.0		2.5	2.55
22	7.0						10.0				10.0	3.5				4.7			5.20
23	2.9		2.5												3.5	5.1		9.7	4.23

Scoring based on range 0 (perfect tree) to 10 (recently dead) Values of 4 or less are considered healthy, 5 to 7 have healthy problems, 8 to 10 very serious health problem

Table 20. Summary of occurrence of tree fruits in leaf litter samples collected in woodlots in the Port Colborne area, 2001.

Frequency of tree species presence *

Woodlot No.	Species								
	Oak	Maple	Ash	Hickory	Basswood	Beech	Elm	Cherry	Other
1	12	1	1	6	1	4	0	0	0
2	5	10	13	3	3	0	0	1	0
3	9	7	5	0	14	0	0	0	0
6	1	12	8	11	1	0	0	0	0
7	15	9	14	1	2	0	0	0	1
8	1	15	13	2	0	0	6	0	0
9	3	14	14	0	0	0	0	0	0
10	1	15	9	0	0	1	0	0	0
11	14	15	0	0	0	0	1	0	0
12	6	15	1	0	0	8	0	0	1
13	6	11	14	7	0	1	0	0	0
14	3	15	0	0	0	1	0	0	0
15	4	15	13	2	10	2	0	0	0
16	15	1	0	0	0	1	0	0	0
17	14	14	0	0	0	0	0	0	0
18	13	0	0	0	0	0	0	0	0
19	1	15	10	0	1	0	0	0	2
20	0	15	7	0	0	0	0	0	0
21	0	15	12	0	0	0	0	0	0
22	0	15	7	0	0	0	0	0	1
23	1	15	0	6	1	0	0	0	0

Abundance Scores of tree species**

Woodlot No	Species								
	Oak	Maple	Ash	Hickory	Basswood	Beech	Elm	Cherry	Other
1	11.00	1.00	0.50	3.83	1.00	2.17	0.00	0.00	0.00
2	3.33	7.17	9.17	3.00	1.17	0.00	0.00	0.50	0.00
3	4.83	3.58	2.17	0.00	13.00	0.00	0.00	0.00	0.00
6	1.00	6.50	4.67	9.83	0.50	0.00	0.00	0.00	0.00
7	12.83	4.00	8.33	0.33	0.58	0.00	0.00	0.00	0.00
8	0.33	15.00	6.00	0.58	0.00	0.00	2.67	0.00	0.02
9	1.67	8.83	12.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.33	14.50	5.00	0.00	0.00	0.50	0.00	0.00	0.00
11	11.50	10.50	0.00	0.00	0.00	0.00	0.33	0.00	0.00
12	2.67	14.50	0.25	0.00	0.00	4.33	0.00	0.00	0.02
13	3.75	5.17	11.83	4.25	0.00	0.33	0.00	0.00	0.00
14	1.50	15.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
15	1.17	15.00	5.67	0.70	4.50	0.67	0.00	0.00	0.00
16	15.00	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00
17	12.00	9.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.33	13.00	7.00	0.00	0.50	0.00	0.00	0.00	0.05
20	0.00	15.00	3.50	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	13.50	7.50	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	15.00	3.33	0.00	0.00	0.00	0.00	0.00	0.03
23	0.50	15.00	0.00	2.83	1.00	0.00	0.00	0.00	0.00

* Occurrence of fruit of indicated species at 15 possible sample points, each 0.25 m^2 in area

** Abundance score derived from sum of reciprocal values of ranking of visual abundance in each of 15 sample points within plots (See text for explanation) Also see Figures 19 and 20

Table 21 A. Summary of **Jaccard's Coefficient of Community** between tree fruits with tree species present at sampling points in woodlots in the Port Colborne area, 2001.

Woodlot	Oak	Maple	Hickory	Ash	Basswood	Beech	Elm
1	0.333	0.125	0.000	0.000	0.000	0.200	0.000
2	0.143	0.250	**1.000**	**0.857**	0.333	---	0.000
3	**0.800**	0.625	---	0.500	0.750	---	0.000
6	0.000	**1.333**	0.333	**0.667**	0.000	---	---
7	**0.667**	**1.600**	0.000	0.167	0.000	---	---
8	0.000	**6.500**	0.000	0.300	---	0.000	0.444
9	0.000	**2.750**	---	**1.333**	---	---	---
10	0.000	---	---	0.250	0.000	0.000	---
11	**0.750**	**14.000**	---	0.000	---	---	0.000
12	0.000	**14.000**	---	0.000	0.000	**1.000**	0.000
13	0.400	0.857	**1.000**	**1.000**	0.000	0.000	---
14	0.000	**2.750**	---	0.000	0.000	0.000	0.000
15	0.000	**2.000**	0.000	0.000	**1.200**	0.500	---
16	**4.000**	0.091	---	---	---	---	---
17	**1.333**	**6.500**	---	---	---	---	0.000
18	**0.556**	0.000	---	0.000	---	---	---
19	0.000	**14.000**	---	0.111	0.000	---	---
20	0.000	**6.500**	---	0.300	---	---	0.000
21	0.000	**14.000**	---	0.167	---	---	0.000
22	0.000	**6.500**	---	0.000	---	---	---
23	0.000	---	0.000	---	0.000	---	0.000

Value shown in bold type indicate statistically significant coefficients

Table 21B. Summary of **Sorensen's Quotient of Similarity** for tree fruits with tree species present at sampling points in woodlots in the Port Colborne area, 2001.

Woodlot	Oak	Maple	Hickory	Ash	Basswood	Beech	Elm
1	0.500	0.222	0.000	0.000	0.000	0.333	0.000
2	0.250	0.400	1.000	0.923	0.500	---	0.000
3	0.889	0.769	---	0.667	0.857	---	0.000
6	0.000	1.143	0.500	0.800	0.000	---	---
7	0.800	1.231	0.000	0.286	0.000	---	---
8	0.000	1.733	0.000	0.462	---	0.000	0.615
9	0.000	1.467	---	1.143	---	---	---
10	0.000	2.000	---	0.400	0.000	0.000	---
11	0.857	1.867	---	0.000	---	---	0.000
12	0.000	1.867	---	0.000	0.000	1.000	0.000
13	0.571	0.923	1.000	1.000	0.000	0.000	---
14	0.000	1.467	---	0.000	0.000	0.000	0.000
15	0.000	1.333	0.000	0.000	1.091	0.667	---
16	1.600	0.167	---	---	---	2.000	---
17	1.143	1.733	---	---	---	---	0.000
18	0.714	0.000	---	0.000	---	---	---
19	0.000	1.867	---	0.200	0.000	---	---
20	0.000	1.733	---	0.462	---	---	0.000
21	0.000	1.867	---	0.286	---	---	0.000
22	0.000	1.733	---	0.000	---	---	---
23	0.000	2.000	0.000	---	0.000	---	0.000

Table 21C. Summary of **Index of Association of Individuals** (Iai) values for tree fruits with tree species present at sampling points in woodlots in the Port Colborne area, 2001.

Woodlot	Oak	Maple	Hickory	Ash	Basswood	Beech	Elm
1	-0.500	-0.778	-1.000	-1.000	-1.000	---	-1.000
2	-0.750	-0.600	0.000	-0.077	-0.500	---	-1.000
3	-0.111	-0.231	---	-0.333	-0.143	---	-1.000
6	-1.000	**0.143**	-0.500	-0.200	-1.000	---	---
7	-0.200	**0.231**	-1.000	-0.714	-1.000	-1.000	---
8	-1.000	**0.733**	-1.000	-0.538	---	---	-0.385
9	-1.000	**0.467**	---	**0.143**	---	-1.000	---
10	-1.000	**1.000**	---	-0.600	-1.000	---	---
11	-0.143	**0.867**	---	-1.000	---	0.000	-1.000
12	-1.000	**0.867**	---	-1.000	-1.000	-1.000	-1.000
13	-0.429	-0.077	0.000	0.000	-1.000	-1.000	---
14	-1.000	**0.467**	---	-1.000	-1.000	-0.333	-1.000
15	-1.000	**0.333**	-1.000	-1.000	0.091	**1.000**	---
16	**0.600**	-0.833	---	---	---	---	---
17	**0.143**	**0.733**	---	---	---	---	-1.000
18	-0.286	-1.000	---	-1.000	---	---	---
19	-1.000	**0.867**	---	-0.800	-1.000	---	---
20	-1.000	**0.733**	---	-0.538	---	---	-1.000
21	0.000	**0.867**	---	-0.714	---	---	-1.000
22	-1.000	**0.733**	---	-1.000	---	---	---
23	-1.000	**1.000**	-1.000	---	-1.000	-1.000	-1.000

Value shown in bold type indicate significant correlations
Values in shaded cells indicate significant negative index values

Table 22 Frequency of occurrence of herbaceous plant species in sample plots in woodlots in the Pt. Colborne area, 2001

Herb Species	Woodlot Number																					
	1	2	3	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Plots
Sensitive Fern	3	4		4					3	3			1	4		6			14	2		10
Ostrich Fern														9	1					12		3
Wood Fern							2	3	5	7	2	2	1	2	3		2		1	6	2	13
Grass		3	3	13	5	6	14	6	4	5	8	6	8			1		13			7	15
Sedge	1	2		2				4				4										5
Solomon's Seal			9						1	1	1									1	2	6
Maianthemum										1		2								10		3
False Solomon's Seal		1							8	1							2			9	1	6
Twistedstalk	6				5																	2
Jack-in-the-Pulpit		3	1	1	1	3		8	3			1				2			2	1	1	12
Woodland Strawberry	2									2		2										3
Avens sp.			9	12	2	14	1			3	14	1	2					10			7	11
Goldenrod/Aster	3		2	4		8	4	1	1	1	8	2	2		2			4		4	10	15
Large-leaved Aster			3										1									2
Aralia nudicaulis														3	1					6		3
Enchanter's Nightshade			6	2		1	1	6	5			3	2					3				9
Euonymus			2		3			1	4	1										1		6
Garlic Mustard	10	13		1	5		1	3						1		2	15					9
Jewelweed														12								1
Tall Meadow-rue		3																	2			2
Virginia Knotweed			5	8		7	1		8	7	1		2								3	9
Violet		5						1														2
Wild Geranium				3	1			3			5	1	1									6
Wood Nettle																				2		1
Spicebush															2	15						2
Freeman's Maple						2	5	1				11			1			6			6	7
Poison Ivy	4	2	2	6	2	10	1		1	3	4		6					1	2			13
Thicket Creeper	2	4	5		5	3	2			3	1			2	11	5	15		2	3	5	15
No Herbs										1			1		1							3
Number of Species	8	10	11	11	9	9	10	11	11	13	9	11	10	7	7	6	4	6	6	12	10	28

* Numbers indicate presence of species at a sample point, Maximum of 15 sample points per woodlot

Table 23. Mean percent* ground cover by herbaceous plant species in sample plots in woodlots in the Pt. Colborne area, 2001

Herb Species	Woodlot Number																					Plots
	1	2	3	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Sensitive Fern	6.34	0.53		1.33					0.40	0.46			0.07	1.33	0.00	4.32			39.67	2.00		11
Ostrich Fern														8.64	0.07					16.64		3
Wood Fern							0.13	2.66	0.87	2.99	0.47	0.47	0.07	0.47	0.20		0.73		0.13	2.28	0.13	13
Grass		2.40	1.46	16.64	3.53	0.40	17.64	2.32	0.61	0.40	7.63	6.68	5.12			0.07		20.45			3.45	15
Sedge	2.00	2.20		1.67				1.47				0.61										5
Solomon's Seal			6.66						0.07	0.07	0.07									1.33	0.27	6
Maianthemum										0.07		0.47								6.13		3
False Solomon's Seal		0.20							0.69	0.07							0.13			2.76	0.33	6
Twistedstalk	5.80				12.67																	2
Jack-in-the-Pulpit		0.26	0.07	0.07	0.07	0.20		1.60	0.20			0.07				0.13			0.27	0.07	0.07	12
Woodland Strawberry	0.47									0.13		0.53										3
Avens sp.			9.00	5.76	0.47	4.57	0.07			0.20	6.53	0.20	0.40					4.07			7.98	11
Goldenrod/Aster	1.66		1.00	1.28		0.80	1.87	0.13	0.07	0.33	4.69	1.33	1.33		0.13			0.61		1.15	14.13	15
Large-leaved Aster			2.00										1.33									2
Aralia nudicaulis														1.14	0.07					4.32		3
Enchanter's Nightshade			4.68	1.00		0.13	0.13	2.28	0.67			0.86	0.40					0.34				9
Euonymus			0.73		1.46			1.00	1.81	0.07										0.67		6
Garlic Mustard	7.67	5.37		0.33	0.93		0.33	1.34						0.33		1.67	46.70					9
Jewelweed														36.00								1
Tall Meadowrue		0.54																	1.33			2
Virginia Knotweed			5.73	4.96	0.00	0.75	0.07		1.55	1.07	0.13		1.07								0.80	10
Violet		2.47						0.07														2
Wild Geranium				2.34	0.07			1.14			2.67	0.33	0.13									6
Wood Nettle																				0.47		1
Spicebush															1.67	9.60						2
Freeman's Maple						0.20	1.07	0.13				5.50			0.07			3.68			6.68	7
Poison Ivy	2.00	0.40	0.47	4.68	0.53	1.47	0.33		0.07	0.26	1.47		16.72					0.07	0.80			13
Thicket Creeper	2.00	0.67	5.00		0.87	0.26	4.13			0.34	0.13			0.40	6.89	4.67	9.80		0.67	1.34	6.13	15
No Herbs										1			1		1							3
Number of Species	8	11	11	11	10	9	10	11	11	13	9	11	10	7	8	6	4	6	6	12	10	21

* Values calculated as arithmetic means for each species at 15 sample points per woodlot; Shading indicates >5% cover for ease of visual interpretation

Table 24. Numbers* of molluscs in litter samples collected in woodlots in the Pt Colborne area, 2001

Woodlot No.	Aquatic Molluscs				Terrestrial Molluscs							
	Clam	*Stagnicola*	*Physa*	*Gyraulis*	*Arion*	*Succinea*	*Stenotrema*	*Colchicopa*	*Zonitoides*	*Anguspira*	*Mesodon*	*Mesomphix*
1												
2												
3								1				
6	4					7						
7								5				
8					6	40			4			
9	131	26	11	1					1			
10	2											
11	2											
12					1							
13						2						
14	3					2						
15						2		1		1		
16					1		1					
17												
18					1				1		1	
19					2		1	2				1
20						1			1			
21									1			
22						1						
23						7						

*Numbers of individuals based on 15 sample points, each 0.25 m^2 in area
See Appendix 5 and text for information on species identification,

Table 25 Correlation matrix for standing litter weights and soil chemistry in samples collected at woodlots in the Pt. Colborne area, 2001

Parameter	Component of Standing Litter			
	Leaves	Twigs	Fruit	Total
Litter Composition				
Twigs	**0.4348**			
Fruit	**0.6416**	0.1285		
Total	**0.9071**	**0.7590**	**0.6007**	
Element in Soil				
Aluminum	**-0.4952**	0.1416	-0.3495	-0.2834
Antimony	**0.5739**	0.1426	**0.5931**	0.5041
Arsenic	**0.6616**	0.0772	**0.6611**	**0.5359**
Barium	-0.0168	0.2671	0.0804	0.1300
Beryllium	**-0.4154**	0.1192	-0.3101	-0.2401
Cadmium	0.4098	0.1485	**0.4834**	0.3915
Chromium	0.1046	0.2211	0.1826	0.1967
Cobalt	**0.6667**	0.0879	**0.6614**	**0.5442**
Copper	**0.6258**	0.0682	**0.5878**	**0.4989**
Iron	0.3995	0.0885	**0.5440**	0.3659
Lead	**0.6406**	0.0807	**0.6606**	**0.5249**
Manganese	**0.5397**	0.2061	**0.7136**	**0.5325**
Molybdenum	-0.3435	**0.8421**	-0.2542	0.0836
Nickel	**0.6499**	0.0777	**0.6245**	**0.5235**
Phosphorus	-0.2944	0.0522	-0.2343	-0.1879
Selenium	**0.6456**	0.0830	**0.6129**	**0.5217**
Silver	**0.7206**	**0.6531**	0.3201	**0.6829**
Titanium	0.3091	0.0503	**0.5297**	0.2912
Vanadium	-0.2710	0.0386	-0.0155	-0.1466
Zinc	**0.6025**	0.2335	**0.6595**	**0.5750**

Correlation coefficients shown in bold type face are statistically significant at P=<0.05 (0.413) and are highly significant in shaded cells P=<0.01 (0.526)

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Appendix 1. Crown condition classification system for deciduous woody plants

Rating	Description
1	Near perfect specimen tree
2	High quality forest tree with self pruning of shaded branches
3	Tree in good condition, may have 1 or two dead branches
4	Tree in fair to moderate condition with 3 or more dead branches
5	Up to one half of crown dead
6	One half to 75% of crown dead
7	75 -90% of crown dead
8	Over 90% of crown dead, some branches retaining foliage
9	Branches with few live leaves still attached
10	Tree dead (Recent, bark generally retained)

Appendix 2. Plant species found in study woodlot plots

Type	Family	Scientific Name	Common Name	Code
Fern	Dryopteridaceae	*Dryopteris carthusiana* (Villars) H.P. Fuchs	Spinulose Wood Fern	1781
Fern	Dryopteridaceae	*Matteuccia struthiopteris* (L.) Tod.	Ostrich Fern	1807
Fern	Dryopteridaceae	*Onoclea sensibilis* L.	Sensitive Fern	1808
Herb	Cruciferae	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	Garlic Mustard	795
Herb	Araliaceae	*Aralia nudicaulis* L.	Wild Sarsaparilla	199
Herb	Araceae	*Arisaema triphyllum* (L.) Schott ssp. *triphyllum*	Small Jack-in-the-pulpit	192
Herb	Asteraceae	*Aster ciliolatus* Lindley	Aster/Solidago sp,	
Herb	Asteraceae	*Aster macropherbyllus* L.	Large-leaved Aster	324
Herb	Onagraceae	*Circaea lutetiana* L. ssp. *canadensis* (L.) Aschers. & Magnus	Yellowish Enchanter's Nightshade	2872
Herb	Rosaceae	*Fragaria vesca* L. ssp. *americana* (Porter) Staudt	Woodland Strawberry	4041
Herb	Geraniaceae	*Geranium maculatum* L.	Wild Geranium	2134
Herb	Rosaceae	*Geum* sp.	Avens sp.	4045
Herb	Balsaminaceae	*Impatiens capensis* Meerb.	Spotted Touch-me-not	679
Herb	Urticaceae	*Laportea canadensis* (L.) Wedd.	Wood Nettle	4662
Herb	Liliaceae	*Maiantbemum canadense* Desf.	Wild Lily-of-the-valley	2658
Herb	Liliaceae	*Maianthemum racemosa* (L.) Link ssp. *racemosum*	False Solomon's Seal	2659
Herb	Liliaceae	*Polygonatum biflorum* (Walter) Elliot	Hairy Solomon's Seal	2669
Herb	Polygonaceae	*Polygonum virginianum* L.	Virginia Knotweed	3636
Herb	Liliaceae	*Streptopus amplexifolius* (L.) DC.	Clasping-leaved Twisted-stalk	2673
Herb	Ranunculaceae	*Thalictrum pubescens* Pursh	Tall Meadow-rue	3927
Herb	Violaceae	*Viola* sp.	Violet sp.	
Shrub	Roaceae	*Crataegus* sp.	Hawthorn sp.	3990
Shrub	Celastraceae	*Euonymus obovata* Nutt.	Running Strawberry-bush	1134
Shrub	Lauraceae	*Lindera benzoin* (L.) Blume	Spicebush	2523
Shrub	Rosaceae	*Rubus idaeus* L. ssp. *idaeus*	Red Raspberry	4168
Shrub	Caprifoliaceae	*Sambucus canadensis* L.	Common Elderberry	1029
Tree	Aceraceae	*Acer rubrum* L.	Red Maple	23
Tree	Aceraceae	*Acer rubrum* x *saccharinum*	Freeman's Maple	4979
Tree	Aceraceae	*Acer saccharinum* L.	Silver Maple	24
Tree	Aceraceae	*Acer saccharum* Marshall ssp. *saccharum*	Sugar Maple	25
Tree	Rosaceae	*Amelanchier arborea* (Michaux) Fern.	Juneberry Downy	3970
Tree	Betulaceae	*Betula alleghaniensis* Britton	Yellow Birch	700
Tree	Betlaceae	*Carpinus caroliniana* Waltr	Blue Beech	714

Appendix 2. Plant species found in study woodlot plots

Type	Family	Scientific Name	Common Name	Code
Tree	Juglandaceae	*Carya ovata* Miller) K. Koch	Shagbark Hickory	2340
Tree	Fagaceae	*Fagus grandifolia* Ehrh.	American Beech	2041
Tree	Oleaceae	*Fraxinus americana* L.	White Ash	2861
Tree	Oleaceae	*Fraxinus pennsylvanica* Marshall spp. *subintegerima*	Green Ash	2864
Tree	Oleaceae	*Fraxinus pennsylvanica* Marshall ssp. *pennsylvanica*	Red Ash	2864
Tree	Juglandaceae	*Juglans cinerea* L.	Butternut	2343
Tree	Betulaceae	*Ostrya virginiana* (Miller) K. Koch	Ironwood	717
Tree	Rosaceae	*Prunus serotina* Ehrh.	Black Cherry	4125
Tree	Rosaceae	*Prunus virginiana* L. ssp. *virginiana*	Choke Cherry	4128
Tree	Fagaceae	*Quercus macrocarpa* Michaux	Bur Oak	2046
Tree	Fagaceae	*Quercus rubra* L.	Red Oak	2051
Tree	Rhamnaceae	*Rhamnus cathartica* L.	European Buckthorn	3937
Tree	Salicaceae	*Salix amygdaloides* Andersson	Peach-leaved Willow	4257
Tree	Tiliaceae	*Tilia americana* L.	American Basswood	4609
Tree	Pinaceae	*Tsuga canadensis* (L.) Carriere	Eastern Hemlock	3268
Tree	Ulmaceae	*Ulmus americana* L.	American Elm	4632
Vine	Vitaceae	*Parthenocissus inserta* (A. Kern.) Fritsch	Thicket Creeper	4763
Vine	Anacardaceae	*Rhus radicans* L. ssp. *negundo* (E. Greene) McNeil	Poison-ivy	4829

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
1	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	24-Oct-2001
1	Golden-crowned Kinglet	Sylviidae	*Regulus calendula* (Linnaeus)	1	24-Oct-2001
1	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	8-Aug-2001
1	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	8-Aug-2001
1	Summer Azure	Lycaenidae	*Celastrina neglecta* (W.H. Edwards, 1862)	2	8-Aug-2001
1	Ringlet, Common	Nymphalidae	*Coenonympha tullia inornata* (Muller, 1764)	1	8-Aug-2001
1	Monarch	Nymphalidae	*Danaus plexippus* (Linnaeus, 1758)	4	8-Aug-2001
1	Mourning Cloak	Nymphalidae	*Nymphalis antiopa antiopa* (Linnaeus, 1758)	1	8-Aug-2001
1	Red Admiral	Nymphalidae	*Vanessa atalanta* (Linnaeus, 1758))	1	8-Aug-2001
1	Sulphur, Clouded	Pieridae	*Colias philodice philodice* Godart, [1819]	1	8-Aug-2001
1	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	1	8-Aug-2001
2	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	24-Oct-2001
2	Stick nest	NA	NA	1	24-Oct-2001
2	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	24-Oct-2001
2	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	4-Sep-2001
2	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	2	2-Nov-2001
2	Dark-eyed Junco	Emberizidae	*Junco hyemalis* (Linnaeus)	1	24-Oct-2001
2	White-throated Sparrow	Emberizidae	*Zonotrichia albicollis* (Gmelin)	1	24-Oct-2001
2	Baltimore Oriole	Icteridae	*Icterus galbula* (Linnaeus)	1	10-Aug-2001
2	Northern Mockingbird	Mimidae	*Mimus polyglottos* (Linnaeus)	1	24-Oct-2001
2	Black-capped Chickadee	Paridae	*Parus atricapillus* Linnaeus	1	10-Aug-2001
2	Downy Woodpecker	Picidae	*Picoides pubescens* (Linnaeus)	1	10-Aug-2001
2	Golden-crowned Kinglet	Sylviidae	*Regulus calendula* (Linnaeus)	1	2-Nov-2001
2	Northern Cardinal	Thraupidae	*Cardinalis cardinalis* (Linnaeus)	1	10-Aug-2001
2	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	10-Aug-2001
2	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	10-Aug-2001
2	Summer Azure	Lycaenidae	*Celastrina neglecta* (W.H. Edwards, 1862)	1	10-Aug-2001
2	Summer Azure	Lycaenidae	*Celastrina neglecta* (W.H. Edwards, 1862)	1	4-Sep-2001
2	Monarch	Nymphalidae	*Danaus plexippus* (Linnaeus, 1758)	1	10-Aug-2001

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
2	Mourning Cloak	Nymphalidae	*Nymphalis antiopa antiopa* (Linnaeus, 1758)	1	10-Aug-2001
2	Mourning Cloak	Nymphalidae	*Nymphalis antiopa antiopa* (Linnaeus, 1758)	1	24-Oct-2001
2	Northern Crescent	Nymphalidae	*Phyciodes cocyta* (Cramer, [1777])	4	4-Sep-2001
2	Fritillary, Great Spangled	Nymphalidae	*Speyeria cybele cybele* (Fabricius, 1775)	1	10-Aug-2001
2	Red Admiral	Nymphalidae	*Vanessa atalanta* (Linnaeus, 1758))	1	10-Aug-2001
2	Clouded Sulphur	Pieridae	*Colias philodice philodice* Godart, [1819]	2	10-Aug-2001
2	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	2	10-Aug-2001
2	Black Knot	Ascomycete	*Apiosporina morbosa* (Schw..Fr.) v. Arx	+	10-Aug-2001
2	Seven-spotted Lady Beetle	Coccinellidae	*Coccinella septempunctata* Linne	+	24-Oct-2001
2	Southern Lady Beetle	Coccinellidae	*Harmonia axyridis*	+	24-Oct-2001
2	Squirrel dray	Sciuridae	*Sciurus carolinensis Gemelin*	1	24-Oct-2001
2	Snake, Brown	Colubridae	*Storeria dekayi*	1	2-Nov-2001
3	American Toad	Bufonidae	*Bufo americanus americanus Le Conte*	1	17-Aug-2001
3	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	24-Oct-2001
3	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	17-Aug-2001
3	Black-capped Chickadee	Paridae	*Parus atricapillus* Linnaeus	1	17-Aug-2001
3	Golden-crowned Kinglet	Sylviidae	*Regulus calendula* (Linnaeus)	1	24-Oct-2001
3	Northern Cardinal	Thraupidae	*Cardinalis cardinalis* (Linnaeus)	1	17-Aug-2001
3	House Wren	Troglodytidae	*Troglodytes aedon* Vieillot	1	17-Aug-2001
3	Monarch	Nymphalidae	*Danaus plexippus* (Linnaeus, 1758)	1	17-Aug-2001
3	Red-spotted Purple	Nymphalidae	*Limenitis arthemis rubrofasicata* (Drury, 1773)	1	17-Aug-2001
3	Red Admiral	Nymphalidae	*Vanessa atalanta* (Linnaeus, 1758))	1	17-Aug-2001
3	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	1	17-Aug-2001
3	Fourteen-spotted Lady Beetle	Coccinellidae	*Propylea quaturodecimpunctata* (L.)	4	17-Aug-2001
3	Sedge Sprite	Coenagrionidae	*Nehalennia irene* (Hagen, 1861)	1	24-Oct-2001
6	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	24-Oct-2001
6	Turkey Vulture	Cathartidae	*Cathartes aura* (Linnaeus)	9	17-Aug-2001
6	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	24-Oct-2001
6	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	17-Aug-2001
6	Swallowtail, Black	Papilioninae	*Papilio polyxenes asterias* Fabricius, 1775	1	17-Aug-2001

