THE ECOLOGY OF OLD TREE STUMPS

ON THE EVERGREEN STATE COLLEGE CAMPUS

WINTER QUARTER PROJECT 1974

EVERGREEN ENVIRONMENT

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METHODS

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The first part of our project involved research work on past sudies and papers on detritus ecology. The purpose of this was to formulate field techniques and to gather present knowledge of stumps and logs and rotten wood and their importance in the forest ecosystem. Once we had established our ideas, we went out and measured each stump's height and width. We thought that size would be important to microclimate, since the thicker the wood, the more insulation against outside temperatures. This would also be important to insect life within the stumps.

Wood identification

We took wedge-shaped wood samples, using a saw, from each stump in an effort to identify each stump's species type. We looked at thinly sliced cross sections, vertical and horizontal, under a 30x dissecting microscope. The structure of the wood fibers was the key to identification. We were interested in knowing whether wood type had any relationship to different successional stages of animals and plants on the stumps.

INTRODUCTION

At the beginning of winter quarter three students joined interests to begin a quarter long study on the ecology of tree stumps on the TESC campus. We understood that rotten stumps play an important role in the forest ecosystem and wished to gain some insight into this role.

In search of these objectives we thought some of the goals of the project would be to 1) identify the species of each stump and bore for approximate age, 2) identify and quantify the flora and fauna occupying the stumps, and determine through this if certain species of plants and animals occupy a specific tree species for their habitat, 3) look for successional trends in the life on each stump, and 4) examine the microclimate of the stumps in comparison with the surrounding atmosphere and ground area, specifically measuring temperature and moisture content.

All of our field work took place on the Evergreen State College campus. For the study we selected four different areas in which two stumps from each locality were chosen for study. The type and age of the vegetation in each area differed.

DESCRIPTION OF STUDY AREAS

The Douglas-fir grove was an even-aged stand of 50-60 year old Pseudotsuga manziesii, with a moderately dense canopy permitting diffuse sunlight to reach the forest floor. A few alders (Alnus rubra) and bigleaf maples (Acer macrophyllum) occurred as scattered individuals. Major understory plants were salal (Gaultheria shallon), Oregon grape (Berberis nervosa), and huckleberry (Vaccinium parvifolium). The soil possessed a humus layer several inches deep, composed primarily of Douglas-fir needles and salal leaves. Mosses formed an extensive ground cover.

The open field was a large meadow (approx. 10 acres) bordered on three sides by second-growth alder and Douglas-fir and on the fourth side by a road. The predominant plant cover was various grass species and clovers (Trifolium spp.), vetch (Vicia spp.), blackberries (Rubus vitifolius), and many small herbaceous plants, not readily identifiable.

Tree stumps occurred scattered and isolated in the field. The study stumps were at least 100 yards from the nearest woods. Stump A had a young alder tree, 15 feet high, growing adjacent to it. The soil of the area was mineral with a very shallow organic

layer.

The mixed conifer grove was located on top of a bluff near Eld Inlet. The tree overstory, perhaps 100-150 years old, consisted of Douglas-fir, western hemlock (Tsuga heterophylla), and western redcedar (Thuja plicata). One large bigleaf maple grew adjacent to Stump A. Understory plants were salal, Oregon grape, huckleberry, and mosses. The dense canopy left the forest floor shaded even on sunny days. A large accumulation of organic litter and a deep humus layer covered the ground.

The alder grove was a pure stand of immature (approx. 30-40 years old) Alnus rubra, growing in a wet, boggy soil. The canopy was open, permitting considerable sunlight to penetrate through. Understory plants, excepting mosses and grasses, were confined to logs and stumps (such as huckleberry and salal) or were annuals and unobserved at the time of the study. A layer of decaying leaves overlaid the waterlogged soil.

Description of Stumps

Stump	Height in cm	Circumference in cm	Type of wood	Remarks
Douglas-fir grove:				
Stump A	65	240	W. Redcedar	
Stump B	90	220	Douglas-fir	
Open field:				
Stump A	220	210	Douglas-fir	15 feet alder growing adjacent
Stump B	88	311	Douglas-fir	
Mixed conifers:				
Stump A	108	218	Douglas-fir	Large conifer growing adjacent
Stump B	165	280	True fir	hollow center
Alder grove:				
Stump A	90	322	True fir	hollow center
Stump B	87	342	W. Hemlock	

Boring for age

We tried boring for the age of the stumps, using a drillbit and borer, but found the rotten wood to be too broken up and wet to form good cores or distinct rings, such as sound wood would produce. Hence we could only estimate the ages of the stumps by size.

Species survey of plants

The species survey was conducted by observation and counting of herbaceous plants and collecting and identification of mosses and lichens. Herbaceous plants were counted individually but counting was not possible for lichens and mosses. Instead, we estimated what percentage of the stump each species covered and what substrate it was growing on. Identifications of plants were made using Gilkey and Dennis (1967). Mosses and lichens were identified using a Nikon dissecting microscope. Moss leaves were stripped off the stems with a razor blade and floated off in water to permit easy observation of their structure. Lichen acid tests were conducted to verify the results of unreliable visual identification. The keys used were Schofield (1969) for mosses and Hale (1961) for lichens.