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
6	Common Green Darner	Aeschnidae	*Anax junius* (Drury, 1770)	1	24-Oct-2001
7	Red-tailed Hawk	Accipitridae	*Buteo jamaicensis* (Gmelin)	1	23-Aug-2001
7	Red-tailed Hawk	Accipitridae	*Buteo jamaicensis* (Gmelin)	1	4-Sep-2001
7	Turkey Vulture	Cathartidae	Cathartes aura (Linnaeus)	2	4-Sep-2001
7	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	23-Aug-2001
7	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	4-Sep-2001
7	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	23-Aug-2001
7	American Goldfinch	Fringillidae	*Carduelis tristis* (Linnaeus)	1	23-Aug-2001
7	Baltimore Oriole	Icteridae	*Icterus galbula* (Linnaeus)	1	23-Aug-2001
7	Northern Cardinal	Thraupidae	*Cardinalis cardinalis* (Linnaeus)	1	23-Aug-2001
7	Northern Cardinal	Thraupidae	*Cardinalis cardinalis* (Linnaeus)	1	4-Sep-2001
7	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	23-Aug-2001
7	Great Crested Flycatcher	Tyrannidae	*Myiarchus crinitus* (Linnaeus)	1	23-Aug-2001
7	Red-eyed Vireo	Vireonidae	*Vireo olivaceus* (Linnaeus)	1	23-Aug-2001
7	Summer Azure	Lycaenidae	*Celastrina neglecta* (W.H. Edwards, 1862)	1	4-Sep-2001
7	Ringlet, Common	Nymphalidae	*Coenonympha tullia inornata* (Muller, 1764)	1	23-Aug-2001
7	Monarch	Nymphalidae	*Danaus plexippus* (Linnaeus, 1758)	3	4-Sep-2001
7	Monarch	Nymphalidae	*Danaus plexippus* (Linnaeus, 1758)	1	23-Aug-2001
7	Crescent, Northern	Nymphalidae	*Phyciodes cocyta* (Cramer, [1777])	20	4-Sep-2001
7	Sulphur, Clouded	Pieridae	*Colias philodice philodice* Godart, [1819]	1	4-Sep-2001
7	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	1	23-Aug-2001
7	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	4	4-Sep-2001
7	Walkingstick	Heteronemiidae	*Diapheromera femorata* (Say)	2\	23-Aug-2001
7	Raccoon	Procyonidae	*Procyon lotor (Linnaeus)*	1	4-Sep-2001
7	White-striped Black	Geometridae	*Trichodezia albovittata* (Guenee)	1	23-Aug-2001
8	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	3-Sep-2001
9	American Toad	Bufonidae	*Bufo americanus americanus Le Conte*	1	24-Aug-2001
9	Leopard frog	Ranidae	*Rana pipiens Schreber*	1	24-Aug-2001
9	Canada Goose	Anatidae	*Branta canadensis* (Linnaeus)	1	24-Aug-2001
9	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	24-Aug-2001

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
9	Common Grackle	Icteridae	*Quiscalus quiscula* (Linnaeus)	1	24-Aug-2001
9	Downy Woodpecker	Picidae	*Picoides pubescens* (Linnaeus)	1	24-Aug-2001
9	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	24-Aug-2001
10	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	24-Aug-2001
10	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	1	9-Aug-2001
11	Red-tailed Hawk	Accipitridae	*Buteo jamaicensis* (Gmelin)	1	15-Aug-2001
11	Red-tailed Hawk	Accipitridae	*Buteo jamaicensis* (Gmelin)	1	15-Aug-2001
11	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	15-Aug-2001
11	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	15-Aug-2001
11	Downy Woodpecker	Picidae	*Picoides pubescens* (Linnaeus)	1	15-Aug-2001
11	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	15-Aug-2001
11	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	15-Aug-2001
12	Wood Thrush	Turdidae	*Hylocichla mustelina* (Gmelin)	1	4-Sep-2001
12	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	4-Sep-2001
12	Fourteen-spotted Lady Beetle	Coccinellidae	*Propylea quaturodecimpunctata* (L.)	4	4-Sep-2001
13	Gray Tree Frog	Hylidiae	*Hyla versicolor* Le Conte	1	22-Aug-2001
13	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer* (Holbrook)	1	24-Oct-2001
13	Northern Harrier	Accipitridae	*Circus cyaneus* (Linnaeus)	1	2-Nov-2001
13	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	24-Oct-2001
13	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	22-Aug-2001
13	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	24-Oct-2001
13	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	22-Aug-2001
13	American Goldfinch	Fringillidae	*Carduelis tristis* (Linnaeus)	1	22-Aug-2001
13	Baltimore Oriole	Icteridae	*Icterus galbula* (Linnaeus)	1	22-Aug-2001
13	Black-capped Chickadee	Paridae	*Parus atricapillus* Linnaeus	1	22-Aug-2001
13	Hairy Woodpecker	Picidae	*Picoides villosus* (Linnaeus)	1	22-Aug-2001
13	Cedar Waxwing	Ptilogonatidae	*Bombycilla cedrorum* Vieillot	1	22-Aug-2001
13	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	24-Oct-2001
13	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	22-Aug-2001
13	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	1	22-Aug-2001

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
13	Artist's Conk	Polyporaceae	*Ganoderma applanatum* (Pers.) Pat.	1	24-Oct-2001
14	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	9-Aug-2001
14	Least Skipperling	Hesperidae	*Ancyloxypha numitor* (Fabricius, 1793)	1	9-Aug-2001
14	Monarch	Nymphalidae	*Danaus plexippus* (Linnaeus, 1758)	1	9-Aug-2001
14	Northern Crescent	Nymphalidae	*Phyciodes cocyta* (Cramer, [1777])	1	9-Aug-2001
14	Canadian Tiger Swallowtail	Papilioninae	*Papilio canadensis* Rothschild, & Jordan, 1906	1	9-Aug-2001
15	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	31-Aug-2001
15	Wood Frog	Ranidae	*Rana sylvatica Le conte*	Many	31-Aug-2001
15	Canada Goose	Anatidae	*Branta canadensis* (Linnaeus)	1	31-Aug-2001
15	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	31-Aug-2001
15	Downy Woodpecker	Picidae	*Picoides pubescens* (Linnaeus)	1	31-Aug-2001
15	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	31-Aug-2001
15	Dead Man's Fingers	Xylariaceae	*Xylaria polymorpha* (Pers. ex Mer) Grev.	1	31-Aug-2001
15	Russula	Russulaceae	*Russula* Sp.	1	31-Aug-2001
15	Fourteen-spotted Lady Beetle	Coccinellidae	*Propylea quaturodecimpunctata* (L.)	1	31-Aug-2001
15	Snake, Brown	Colubridae	*Storeria dekayi*	1	31-Aug-2001
16	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	24-Oct-2001
16	Lead-backed Salamander	Plethodontidae	*Plethodon cinereus*	1	16-Aug-2001
16	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	16-Aug-2001
16	Cedar Waxwing	Ptilogonatidae	*Bombycilla cedrorum* Vieillot	1	16-Aug-2001
16	Northern Cardinal	Thraupidae	*Cardinalis cardinalis* (Linnaeus)	1	16-Aug-2001
16	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	16-Aug-2001
16	Eastern Wood-Pewee	Tyrannidae	*Contopus virens* (Linnaeus)	1	16-Aug-2001
16	Cabbage White	Pieridae	*Pieris rapae rapae* (Linnaeus, 1758)	1	16-Aug-2001
16	White-striped Black	Geometridae	*Trichodezia albovittata* (Guenee)	1	16-Aug-2001
17	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	2-Nov-2001
17	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	4	24-Oct-2001
17	American Crow	Corvidae	*Corvus brachyrhynchos* Brehm	1	30-Aug-2001
17	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	30-Aug-2001
17	Downy Woodpecker	Picidae	*Picoides pubescens* (Linnaeus)	1	24-Oct-2001

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
17	Downy Woodpecker	Picidae	*Picoides pubescens* (Linnaeus)	1	30-Aug-2001
17	White-breasted Nuthatch	Sittidae	*Sitta carolinensis* Latham	1	24-Oct-2001
17	Northern Cardinal	Thraupidae	*Cardinalis cardinalis* (Linnaeus)	1	30-Aug-2001
17	American Robin	Turdidae	*Turdus migratorius* Linnaeus	1	24-Oct-2001
17	Red-eyed Vireo	Vireonidae	*Vireo olivaceus* (Linnaeus)	1	30-Aug-2001
17	Birch Polypore	Polyporaceae	*Piptoporus betulinus* (Bull..Fr.) Karst	1	2-Nov-2001
17	Turkey-tail	Polyporaceae	*Trametes versicolor* (Fr.) Pil.	1	2-Nov-2001
17	Pigskin Poison Puffball	Sclerodermataceae	*Scleroderma citrinum* Pers.	1	2-Nov-2001
17	Seven-spotted Lady Beetle	Coccinellidae	*Coccinella septempunctata* Linne	1	24-Oct-2001
17	Southern Lady Beetle	Coccinellidae	*Harmonia axyridis*	1	24-Oct-2001
17	Katydid	NA	NA	1	24-Oct-2001
18	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	24-Oct-2001
18	Blue Jay	Corvidae	Cyanocitta cristata (Linnaeus)	1	3-Sep-2001
18	Downy Woodpecker	Picidae	Picoides pubescens (Linnaeus)	1	24-Oct-2001
18	Ruby-crowned Kinglet	Sylviidae	Regulus satrapa Lichtensein	1	24-Oct-2001
18	Northern Cardinal	Thraupidae	Cardinalis cardinalis (Linnaeus)	1	3-Sep-2001
18	Monarch	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	1	3-Sep-2001
18	Monarch	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	1	3-Sep-2001
18	Crescent, Northern	Nymphalidae	Phyciodes cocyta (Cramer, [1777])	1	3-Sep-2001
18	Swallowtail, Black	Papilioninae	Papilio polyxenes asterias Fabricius, 1775	1	3-Sep-2001
18	Cabbage White	Pieridae	Pieris rapae rapae (Linnaeus, 1758)	1	3-Sep-2001
18	Seven-spotted Lady Beetle	Coccinellidae	Coccinella septempunctata Linne	1	3-Sep-2001
18	Seven-spotted Lady Beetle	Coccinellidae	Coccinella septempunctata Linne	1	24-Oct-2001
18	Southern Lady Beetle	Coccinellidae	Harmonia axyridis	1	24-Oct-2001
18	Gray Squirrel	Sciuridae	*Sciurus carolinensis Gemelin*	1	3-Sep-2001
18	Red Squirrel	Sciuridae	*Tamiasciurus hudsonicus (Erxleben)*	1	3-Sep-2001
18	Blackfoot Polypore	Polyporaceae	Polyporus varius Fr.	1	27-Jul-2001
19	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	30-Aug-2001
19	American Crow	Corvidae	Corvus brachyrhynchos Brehm	1	30-Aug-2001
19	American Goldfinch	Fringillidae	Carduelis tristis (Linnaeus)	1	30-Aug-2001

Appendix 3. Other species found in study woodlot plots

Woodlot	Common Name	Family	Scientific Name	Number	Date
19	American Robin	Turdidae	Turdus migratorius Linnaeus	1	30-Aug-2001
19	Mourning Cloak	Nymphalidae	Nymphalis antiopa antiopa (Linnaeus, 1758)	1	30-Aug-2001
19	Birch Polypore	Polyporaceae	Piptoporus betulinus (Bull..Fr.) Karst	1	30-Aug-2001
20	Eastern Wood-Pewee	Tyrannidae	Contopus virens (Linnaeus)	1	30-Aug-2001
20	Monarch	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	1	30-Aug-2001
20	Swallowtail, Canadian Tiger	Papilioninae	Papilio canadensis Rothschild, & Jordan, 1906	1	30-Aug-2001
20	Cabbage White	Pieridae	Pieris rapae rapae (Linnaeus, 1758)	1	30-Aug-2001
21	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	2-Nov-2001
21	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	24-Oct-2001
21	Song Sparrow	Emberizidae	Melospiza melodia (Wilson)	5	24-Oct-2001
21	Song Sparrow	Emberizidae	Melospiza melodia (Wilson)	4	2-Nov-2001
21	Black-capped Chickadee	Paridae	Parus atricapillus Linnaeus	1	24-Oct-2001
21	Eastern Wood-Pewee	Tyrannidae	Contopus virens (Linnaeus)	1	15-Aug-2001
21	Monarch	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	2	15-Aug-2001
21	Sulphur, Orange	Pieridae	Colias eurytheme Boisduval, 1852	1	24-Oct-2001
21	Cabbage White	Pieridae	Pieris rapae rapae (Linnaeus, 1758)	4	15-Aug-2001
22	American Toad	Bufonidae	*Bufo americanus americanus Le Conte*	1	22-Aug-2001
22	Spring Peeper	Hylidiae	*Pseudacris crucifer crucifer (Holbrook)*	1	22-Aug-2001
22	Wood Frog	Ranidae	*Rana sylvatica Le conte*	1	22-Aug-2001
22	Black-capped Chickadee	Paridae	Parus atricapillus Linnaeus	1	22-Aug-2001
22	Downy Woodpecker	Picidae	Picoides pubescens (Linnaeus)	1	22-Aug-2001
22	Cedar Waxwing	Ptilogonatidae	Bombycilla cedrorum Vieillot	1	22-Aug-2001
22	Monarch	Nymphalidae	Danaus plexippus (Linnaeus, 1758)	1	22-Aug-2001
22	Sulphur, Orange	Pieridae	*Colias eurytheme* Boisduval, 1852	1	22-Aug-2001
23	Green frog	Ranidae	*Rana clamitans clamitans Latreille*	1	3-Sep-2001
23	Blue Jay	Corvidae	*Cyanocitta cristata* (Linnaeus)	1	3-Sep-2001
23	Black-capped Chickadee	Paridae	*Parus atricapillus* Linnaeus	1	3-Sep-2001
23	Comma, Eastern	Nymphalidae	*Polygonia comma* (Harris,1842)	1	3-Sep-2001
23	Crayfish, Meadow	Astacidae	*Cambarus diogenes diogenes* Girard, 1852	1	3-Sep-2001

Appendix 4. Mollusc species found in study woodlot plots

Type	Family	Scientific name	Common Name
F	Planorbidae	*Gyraulus circumstriatus (Tyron, 1866)*	Flatly Coiled Gyraulus
F	Sphaeridae	*Sphaerium occidentale* (Prime, 1853)	Herrington's Fingernail Clam
F	Lymnaeidae	*Stagnicola elodes (Say, 1821)*	Common Stagnicola
F	Physidae	*Physa gyrina gyrina Say, 1821*	Tadpole Snail
L	Helicidae	*Mesodon thyroidus* (Say)	Common White-lipped Forest Snail
L	Arionidae	*Arion circumscriptus* (Johnston)	Banded Slug
L	Entodontidae	*Anguispira alternata* (Say)	Striped Forest Snail
L	Colchicopidae	*Colchicopa lubrica* (Muller)	Apple-seed Snail
L	Succineidae	*Succine*a sp,	Amber Snail
L	Zonitidae	*Mesomphix inornata* (Say)	Plain Great Zonite
L	Zonitidae	*Zonitoides nitida* (Muller)	Shining Zonite Snail

F = Freshwater species
L = Terrestrial Species

Appendix 5. Ecological Land Classification descriptions for woodlots sampled in the Port Colborne area, 2001

Woodlot	General Soil Type	ELC Community Unit	Code
1	Mineral	Fresh-Moist- Oak-Maple-Hickory Deciduppous Forest Ecosite	FOD9
2	Mineral	White Elm Mineral Deciduous Swamp Ecosite	SWD4-2
3	Mineral	Fresh-Moist Lowland Deciduous Forest Ecosite	FOD7
6	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3
7	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3
8	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3
9	Mineral	Ash Mineral Deciduous Swamp Ecosite	SWD2
10	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3-4
11	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3
12	Mineral	Maple Mineral Deciduous Swamp Ecosite	FOD6
13	Mineral	Ash Mineral Deciduous Swamp Type	SWD2
14	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3
15	Mineral	Maple Mineral Deciduous Swamp Ecosite	SWD3
16	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3
17	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3
18	Organic	Deciduous swamp	SWD
19	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3
20	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3
21	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3
22	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3
23	Organic	Swamp Maple Organic Deciduous Swamp Type	SWD6-3

Classification based on soil and vegetation community characteristics from vegetation records, tree abundance, tree basal area measurements, and litter composition data.
Codes and descriptions follow Lee *et al*. [111]

Appendix 6. Location of study woodlots in the Port Colborne area, 2001

Woodlot	General Location	Zone	Easting	Northing	Error	Municipality	Date Established
1	Elizaeth Street south of Hwy 3	17	644017	4750715	6.3	City of Port Colborne	8-Aug-2001
2	Lorraine Road south or railroad	17	645962	4749781	8.9	City of Port Colborne	10-Aug-2001
3	Northeast side Hwy 3 at Hwy 140	17	644303	4751414	19.2	City of Port Colborne	17-Aug-2001
6	Miller Road between railroad and Kilally	17	647488	4750139	10.1	City of Port Colborne	14-Aug-2001
7	Between Weaver Rd and Miller Rd south of railroad	17	646914	4749631	5.9	City of Port Colborne	23-Aug-2001
8	East side of Miller Road south of railroad	17	647527	4749373	11.3	City of Port Colborne	8-Sep-2001
9	West side of Carl Road south of Concession 2	17	646441	4752276	7.7	City of Port Colborne	24-Aug-2001
10	Concession 2 East of Carl Road	17	647072	4752515	14.7	City of Port Colborne	9-Aug-2001
11	East Side of Overholt Road Wainfleet	17	634843	4755114	11.2	Wainfleet	15-Aug-2001
12	West Side of Overholt Road Wainfleet	17	634745	4755154	6.4	Wainfleet	4-Sep-2001
13	Station Road south of landfill	17	632543	4748492	15.8	Wainfleet	22-Aug-2001
14	8309 Carl Road (Niagara Falls)	17	651823	4765148	11.7	City of Niagara Falls	9-Aug-2001
15	Crowland Road north of Schisler Road	17	651422	4763489	12.0	City of Niagara Falls	30-Aug-2001
16	Reuter Road South forest block	17	644593	4748720	7.7	City of Port Colborne	16-Aug-2001
17	Reuter Road Middle forest block	17	644594	4749107	4.5	City of Port Colborne	30-Aug-2001
18	Reuter Road North forest block	17	644648	4749289	11.3	City of Port Colborne	26-Jul-2001
19	Forest between Snider and Lorraine Road	17	645250	4749292	7.1	City of Port Colborne	30-Aug-2001
20	Brookfield Road in Humberstone marsh	17	649997	4753264	8.7	City of Port Colborne	16-Aug-2001
21	South end of Michael Road, Sherkston property	17	651582	4748956	11.9	City of Port Colborne	15-Aug-2001
22	Willoughby Marsh South of Sauer Road	17	655037	4761259	6.9	City of Niagara Falls	29-Aug-2001
23	Willoughby Marsh North of Sauer Road	17	654982	4761382	12.3	City of Niagara Falls	3-Sep-2001

UTM Reading made with GPS set to NAD 83
Error = FOM measurement on GPS

ECOTOXICITY EVALUATION OF SOILS FOR A SITE-SPECIFIC ECOLOGICAL RISK ASSESSMENT

DRAFT REPORT: PHASE ONE

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Appendix A – Results of the Ecotoxicity Evaluation of Soils for a Site-specific Ecological Risk Assessment Phase 1: Acute Testing

Appendix B – Results of the Ecotoxicity Evaluation of Soils for a Site-specific Ecological Risk Assessment Phase 1: Chronic Testing

1. INTRODUCTION

In July 2001, ESG International was contracted by Jacques Whitford Environmental Ltd. (JWEL) to provide an ecotoxicity assessment of site soils contaminated with a mixture of metals. The soils originated from an area in south-central Ontario from a site undergoing an ecological risk assessment by Jacques Whitford Environmental Ltd. The goal of the assessment is to provide quantitative earthworm toxicity data that can be incorporated into an Ecological Risk Assessment (ERA). Representative soil samples were collected by JWEL and were received by ESG International Inc., 361 Southgate Dr., Guelph, ON, N1G 3M5. The clayey and organic surface soils on the site were historically contaminated by atmospheric deposition of metals (predominantly nickel, lead and iron) from a refinery operation in the vicinity.

The testing comprises two components: Phase 1 tests involved the testing of the four undiluted site soils and one experimental control soil (a field-collected, clay-loam reference soil [RS]); and, Phase 2 involved dilution tests from which ECxs (effect concentrations) of the site soils can be derived. Both Phase 1 and Phase 2 are further divided into tests of short (acute) (e.g. Phase 1, Part A) and longer (chronic) duration (Phase 1, Part B). Phase 2 will be completed only if significant toxicity of the soil samples is observed during Phase 1 acute testing. This report presents data obtained from the acute and chronic (Parts A and B) tests of Phase 1.

The soils were received by ESG on August 21, 2001. Upon arrival at ESG's Southgate Laboratory, the soil samples (e.g. 40-L buckets) were assigned identification numbers and were entered into a log book (Table A.1; Appendix A). Soil from four sites was received: organic soil with background metal concentrations; organic soil contaminated with metals at high concentrations; clay soil with background metal levels; and clay soils contaminated with metals at high levels. The samples were denoted as org-con, org-Ni, clay-con and clay-Ni, respectively.

The experimental control soil was a field-collected reference soil, a clay loam (RS). This reference soil was a black chernozem from Alberta. The reference soil had been characterized and found to be free of contaminants. The physico-chemical characteristics of the experimental control soil are listed in Table A.2 (Appendix A).

The objective of this research was to determine if the metal-contaminated organic and clay soils had similar ecotoxicity to the organic and clay soils with background metal levels, respectively. The experimental control soil provided QA/QC data on test organism health and experimental conditions.

2. SAMPLE PREPARATION

After receiving the soils from JWEL, they were stored at room temperature (20 ± 2°C) until use. Prior to testing, the soil samples were examined to determine if sieving or homogenization were necessary. Sieving and homogenization were not essential to test soil preparation for any of the samples. The soil moisture content of each soil was determined prior to testing. Testing started on August 29, 2001.

3. PHASE 1 (PART A): ACUTE TOXICITY TO *EISENIA ANDREI*

3.1 Experimental Design and Conditions

The experimental design and conditions of the test were as follows:

- Test type was static acute;
- 14-day duration;
- Test endpoint: adult survivorship
- Constant 20 ± 2°C temperature; and,
- Continuous fluorescent illumination (24-h).

Soils used were reference soil (RS), organic background soil (org-con), organic contaminated soil (org-Ni), clay background soil (clay-con) and clay contaminated soil (clay-Ni).

Test units consisted of 500-mL, wide-mouthed glass mason jars filled with 270 to 295 g soil wet weight (w.w.) of test soil. Mass of soil added per test unit varied depending on the bulk density of the soil. Jars were covered with perforated tin foil held by a metal screw ring to facilitate gas exchange for the earthworms. The experimental control soil treatment (RS) consisted of 6 replicate test units. Each site-soil treatment (org-con, org-Ni, clay-con, clay-Ni) had 6 replicate test units. Five adult earthworms were added to each test unit.

Methods and procedures for site soil amendment are described in detail elsewhere (EC, 1998).

3.2 Soil Preparation

On Day 0, the site and control soils were prepared on a dry weight basis, but were adjusted to compensate for differences in bulk density in the various soils. Because of the different water-holding capacities among the test soils, the moisture content of the soils ranged from 26 to 65 %. Physico-chemical soil parameters such as pH, electrical conductivity and moisture content were measured following test soil preparation and at the end of the test (Table A.3; Appendix A).

On Day 0, five clitillate *Eisenia andrei* were added to each test unit and the soils in the test units were misted gently with deionized water as necessary. Substantially more water was added to the test units of the clay background soil treatment after the earthworms were added to the test units, as compared to the other soil treatments. The extremely clayey nature of the soil precluded the addition of the required volume of deionized water while homogenizing the soil, therefore the majority of the water was added at the same time as the addition of the earthworms.

3.3 Statistical Analyses

Analysis of variance (ANOVA) procedures were applied to the data to determine if there were significant treatment effects. The assumptions of the analytical models were tested; the data and residuals were examined for normality and for heteroscedasticity (e.g., homogeneity of variance among treatments). All analyses were performed with SYSTAT 7.0.1 (SPSS, 1997).

3.4 Results

On Day 7, each test unit was inspected to determine the number and condition of surviving *E. andrei*. Only one death occurred in each of two of the treatments, and all surviving worms appeared healthy (Table A.4, Figure A.1; Appendix A).

On Day 14, each test unit was inspected again to determine the number and condition of surviving *E. andrei*. In total, four deaths occurred among the treatments (2 following 7 days of exposure, 2 following 14 days of exposure). However when the data were subjected to an ANOVA, no significant effect of soil treatment was observed, and all surviving worms appeared healthy (Table A.4, Figure A.1; Appendix A). Soil pH, electrical conductivity and soil moisture content were measured and compared between the reference soil, organic background soil, organic contaminated soil, clay background soil and clay contaminated soil. Soil pH was comparable among the soils, and in general was highest in the clay site soils, lowest in the reference soil, and intermediate in the organic site soils. Soil electrical conductivity in general was comparable among the site soils, which was almost double the conductivity in the reference soil (Table A.3; Appendix A).

4. PHASE 1 (PART B): CHRONIC TOXICITY TO *EISENIA ANDREI*

4.1 Experimental Design and Conditions

The experimental design and conditions of the test were as follows:

- Test type was static acute;
- 63-day duration;
- Test endpoints: adult 35-d survivorship, 63-d juvenile production, juvenile wet mass, juvenile dry mass, number of hatched, and number of unhatched cocooons;
- Constant 20 ± 2°C temperature; and,
- Continuous fluorescent illumination (24-h).

Soils used were reference soil (RS), organic background soil (org-con), organic contaminated soil (org-Ni), clay background soil (clay-con) and clay contaminated soil (clay-Ni).

Test units consisted of 500-mL, wide-mouthed glass mason jars filled with 270 to 295 g soil wet weight (w.w.) of test soil. Mass of soil added per test unit varied depending on the bulk density of the soil. Jars were covered with perforated tin foil held by a metal screw ring to facilitate gas exchange for the earthworms. The experimental control soil treatment (RS) consisted of 10 replicate test units. Each site-soil treatment (org-con, org-Ni, clay-con, clay-Ni) had 10 replicate test units. Two reproductively mature (clitellated) earthworms were added to each test unit.

Methods and procedures for site soil amendment are described in detail in EC, 1998.

4.2 Soil Preparation

On Day 0, the site and control soils were prepared on a dry weight basis, but were adjusted to compensate for differences in bulk density in the various soils. Because of the different water-holding capacities among the test soils, the moisture content of the soils ranged from 35 to 65 %. Physico-chemical soil parameters such as pH, electrical conductivity and moisture content were measured following test soil preparation and at the end of the test (Table B.1; Appendix B).

On Day 0, two clitillate *Eisenia andrei* were added to each test unit and the soils in the test units were misted gently with deionized water as necessary. Substantially more water was added to the test units of the clay background soil treatment after the earthworms were added to the test units, as compared to the other soil treatments. The extremely clayey nature of the soil precluded the addition of the required volume of deionized water while homogenizing the soil, therefore the majority of the water was added at the same time as the addition of the earthworms.

4.3 Statistical Analyses

Analysis of variance (ANOVA) procedures were applied to the data to determine differences among treatment means. The assumptions of the analytical models were tested; the data and residuals were examined for normality and for heteroscedasticity (e.g., homogeneity of variance among treatments). Pairwise comparison tests (Least Significant Difference) were also conducted following the analyses of variance. All analyses were performed with SYSTAT 7.0.1 (SPSS, 1997).

4.4 Results

On Day 35, each test unit was inspected to determine the number and condition of surviving adult *Eisenia andrei*. There were no statistically significant differences in adult mortality following 35-d of exposure to the site soils. All surviving worms appeared healthy, and performance criteria (< 30% mortality in controls) were met.(Table B.2, Figure B.1; Appendix B).

On Day 63, each test unit was inspected again to determine the number of juveniles, juvenile wet and dry mass, and number of hatched and unhatched cocoons. No significant differences were found in the number of unhatched cocoons among the different soil treatments (Table B.3, Figure B.2, Appendix B). However, for all other endpoints, there were significant differences attributable to soil treatment. There were significantly fewer juveniles and hatched cocoons found in the contaminated clay soil (clay-Ni) as compared to all other soil types, including the clay background soil (clay-con). The wet and dry masses of juveniles exposed to the contaminated clay soil were also significantly decreased compared to all other soil treatments. Juvenile wet mass from the clay background soil treatment was, however, significantly greater than that derived from all other soil treatments, and juvenile dry mass was significantly greater than that derived from all soil treatments except contaminated organic soil (org-Ni). No significant differences in reproduction metrics were found between the contaminated and background organic soil treatments (Table B.3, Figure B.2, Appendix B).

Soil pH, electrical conductivity and soil moisture content were measured and compared between the reference soil, organic background soil, organic contaminated soil, clay background soil and clay contaminated soil. Soil pH was comparable among the soils, and in general was highest in the clay site soils, lowest in the reference soil, and intermediate in the organic site soils. Soil electrical conductivity in general was comparable among the site soils, which was almost double the conductivity in the reference soil, particulary at the end of the 63-day test (Table B.1; Appendix B). It is worth noting, however, that the electrical conductivity and soil pH in the clay background soil (clay-con) were slightly more moderate as compared to the other soils (higher pH, lower conductivity). The slight difference might have contributed to the reproductive success of *Eisenia andrei* exposed to the clay background soil.

5. DISCUSSION

The results of the acute screening tests for Phase 1 indicate that the site soils were not acutely toxic to earthworms. Therefore the testing program advanced to Part B of Phase 1. Part B comprised the chronic test with the undiluted site and control soils with the earthworm species *Eisenia andrei*. Following the 63-d reproduction test, chronic toxicity to *E. andrei* occurred in the contaminated clay soil. The contaminated organic soil was not found to be chronically toxic to *E. andrei*. Therefore it is recommended that the testing program advance to Phase 2, chronic dilution testing, with the clay-contaminated site soil only.

Natalie Feisthauer, Project Manager

Gladys Stephenson, Project Director

6. REFERENCES

Environment Canada. 1998. Development of Earthworm Toxicity Tests for Assessment of Contaminated Soils. Prepared by Aquaterra Environmental for the Method Development and Application Division, Technology Development Directorate, Environment Canada, Ottawa, Ontario, pp. 52 (Appendices).

SPSS. 1997. SYSTAT 7.0.1. for Windows. SPSS Inc. 7/97, Standard Version. Chicago, Illinois, USA.

Appendix A

Results of the Ecotoxicity Evaluation of Soils for a Site-specific Ecological Risk Assessment
Phase 1: Acute Testing

Table A.1. Identification and description of the Ontario site soils received from Jacques Whitford Environmental Limited.

Sample	Date Received	Assigned Sample Identification	Observations
Organic background 40L Worm Study	8/21/01	G1378-org-con	Sieved, well homogenized dark, rich soil
Organic Ni 40L Worm Study	8/21/01	G1378-org-Ni	Sieved, well homogenized dark, rich soil
Welland background 40L pH adjusted July 13/01	8/21/01	G1378-clay-con	Sieved, well homogenized, very dry, clayey soil, light grey
Welland Ni 40L Worm Study	8/21/01	G1378-clay-Ni	Sieved, well homogenized, dark rich soil

Table A.2. Physico-chemical characteristics of the reference control soil.

Parameter	Alberta Clay Loam (RS)	Analytical Method
Phosphorous (mg/kg)	12	Nitric/perchloric acid digestion
Potassium (mg/kg)	748	NH4Ac extractable
Magnesium (mg/kg)	553	NH4Ac extractable
Calcium (mg/kg)	5127	NH4Ac extractable
Sodium (mg/kg)	57	NH4Ac extractable
Sodium Absorption	0.42	
Total Carbon (%)	6.83	Leco furnace method
Total Nitrogen (%)	0.59	Kjeldahl method
C.E.C. (Cmol+/kg)	34.5	Barium chloride method
Soil Texture	Clay Loam	Gravimetric grain size distribution
Sand (%)	26.6	
Silt (%)	43.3	
Clay (%)	30.1	
Organic Matter (%)	12.8	Dichromate oxidation
Bulk Density (g/cm^3)	0.83	Clod method
pH (units)	6.05	Water method (1:2)
Conductivity (mS/cm)	1.52	Saturated paste method
Source	Field-collected from Alberta	

C.E.C. Cation Exchange Capacity

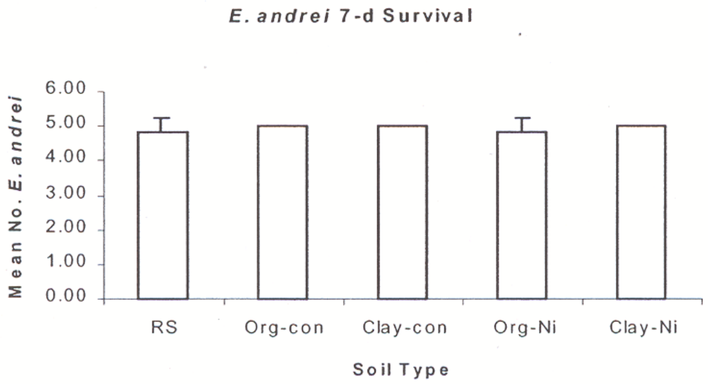
Table A.3. Physico-chemical characteristics of treatment soils from the Phase 1 acute *Eisenia andrei* test following test preparation and processing.

Soil	Initial pH[1]	Final pH[2]	Initial Conductivity (µS/m)	Final Conductivity (µS/cm)	Initial Moisture Content (%)	Final Moisture Content (%)
RS	5.63	5.64	364	408	64.28	64.99
Org-con	5.84	5.87	712	772	*	37.60
Clay-con	6.60	5.91	430	726	26.33**	66.29
Org-Ni	5.97	5.64	709	749	35.99	35.71
Clay-Ni	6.28	6.06	685	767	56.85	57.11

[1] measured at the beginning of the test (t=0 d)
[2] measured at the end of the test (t=14 d)
*sample measurement was unreliable
**deionized water was added after soil m.c. measurements were taken at the beginning of the test (see Section 3.2)

Table A.4. **7- and 14-day survival of *Eisenia andrei* exposed to soil treatment. Each test unit contains 5 adult earthworms (n=30 per treatment).**

Soil	Day 7	Day 14
	Number of surviving *E. andrei* per treatment	Number of surviving *E. andrei* per treatment
RS	29	28
Org-con	30	29
Clay-con	30	30
Org-Ni	29	29
Clay-Ni	30	30



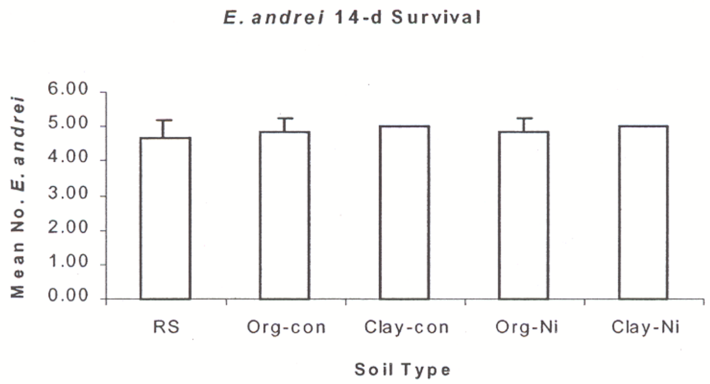


Figure A.1. 7- and 14-day survival of *Eisenia andrei* exposed to treatment soils. Columns represent mean number of *E. andrei* per treatment (n= 30) and error bars indicate one standard deviation.

APPENDIX B

RESULTS OF THE ECOTOXICITY EVALUATION OF SOILS FOR A SITE-SPECIFIC ECOLOGICAL RISK ASSESSMENT
PHASE 1: CHRONIC TESTING

Table B.1. Physico-chemical characteristics of treatment soils from the Phase 1 definitive *Eisenia andrei* test following test preparation and processing.

Soil	Initial pH[1]	Final pH[2]	Initial Conductivity (µS/m)	Final Conductivity (µS/cm)	Initial Moisture Content (%)	Final Moisture Content (%)
RS	5.64	5.61	371	354	34.75	33.60
Org-con	5.84	5.58	652	732	60.57	61.96
Clay-con	6.55	6.04	472	532	30.59	35.42
Org-Ni	6.00	5.95	617	628	64.79	65.49
Clay-Ni	6.21	5.95	625	746	43.14	44.45

[1] measured at the beginning of the test (t=0 d)
[2] measured at the end of the test (t=14 d)

Table B.2. 35-day survival of adult *Eisenia andrei* exposed to soil treatment. Each test unit contains 2 adult earthworms (n=20 per treatment).

Soil	Day 35 Number of surviving *E. andrei* per treatment
RS	18
Org-con	18
Clay-con	20
Org-Ni	19
Clay-Ni	19

Table B.3. Effect of soil treatment on *Eisenia andrei* reproduction following 63 days of exposure to site and experimental control soils. Values in brackets indicate standard deviation.

Soil	Number of Juveniles	Juvenile Wet Mass (g)	Juvenile Dry Mass (g)	Number of Hatched Cocoons	Number of Unhatched Cocoons
RS	19.5 (5.7)	0.39 (0.17)	0.078 (0.034)	4.3 (2.8)	0.5 (1.0)
Org-con	22.8 (11.7)	0.46 (0.26)	0.077 (0.049)	4.8 (3.2)	0.9 (1.3)
Clay-con	28.0 (13.8)	0.72 (0.35)	0.144 (0.066)	4.0 (2.8)	0.6 (0.8)
Org-Ni	21.6 (11.0)	0.51 (0.27)	0.088 (0.049)	3.2 (2.2)	0.9 (0.7)
Clay-Ni	0.40 (0.7)	0.01 (0.006)	0.001 (0.001)	0.2 (0.4)	0.9 (1.7)

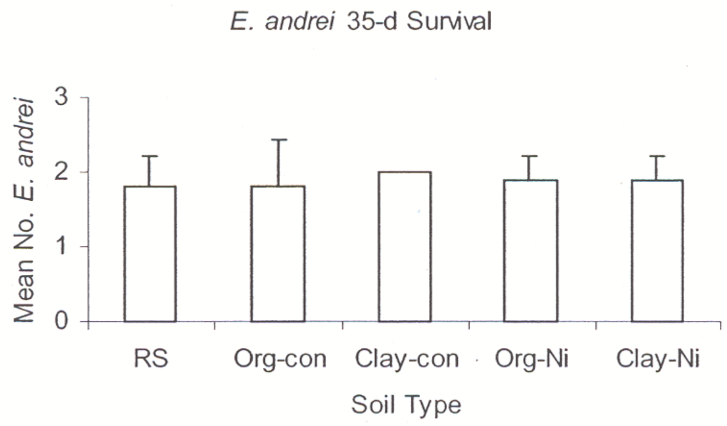


Figure B.1. 35-day survival of *Eisenia andrei* adults exposed to treatment soils. Columns represent mean number of *E. andrei* per treatment (n= 20) and error bars indicate one standard deviation.

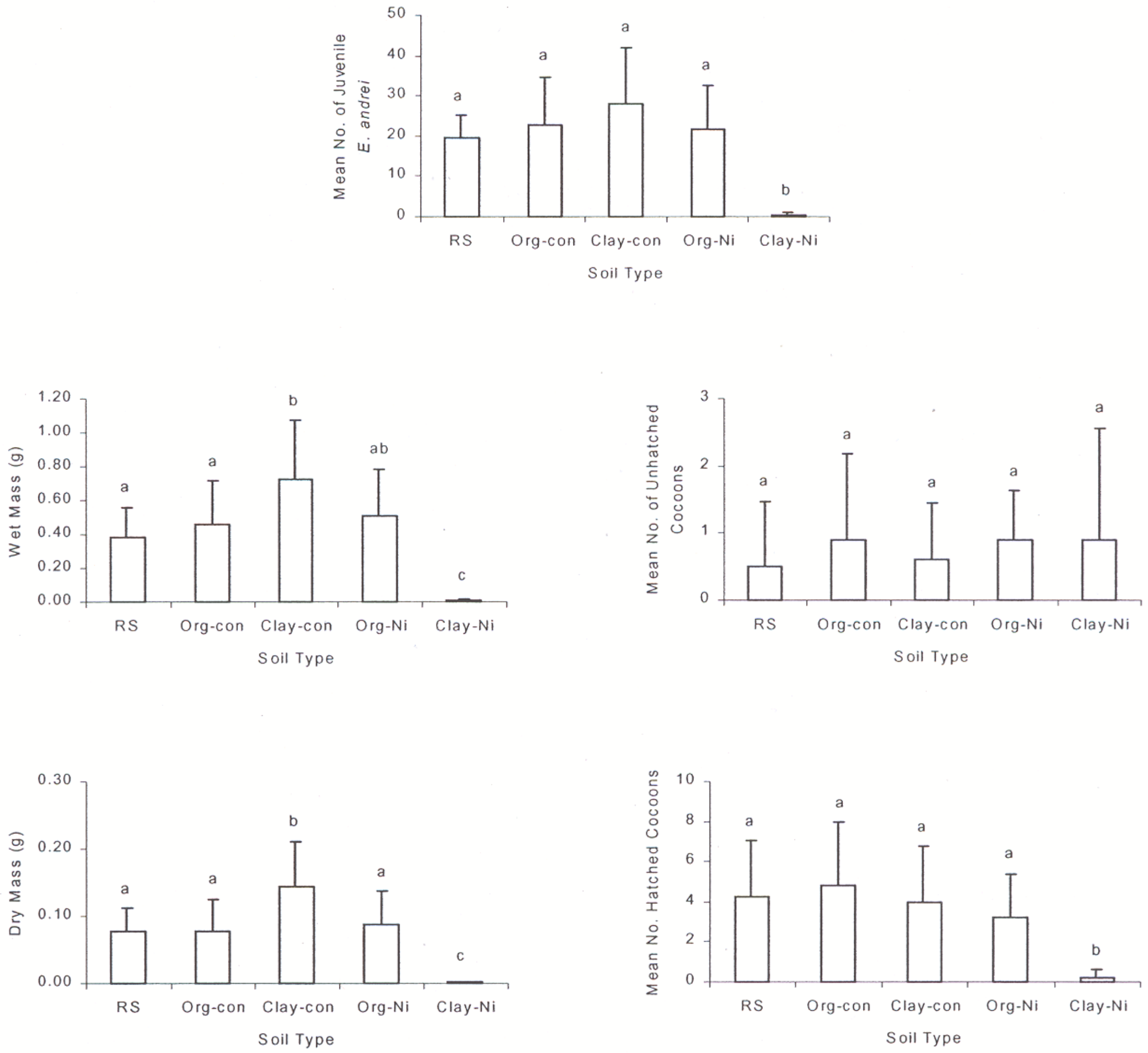


Figure B.2. Effect of soil treatment on *Eisenia andrei* reproduction following 63 days of exposure. Columns represent mean values and error bars indicate one standard deviation. Letters indicate significant differences among treatments.

ECOTOXICITY EVALUATION OF SOILS FOR A SITE-SPECIFIC ECOLOGICAL RISK ASSESSMENT

RESULTS FROM PHASE 2: ACUTE AND CHRONIC TESTING

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Acute testing with diluted organic site soil – page 3

Chronic testing with diluted organic site soil – pages 4-8

Chronic testing with diluted clay site soil – pages 9-12

Description of statistical analyses – page 13

Table 1. Physico-chemical characteristics of treatment soils from the Phase 2 acute and chronic *Eisenia andrei* tests following test preparation and processing.

Soil	Initial pH[1]	Final pH[2]	Initial[1] Conductivity (µS/m)	Final[2] Conductivity (µS/cm)	Initial[1] Moisture Content (%)	Final[2] Moisture Content (%)
Acute Organic Test						
RS	5.35	5.42	412	463	35.7	35.7
0	5.7	5.67	610	740	63.5	64.5
5	5.77	5.72	617	711	62.9	63.9
12	5.79	5.74	626	690	64.1	64.8
25	5.8	5.78	563	664	65.6	65.8
50	5.78	5.73	561	669	67.0	67.0
80	5.74	5.67	501	614	69.0	69.4
100	5.65	5.56	414	537	72.8	35.7
Chronic Organic Test						
RS	5.49	5.52	386	332	35.4	34.8
0	5.76	5.57	594	677	62.7	63.8
5	5.78	5.7	583	764	62.8	64.2
12	5.81	5.75	577	702	63.9	65.0
25	5.81	5.79	520	638	64.7	65.1
50	5.78	5.78	511	640	66.6	*
80	5.73	5.79	457	548	68.5	68.8
100	5.73	5.77	308	425	72.6	71.8
Chronic Clay Test						
RS	5.61	5.5	396	379	35.2	34.0
0	5.87	5.34	250	524	34.1**	35.2
5	5.56	5.27	377	542	34.3**	34.5
12	5.67	5.39	374	549	35.4**	35.2
25	5.79	5.56	432	606	35.5**	36.6
50	5.86	5.75	527	609	39.3**	40.3
80	5.95	5.9	524	631	41.8**	43.2
100	6.01	6.03	608	628	44.1**	43.6

[1] measured at the beginning of the test (t=0 d)
[2] measured at the end of the test (t=14 or 63d)
*sample measurement was unreliable
**because of the nature of the clay soils, deionized water was added after soil moisture content measurements were taken at the beginning of the test

Table 2. Acute *Eisenia andrei* survival following 7 and 14 days of exposure to contaminated organic site soil diluted with uncontaminated organic reference control site soil.

Concentration	7-day Exposure		14-day Exposure	
(% contaminated soil)	Mean Number of Adults	Standard Error	Mean Number of Adults	Standard Error
RS	5	0	5	0
0	5	0	5	0
5	5	0	5	0
12	5	0	5	0
25	5	0	5	0
50	5	0	5	0
80	5	0	5	0
100	5	0	5	0

RS Experimental control soil, which is a clay loam soil

Table 3. Chronic *Eisenia andrei* (adult) survival following 35 days of exposure to contaminated organic site soil diluted with uncontaminated organic reference control soil.

Concentration. (% contaminated soil)	Mean Number of Adults (n=20)	Standard Error	Significant Differences?
RS	2.00	0	No
0	2.00	0	No
5	2.00	0	No
12	2.00	0	No
25	2.00	0	No
50	2.00	0	No
80	2.00	0	No
100	2.00	0	No

RS Experimental control soil, which is a clay loam soil

Table 4. Effect of exposure to contaminated organic site soil diluted with uncontaminated organic reference control soil on *Eisenia andrei* reproduction following 63 days of exposure. Values are means expressed as percent of contaminated soil.

Concentration (% contaminated soil)	No. Juveniles	Standard Error	No. Unhatched Cocoons	Standard Error	No. Hatched Cocoons	Standard Error	Wet Mass (g)	Standard Error	Dry Mass (g)	Standard Error
RS	20.40	2.48	1.70	0.73	3.40	0.87	0.62	0.10	0.13	0.02
0	28.50	5.94	1.70	0.33	5.60	1.07	0.62	0.10	0.11	0.02
5	23.10	2.88	2.20	0.66	3.60	0.73	0.46	0.06	0.08	0.01
12	16.80	2.21	1.30	0.65	3.80	0.49	0.57	0.06	0.10	0.01
25	22.20	1.82	0.90	0.18	4.40	1.11	0.45	0.05	0.08	0.01
50	15.70	1.81	0.90	0.23	2.50	0.45	0.16	0.01	0.03	0.00
80	7.60	1.19	1.10	0.41	0.90	0.41	0.07	0.01	0.01	0.002
100	0	0	0.90	0.55	0.40	0.22	N/A	N/A	N/A	N/A

RS Experimental control soil, which is a clay loam soil

N/A Data not applicable

Table 5. Summary of the results of regression analyses of the *E. andrei* reproduction test conducted with the contaminated organic soil diluted with uncontaminated organic reference control site soil. Values are expressed as percent of contaminated soil.

Soil	Endpoint	Parameter	Model	EC_{50} (% contamin. soil)	LCL	UCL	EC_{20} (% contamin. soil)	LCL	UCL	W?
Organic	Juveniles	Number	Linear	53.79	43.89	63.69	21.51	17.55	25.47	No
		Wet Mass	Logistic	39.12	28.72	49.53	25.72	14.31	37.12	No
		Dry Mass	Logistic	37.92	27.11	48.72	24.84	13.26	36.43	No
	Cocoons	Hatched	Linear	52.87	40.39	65.36	21.15	16.15	26.14	No
		Unhatched	Hormesis	71.00	< 0	240.03	16.66	< 0	48.39	No

LCL Lower confidence limit

UCL Upper confidence limit

W? Indicates if data has been weighted

Table 6. Summary of the results of the analyses of variance of the *E. andrei* reproduction test conducted with the contaminated organic soil diluted with uncontaminated organic reference control site soil. Values are expressed as percent of contaminated soil.

Soil	Endpoint	Parameter	Analysis	Sig. Factor Effect? ($p<0.05$)	Pairwise Comparison Test	NOEC (% contam. soil)	LOEC (% contam. soil)	Data Transformed?
Organic	Juveniles	Number	ANOVA	Yes	Dunnett's	25*	50*	No
		Wet Mass	ANOVA	Yes	Dunnett's	25	50	No
		Dry Mass	ANOVA	Yes	Dunnett's	25	50	No
	Cocoons	Hatched	ANOVA	Yes	Dunnett's	25	50	No
		Unhatched	ANOVA	No	Dunnett's	N/A	N/A	No

LOEC Lowest Observed Effect Concentration (values of the lowest concentration significantly different from those of zero)

NOEC No Observed Effect Concentration (highest concentration of which the values are not significantly different from zero)

*The number of juveniles at 12%, 50, 80 and 100 % was significantly different from the control, but the number at 25% was not.

N/A Data not applicable

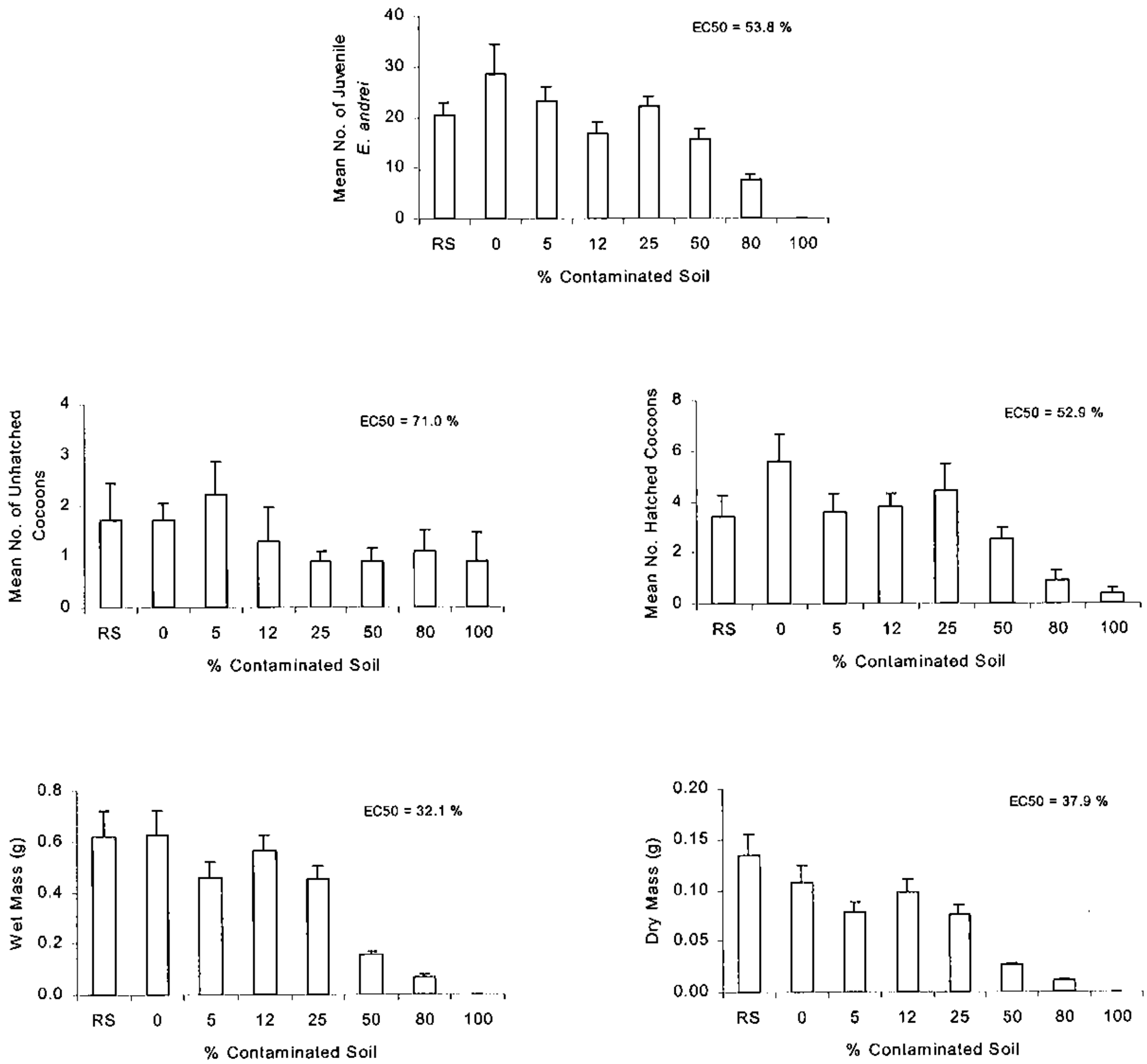

Figure 1. *Eisenia andrei* reproduction following 63 days of exposure to contaminated organic site soil diluted with an uncontaminated organic reference control site soil. RS is the experimental control soil. Columns represent mean values and error bars indicate one standard error.

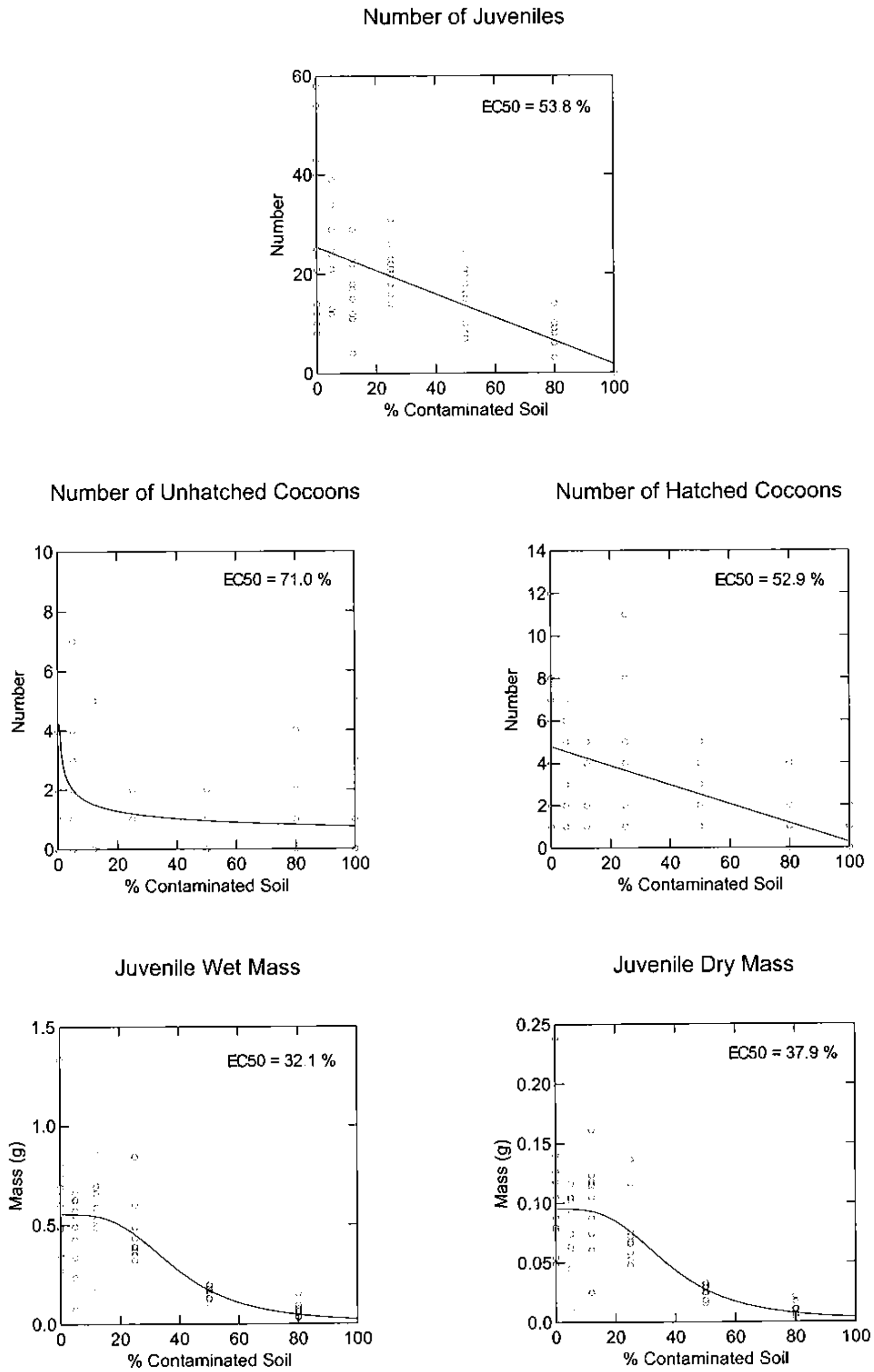

Figure 2. Results of exposure to contaminated organic site soil diluted with uncontaminated organic reference control site soil on *Eisenia andrei* reproduction following 63 days of exposure. Data were subjected to regression analyses.

Table 7. Chronic *Eisenia andrei* (adult) survival following 35 days of exposure to contaminated clay site soil diluted with uncontaminated clay reference control site soil.

Concentration. (% contaminated soil)	Mean Number of Adults (n=20)	Standard Error	Significant Differences?
RS	2.00	0.00	No
0	1.50	0.50	No
5	1.80	0.30	No
12	1.50	0.50	No
25	1.70	0.34	No
50	1.90	0.22	No
80	1.60	0.37	No
100	1.90	0.22	No

RS Experimental control soil, which is a clay loam soil

Table 8. Effect of exposure to contaminated clay site soil diluted with uncontaminated clay reference control site soil on *Eisenia andrei* reproduction following 63 days of exposure. Values are means expressed as percent of contaminated soil.

Concentration (% contaminated soil)	No. Juveniles	Standard Error	No. Unhatched Cocoons	Standard Error	No. Hatched Cocoons	Standard Error	Wet Mass (g)	Standard Error	Dry Mass (g)	Standard Error
RS	8.78	2.00	1.11	0.19	2.89	0.68	0.31	0.05	0.06	0.01
0	7.00	1.21	0.30	0.15	1.00	0.42	0.21	0.04	0.04	0.01
5	4.70	1.23	0.40	0.22	0.60	0.34	0.09	0.03	0.02	0.005
12	4.80	1.13	1.20	0.47	0.70	0.40	0.09	0.02	0.02	0.004
25	0.80	0.55	1.00	0.37	0	0	0.03	0.01	0.01	0.002
50	0.10	0.10	1.00	0.39	0.10	0.10	0.004	0.001	0.001	0
80	0	0	0.60	0.31	0	0	N/A	N/A	N/A	N/A
100	0.20	0.13	0.60	0.27	0	0	0.02	N/A	0.01	0.003

RS Experimental control soil, which is a clay loam soil

N/A Data not applicable

Table 9. Summary of the results of regression analyses of the *E. andrei* reproduction test conducted with contaminated clay soil diluted with uncontaminated clay reference control site soil. Values are expressed as percent of contaminated soil.

Soil	Endpoint	Parameter	Model	EC_{50} (% contamin. soil)	LCL	UCL	EC_{20} (% contamin. soil)	LCL	UCL	W?
Clay	Juveniles	Number	Gompertz	15.44	8.94	21.94	8.45	1.38	15.52	No
		Wet Mass	Gompertz	4.54	< 0	12.53	0.37	< 0	2.25	No
		Dry Mass	Gompertz	4.44	< 0	12.74	0.36	< 0	2.36	No
	Cocoons	Hatched	Gompertz	16.73	< 0	36.99	13.01	< 0	27.70	No
		Unhatched	Hormesis	> 100	N/A	N/A	> 100	N/A	N/A	No

N/A Data not applicable
LCL Lower confidence limit
UCL Upper confidence limit
W? Indicates if data has been weighted

Table 10. Summary of the results of the analyses of variance of the *E. andrei* reproduction test conducted with the contaminated clay soil diluted with uncontaminated clay reference control site soil. Values are expressed as percent of contaminated soil.

Soil	Endpoint	Parameter	Analysis	Sig. Factor Effect? ($p<0.05$)	Pairwise Comparison Test	NOEC (% contam. soil)	LOEC (% contam. soil)	Data Transformed?
Clay	Juveniles	Number	ANOVA	Yes	Dunnett's	12	25	No
		Wet Mass	ANOVA	Yes	Dunnett's	0	5	No
		Dry Mass	ANOVA	Yes	Dunnett's	0*	5*	No
	Cocoons	Hatched	ANOVA	Yes	Dunnett's	12**	25**	No
		Unhatched	ANOVA	No	Dunnett's	N/A	N/A	No

LOEC Lowest Observed Effect Concentration (values of the lowest concentration significantly different from those of zero)
NOEC No Observed Effect Concentration (highest concentration of which the values are not significantly different from zero)
N/A Data not applicable
*The dry mass from all concentrations was significantly different from the control, except for the highest (100%).
**The number of hatched cocoons at 50% was not significantly different from the control, but the numbers at 25, 80 and 100% were.

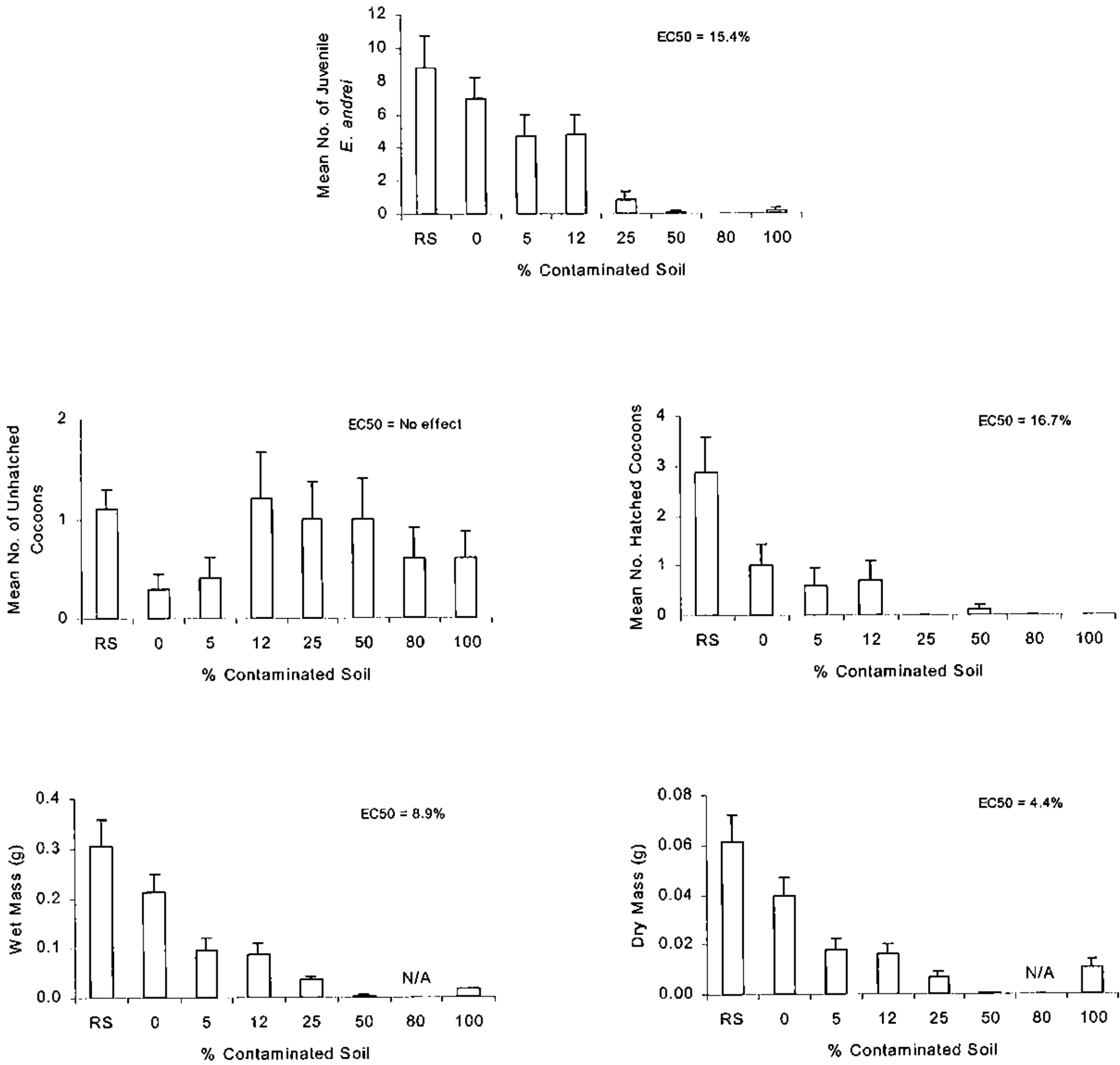

Figure 3. *Eisenia andrei* reproduction following 63 days of exposure to contaminated clay site soil diluted with an uncontaminated clay reference control site soil. RS is the experimental control soil. Columns represent mean values and error bars indicate one standard error.

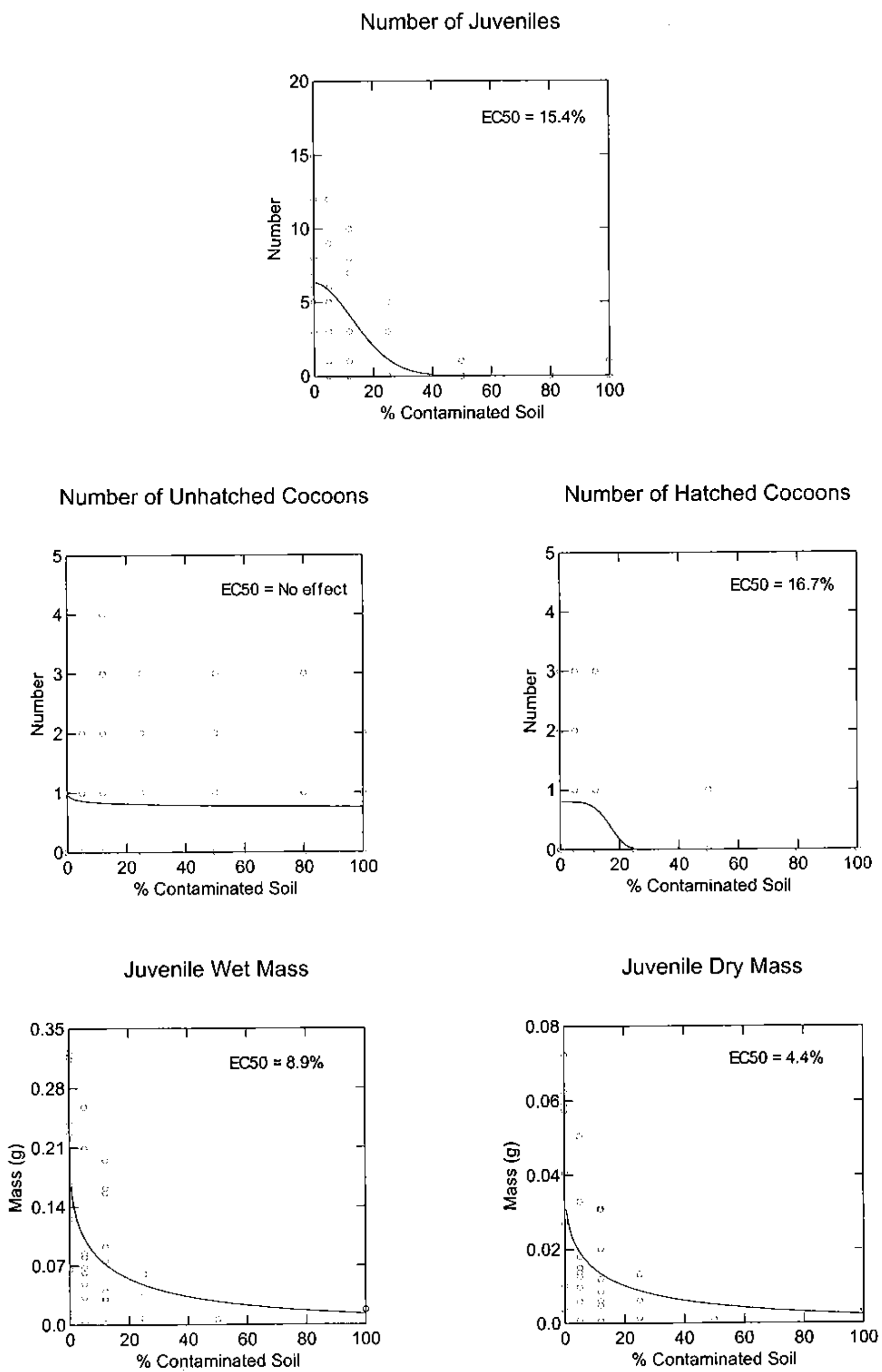

Figure 4. Results of exposure to contaminated clay site soil diluted with uncontaminated clay reference control site soil on *Eisenia andrei* reproduction following 63 days of exposure. Data were subjected to regression analyses.

Statistical Analyses

The results of 14-d earthworm acute mortality tests are normally entered manually into data spreadsheets, graphed, and analyzed using the Probit, the Moving Average, and the Trimmed Spearman-Karber methods of analysis (Stephan, 1989). However, as there was no mortality among any of the treatments in the acute test conducted with the contaminated organic site soil, statistical analyses were not required.

The results of the chronic earthworm tests (both with the clay and organic-contaminated soils) were analyzed by applying linear, or nonlinear regression procedures to the earthworm reproductive data after the data were entered into electronic spreadsheets. The analyses consisted of using a linear or four nonlinear regression models (i.e. logistic, gompertz, exponential and logistic with hormesis; where c = % contaminated soil) that had been re-parameterized to include the ECx and the associated 95% confidence limits. The ECx is the effect concentration (EC) resulting in a specified percentage (x) effect. The residuals were examined for homogeneity of variance among treatments. If data showed heteroscedasticity among treatments, data were weighted with the inverse of the variance of each treatment (Myers, 1986; Stephenson *et al.*, 2000). Analyses of variance procedures were applied to the data and a two-tailed Dunnett's test was used to compare each treatment mean to the mean of the control treatment. The Dunnett's pairwise comparison test was used to determine the NOEC (no observable effect concentration) and LOEC (lowest observable effect concentration) values (SPSS, 1997). 35-day adult survival data were analyzed using analysis of variance procedures followed by a two-tailed Dunnett's and a Fisher's protected Least Significant Difference pairwise comparison tests. All analyses were performed with SYSTAT 7.0.1 (SPSS, 1997). A more detailed description of the statistical procedures used to analyze earthworm test data can be found in either Environment Canada (1998) or Stephenson *et al.* (2000).

Environment Canada. 1998. Development of Earthworm Toxicity Tests for Assessment of Contaminated Soils. Prepared for Method Development and Application Division, Technology Development Directorate, Environment Canada, Ottawa, Ontario, 52 p. (Appendices).

Myers, R.H. 1986. "Classical and Modern Regression with Applications." Prindle, Weber and Schmidt Publishers, Massachusetts, CN, 359 p.

SPSS. 1997. SYSTAT 7.0.1. for Windows. SPSS Inc. 7/97, Standard Version. Chicago, Illinois, USA.

Stephen, C.E. 1989. "Software to Calculate LC50 Values with Confidence Intervals using Probit, Moving Averages, and Spearman-Karber Procedures". Modified by R.G. Clements and M.C. Harraass. U.S. Environmental Protection Agency, Duluth, Minnesota.

Stephenson, G.L., Koper, N., Atkinson, G.F., Solomon, K.R. and Scroggins, R.P. 2000. Use of nonlinear regression techniques for describing concentration-response relationships for plant species exposed to contaminated site soil. Environmental Toxicology and Chemistry, 19(12):229-242.

ADULT 35 DAY REPRODUCTION ON ORGANIC SOIL

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Acute *E. andrei* test
Set-up Date: 05-Mar-02
7-Day Check: 12-Mar-02
Process Date: 19-Mar-02
Species: *Eisenia andrei*
Soil Type: organic field-collected soil
Notes: RS is experimental control soil

Conc. (%)	Rep	7-day chk No. alive	14-d process No. alive
RS	1	5	5
RS	2	5	5
RS	3	5	5
RS	4	5	5
RS	5	5	5
RS	6	5	5
0	1	5	5
0	2	5	5
0	3	5	5
0	4	5	5
0	5	5	5
0	6	5	5
5	1	5	5
5	2	5	5
5	3	5	5
5	4	5	5
5	5	5	5
5	6	5	5
12	1	5	5
12	2	5	5
12	3	5	5
12	4	5	5
12	5	5	5
12	6	5	5
25	1	5	5
25	2	5	5
25	3	5	5
25	4	5	5
25	5	5	5
25	6	5	5
50	1	5	5
50	2	5	5
50	3	5	5
50	4	5	5
50	5	5	5
50	6	5	5
80	1	5	5
80	2	5	5
80	3	5	5
80	4	5	5
80	5	5	5
80	6	5	5

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Acute *E. andrei* test
Set-up Date: 05-Mar-02
7-Day Check: 12-Mar-02
Process Date: 19-Mar-02
Species: *Eisenia andrei*
Soil Type: organic field-collected soil
Notes: RS is experimental control soil

Conc. (%)	Rep	7-day chk No. alive	14-d process No. alive
100	1	5	5
100	2	5	5
100	3	5	5
100	4	5	5
100	5	5	5
100	6	5	5

RESULTS OF 35 DAY REPRODUCTION ON ORGANIC SOIL

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 7 2002
35-d Adult Removal March 14 2002
Process Date: (63-d) April 11 2002
Species: *Eisenia andrei*
Soil Type: RS, organic-Ni contam diluted with organic control soil
Notes: RS is experimental control soil

Soil	Rep	35-Day No. alive adults	Comments c = cocoons, j = juveniles
RS	1	2	c,j
RS	2	2	j
RS	3	2	c
RS	4	2	
RS	5	2	c
RS	6	2	c
RS	7	2	c
RS	8	2	c
RS	9	2	c
RS	10	2	j
0	1	2	c
0	2	2	j
0	3	2	j
0	4	2	c
0	5	2	c
0	6	2	c,j
0	7	2	c,j
0	8	2	c,j
0	9	2	c
0	10	2	c,j
5	1	2	c
5	2	2	c,j
5	3	2	c,j
5	4	2	c,j
5	5	2	c
5	6	2	c
5	7	2	c,j
5	8	2	c
5	9	2	c,j
5	10	2	j
12	1	2	c
12	2	2	c
12	3	2	c,j
12	4	2	c,j
12	5	2	c,j
12	6	2	c
12	7	2	c
12	8	2	c,j
12	9	2	c,j
12	10	2	c,j
25	1	2	c,j

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 7 2002
35-d Adult Removal March 14 2002
Process Date: (63-d) April 11 2002
Species: *Eisenia andrei*
Soil Type: RS, organic-Ni contam diluted with organic control soil
Notes: RS is experimental control soil

Soil	Rep	35-Day No. alive adults	Comments c = cocoons, j = juveniles
25	2	2	,cj
25	3	2	c
25	4	2	c
25	5	2	c
25	6	2	c
25	7	2	c,j
25	8	2	c,j
25	9	2	c,j
25	10	2	c,j
50	1	2	c,j
50	2	2	c
50	3	2	c
50	4	2	j
50	5	2	
50	6	2	c
50	7	2	
50	8	2	c,j
50	9	2	
50	10	2	
80	1	2	c
80	2	2	
80	3	2	c
80	4	2	
80	5	2	
80	6	2	c,j
80	7	2	j
80	8	2	c
80	9	2	j
80	10	2	
100	1	2	
100	2	2	
100	3	2	
100	4	2	
100	5	2	
100	6	2	c
100	7	2	c
100	8	2	
100	9	2	
100	10	2	

ADULT 35 DAY REPRODUCTION ON CLAY

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 7 2002
35-d Adult Removal: March 14 2002
Process Date: (63-d) April 11 2002
Species: *Eisenia andrei*
Soil Type: RS, organic-Ni contam diluted with organic control soil
Notes: RS is experimental control soil

Soil (% contam)	Rep	No. Alive Juveniles	No. Full Cocoons	No. Empty Cocoons	Boat weight (g)	Boat + wet weight (g)	Boat + dry weigh (g)	Wet Mass (g)	Dry Mass (g)
RS	1	23	3	1	0.9553	2.0347	1.1939	1.0794	0.2386
RS	2	18	0	1	0.9499	1.8724	1.1450	0.9225	0.1951
RS	3	19	1	2	0.9527	1.3868	1.0498	0.4341	0.0971
RS	4	19	1	4	0.9546	1.4047	1.0442	0.4501	0.0896
RS	5	33	0	4	0.9513	1.7182	1.1212	0.7669	0.1699
RS	6	29	4	10	0.9496	1.8488	1.1364	0.8992	0.1868
RS	7	8	0	2	0.9550	1.3500	1.0535	0.3950	0.0985
RS	8	9	7	1	0.9523	1.0936	0.9820	0.1413	0.0297
RS	9	21	0	5	0.9460	1.3078	1.0336	0.3618	0.0876
RS	10	25	1	4	0.9483	1.7232	1.1022	0.7749	0.1539
0	1	10	1	4	0.9594	1.4399	1.0472	0.4805	0.0878
0	2	58	2	12	0.9611	2.2973	1.1992	1.3362	0.2381
0	3	54	2	7	0.9586	1.7038	1.0987	0.7452	0.1401
0	4	21	2	7	0.9591	1.6477	1.064	0.6886	0.1049
0	5	8	2	2	0.9592	1.2316	1.0082	0.2724	0.0490
0	6	25	1	1	0.9576	1.4372	1.0350	0.4796	0.0774
0	7	12	2	2	0.9580	1.3055	1.0125	0.3475	0.0545
0	8	40	0	8	0.9556	1.5567	1.0732	0.6011	0.1176
0	9	14	4	7	0.9556	1.4455	1.0352	0.4899	0.0796
0	10	43	1	6	0.9518	1.7558	1.0785	0.8040	0.1267
5	1	13	7	2	0.9540	1.2904	1.0159	0.3364	0.0619
5	2	24	2	5	0.9503	1.5727	1.0666	0.6224	0.1163
5	3	25	2	6	0.9484	1.5194	1.0526	0.5710	0.1042
5	4	34	4	7	0.9577	1.5062	1.0518	0.5485	0.0941
5	5	39	1	2	0.9508	1.4415	1.0250	0.4907	0.0742
5	6	12	0	1	0.9559	1.0290	0.9665	0.0731	0.0106
5	7	21	1	3	0.9549	1.6119	1.0599	0.6570	0.1050
5	8	21	3	5	0.9539	1.1881	0.9989	0.2342	0.0450
5	9	29	0	5	0.9546	1.5813	1.0570	0.6267	0.1024
5	10	13	2	0	0.9536	1.3781	1.0171	0.4245	0.0635
12	1	22	1	4	0.9550	1.6435	1.0785	0.6885	0.1235
12	2	18	0	5	0.9538	1.5676	1.0589	0.6138	0.1051
12	3	11	5	5	0.9514	1.5367	1.0656	0.5853	0.1142
12	4	17	2	2	0.9519	1.6495	1.0677	0.6976	0.1158
12	5	29	0	5	0.9546	1.8114	1.1158	0.8568	0.1612
12	6	4	0	1	0.9546	1.1203	0.9796	0.1657	0.0250
12	7	12	5	5	0.9564	1.4434	1.0307	0.4870	0.0743
12	8	15	0	4	0.9568	1.4805	1.0441	0.5237	0.0873

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 7 2002
35-d Adult Removal: March 14 2002
Process Date: (63-d) April 11 2002
Species: *Eisenia andrei*
Soil Type: RS, organic-Ni contam diluted with organic control soil
Notes: RS is experimental control soil

Soil (% contam)	Rep	No. Alive Juveniles	No. Full Cocoons	No. Empty Cocoons	Boat weight (g)	Boat + wet weight (g)	Boat + dry weigh (g)	Wet Mass (g)	Dry Mass (g)
12	9	17	0	2	0.9599	1.3592	1.0205	0.3993	0.0606
12	10	23	0	5	0.9629	1.6212	1.0808	0.6583	0.1179
25	1	31	1	11	0.9607	1.3109	1.0264	0.3502	0.0657
25	2	31	0	5	0.9585	1.3231	1.0305	0.3646	0.0720
25	3	21	2	4	0.9615	1.8040	1.0979	0.8425	0.1364
25	4	20	1	8	0.9547	1.3451	1.0210	0.3904	0.0663
25	5	26	1	1	0.9603	1.3461	1.0186	0.3858	0.0583
25	6	14	1	2	0.9588	1.3904	1.0062	0.4316	0.0474
25	7	16	1	2	0.9531	1.2747	1.0210	0.3216	0.0679
25	8	23	0	1	0.9535	1.3288	1.0057	0.3753	0.0522
25	9	18	1	2	0.9594	1.4477	1.0346	0.4883	0.0752
25	10	22	1	8	0.9562	1.5532	1.0724	0.5970	0.1162
50	1	24	1	1	0.9588	1.1538	0.9903	0.1950	0.0315
50	2	15	2	2	0.9532	1.1318	0.9861	0.1786	0.0329
50	3	8	2	2	0.9524	1.0583	0.9706	0.1059	0.0182
50	4	20	1	5	0.9530	1.1135	0.9830	0.1605	0.0300
50	5	10	0	2	0.9583	1.1573	0.9877	0.1990	0.0294
50	6	21	1	3	0.9623	1.0878	0.9869	0.1255	0.0246
50	7	7	1	1	0.9610	1.1292	0.9767	0.1682	0.0157
50	8	18	0	4	0.9560	1.1047	0.9840	0.1487	0.0280
50	9	18	0	1	0.9490	1.1244	0.9744	0.1754	0.0254
50	10	16	1	4	0.9501	1.0806	0.9735	0.1305	0.0234
80	1	10	0	1	0.9512	1.0314	0.9614	0.0802	0.0102
80	2	9	0	1	0.9560	1.0176	0.9669	0.0616	0.0109
80	3	10	2	4	0.9527	1.0202	0.9643	0.0675	0.0116
80	4	3	0	1	0.9559	0.9900	0.9614	0.0341	0.0055
80	5	3	0	0	0.9509	1.0085	0.9592	0.0576	0.0083
80	6	10	1	0	0.9494	1.1026	0.9716	0.1532	0.0222
80	7	14	1	0	0.9506	1.0440	0.9675	0.0934	0.0169
80	8	8	1	0	0.9553	0.9918	0.9617	0.0365	0.0064
80	9	3	4	2	0.9506	0.9788	0.9543	0.0282	0.0037
80	10	6	2	0	0.9524	1.0268	0.9631	0.0744	0.0107
100	1	0	0	1	*				
100	2	0	5	0	*				
100	3	0	0	0	*				
100	4	0	0	0	*				
100	5	0	0	2	*				

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 7 2002
35-d Adult Removal: March 14 2002
Process Date: (63-d) April 11 2002
Species: *Eisenia andrei*
Soil Type: RS, organic-Ni contam diluted with organic control soil
Notes: RS is experimental control soil

Soil (% contam)	**Rep**	No. Alive Juveniles	No. Full Cocoons	No. Empty Cocoons	Boat weight (g)	Boat + wet weight (g)	Boat + dry weigh (g)	Wet Mass (g)	Dry Mass (g)
100	6	0	1	0	*				
100	7	0	3	1	*				
100	8	0	0	0	*				
100	9	0	0	0	*				
100	10	0	0	0	*				

*no weight data were entered as there were no juveniles

RESULTS OF 35 DAY REPRODUCTION ON CLAY

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 5 2002
35-d Adult Removal March 12 2002
Process Date: (63-d) April 9 2002
Species: *Eisenia andrei*
Soil Type: RS, heavy clay-Ni contam diluted with heavy clay control soil
Notes: RS is experimental control soil

Soil	Rep	35-Day No. alive adults	Comments c = cocoons, j = juveniles
RS	1	2	c
RS	2	2	c
RS	3	2	c
RS	4	2	
RS	5	2	c
RS	6	2	c
RS	7	2	j
RS	8	2	
RS	9	2	j
RS	10	2	j
0	1	0	1 dead*, moisture content good
0	2	2	c
0	3	2	c
0	4	2	c
0	5	2	c
0	6	1	1 dead, c
0	7	1	1 dead, c
0	8	2	c
0	9	2	
0	10	1	j
5	1	2	c
5	2	1	1 dead
5	3	2	nematodes
5	4	1	1 dead, c
5	5	2	
5	6	2	c
5	7	2	
5	8	2	
5	9	2	
5	10	2	c
12	1	2	
12	2	1	c
12	3	2	c
12	4	2	
12	5	2	
12	6	2	
12	7	1	1 dead, c
12	8	1	1 dead
12	9	0	
12	10	2	
25	1	1	

Test: Ecotoxicity testing: Jacques-Whitford: Phase 2 Chronic *E. andrei* test
Set-up Date: February 5 2002
35-d Adult Removal March 12 2002
Process Date: (63-d) April 9 2002
Species: *Eisenia andrei*
Soil Type: RS, heavy clay-Ni contam diluted with heavy clay control soil
Notes: RS is experimental control soil

Soil	Rep	35-Day No. alive adults	Comments c = cocoons, j = juveniles
25	2	2	
25	3	2	c
25	4	1	
25	5	2	c
25	6	2	c
25	7	2	c
25	8	1	
25	9	2	
25	10	2	
50	1	2	
50	2	2	c
50	3	2	
50	4	2	
50	5	1	c
50	6	2	
50	7	2	
50	8	2	
50	9	2	c
50	10	2	
80	1	1	
80	2	2	
80	3	1	1 dead
80	4	2	
80	5	1	1 dead
80	6	2	c
80	7	2	
80	8	2	
80	9	1	
80	10	2	
100	1	2	
100	2	2	j
100	3	2	c
100	4	2	
100	5	2	
100	6	2	
100	7	2	
100	8	1	
100	9	2	
100	10	2	c

*the significance of seeing a dead worm, as opposed to a worm missing, is that the death was recent

Port Colborne Community Based Risk Assessment

Woodlot Health Assessment Study

Prepared by:

TREES UNLIMITED
FORESTRY CONSULTANT

Prepared for:
Jacques Whitford Environment Limited
&
Inco Limited, Port Colborne Refinery

November 2002

METHODS

Eighteen woodlots were identified within the Primary Study Area (PSA). If necessary, woodlots were partitioned into compartments. Criteria to divide a woodlot into compartments include different species composition, age, and structure along with past management and ownership considerations. A total of 32 compartments were identified within the 18 woodlots, totaling 231.7 hectares (572.6 acres). Access was granted to 25 primary study area compartments (PSAC) within the PSA, totaling 160.3 ha (396.2 ac). Six control woodlots were identified outside the PSA, totaling 79.6 ha (196.8 ac). Selection of the control woodlots was based on the Ecological Land Classification, access and geographic location. The 6 control woodlots were partitioned into seven control compartments (CTLC). Access was granted to six of the seven compartments. The Ecological Land Classification system developed for southern Ontario (Lee et. al. 1998) was used to describe each of the compartments within the PSA and the Control area. Cruise lines and plot centres were laid out for each of the compartments using 1994 Region of Niagara aerial photographs at a scale of 1:5000. Plot centres were established to provide a random sample of at least one plot per hectare. Appendix A contains a copy of the data sheet used in the inventory.

Basal area (BA), percent acceptable growing stock (AGS) and unacceptable growing stock (UGS), tree species diversity, stocking and mean stand diameter were all developed using the Tree Tally section of the data sheet. At plot centres, trees which were determined to be “in”, using the basal area factor 2 m^2/ha prism, were tallied according to size class , species, and quality. Six size classes were used; saplings (4-8cm), polewood (12-28cm), small sawlogs (30-36cm), medium sawlogs (38-48cm), large sawlogs (50-60cm), and oversized or extra-large sawlogs (>60-cm). Each tree determined to be “in” was measured at breast height (1.4m) using a caliper or diameter tape. Tree quality or AGS and UGS were determined using standard forestry guidelines (OMNR 1990). BA was determined by dividing the total number of trees tallied in each size and species class by the total number of plots inventoried then multiplied by the basal area factor of 2 to produce a ratio measured in m^2/ha. A BA measure was produced for the compartment as a whole, each of the size classes, quality, and each of the species present.

Stocking was estimated using the basal area measurements and the Mean Stand Diameter (MSD). To determine the mean stand diameter, the mid-point diameter of each size class is multiplied by the number of trees tallied in each size class. Totals for each size class are then added together then divided by the total number of trees tallied for the compartment. This number is the MSD in centimeters. The MSD and the total BA are then applied to a stocking guide for the forest type and a stocking percentage is obtained (OMNR 1990). To determine stocking numbers for the total compartment and the different size classes, the BA for each size class was divided by the mid-point stem area for each size class resulting in a value in stems/ha. The individual size class stocking numbers were added for a total stocking in stems/ha.

Compartment age was measured by using an increment borer to produce a wood core which was visually analyzed to determine age by counting rings. The core was taken at breast height and 10 years was added to the ring count to compensate for taking the core 1.4 m off the ground. In most compartments an ash, either white or green, was cored along with another tree to produce an average age. The ash cores from woodlots along a northeast transect from the INCO refinery stack were sent for laboratory analysis for Chemicals of Concern (CoCs).

Wildlife trees were also inventoried using the 2 m^2/ha basal area factor prism. Cavity trees, in which a living tree had a “usable” cavity, were tallied with the prism. Snags, which are standing or leaning dead trees which were at least 2m above the ground, were also tallied with the prism. Downed Woody Debris (DWD), which is dead wood on the ground was also tallied with the prism. A basal area measure, in m^2/ha, was established for each of the three wildlife tree habitat types and for the total wildlife trees.

Tree species regeneration was inventoried within a 5 m radius plot around the plot centre. Within the plot, tree species were tallied according to a series of 4 “cover codes”. Cover code 1 represented 1-10% of the plot covered with the species in question. Cover code 2 is 11-25%, cover code 3 is 26-60% and cover code 4 is >60%. Each tree species tally was multiplied by the cover code number, added together then divided by the total points to develop a percent composition for each species present.

Shrubs, vines, and herbaceous vegetation were also recorded within the 5 m radius plot. This is strictly a measure of the presence of a particular species. The total number of shrub and vine species for each compartment was produced.

Management and disturbance was measured using the Management/Disturbance table taken from the guide to Ecological Land Classification for Southern Ontario (Lee et. al. 1998). The table records the intensity and the extent of a number of disturbances. Livestock, alien species, recreational use, access trails, dumping, earth displacement, time since logging, intensity and extent of logging, gaps in forest canopy, disease/death of trees, windthrow, browse, seasonal flooding and ice damage were the disturbances measured. Intensity is measured as; 0 points = None, 1 point = light, 2 points = moderate, and 3 points = heavy. Extent of disturbance is measured as; 0 points = none, 1 point = local, 2 points = widespread, and 3 points = extensive. Intensity points were multiplied by the extent points to produce a point total for each type of disturbance. Each disturbance point total was added to produce a grand total for each compartment.

The diameter (cm) of the largest tree found in each plot was also recorded.

In each compartment a qualitative assessment of roots, trunks, crowns, presence of diseases, tree health and regeneration was determined. Additionally, maximum tree height and average canopy height in metres were determined using a clinometer.

Any other notes and a silvicultural prescription were also recorded at the time of inventory.

The data generated was analyzed without transformation to produce means, medians, standard deviations, variances, and standard errors for each of the parameters measured. Percent AGS was arcsine transformed to aid in analysis. Variances were analyzed with an *F*-test to be certain that the variances were homogenous. If the variances were found to be homogenous then a *t*-test was used to compare means.

RESULTS AND DISCUSSION

A summary of the data set is provided in Appendix B. A series of photographs are presented in Appendix C.

Stand Structure

Basal Area

Mean basal area measurements for the PSAC, CTLC and the Total Study Area are given in Table 1. Mean basal area for the PSAC (28.3 m^2/ha) and the CTLC (28.9 m^2/ha) were found to be not significantly different from each other. Within the Total Study Area, the PSAC, and the CTLC, the basal area ranged from 21.3 in compartment 01B to 37.6 in 18C. This range was the same for the PSAC. In the CTLC, the BA range was from 26.0 in C2A to 34.0 in C1A.

Table 1. Mean Basal Area and Stocking by Study Area.

Mean Basal Area and Stocking ± Std. Error		
Study Area	Basal Area (m^2/ha)	Stocking (stems/ha)
PSAC	28.3 ± 1.1	1110 ± 112
CTLC	28.9 ± 1.5	903 ± 185
Total Study Area	28.4 ± 0.9	1070 ± 97

In Table 2 and Charts 1 and 2, we see that the overall mean BA for both the PSAC and CTLC is higher than the BA targets for any of the management objectives derived from the *Silvicultual Guide for Southern Ontario* (OMNR, 2000). Management targets are 1) Maximizing Sawlog Production (Sawlog), 2) Developing Old-Growth Structural Characteristics (Dev. O-G) and 3) Maintaining Old-Growth Structural Characteristics (Main. O-G). Mean PSAC and CTLC BA levels are also well above the Region Of Niagara's Tree Conservation Bylaw 20 m^2/ha standard for residual BA after a harvesting operation (Regional Niagara 1996). All individual PSACs and CTLCs have basal areas above the minimum standard for the Regional Bylaw and for Maximizing Sawlog Production. However, there are some individual PSACs and CTLCs that are below the "Developing Old-Growth" and "Maintaining Old-Growth" targets. Only compartment 16A (27.7 m^2/ha) has had a recent harvest operation.

Table 2. Mean Primary Study Area and Control Woodlots Basal Area (m^2/ha) and Recommended OMNR Target Basal Area Managing for Sawlogs, Developing Old-Growth Characteristics and Maintaining Old-Growth Characteristics in Site Region 7E (OMNR 2000).

Mean Primary Study Area and Control Woodlots Basal Area (m^2/ha)									
PSAC					CTLC				
Size Classes	Woodlot	Sawlog	Dev. O-G	Main. O-G	Size Classes	Control	Sawlog	Dev. O-G	Main. O-G
Saplings	2.4	1	1	1	Saplings	1.7	1	1	1
Poles	11.6	5	7	8	Poles	10.7	5	7	8
Sm. Sawlog	4.8	4	5	5	Sm. Sawlog	6.5	4	5	5
Med. Sawlog	5.7	5	5	6	Med. Sawlog	6.0	5	5	6
Lg. Sawlog	2.4	4	4	5	Lg. Sawlog	2.4	4	4	5
X-Lg. Sawlog	1.3	2	3	3	X-Lg. Sawlog	1.7	2	3	3
Total	28.3	21	25	28	Total	28.9	21	25	28

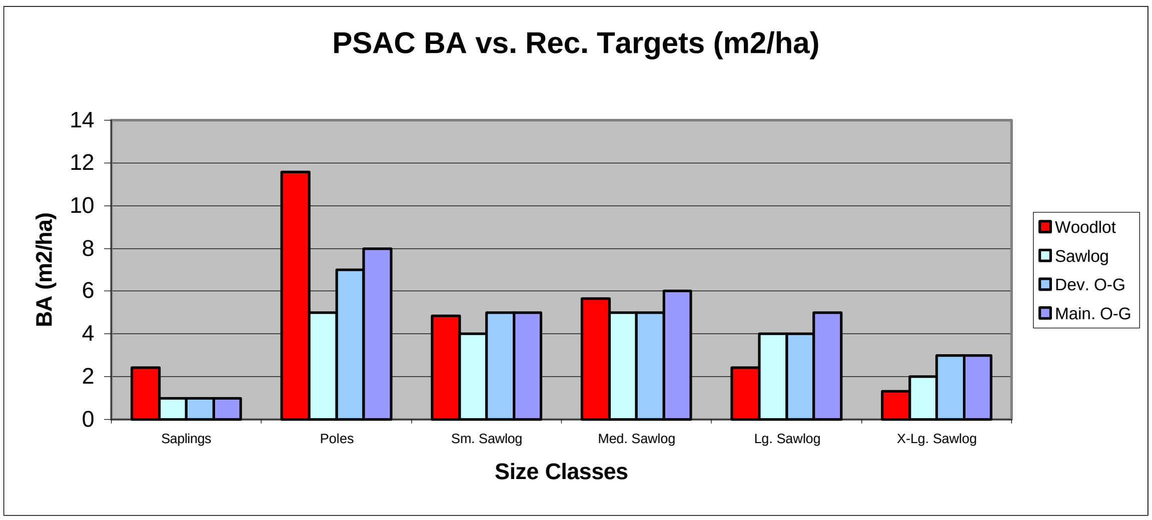

Chart 1. PSAC Mean BA vs. Recommended Targets.

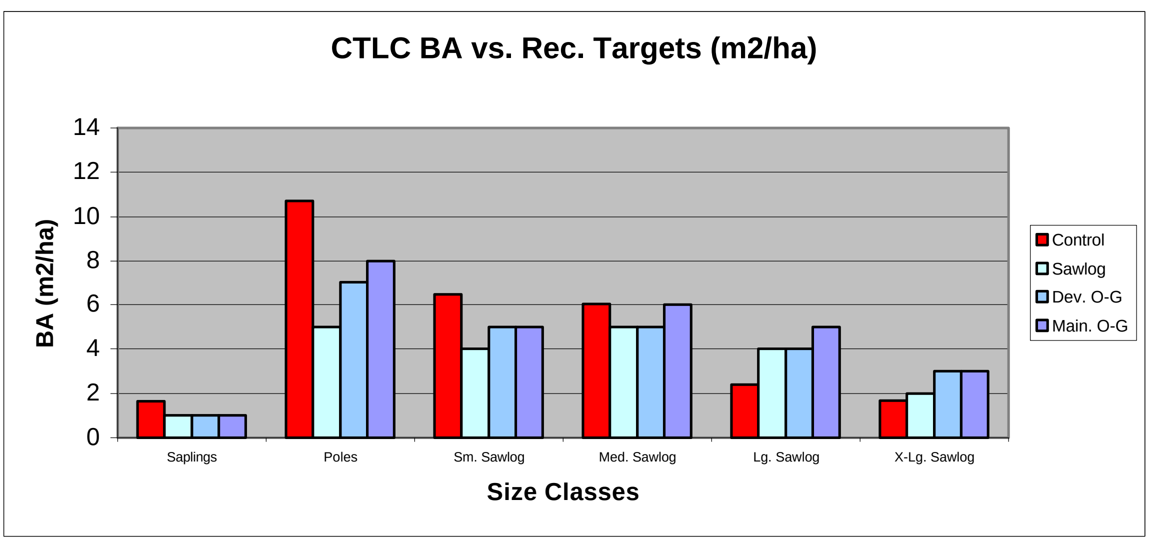

Chart 2. CTLC Mean BA vs. Recommended Targets.

Compartments with low BA tend to be the forested swamps SWD3-4 as defined by the ELC (Chart 3.). There would be an expectation of lower BA on these sites as canopy cover in deciduous swamps is, by definition, between 25% and 60% (Lee et. al. 2000). Alternatively, the woodlot compartments that showed the highest BA tended to be the transition FOD9 and upland deciduous FOD2 sites. These sites tend to have higher productivity than the wet or swampy sites due to decreased soil moisture.

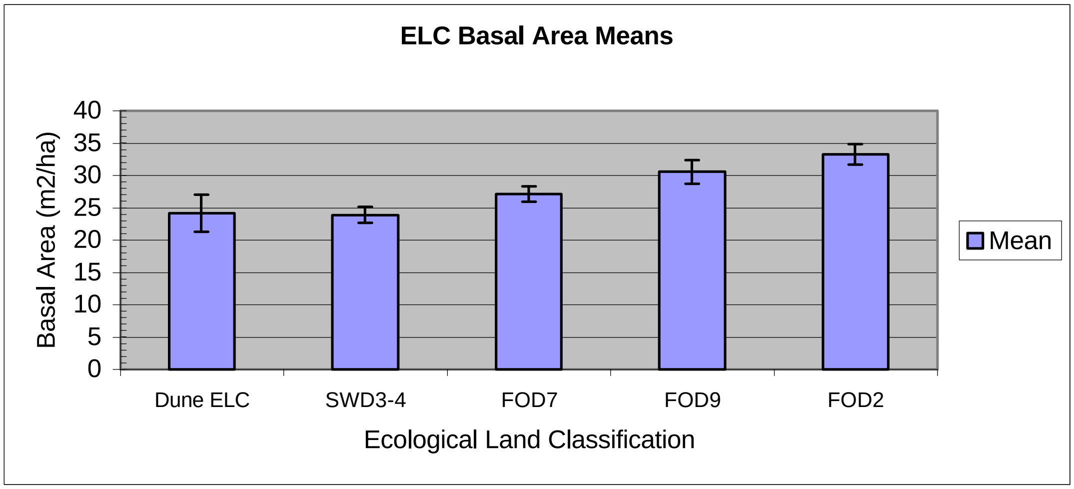

Chart 3. Basal Area Means by ELC

We see significantly greater amounts of Polewood class in both the PSAC and CTLC than in any of the management classes. We also see that there are deficiencies in both the PSACs and CTLCs within the Large and X-Large Sawlog classes.

Within the PSAC and the CTLC, the Polewood class makes up 41% and 37% of the total basal area respectively. This result is unexpected. Comparing this result against recommended basal area targets, when managing for different objectives, we see that this amount of polewood is significantly higher than that recommended. Based on an average growth rate of 6 mm/year we can estimate that the polewood was likely established between the years 1957 and 1972.

There are a number of possible explanations for this result. Harvesting operations 30-45 years ago could have resulted in the initiation of a high number of stems in this class. During that period Dutch elm disease (*Ophiostoma ulmi*) was decimating American elm populations in Ontario (Armson 2002). Stands with large elm populations would have become understocked at this time resulting in an eventual restocking of other species. Additionally, in the 1960s and 1970s, the OMNR and Ministry of Agriculture representatives were trying to discourage farmers in all of southern Ontario from pasturing livestock into their woodlots (Boysen 2002). It's possible that the exclusion of the cattle and other livestock at this time has resulted in a wealth of trees in this age (size) class. Additionally, it is possible that CoCs negatively affected the growth of mature and overmature trees. If this resulted in dieback of the overstorey trees, this may also account for the proliferation of regeneration about 30-45 years ago.

Within the Large- and X-Large Sawlog classes, we have less than the recommended amount of BA. This lack of BA in the larger size classes may be due to a number of factors. Harvesting, windthrow, ice storms and CoCs, in whole or in part, may have negatively affected the number of trees in these size classes.

Polewood species composition by study area is presented in Table 3. The species composition of the Polewood class across the total study area shows that 32% is soft maple (Ms), 21% is ash (8% green ash (Ag) and 13% white ash (Aw)), 10 % white elm (Ew), 5% shagbark hickory (Hs) and 4% yellow birch (By). All species except for the hickory tend to fruit heavily with light, winged seed and are mid-tolerant or intolerant of shade. This dominance by soft maple, the ashes, and white elm is also seen in the PSAC. Polewood species composition in the CTLC reflects that of the Total Study Area and PSAC except that there is a significant component of hard maple (Mh). This hard maple component comes mainly from one control compartment, C2A.

Polewood species composition by ELC, presented in Table 4, shows that soft maple, the ashes, and white elm dominate the SWD3-4, FOD7 and FOD9 sites. The Dune ELC shows a significant component of red oak (Or) and hard maple while the FOD2, in addition to the soft maple, shows a significant amount of beech (Be), black cherry (Cb), and red oak.

Table 3. Polewood Species Composition by Study Area.

Polewood Species Composition by Study Area	
Study Area	Species Composition
PSAC	Ms_{30} Ag/w_{23} Ew_{11} Hs_{6} OH_{20}
CTLC	Ms_{35} Ag/w_{15} Mh_{13} By_{8} Be_{5} $Hs_{4}OH_{20}$
Total Study Area	Ms_{32} Ag/w_{21} Ew_{10} Hs_{5} By_{4} OH_{28}

Table 4. Polewood Species Composition by ELC.

Polewood Species Composition by ELC	
ELC	Species Composition
Dune ELC	Mh_{40} Or_{11} Aw_{14} Id_{12} Ps_{14} OH_{9}
SWD3-4	Ms_{48} Ew_{14} Ag/w_{13} By_{5} Cb_{4} $Hs_{4}OH_{12}$
FOD7	Ms_{35} Ag/w_{22} Hs_{6} By_{6} Bu_{5} OH_{26}
FOD9	Ms_{36} Ag/w_{25} Hs_{10} Ew_{9} OH_{20}
FOD2	Aw_{22} Ms_{20} Be_{12} Cb_{8} Or_{5} OH_{33}

Stocking

Mean stocking estimates for the PSAC, CTLC and the Total Study Area are given in Table 5. Mean estimated stocking for the PSAC and the CTLC were found to be not significantly different from each other. Stocking ranged from an estimated 269 stems/ha in compartment C2B to 2,295 stems/ha in compartment 06A. The PSAC had a range from 467 stems/ha in 17A to 2,295 stems/ha in 06A. The range among CTLC was 269 stems/ha in C2B to 1,658 stems/ha in C4A.

Table 5 and Chart 4 show the estimated stocking levels for the PSAC and CTLC compared to recommended stocking levels for different management criteria (OMNR 2000). Stocking within all the size classes, except for the Sapling class, are similar between the PSAC and CTLC. In the Sapling class, there is a significant difference between the PSAC and the CTLC. The PSAC Sapling class averages more than 200 stems/ha more than the CTLC. Total stocking for both the PSAC and CTLC exceeds that for any of the three management criteria. Stocking is very low in compartment C2B which is likely the closest to “old-growth” that was inventoried. Additionally, other understocked compartments tended to be the SWD3-4 sites.

Stocking across ELC sites is presented in Chart 5. There are significant differences between the ELC sites with FOD2 showing the highest stocking and SWD3-4 and Dune ELC having the lowest stocking. This is to be expected as the FOD2 which represents a "better" site and should have higher stocking due to increased germination capability and a greater amount of productive area when compared to a similar sized woodlot of a poorer drained or excessively-drained classification.

Table 5. Estimated Stocking and Recommended Stocking Levels and Recommended OMNR Target Basal Area Managing for Sawlogs, Developing Old-Growth Characteristics and Maintaining Old-Growth Characteristics (stems/ha) in Site Region 7E (OMNR 2000).

Stocking (stems/ha)					
Size Classes	PSAC	CTLC	Sawlog	Dev. O-G	Main. O-G
Saplings	632	430	259	303	341
Poles	368	341	205	241	271
Sm. Sawlog	57	76	40	46	52
Med. Sawlog	39	42	33	38	43
Lg. Sawlog	10	10	16	18	21
X-Lg. Sawlog	3	4	7	8	9
Total	1110	903	560	654	737

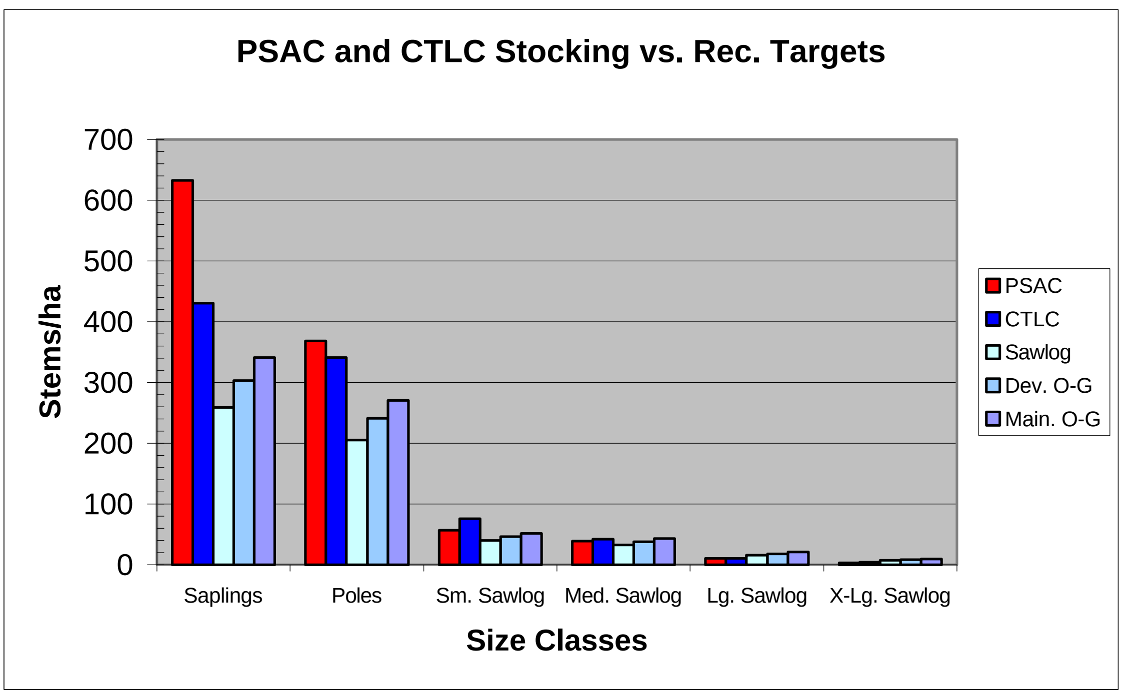

Chart 4. PSAC and CTLC Stocking Means vs. Recommended Targets.

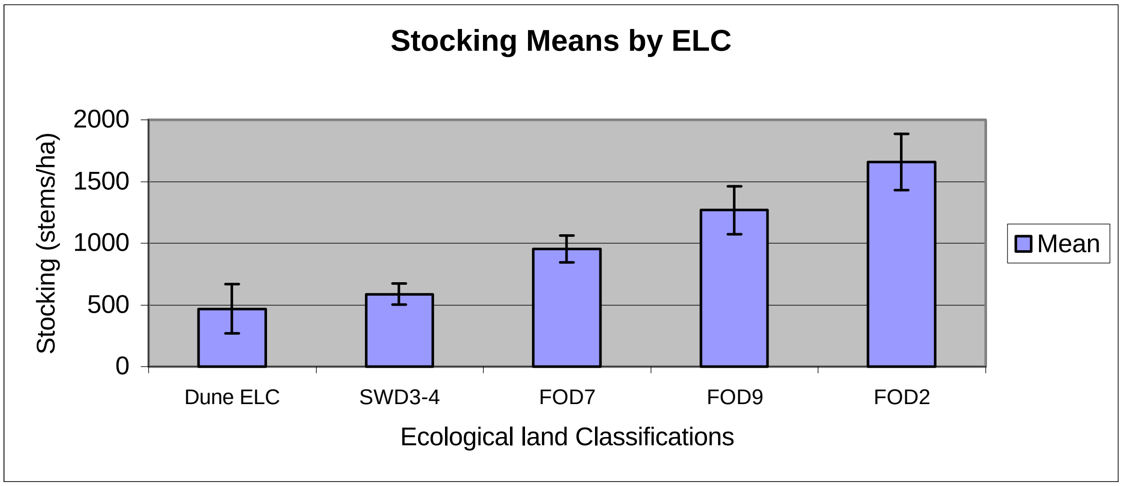

Chart 5. Stocking Means by ELC.

Acceptable Growing Stock (AGS)

Results of the percentage of Acceptable Growing Stock (AGS) is presented in Table 6. There is no statistically significant difference between means for PSAC and CTLC. The range for the PSAC and the Total Study Area starts at a low of 53% in compartment 12A to a high of 80% in compartment 18C. Within the CTLC, the low was 58% found in C4A to a high of 78% in C6A.

Table 6. Mean Acceptable Growing Stock (AGS) Percentage.

Acceptable Growing Stock (%) ± Std. Error	
Study Area	Percentage
PSAC	66.4 ± 1.3
CTLC	68.0 ± 3.6
Total Study Area	66.7 ± 1.6

Mean percent AGS by ELC is shown in Chart 6. Across the ELC sites, a low of 62.0% was found in SWD3-4 while a high of 72.6% was found in FOD2. The difference in AGS between FOD2 and SWD3-4 is likely due to the fact that FOD2 has higher productivity and the compartments found on the ELC site are more intensively managed. Although there is no statistical difference, the compartments, as a whole have an unacceptable amount of UGS. Silviculturally, a UGS level greater than 20% would warrant a stand improvement harvest to prevent the introduction of disease and insects, maintain vigour and overall stand quality (Robertson 2002).

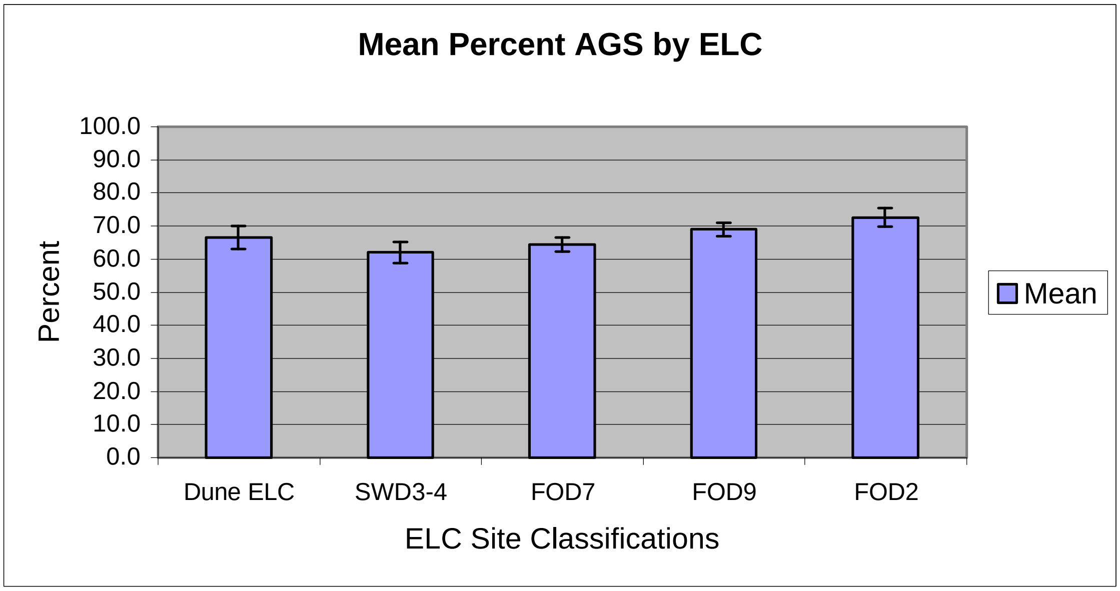

Chart 6. Mean Percent AGS by ELC

Table 7. Mean Basal Area by Size Class and Quality.

Mean Basal Area by Size Class and Quality (m^2/ha)							
PSAC				CTLC			
Size Classes	AGS	UGS	Total	Size Classes	AGS	UGS	Total
Saplings	0.8	1.6	2.4	Saplings	0.8	0.8	1.7
Poles	7.6	4.0	11.6	Poles	6.7	4.0	10.7
Sm. Sawlog	3.6	1.2	4.8	Sm. Sawlog	4.6	1.8	6.5
Med. Sawlog	4.3	1.4	5.7	Med. Sawlog	5.0	1.1	6.0
Lg. Sawlog	1.6	0.8	2.4	Lg. Sawlog	2.0	0.4	2.4
X-Lg. Sawlog	0.7	0.5	1.2	X-Lg. Sawlog	1.0	0.7	1.7
Total	18.7	9.5	28.3	Total	20.2	8.8	28.9

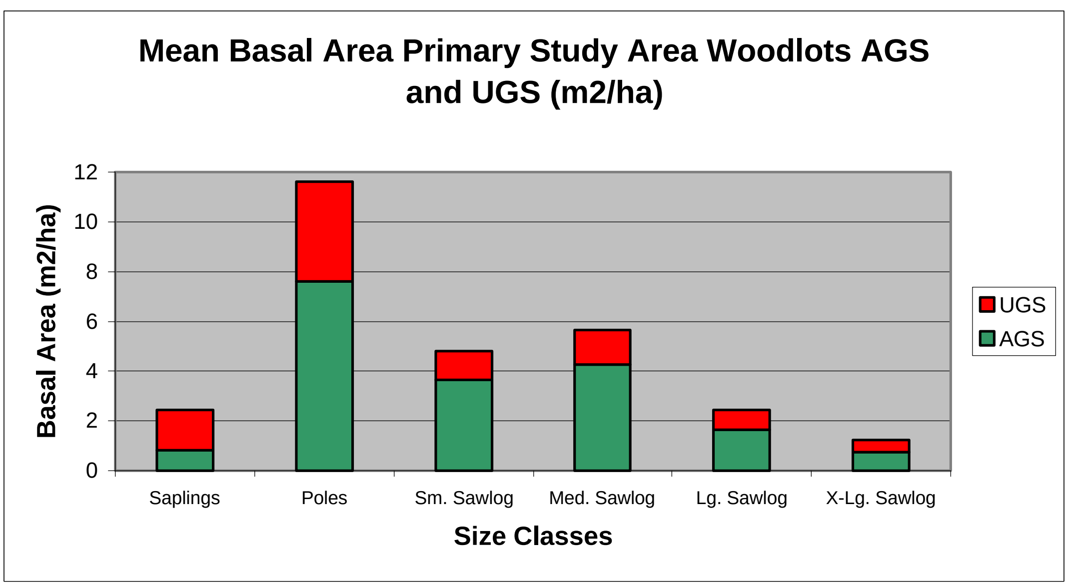

Chart 7. PSAC Mean Basal Area by Quality and Size Class.

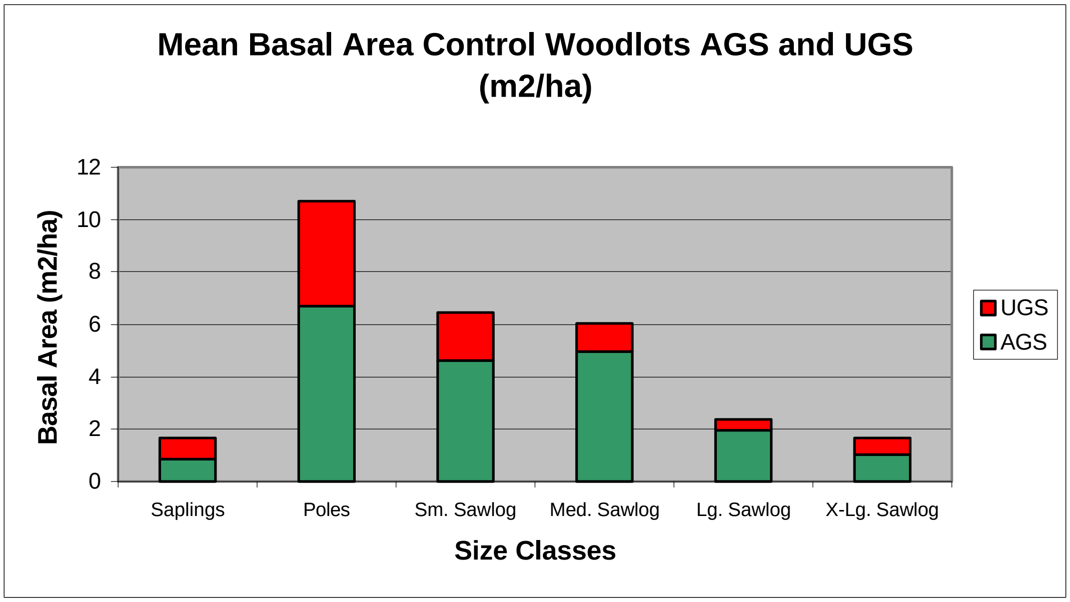

Chart 8. CTLC Mean Basal Area by Quality and Size Class.

Table 7 presents BA by size class and quality for the PSAC and CTLC. Charts 7 and 8 are graphic representations of the same data. The amounts AGS and UGS within size classes and between the PSAC and the CTLC are remarkably similar. In the Polewood class, UGS amounts for almost 40% of BA. This is seen in both the PSAC and the CTLC. The high percent of UGS in the Polewood class is likely due to density induced mortality from overstocking in this size class. The similarity in AGS percentage across size classes between the PSAC and the CTLC points to very similar management regimes.

Species Composition

Woody Species Diversity

Woody species diversity was recorded for all compartments. Results of the mean woody species diversity is presented in Table 8. There was no statistically significant difference in the total number of woody species; tree species, or shrub and vine species, found between the PSAC and the CTLC. Within the Total Study Area and the PSAC, the total number of woody species ranged from a low of 8 species in compartments 05B, 12A and 17C to a high of 26 species present in compartment 01C. Within the CTLC, the range was from 14 species in C1A to 25 species in C6A. Tree species ranged from 3 species in 05B, 12A and 17C to 14 species in C6A. Within the PSAC, the range was from 3 tree species in compartments 05B, 12A and 17A to 13 species in 16A. In the CTLC, the range of tree species was from 6 in C1A and C2A to 14 in C6A. In the Total Study Area and the PSAC, the number of shrub and vine species was lowest in 17C with 3 to a high of 17 in 05D. Within the CTLC, the range was from 7 in C5A to 12 in C2B and C4A.

Table 8. Mean Woody Species Diversity.

Mean Woody Species Diversity ± Std. Error			
Study Area	Tree Species	Shrub and Vine Species	Total Woody Species
Primary Study Area	7.7 ± 0.56	8.9 ± 0.78	16.6 ± 1.07
Control Study Area	9.8 ± 1.33	9.8 ± 0.87	19.7 ± 1.82
Total	8.2 ± 0.53	9.2 ± 0.65	17.4 ± 0.95

Presently, there are no provincial guidelines or standards for woody species diversity. It is advantageous for woodlot health to have as many species as possible. Generally, woodlots with more species are less susceptible to major pest outbreaks and have increased wildlife diversity than those with limited species diversity (OMNR 2000).

Mean woody species diversity by ELC is presented in Chart 9. Across the ELC sites there was a high of 19.6 species in FOD2 to a low of 16.3 in FOD9. However, there is no statistically significant difference between ELC types.

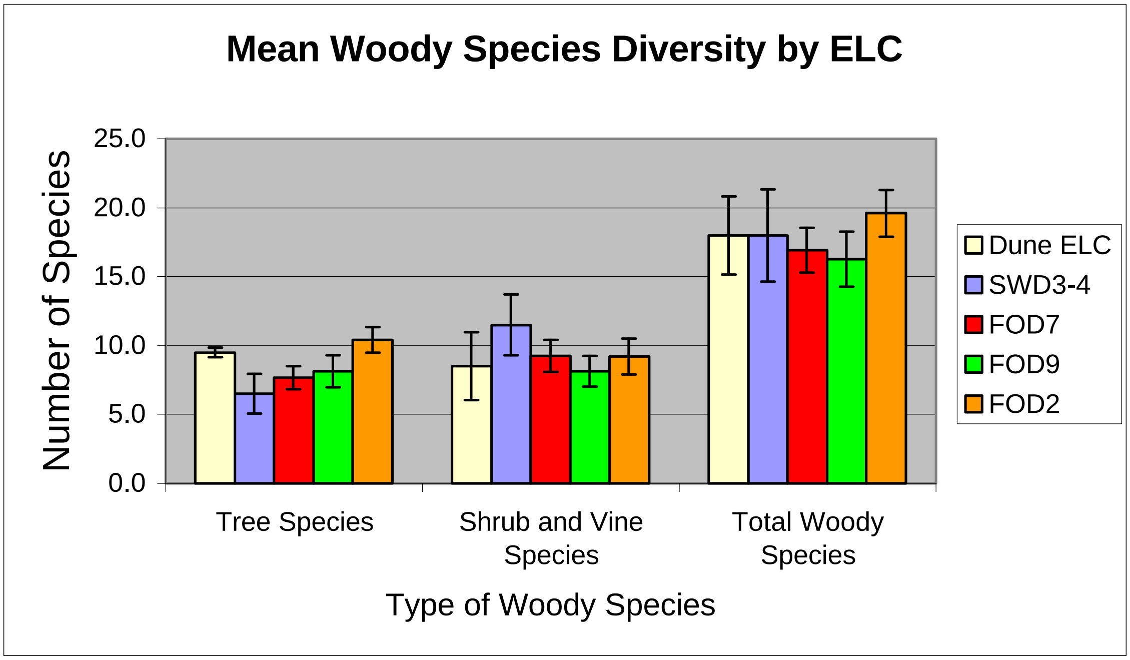

Chart 9. Mean Woody Species Diversity by ELC.

Twenty-seven of the 31 total compartments contained alien species. Some alien species are more benign than others but Garlic Mustard (*Alliaria petiolata* Cavara and Grande), which was found to be nearly ubiquitous, is a concern. The prevalence of this herbaceous plant can retard the natural regeneration of native trees and shrubs and thus affect the future forest tree composition. Only compartments 16A, 17C, C1A and C6A were without this exotic invasive.

Species Composition

The species composition for the PSAC, CTLC, and Total Study Area is shown in Table 9 and for the ELCs in Table 10. The Total Study Area, PSAC, CTLC, SWD3-4, FOD7, FOD9, and FOD2 are dominated by soft maple and the ashes. The trend toward dominance by soft maple is a phenomenon that is being seen increasingly across eastern North America (Abrams 1998). Mesic forests once dominated by oak species are particularly susceptible to this change. The ecological ability of a species like red maple (Ms) to occupy and dominate sites which show a wide amplitude of moisture and nutrient regimes is partially responsible for this state. Additionally, the anthropogenic disturbances responsible for the generation of many of the oak forests are not as common as they once were. In particular, the suppression of fire over the last 80 years has meant that many species of oak cannot compete with other species that are more tolerant of less intense or fewer disturbances (Abrams 1996).

Only the Dune ELC compartments show species dominance other than soft maple and the ashes. Hard maple, in particular black maple (Mh), dominate the Dune ELC sites. The Dunes and FOD2 sites have a significant component of red oak. With respect to the dunes, the ability of red oak to tolerate excessive drainage and the lack of harvesting is likely responsible for the species' presence.

Table 9. Species Composition by Study Area.

Species Composition by Study Area	
Study Area	Species Composition
PSAC	Ms_{37} Ag/w_{20} Ew_{8} OH_{35}
CTLC	Ms_{37} Or_{11} Aw_{11} Mh_{9} OH_{32}
Total Study Area	Ms_{37} Ag/w_{19} Ew_{7} Or_{4} OH_{33}

Table 10. Species Composition by ELC.

Species Composition by ELC	
ELC	Species Composition
Dune ELC	Mh_{33} Or_{26} OH_{51}
SWD3-4	Ms_{60} Ag/w_{13} Ew_{5} OH_{22}
FOD7	Ms_{45} Ag/w_{25} Ew_{7} OH_{23}
FOD9	Ms_{36} Ag/w_{25} Ew_{7} OH_{42}
FOD2	Ms_{20} Aw_{20} Or_{9} OH_{51}

Regeneration

The regeneration composition for the PSAC, CTLC, and Total Study Area is shown in Table 11 and for the ELC sites in Table 12. The PSAC is dominated by the ashes, black cherry, soft maple and white elm which are intolerant or mid-tolerant species. Blue beech (Bu), beech and hard maple are also present to a lesser degree. The CTLC is dominated more by mid-tolerant and tolerant species such as soft maple, blue beech, hard maple and beech. The intolerant and mid-tolerant species such as black cherry, the ashes and white elm are present but in lesser amounts.

All the ELC sites except for the Dune ELC tend to be dominated by the mid-tolerant or intolerant species such as the ashes, soft maple, black cherry and white elm. There is also a significant amount of blue beech which is tolerant of shade but usually exists as a tall understorey shrub. The amount of blue beech is a minor concern as it is considered an “undesirable” species from a timber management point of view (OMNR 1990). Additionally, the lack of oak regeneration is also a concern which, as stated above, is being seen across eastern North America.

Table 11. Regeneration Species Composition by Study Area.

Regeneration Species Composition by Study Area	
Study Area	Species Composition
PSAC	Ag/w_{18} Cb_{17} Ms_{11} Ew_{11} Bu_{8} Be_{5} Mh_{2}
CTLC	Ms_{16} Bu_{12} Mh_{10} Be_{8} Cb_{7} Ag/w_{7} Ew_{4}
Total Study Area	Ag/w_{16} Cb_{15} Ms_{12} Ew_{10} Bu_{9} Be_{5} Mh_{3}

Table 12. Regeneration Species Composition by ELC.

Regeneration Species Composition by ELC	
ELC	Species Composition
Dune ELC	Mh_{31} Cb_{21} Id_{13} OH_{35}
SWD3-4	Ag/w_{29} Ms_{22} Ew_{9} Cb_{9} OH_{31}
FOD7	Cb_{21} Ms_{17} Ag/w_{14} Ew_{12} Bu_{12} OH_{24}
FOD9	Ag/w_{16} Bu_{15} Ew_{12} Ms_{10} Cb_{10} OH_{27}
FOD2	Cb_{20} Be_{19} Ag/w_{12} Ew_{11} Bu_{10} OH_{28}

Site Productivity

Mean Maximum Height and Average Compartment Age

Results of mean maximum height are presented in Table 13. There is no statistically significant difference between means for the PSAC and the CTLC. The range for the Total Study Area and PSAC goes from a high of 30.0 m in compartment 16A to a low of 20.0 m in compartments 06A, 07A and 17B. Within the CTLC the high was 27.0 m in C1A, C2B and C6A to a low of 22.0 m in compartment C4A.

Table 13. Mean Maximum Height by Study Area.

Mean Maximum Height (m) ± Std. Error	
Study Area	Height (m)
Primary Study Area	24.2 ± 0.5
Control Study Area	25.5 ± 0.8
Total	24.5 ± 0.5

Table 14. Maximum Height by ELC

Maximum Height (m) by ELC	
ELC	Mean Ht (m)
Dune ELC	25.0
SWD3-4	24.8
FOD7	24.3
FOD9	24.3
FOD2	24.7

Maximum heights across the ELC sites showed a high of 25.5 m in the Dune ELC to a low of 24.1 m in FOD7 and FOD9. Mean maximum height is a function of age and site quality. Therefore, the absolute number means something only in that context. In this case, both the PSAC and the CTLC have fairly tall mean maximum heights.

Average age of the dominant canopy trees for the compartments within the study areas and ELCs are shown in Tables 15 and 16. With the exception of 15A and 18C, all the compartments would be considered unevenaged where there are multiple age classes within the compartment (OMNR 2000). On average the PSAC was 16 years younger than the CTLC. The older age of the CTLC is more likely a reflection of the site selection process than any growth or age inhibitor.

Table 15. Average Age of Compartments by Study Area.

Average Age of Compartments by Study Area	
Study Area	Average Age (yrs)
PSAC	74
CTLC	90
Total Study Area	77

Table 16. Average Age of Compartments by ELC.

Average Age of Compartments by ELC	
ELC	Average Age (yrs)
Dune ELC	107
SWD3-4	67
FOD7	77
FOD9	79
FOD2	72

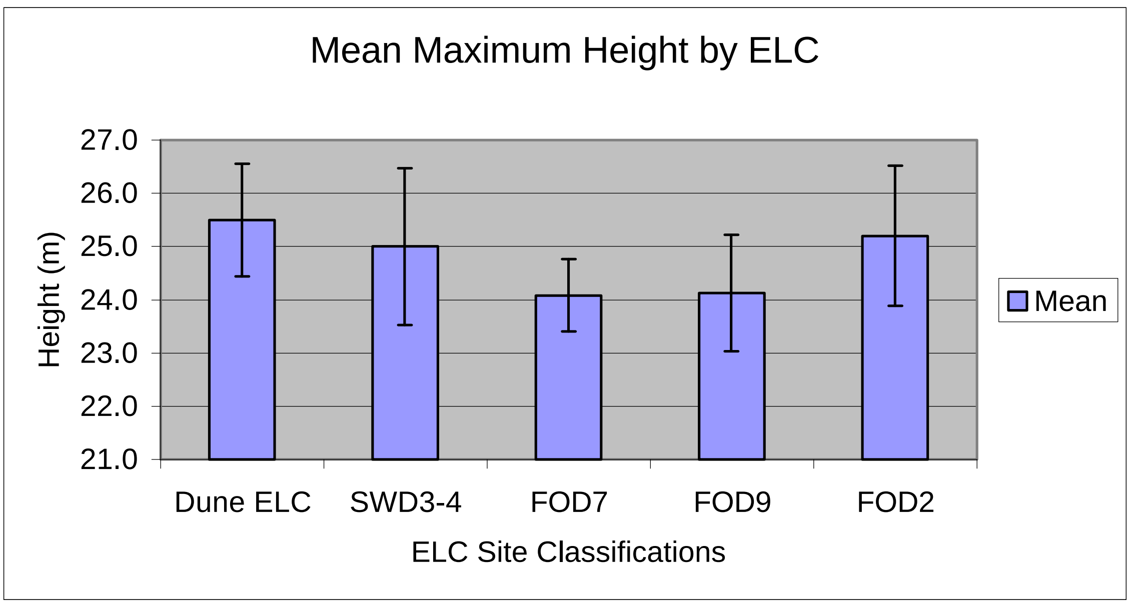

Chart 10. Mean Maximum Height by ELC.

Mean Stand Diameter

Results of the mean stand diameter are found in Table 17. There is no statistically significant difference between means for the PSAC and the CTLC. The range for the Total Study Area and PSAC goes from a high of 45.6 cm in compartment 05E to a low of 21.3 cm in compartments 07A and 18C. Within the CTLC the range is from 44.7 cm in C2B to a low of 23.5 in compartment C4A.

Table 17. Mean Stand Diameter.

Mean Stand DBH (cm) ± Std. Error	
Study Area	DBH (cm)
Primary Study Area	31.4 ± 1.4
Control Study Area	32.8 ± 3.2
Total	31.7 ± 1.3

The mean stand diameter across ELC sites is presented in Chart 11. Across the ELC sites, the largest mean stand diameter was found in Dune ELC with a mean DBH of 40.8 to a low of 26.6 cm in FOD2.

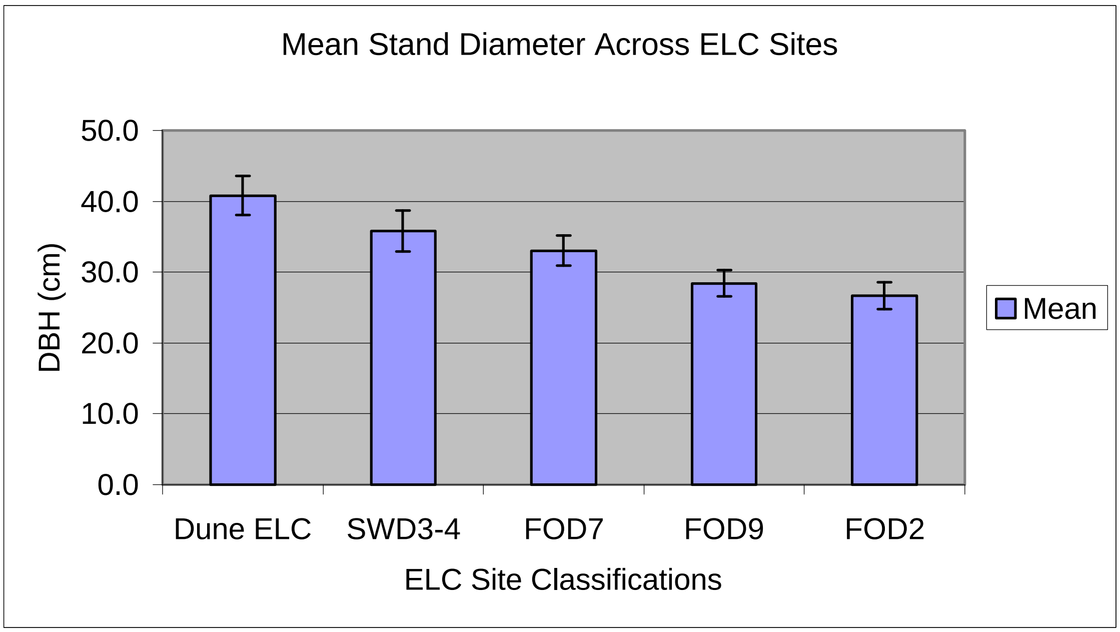

Chart 11. Mean Stand Diameter across ELC Sites.

The range of the mean stand diameters was skewed due to several compartments that had low stocking but were dominated by very large trees (02A, 05D, 05E, and C2B).

Wildlife Habitat

Wildlife Trees

Wildlife habitat trees were inventoried for all compartments. The mean BA of wildlife trees measured in m^2/ha partitioned into habitat tree types is given in Table 18. Mean total BA of wildlife trees for the PSAC and the CTLC were compared and were found not to be significantly different from each other. The range for the Total Study Area and PSAC was from a low of 2.0 m^2/ha for compartment 06A to a high of 15.6 m^2/ha for compartment 17B. The range within the CTLC was 4.6 m^2/ha in compartment C5A to 15.1 m^2/ha in compartment C2A. OMNR targets for residual snags, cavity trees and downed woody debris (DWD) are estimated to total about 5 m^2/ha (LandOwner Resource Centre 1997). These targets are interpolated from the size and number of stems/ha recommended for each of the habitat types. Only three compartments, 06A, 12B and 18B, within the PSAC fail to meet the minimum target while in the CTLC, compartments C5A and C6A don't meet this minimum standard. Therefore, 26 of 31 total woodlot compartments are above the minimum threshold.

Table 18. Mean Basal Area of Wildlife Trees.

Mean Wildlife Trees (m^2/ha) ± Std. Error				
Study Area	Cavity Trees (m^2/ha)	Snags (m^2/ha)	Downed Woody Debris (m^2/ha)	Total Wildlife Trees (m^2/ha)
Primary Study Area	2.4 ± 0.34	2.7 ± 0.41	4.0 ± 0.39	9.1 ± 0.69
Control Study Area	1.7 ± 0.74	2.4 ± 0.39	4.1 ± 0.66	8.1 ± 1.60
Total	2.3 ± 0.31	2.6 ± 0.34	4.0 ± 0.33	8.9 ± 0.63

Chart 12 shows the different wildlife habitat tree types charted against the ELC site classifications. Across the ELC sites there is a low of 5.8 m^2/ha in FOD2 to a high of 13.1 m^2/ha in SWD3-4.

Wildlife habitat trees have obvious benefits to a woodlot. Beyond providing food and shelter to all manner of wildlife from large mammals to microscopic organisms, habitat structures such as downed woody debris aid in soil production and preserve soil moisture during dry periods (OMNR 2000).

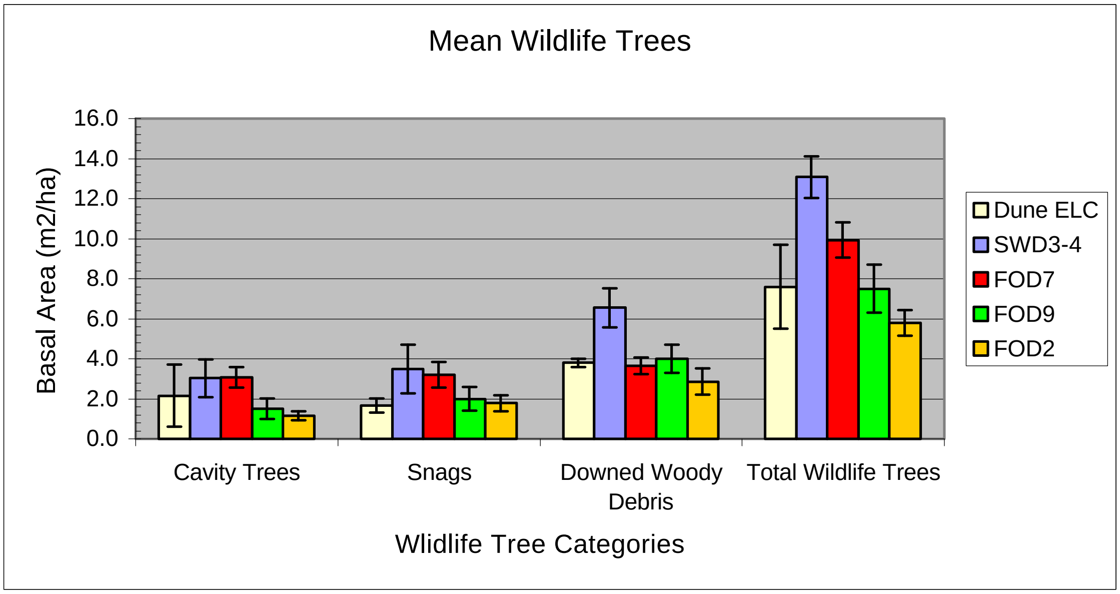

Chart 12. Mean Basal Area of Wildlife Trees across ELC Sites.

The volume of wildlife trees and features are predictable in that the SWD3-4 had larger amounts of DWD likely due to the susceptibility of these types of sites to windthrow and slower rates of decomposition. The better quality sites, FOD2 and FOD9, had lower amounts of wildlife trees likely due to improved tree vigour, better stand structure, better soil stability, more intensive management and more rapid rates of decomposition. Chemicals of Concern may have a role to play in the increased amount of wildlife habitat trees in the SWD3-4 sites. Chemicals of Concern in general and nickel in particular tend to have greater effect on sites where the pH is lower. SWD3-4 sites would have lower pH and thus may be more affected by CoCs than other ELC sites.

Management and Disturbance

Management and Disturbance

A Management and Disturbance table from the Guide to Ecological Land Classification in Southern Ontario (Lee et. al. 1998) was included in the inventory. The table was completed for each compartment and points were totaled. Management and Disturbance is measured such that a lower score is a reflection of fewer and less intense disturbances. Means for each of the study areas is shown in Table 19. There was no statistically significant difference between the means for PSAC and CTLC. In the Total Study Area and the PSAC, point totals ranged from a low of 12 points in compartment 18C to a high of 42 points for compartment 17A. Low total for the CTLC was 16 in C2A and C5A and a high of 35 in C2B. Across the ELC sites we found a low of 20.6 points in FOD2 to a high of 31.0 points in SWD3-4 (Chart 13).

Table 19. Mean Management and Disturbance Points.

Management and Disturbance ± Std. Error	
Study Area	Points
Primary Study Area	24 ± 3.0
Control Study Area	27 ± 1.9
Total Study Area	26 ± 1.6

At the present time, there is no interpretation of the absolute values generated by the ELC Management/Disturbance table (Lee 2002). Therefore, it is difficult to draw conclusion about the severity of disturbance. The most common disturbances that had moderate to heavy levels were alien species, logging, disease and death of trees and windthrow. Flooding was difficult to assess due to the severity of the draught at the time of the inventory. Criteria such as dumping and earth displacement primarily reflected aesthetics and stewardship practices versus having any impact on tree health. The 36 points for 16A is a result of the compartment being recently logged. Another notable finding is the seven highest rating of 35 points in C2B, the provincially significant Marcy Woods dune property.

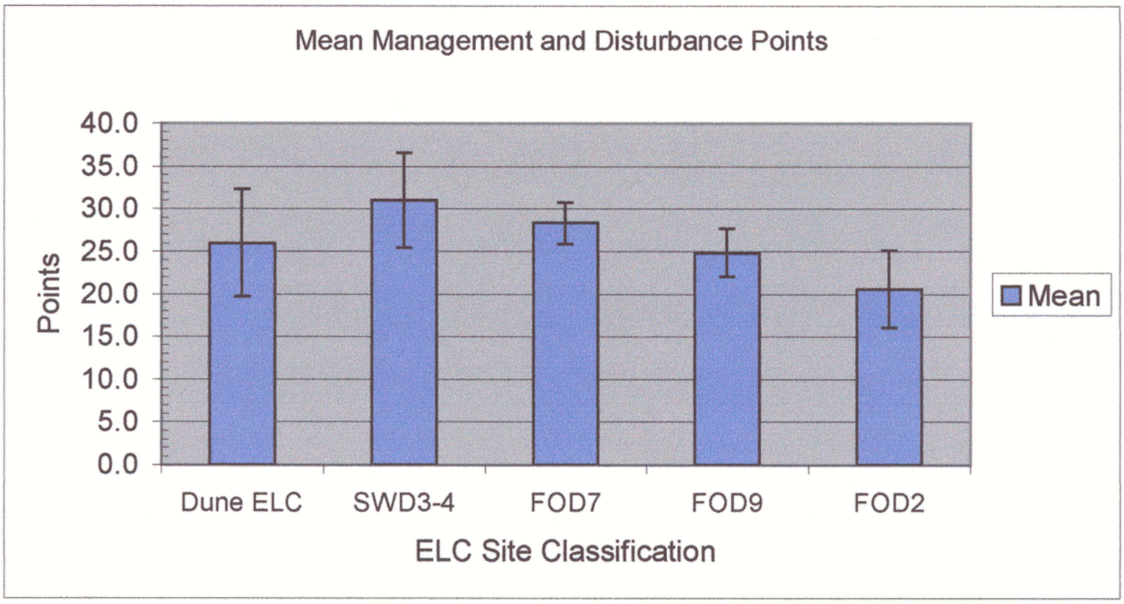

Chart 13. Mean Management and Disturbance Points across ELC Sites.

Time since logging

The time since logging was recorded for each of the compartments inventoried. There were four classes of logging disturbance as listed in the Management and Disturbance Table of the Methods section. The number of occurrences for each of the classes was recorded for each of the study areas and each of the ELCs. The number of occurrences were then multiplied by the points for each class then averaged for a mean point total for the study area and ELCs. The mean point total gives an idea of the time since logging for each of the study areas or ELCs. The potential mean point range is from 1 to 4, with the higher the point total, the more recent the logging.

The mean point totals for the study areas are recorded in Table 20. The CTLC shows most of the logging happening in the period 16 - 30 years ago while the PSAC total shows the logging closer to 6-15 years ago. The mean point totals for the ELCs are seen in Table 21. The Dune ELC and the SWD3-4 show that logging tended to occur closer to or more than 30 years ago. The FOD7 and FOD2 sites had logging between 6 - 30 years ago. The FOD9 point total shows logging within the last 5 - 8 years. The explanation for this may lie in the fact that due to dryer conditions over the last 4 of 5 years woodlots which may have been too wet to allow harvesting have been accessible. Additionally, FOD9 and FOD2 sites tend to have better productivity than the wetter ELC sites. Because of the increased productivity there would be a greater likelihood of harvesting to occur.

Table 20. Number of Compartments with Time since Logging by Study Area and the Mean Points for each Study Area.

Number of Compartments with Time since Logging by Study Area					
Study Area	0 – 5 years (4 pts.)	6 – 15 years (3 pts.)	16 – 30 years (2 pts.)	> 30 years (1 pt.)	Mean Points
PSAC	10	5	2	8	2.68
CTLC	1	1	1	3	2.00
Total Study Area	11	6	3	11	2.55

Table 21. Number of Compartments with Time since Logging by ELC and the Mean Points for Study Area.

Number of Compartments with Time since Logging by ELC					
ELC	0 – 5 years (4 pts.)	6 – 15 years (3 pts.)	16 – 30 years (2 pts.)	> 30 years (1 pt.)	Mean Points
Dune ELC	0	0	0	2	1.00
SWD3-4	0	1	1	3	1.60
FOD7	2	2	0	4	2.25
FOD9	7	3	0	0	3.70
FOD2	2	0	2	2	2.33

Diameter Limit Cutting

Diameter limit cutting, which selects the largest and best trees for harvests, tends to represent dysgenic selection as it removes the best trees from the stand and leaves poorer quality trees to dominate the subsequent forest and allow these poorer trees provide a seed source for regeneration. Repeated diameter limit cutting will often result in a woodlot that tends to be shorter, has an unacceptable amount of UGS, has less species diversity, decreased wildlife habitat, and fewer high quality trees (Eyre and Zillgitt 1953).

Tables 22 and 23 show how diameter limit cutting is partitioned across study areas and ELCs. Diameter limit cutting occurs in about 50% of the PSAC and about 30% of CTLC. This is to be expected as one of the criteria for selecting the CTLC was a relative lack of disturbance. From

Table 22. Number of Compartments with Diameter Limit Cutting by Study Area.

Number of Compartments with Diameter Limit Cutting by Study Area	
Study Area	Number of Compartments
PSAC	11
CTLC	2
Total Study Area	13

Table 23. Number of Compartments with Diameter Limit Cutting by ELC.

Number of Compartments with Diameter Limit Cutting by ELC	
ELC	Number of Compartments
Dune ELC	0
SWD3-4	3
FOD7	4
FOD9	3
FOD2	3

Table 23 we see that the diameter limit cutting is evenly spread across all ELCs except for the Dune ELC. Diameter limit cutting is not considered "good forestry" practice and does not allow for the woodlot to express its full economic and environmental potential in the long-term.

CONCLUSIONS

The Study reviewed 793.4 acres, 572.6 ac in the PSA and 216.8 ac. in the Control area. The Study inventoried 396.2 ac. in the PSA and 196.8 ac. in the Control area. Five ELC types were identified producing 31 compartments in 21 woodlots. The Study assessed each compartment using 12 forest health criteria. Individual tree health was not measured by this Study.

No significant differences were found between the compartments within the PSA and those within the Control area.

This is not to say that the woodlots and compartments in both the PSA and the Control area are perfectly healthy. Although the total compartment basal area met all provincial and regional guidelines, the Study found that the majority of the compartments have deficiencies in mature and over-mature size trees and are very over-stocked in polewood size trees. With the exception of the Dunes ELC, species composition was dominated by soft maple. High-grade harvesting of the more valuable oaks, ash and hard maple, the elimination of woodlot pasturing and the decline of white elm due to Dutch elm disease have contributed to this phenomenon. For the most part tree regeneration reflected what species were in the over-storey. Tree regeneration was primarily white and green ash, soft maple and white elm. We can conclude that without intervention the forests of the future will comprise largely of soft maple.

As a whole, the percent of UGS across all diameter classes is a concern. Ina well-managed woodlot the percent UGS would range form 10-20%. The Study found that the lowest percent of UGS was 20% with a high of 47%. The unusually high percentage of UGS could lead to greater amounts of wildlife habitat but lower future timber production and quality and higher tending costs due to increased amounts of insects and disease. Improved or more intensive silviculture will help to reduce the percent UGS and improve overall woodlot health and quality.

Presently, there are no interpretation of the absolute values generated by the ELC Management /Disturbance table. Therefore, it is difficult to draw any conclusion about the severity of the disturbances. However, 40% of the PSAC have had some degree of harvesting in the last five years compared to only 17% of CTLC which would explain why PSAC stocking in the sapling size class was significantly higher. Further, 44% of the PSAC have had diameter limit harvests compared to 33% of the CTLC. Although harvesting was only one component of the Management/Disturbance criteria, it can have greatest impact on forest health and quality. Also, the widespread level and severity of indiscriminant dumping inside the PSA was regionally high.

Woodlot health was not affected by either the location of the compartment or within the compartment. It was observed that root exposure and windthrow were greater in compartments closer to Lake Erie or adjacent to municipal drains. The increased rate of drainage caused by the extensive network of municipal drains and maybe the lower lake levels are causing the woodlots to become drier. This would explain the difficulty of accurately identifying the ELC boundaries of swamps and lowland hardwood forests. The municipal drains were also primarily responsible for the introduction of the exotic invasive Garlic Mustard. Although the impact of Garlic Mustard on forest succession is uncertain, its heavy cover appears to be already limiting herbaceous and woody species regeneration in the areas it has invaded.

There was no pronounce difference of woodlot health within the compartments. We found no apparent “snowfence/rain shadow” effect where woodlot health would be effected on the windward edge of the compartment due to accumulated levels of CoC’s.

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APPENDIX A

WOODLOT HEALTH DATA SHEET	Assessor(s): P. Robertson K. Vitols	☐ ☐	Date(s) Inventoried:

1. SITE INFORMATION

Woodlot No.:	Compartment:	Size (ac):	Twp.:	Lot(s):	Conc(s).:
Drainage:		Topography:		Aspect:	
UTM Coord.:		Aerial Photo:	Digital:	Other:	

2. SITE DATA:

1) Plot Locations (plot interval in meters):

Start at Offset m @ ° P Head m @ ° P P	Start at Offset m @ ° P Head m @ ° P
Offset m @ ° P Head m @ ° P Offset m @ ° P	Offset m @ ° P Head m @ ° P Offset m @ ° P
Head m @ ° P Offset m @ ° P Head m @ ° P	Head m @ ° P Offset m @ ° P Head m @ ° P
Offset m @ ° P Head m @ ° P Offset m @ ° P	Offset m @ ° P Head m @ ° P Offset m @ ° P
Head m @ ° P Offset m @ ° P Head m @ ° P	Head m @ ° P Offset m @ ° P Head m @ ° P

2) Plot Tally / Max. DBH (cm):

Plot #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
DBH																									

3) Tree Tally (prism factor 2 m ²/ ha):

Class (cm)	Saplings (4-10)		Poles (12-28)		Sawlogs (30-36)		Sawlogs (38-48)		Sawlogs (50-60)		Oversized (> 60)		Total (all)	
Spp.	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS	AGS	UGS
1.														
2.														
3.														
4.														
5.														
6.														
7.														
8.														
9.														
10.														
11.														
12.														
13.														
14.														
15.														
Total trees														
BA (m ²/ ha)														
BA (m ²/ ha)														

4) Compartment Tree Age

Spp.	Age:	Spp.	Age:	Spp.	Age:	Spp.	Age:	Average:

5 Wildlife Trees (prism factor 2 m ²/ ha):

Cavity: Total: m ²/ha:	Snag: Total: m ²/ha	Downed Woody Debris : Total m ²/ha:	Total m ²/ha:

6) Tree Regeneration (Cover Codes - (1 : 0 % - 10 %) , (2 : 10 % - 25 %) , (3 : 25 % - 60 %) , (4 : > 60 %)):

Species / Value	1	2	3	4	Pts	Species	1	2	3	4	Pts	Species	1	2	3	4	Pts
1.						6.						11.					
2.						7.						12.					
3.						8.						13.					
4.						9.						14.					
5.						10.						15.					

7) Shrubs / Vines (5 m radius):

Species	Species	Species	Species	Species
1.	6.	11.	16.	21.
2.	7.	12.	17.	22.
3.	8.	13.	18.	23.
4.	9.	14.	19.	24.
5.	10.	15.	20.	25.

8) Management / Disturbance:

Disturbance/Extent	0	1	2	3	Score	Disturbance/Extent	0	1	2	3	Score
Livestock (Grazing)	None	Light	Moderate	Heavy		Gaps in Forest Canopy	None	Small	Intermediate	Large	
Extent of Livestock	None	Local	Widespread	Extensive		Extent of Gaps	None	Local	Widespread	Extensive	
Alien Species	None	Occasional	Abundant	Dominant		Disease/Death of Trees	None	Light	Moderate	Heavy	
Extent of Alien Species	None	Local	Widespread	Extensive		Extent of Disease/Death	None	Local	Widespread	Extensive	
Recreational Use	None	Light	Moderate	Heavy		Wind Throw (Blow Down)	None	Light	Moderate	Heavy	
Extent of Recreational Use	None	Local	Widespread	Extensive		Extent of Wind Throw	None	Local	Widespread	Extensive	
Access Trails	None	Faint Trails	Well-Marked	Tracks or Roads		Browse (eg. Deer)	None	Light	Moderate	Heavy	
Extent of Trails	None	Local	Widespread	Extensive		Extent of Browse	None	Local	Widespread	Extensive	
Dumping (Rubbish)	None	Light	Moderate	Heavy		Flooding	None	Light	Moderate	Heavy	
Extent of Dumping	None	Local	Widespread	Extensive		Extent of Flooding	None	Local	Widespread	Extensive	
Earth Displacement	None	Light	Moderate	Heavy		Ice Damage	None	Light	Moderate	Heavy	
Extent of Displacement	None	Local	Widespread	Extensive		Extent of Ice Damage	None	Local	Widespread	Extensive	
Time since Logging	> 30 Yrs.	15-30 Yrs.	5-15 Yrs.	0-5 Yrs.		Other:	None	Light	Moderate	Heavy	
Intensity of Logging	None	Fuel Wood	Selective	Diameter Limit		Extent of ...	None	Local	Widespread	Extensive	
Extent of Logging	None	Local	Widespread	Extensive						Intensity Score	

9: General Comments

Root:	Trunk:	Crown:
		Canopy Closure (%):
Diseases:	Tree Health	Regeneration:
	Tree Heights (m): Average Tree Height (m):	

10 Notes :

11 Map :

Site Information

Woodlot #	Compart. Size (ac)	Twp.	Lot(s)	Conc.	Access	Landform(s)	Soil Type(s) and Texture(s)	Topography	Aspect	Drainage	ELC	Wetland	Wetland Class	ANSI	CCA	ESA
01A	36.70	Port	24	1	Granted	Lacustrine He	Quarry: Organic soil, swamp as	Flat	Level	Imperfect	FOD7, SWD4-wMs	Yes	3			Yes
01B	29.90	Port	24	1	Granted	Lacustrine He	Quarry: Organic soil, swamp as	Flat	Level	Imperfect-Poor-	FOD7, SWD4-wMs	No				Yes
01C	22.20	Port	24	1	Granted	Lacustrine He	Plainfield: Aeolian fine sand for	Sand Dune	Variable	Well-Rapid	FOD2	No				Yes
02A	22.90	Port	22	1	Granted	Lacustrine He	Quarry: Organic soil, swamp as	Flat	Level	Poor-Imperfect	FOD7	No				
03A	6.00	Port	20	1	NA	Lacustrine He	Farmington: 50-100 cm variable	Flat	Level	Poor-Imperfect-	FOD7	No				
04A	14.00	Port	19	1	Granted	Lacustrine He	Welland: 15-40 cm peaty mater	Flat	Level	Imperfect-Very	FOD9,FOD7-wHe	No				
05A	22.10	Port	18	1	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Poor-Imperfect	FOD7	No				Yes
05B	5.60	Port	17,18	1	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Poor-Imperfect	FOD7	No				Yes
05C	12.00	Port	17	1	NA	Lacustrine He	Welland: Mainly reddish-hued la									Yes
05D	35.40	Port	17	1	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Poor-Imperfect	SWD3	No				Yes
05E	27.40	Port	16	1	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Poor-Imperfect	FOD7/SWD3	No				Yes
05F	20.40	Port	16	1	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Imperfect	FOD9	No				Yes
06A	4.60	Port	16	2	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Imperfect	FOD9-wAw	No				
07A	12.00	Port	17	2	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Imperfect-Well	FOD9	No				
08A	9.60	Port	20	2	Denied	Lacustrine He	Jeddo: Mainly reddish-hued cla									
09A	6.50	Port	21	2	Denied	Lacustrine He	Jeddo: Mainly reddish-hued cla									
10A	16.80	Port	24	2	Denied	Lacustrine He	Welland: mainly reddish-hued la									
11A	12.10	Port	19,20	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect	FOD9	No				
12A	24.00	Port	19	2	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect-Poor	FOD9,FOD7-wOr	No				
12B	18.80	Port	19	2	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperect-Poor	FOD9,FOD7-wOr	No				
13A	13.50	Port	16	2	Granted	Lacustrine He	Chinguacousy: mainly reddish-h	Flat	Level	Imperfect	FOD9-wAw	No				
14A	13.00	Port	15	2	NA	Lacustrine He	Jeddo: Mainly reddish-hued cla									
14B	0.00	Port	14	2	NA	Lacustrine He	Jeddo: Mainly reddish-hued cla									
15A	7.90	Port	14	2	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect	FOD7	No				
16A	13.20	Port	13	2	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	level	Imperfect-	FOD2	No				
17A	8.50	Port	14	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Poor	SWD3	Yes		Life Science		Yes
17B	11.20	Port	14	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect-Poor	FOD7	No		Life Science		Yes
17C	11.20	Port	14	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect-Well	FOD9,FOD2	No		Life Science		Yes
17D	11.40	Port	14	2	Denied	Lacustrine He	Jeddo: Mainly reddish-hued clay loam till and Quarry: Organic soil, swamp associated, 40-160 cm deep over clayey mineral soil ma							Life Science		Yes
18A	6.30	Port	16	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect-Well	FOD9,FOD2	No				
18B	2.90	Port	16	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Well-Imperfect	FOD9,FOD2	No				
18C	9.40	Port	16	3	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Imperfect	FOD9,FOD2	No				
C1A	10.90	Port	11	1	Granted	Lacustrine He	Jeddo: Mainly reddish-hued cla	Flat	Level	Poor-Imperect	FOD9-wOr,Hi	No				
C2A	44.20	Fort	34	A	Granted	Lacustrine He	Holly: Organic soil, swamp ass	Flat	Level	Poor-Very Poor	FOD7/SWD3	Yes	2			Yes
C2B	71.40	Fort	34	A	Granted	Lacustrine He	Plainfield: Aeolian fine sand for	Sand Dune	Variable	Rapid-Imperfect	FOD2	No		Life Science	Yes	Yes
C3A	20.00	Port	10	3	NA	Lacustrine He	Welland: Mainly reddish-hued la				FOD7	No				
C4A	16.70	Niaga	4	6	Granted	Haldimand Cl	Quarry: Organic soil, swamp as	Flat	Level	Poor-Imperfect	SWD4	Yes	1	Life Science		Yes
C5A	17.50	Wain	20	1	Granted	Lacustrine He	Welland: Mainly reddish-hued la	Flat	Level	Imperect	FOD2	No				
C6A	35.00	West	23	1	Granted	Haldimand Cl	Lincoln: Mainly lacustrine heavy	Gently Rolling	Mostly Level	Well-Imperfect	FOD9	Yes	2			

Ownership Information

Woodlot #	Comp.	Landowner Name(s)	Size (ac)	Property Address (Lot and Conc)	Mailing Address	Home Telephone
01	A	INCO	36.7	Lot 24, Conc.1, Port Colborne		
01	B	INCO	29.9	Lot 24, Conc. 1, Port Colborne		
01	C	INCO	22.2	Lot 24, Conc. 1, Port Colborne		
02	A	Sibbezinea, Ben	22.9	Lot 22, Conc.1, Port Colborne	791 Killally St.East, Port Colborne L3K 5V3	905.835.1340
03	A	Van Kralingen, Allert	4	Lot 20, Conc. 1, Port Colborne	773 Lorraine Rd., Port Colborne, ON L3K 5V3	905.835.8482
04	A	Bankert, Wallace and Anne	2.2	Lot 16, Conc. 1, Port Colborne	856 Weaver Rd., Port Colborne L3K 5V3	905.835.5241
04	A	Leon, Mark C/O Larry Jones	10.4	Lot 16, Conc. 1, Port Colborne	654 Pinecrest Rd., Port Colborne L3K 5V3	905.835.9896
05	E	Keatley, Gary	NA	Lot 18, Conc. 1, Port Colborne	693 Weaver Rd., Port Colborne	905.834.1428
05	D	Flickinger, Thomas	41.8	Lot 17, Conc. 1, Port Colborne	1849 Firelane 2, Port Colborne, ON L3K 5V3	905.834.7994,
05	F	Nevar, Susan and Mark	20.4 Part	Lot 18, Conc. 1, Port Colborne	805 Weaver Rd., Port Colborne, ON L3K 5V3	905.835.5339
05	F	Peyton, Cal	20.4 Part	Lot 18, Conc. 1, Port Colborne	1499 Firelane 2, Port Colborne, ON L3K 5V3	905.835.5765
05	E	Czinege, Larry and Irene	27.4 Part	Lot 18, Conc. 1, Port Colborne	671 Weaver Rd., Port Colborne, ON L3K 5V3	905.835.2959
05	D	Hatch, Harry	38.4	Lot 16, Conc. 1, Port Colborne	2537 Cataract Rd., Fonthill, ON L0S 1E6	905.687.0112
05	B	Toepp, Rudy and Doris	5.6	Lot 17, Conc. 1, Port Colborne	Killally St. East, Port Colborne L3K 5V3	905.834.7473
05	A	Yalowica, Marion and Sam	7.2	Lot 16, Conc. 1, Port Colborne	2145 Killally St. East, Port Colborne L3K 5V3	
05	A	Simpson, Diane and Barry	7.3	Lot 16, Conc. 1, Port Colborne	2015 Killally St. East, Port Colborne L3K 5V3	905.834.7439
06	A	Carbone, Frank	4.6	Lot 16, Conc. 2, Port Colborne		
07	A	Young,	12	Lot 17, Conc. 2, Port Colborne		
12	A,B	Fehrman, Paul and Amy	42.8 (24,18.8)	Lot 18&19, Conc. 2, Port Colborne	1577 Hwy. 3, Port Colborne L3K 5V3	905.834.6440
13	A	Bowman, Doug	13.5	Lot 16, Conc. 2, Port Colborne	2261 2nd Concession Port Colborne L3K 5V3	905.835.8525
15	A,B	Sneek, Paula	14.8 (7.9,6.9)	Lot 14, Conc. 2, Port Colborne	2702 Hwy#3, Port Colborne	905.835.2023
16	A	Bearss, Fgerald and Lorraine	13.2	Lot 13, Conc. 2, Port Colborne	1166 Sherk Rd., Port Colborne L3K 5V3	905.835.2192
17	A,B,C	Smith, Ian and Sonya	30.9	Lot 13, Conc. 3, Port Colborne	R.R.#3, Port Colborne L3K 5V5	905.834.7427
18	A	Tice, George and Jacoba	6.3	Lot 17, Conc. 3, Port Colborne	R.R.#3, Port Colborne L3K 5V5	905.835.2089
18	B	Huffman, Raymond and	2.9	Lot 17, Conc. 3, Port Colborne	2084 Miller Rd, Port Colborne L3K 5V5	905.835.2739
18	C	Noonan, Patrick	6	Lot 16, Conc. 3, Port Colborne	2317 Miller Rd., Port Colborne L3K 5V5	905.834.0991
18	C	Vanderlaan, Jack	3.4	Lot 16, Conc. 3, Port Colborne	2187 Miller Rd., Port Colborne L3K 5V5	905.834.7248
C1	A	Favaro, Dominic	11	Lot 11, Conc. 1, Port Colborne	766 Silver Bay Rd., Port Colborne L3K 5V3	905.834.7184
C2	A,B	Richards, Martha	119.7	Lot 34&35, Conc. A, Fort Erie	45 Lexington Ave., Buffalo, New York, USA	
C4	A	NPCA	16.7	Lot 4, Conc. 6, Niagara Falls		
C5	A	Niagara Region	17.5	Lot 20, Conc. 1, Wainfleet		
C6	A	Oliver,	33.6	Lot 23, Conc. 1, West Lincoln		

Vegetation Analysis 1)

Woodlot #	Tree Sp.. Comp. (10%+)	# of Tree Sp.	Rank of Tree Sp.	Avg. Age	Rank Avg. Age	Stocking %	Wgt. Score Stocking	Rank Stocking	Mean DBH (cm)	Rank Mean DBH	Max. DBH (cm)	Rank Max. DBH
01A	Ms61Cb16Cd16	10	8	70	19	76	10	27	33.2	14	92	10
01B	Ms49By13OH38	9	11	75	17	73	10	27	36.9	7	88	11
01C	Or32Ps16Mh13He12Id10OH17	12	3	85	12	76	10	27	34.1	12	94	9
02A	Ms35Ag31OH34	11	6	114	2	80	5	20	41.5	4	130	3
03A	Ob/s29Ms24Hs15Ew12Aw12	8	15	86	8	120	3	10	35.5	9	58	21
04A	Ms65By18He10	8	15	74	18	93	5	20	38.9	5	70	16
05A	Ms41Ag14Hs12	9	11	77	14	106	1	1	28.5	21	96	7
05B	Ms50Ag25Ew25	3	29	57	29	82	5	20	36.9	7	86	12
05C	NA											
05D	Ms44Ag32Ew14	7	20	68	20	87	5	20	42.7	3	132	2
05E	Ms59Aw16Ew13OH23	8	15	64	22	105	1	1	45.6	1	138	1
05F	Ms56Aw23OH21	7	20	65	21	120	3	10	30.7	17	128	4
06A	Hs38Aw24Ew17Os10Op10	5	26	90	7	110	3	10	23	27	50	30
07A	Ag32Ew21Ba15OH32	12	3	58	28	95	1	1	21.3	30	52	28
08A												
09A												
10A												
11A	Ag70Hs10OH20	7	20	63	24	92	5	20	23.8	25	58	21
12A	Ms64Ew20Ag16	3	29	85	12	78	10	27	25.6	24	54	26
12B	Ms68Ag16Ew12	6	23	97	3	108	1	1	34.9	10	96	7
13A	Aw44Ms26Or10OH20	9	11	86	8	115	3	10	33.4	13	68	17
14A												
14B												
15A	Aw47Ew27Ms20	5	26	59	27	105	1	1	21.9	29	50	30
16A	Ms19Or14Mh11OH56	13	2	76	16	98	1	1	31	16	74	15
17A	Ms91OH9	3	29	48	30	40	10	27	29.2	19	52	28
17B	Ms65By16OH19	8	15	86	8	102	1	1	29.2	19	62	18
17C	Cb29By24Be22Ms22	5	26	62	25	118	3	10	33	15	56	25
17D												
18A	Aw42Ms35Ew10	8	15	92	6	130	3	10	23	27	54	26
18B	Aw27Ew18Be18Op12OH25	9	11	64	22	120	3	10	29.4	18	76	14
18C	Aw28Ms21Or15Ew13OH23	10	8	45	31	120	3	10	21.3	30	62	18
C1A	Ms61Aw22OH17	6	23	77	14	118	3	10	34.6	11	86	12
C2A	Ms74By12OH14	6	23	61	26	88	5	20	38.1	6	116	5
C2B	Mh53Or20Aw14	10	8	128	1	90	5	20	44.7	2	100	6
C3A												
C4A	Ms41Aw15By15	11	6	86	8	100	1	1	23.5	26	58	21
C5A	Or23Ms21Aw18OH38	12	3	94	5	121	3	10	28.5	21	60	20
C6A	Or22Ms22Ow21OH35	14	1	95	4	100	1	1	27.5	23	58	21

Vegetation Analysis 2)

Woodlot #	Tot. BA (m2/ha)	Rank Total BA	AGS BA (m2/ha)	Rank AGS	AGS (%)	Rank (AGS %)	UGS BA (m2/ha)	Rank UGS	Tree Regen. Comp. (10%+)	# Shrub and Vine Sp.	Rank Shrub and Vine Sp.
01A	21.5	29	14	27	65	16	7.5	5	Ms33By16Wi16	13	6
01B	21.3	30	10.6	31	69	11	6.7	3	Cb39Ms22Bu22By11	5	27
01C	22	27	15.8	21	72	9	6.2	2	Cb42Mh15Id11OH32	14	3
02A	24	23	14.5	26	60	25	9.5	18	Cb53Bu12Ag12OH24	9	15
03A	34	6	21	10	62	23	13	30	Ew34Bd34Aw17Bu17	6	23
04A	27.2	16	17.6	17	65	16	9.6	19	Cb39Ms22Aw17Bd11Mh11	10	12
05A	29.4	12	19.6	16	67	14	9.8	21	Cb25Bu16Ba14Ew12Hs12Ms10OH11	4	30
05B	24	23	13.3	28	56	29	10.7	26	Ew33Cb25Ag16Hs16	5	27
05C											
05D	26	20	15.4	23	59	26	10.6	24	Ms37Ag37Ew22	17	1
05E	25.6	22	16.4	20	64	19	9.2	15	Aw42Ew21Pw14OH23	11	10
05F	35.8	3	26.6	2	74	5	9.2	15	Ew17Bu17Ms14Bd11OH41	13	6
06A	29	13	20	14	69	11	9	12	Hs38Ag24Ew17Os10Op10	6	23
07A	24	23	15.3	25	64	19	8.7	11	Bu22Cb20Ew17Ag11OH30	8	17
08A											
09A											
10A											
11A	24	23	15.6	22	65	16	8.4	10	Ag24Ew18Hs18Bu12OH28	6	23
12A	21.1	31	11.1	30	53	31	10	22	Ms29Ew29Ag24OH18	5	27
12B	33.7	8	22.4	8	66	15	11.3	27	Ag23Bu23Ms13Ob13Op13Ew10	14	3
13A	36.7	2	25	4	68	13	11.7	28	Bu34Cb23Aw11OH32	10	12
14A											
14B											
15A	30	11	23	7	77	3	7	4	Bu31Aw23Ms23Ew15	15	2
16A	27.7	15	19.7	15	71	10	8	8	Aw29Bu23Cb15Mh14OH19	10	12
17A	22	27	12	29	55	30	10	22	Ag50Cb25Ms25	7	20
17B	28.4	14	20.8	12	73	6	7.6	6	Cb29Ms29Ap21Ag21	6	23
17C	34	6	20.7	13	61	24	13.3	31	Be66Cb33	3	31
17D											
18A	34.7	4	22	9	63	22	12.7	29	Ew17Aw13Cb13Ms13OH44	8	17
18B	33	10	24	6	73	6	9	12	Cb40Be30Ew20Aw10	7	20
18C	37.6	1	30	1	80	1	7.6	6	Aw20Ew20Cb17Bu13Ms10OH20	14	3
C1A	34.6	5	24.8	5	73	6	9.2	15	Bu23Be20Ms17Cb11Aw11OH18	8	17
C2A	26	20	15.4	23	59	26	10.6	24	Ms48By16OH36	9	15
C2B	27	17	17.3	18	64	19	9.7	20	Mh47Id14OH30	12	8
C3A											
C4A	26.1	19	17	19	58	28	9.1	14	Cb20Ms16Aw14Hs10Bu10OH30	12	8
C5A	33.4	9	25.4	3	76	4	8	8	Bu22Be17Ms12Mh12Ew10OH30	7	20
C6A	27	17	21	10	78	2	6	1	Ew16Bu16Ag14Cb10Be10OH34	11	10

Woodlot Quality

Woodlot #	Stocking %	Wgt. Score Stocking	Rank Stocking	AGS (%)	Rank (AGS %)	Max.Hgt. (m)	Rank (Max.Hht.)	Mean DBH (cm)	Rank Mean DBH	Wildlife Trees (m2/ha)	Overall Wildlife Rank	Rank Score	Overall Rank
01A	76	10	27	65	16	24	17	33.2	14	11.6	6	80	20
01B	73	10	27	69	11	24	17	36.9	7	6.5	26	88	24
01C	76	10	27	72	9	23	22	34.1	12	8.7	13	83	21
02A	80	5	20	60	25	25	11	41.5	4	9.6	14	74	16
03A	120	3	10	62	23	28	3	35.5	9	7	20	65	12
04A	93	5	20	65	16	24	17	38.9	5	12.3	4	62	11
05A	106	1	1	67	14	25	11	28.5	21	8.2	18	65	12
05B	82	5	20	56	29	25	11	36.9	7	12	8	75	17
05C													
05D	87	5	20	59	26	29	2	42.7	3	14.6	3	54	6
05E	105	1	1	64	19	27	4	45.6	1	11.2	5	30	1
05F	120	3	10	74	5	26	9	30.7	17	10	7	48	4
06A	110	3	10	69	11	20	29	23	27	2	31	108	29
07A	95	1	1	64	19	20	29	21.3	30	12.6	8	87	23
08A													
09A													
10A													
11A	92	5	20	65	16	24	17	23.8	25	5.2	26	104	28
12A	78	10	27	53	31	22	23	25.6	24	10	11	116	31
12B	106	1	1	66	15	26	9	34.9	10	4.9	25	60	10
13A	115	3	10	68	13	27	4	33.4	13	10	11	51	5
14A													
14B													
15A	105	1	1	77	3	22	23	21.9	29	13	14	70	15
16A	96	1	1	71	10	30	1	31	16	7.3	19	47	2
17A	40	10	27	55	30	22	23	29.2	19	11	16	115	30
17B	102	1	1	73	6	20	29	29.2	19	15.6	1	56	8
17C	118	3	10	61	24	22	23	33	15	7.4	24	96	26
17D													
18A	130	3	10	63	22	25	11	23	27	6.7	22	92	25
18B	120	3	10	73	6	24	17	29.4	18	4	28	79	19
18C	120	3	10	80	1	22	23	21.3	30	6.4	22	86	22
C1A	118	3	10	73	6	27	4	34.6	11	8	17	48	3
C2A	88	5	20	59	26	25	11	38.1	6	15.1	2	65	12
C2B	90	5	20	64	19	27	4	44.7	2	7.7	10	55	7
C3A													
C4A	100	1	1	58	28	22	23	23.5	26	6.6	21	99	27
C5A	121	3	10	76	4	25	11	28.5	21	4.6	30	76	18
C6A	100	1	1	78	2	27	4	27.5	23	4.8	28	58	9

Management and Edge

Woodlot #	Mgt./Dist. Points	Rank (Mgt./Dist.)	Size (ac)	Rank (Size)	Edge (m)	Size (ha)	Edge:Area (m/ha)	Rank (Edge:Area)
01A	36	25	36.7	3	884	14.9	59.5	6
01B	17	6	29.9	6	1670	12.1	138.0	17
01C	26	15	22.2	10	840	9.0	93.5	10
02A	40	29	22.9	9	1381	9.3	149.0	18
03A	38	27	4	30	520	1.6	321.1	34
04A	24	14	14	16	972	5.7	171.5	21
05A	31	21	22.1	11	895	8.9	100.0	11
05B	31	21	5.6	28	546	2.3	240.8	29
05C				0				
05D	30	20	35.4	4	833	14.3	58.1	5
05E	37	26	27.4	7	2242	11.1	202.1	26
05F	20	9	20.4	12	1024	8.3	124.0	13
06A	14	3	4.6	29	587	1.9	315.2	33
07A	41	30	12	20	969	4.9	199.5	25
08A				0	802	3.9	206.3	27
09A				0	731	2.6	277.8	31
10A				0	770	6.8	113.2	12
11A	26	15	12.1	19	948	4.9	193.5	24
12A	21	11	24	8	1319	9.7	135.7	16
12B	18	8	18.8	13	1147	7.6	150.7	19
13A	22	13	13.5	17	953	5.5	174.4	22
14A				0	1159	5.3	220.2	28
14B				0	1012	3.0	337.8	36
15A	13	2	7.9	26	960	3.2	300.2	32
16A	38	27	13.2	18	933	5.3	174.6	23
17A	42	31	8.5	25	434	3.4	126.1	14
17B	34	23	11.2	21	171	4.5	37.7	4
17C	27	17	11.2	21	99	4.5	21.8	2
17D								
18A	17	6	6.3	27	843	2.6	330.5	35
18B	20	9	2.9	31	526	1.2	448.0	37
18C	12	1	9.4	24	999	3.8	262.5	30
C1A	21	11	11	23	745	4.5	167.3	20
C2A	16	4	45	2	600	18.2	32.9	3
C2B	35	24	74.7	1	530	30.2	17.5	1
C3A					695	8.1	85.8	8
C4A	27	17	16.7	14	630	6.8	93.2	9
C5A	16	4	15.5	15	825	6.3	131.5	15
C6A	28	19	33.9	5	1105	13.7	80.5	7

Species and Wildlife

Woodlot #	# Tree Sp.	Rank Tree Sp.	# Shrub and Vine Sp.	Rank Shrub and Vine Sp.	# Tree, Shrub, and Vine Sp.	Rank Total # Sp.	Cavity Trees (m2/ha)	Ranking Cavity Trees	Snags (m2/ha)	Ranking Snags	Downed Woody Debris (m2/ha)	Ranking DWD	Wld. Trees (m2/ha)
01A	10	8	13	6	23	5	0.9	24	5.2	2	5.5	6	11.6
01B	9	11	5	27	14	21	0.6	27	1.3	22	3.6	17	5.5
01C	12	3	14	3	26	1	1.8	18	2.7	13	4.2	12	8.7
02A	11	6	9	15	20	9	4.6	3	1.8	18	3	23	9.6
03A	8	15	6	23	14	21	2	15	3	10	2	28	7
04A	8	15	10	12	18	17	4.3	4	3.3	8	4.7	9	12.3
05A	9	11	4	30	13	25	3.3	10	1.6	18	3.1	21	8.2
05B	3	29	5	27	8	29	6.7	1	1.3	22	4	13	12
05C													
05D	7	20	17	1	24	3	4.9	2	5.1	4	4.8	10	14.6
05E	8	15	11	10	19	14	3.6	9	2.4	15	5.2	7	11.2
05F	7	20	13	6	20	9	3	11	3	10	4	13	10
06A	5	26	6	23	11	27	1	20	0	30	1	29	2
07A	12	3	8	17	20	9	0.3	29	5	5	7.3	2	12.6
08A													
09A													
10A													
11A	7	20	6	23	13	25	1	20	0.6	29	3.6	17	5.2
12A	3	29	5	27	8	29	2.6	13	4.3	6	3.1	21	10
12B	6	23	14	3	20	9	2.7	12	1.3	22	0.9	31	4.9
13A	9	11	10	12	19	14	2.3	14	1.7	21	6	5	10
14A													
14B													
15A	5	26	15	2	20	9	0	30	9	1	4	13	13
16A	13	2	10	12	23	5	1	20	1.3	22	5	8	7.3
17A	3	29	7	20	10	26	2	15	0	30	9	1	11
17B	8	15	6	23	14	21	4	6	5.2	2	6.4	4	15.6
17C	5	26	3	31	8	29	4	8	0.7	26	2.7	25	7.4
17D													
18A	8	15	8	17	16	18	0.7	26	2.7	13	3.3	19	6.7
18B	9	11	7	20	16	18	2	15	1	27	1	29	4
18C	10	8	14	3	24	3	1.2	19	2.8	12	2.4	27	6.4
C1A	6	23	8	17	14	21	0.4	26	3.2	9	4.4	11	8
C2A	6	23	9	15	15	20	4.3	4	3.7	7	7.1	3	15.1
C2B	10	8	12	8	22	8	3.7	8	2	17	4	13	9.7
C3A													
C4A	11	6	12	8	23	5	1	20	2.3	18	3.3	19	6.6
C5A	12	3	7	20	19	14	0.9	24	1.1	26	2.6	26	4.6
C6A	14	1	11	10	25	2	0	30	1.8	18	3	23	4.8

Port Colborne Community Based Risk Assessment

Woodlot Health Assessment Study

Appendix C

Prepared by:

TREES UNLIMITED
FORESTRY CONSULTANT

Prepared for:
Jacques Whitford Environment Limited
&
Inco Limited, Port Colborne Refinery

Example of a snag & cavity

High stocking of polewood

Vigourously growing sawlog red oak

Vigourously growing sawlog red oak

White elm butt flare

White elm butt flare

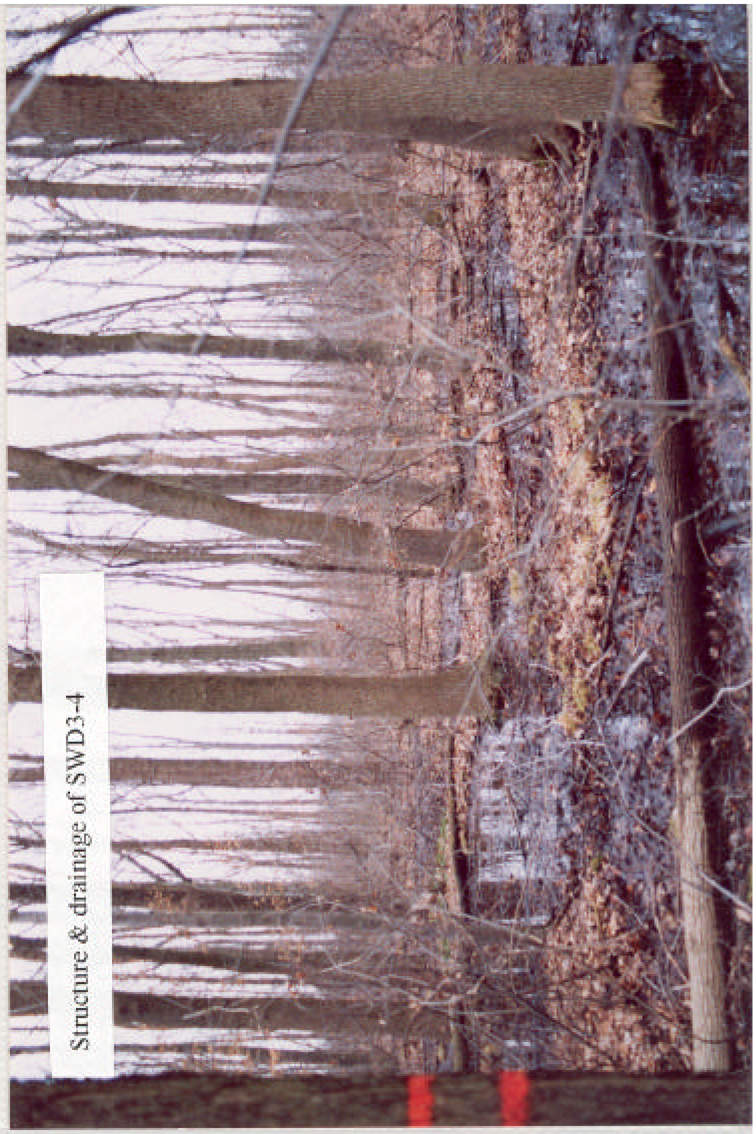
Compartment plot centre

Increment coring of soft maple

Soft maple core ready to be counted

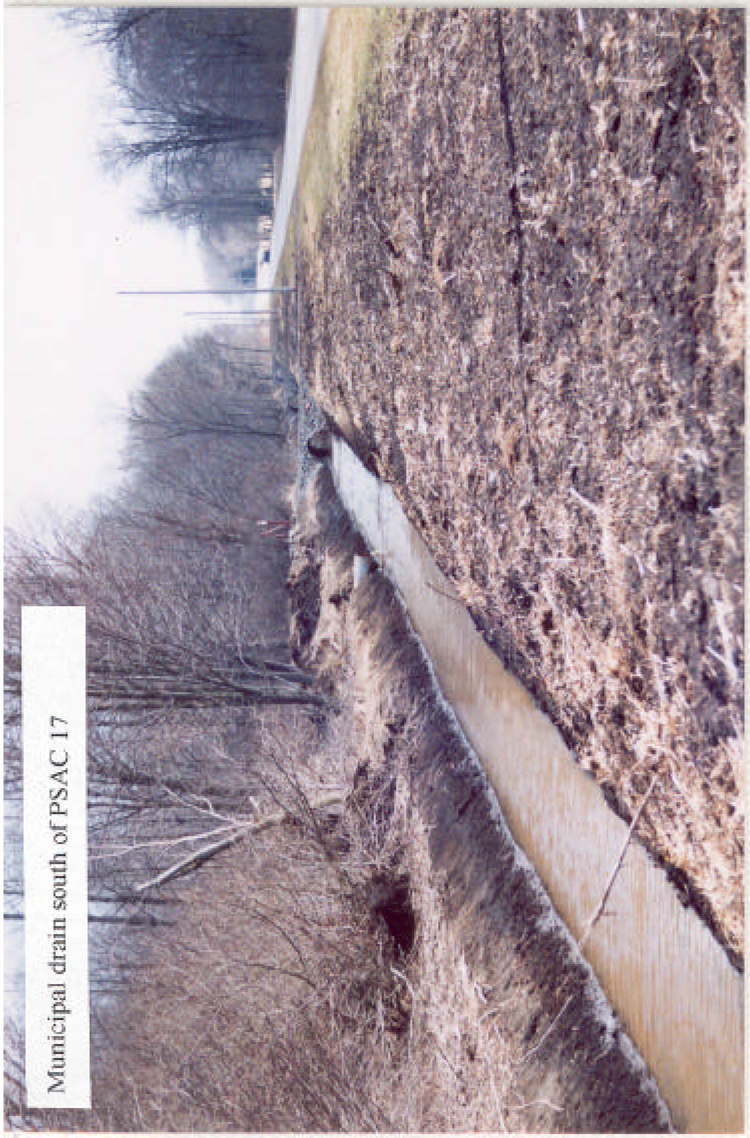
Core hole compared to a dime

Core hole compared to a dime



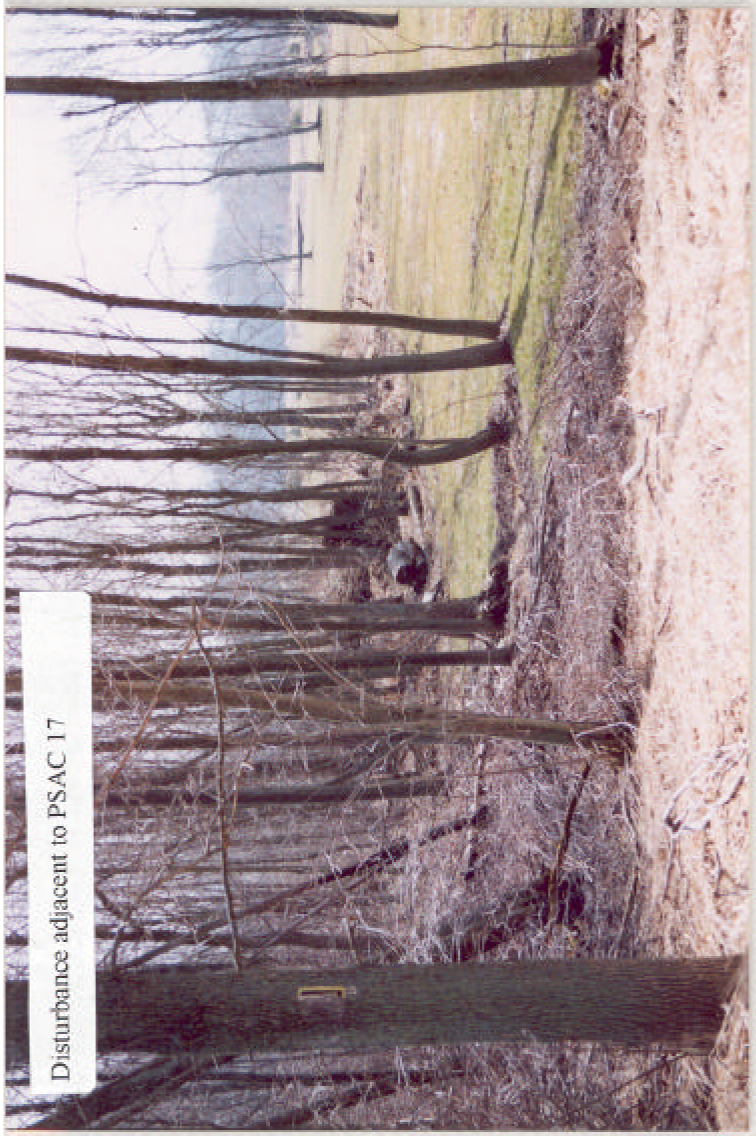
Structure & drainage of SWD3-4

Structure & drainage of SWD3-4


Municipal drain south of PSAC 17


Forest floor of SWD3-4


Disturbance adjacent to PSAC 17



Disturbance adjacent to PSAC 17

Soil profile

Municipal drains adjacent to PSAC 17

Spicebush in SWD3-4

Wildlife den amongst roots

Root exposure

FOD7

Snags in SWD3-4

Root exposure

Windthrow

Garlic mustard along municipal drain

Garlic mustard along municipal drain


Cavity in soft maple


Turkey vulture in cavity