Soil tests

Soil tests were conducted using the La Motte Soil Test Kit, relying primarily on color comparisons to obtain values. pH was determined by using drops of colored pH solutions and comparing with colored charts.

Litter fall

Litter fall was determined by removing all the litter by hand from the tops of stumps, including vertical cracks and gaps between the bark and the wood. The litter was stored in plastic bags and weighed on a Dial-O-Gram balance scale. Wet and dry weights were measured. A tape measure was used to determine stump circumference and hence to calculate the surface area and the litter weight/unit area ratio.

Microclimate

Another chapter of our field work was the study of microclimate. In our research we found that stumps often harbor different plant and animal life than the rest of the forest because of their different temperatures and moisture contents inside as compared to the exterior environment. For this reason, ecological isolation may be displayed by these stumps for certain plant and animal species.

Temperature

The temperature readings were done in a four day time period in February. One stump in each of the areas was used as follows:

Stump A in the Douglas-fir grove
Stump A in the old field
Stump B in the mixed conifer grove
Stump A in the alder grove

A probe from a telethermometer (YSI Model 46 TUC), accurate to 0.1 degrees Centigrade, was placed horizontally in each stump and left there for the duration of the experiment. A hole was drilled with an increment borer, the diameter of which was close to that of the probe. The outside of the hole was stuffed with litter or sawdust to insulate the probes from the outside air.

Temperatures were read on a twelve hour basis, at 8:00 AM and 8:00 PM, allowing travel time from area to area. Four readings were taken at each stump: core temperature, temperature at one half the distance between the core and the bark surface, temperature just under the surface of the bark (if any), and outside air temperature near the ground.

Moisture content

The method utilized was essentially that used to determine soil moisture by the gravitational method (Dawson, 1972). Samples were placed in metal film cans and left to dry for eleven

hours at approximately 100 degrees C in a kitchen oven. Lids were removed from the cans prior to drying.

Samples were obtained by using a brace with a 3/4 inch wood bit. "Inner" and "outer" refer to the depth from which the samples were taken. "Outer" samples are those taken from approximately the outer one quarter of each stump. "Inner" samples were obtained from the center of each stump. In tables #2 and #3 "soil roots" refers to soil samples obtained at the base of the stump and "soil outer" refers to soil samples obtained approx. two feet away from the stump. In table #1 samples were taken at mid-stump vertically.

The numbers heading each of the columns in the data represent the following information:

#1 - weight of the empty film can
#2 - weight of can plus wet wood or soil
#3 - weight of can plus dried wood or soil
#4 - weight of water - #2 minus #3
#5 - weight of dry wood or soil - #3 minus #1
#6 - percent water content - #3 divided by #4 X 100

DISCUSSION

The Detritus Cycle

The herbivore-detritus food chain is of more importance in forests than the herbivore-browsing/grazing chain. As much as 90% of the energy flow in forest ecosystems may pass through detritus feeders (Kormondy, 1967). Direct grazing by herbivores on living plants is limited in comparison. It includes deer browsing on foliage, porcupines eating bark, and leaf-eating insects. Most of the plant material in forests falls to the ground in the form of litter or detritus. The detritus serves as an energy source for millions of decomposers in the soil and in stumps and logs. These decomposers include mites, spring-tails, wood-eating insects, earthworms, fungi, and bacteria. The animal decomposers are preyed upon by predators and the plant decomposers are grazed upon by herbivores, such as ones that live on fungi. Thus a complex system of decomposers, herbivores, and carnivores is supported by the accumulation of detritus on the forest floor.

In addition, the decomposition of detritus returns nutrients stored in plant tissues to the soil. These nutrients are locked

up in complex organic compounds which the decomposers break down into useable forms for absorption by plant from the soil.

Plant debris is composed of organic and inorganic substances. Inorganic elements such as K, Mg, Fe, P, and S remain as ash when all organic substances are removed. The recycling of phosphorus, accomplished by phosphatising bacteria, is important because frequently phosphorus is a limiting nutrient of the productivity of ecosystems (Collier, 1973). Calcium is recycled directly through decomposition of litter while sodium and potassium are recycled through the decay of wood (Collier, et.al.). The organic portion of detritus consists of non-nitrogenous compounds suchas starches.and sugars. Cellulose ($C_6H_{12}O_6$), a product of photosynthesis, is one of these sugars. Breakdown of these compounds recycles carbon, hydrogen, and oxygen through the ecosystem. About 75% of these substances break down into CO_2 and H_2O in the soil while 25% become incorporated in the tissues of decomposers, who eventually die and release these elements again.

Detritus also is composed of nitrogenous substances such as protein, containing C, O, H, S, phosphoric acid, and organic acids, resins and oils composed of C, O, and H. C, O, H, S, and P are re-

cycled through breakdown of these compounds too, but the most important recycled element is nitrogen.

Plants store nitrogen in the form of ammonia (NH_3) in proteins. Shortly after death the ammonia is released from the rest of the protein by pioneering decomposers. They either release it directly or through their excretion. This process is called deanimation. The ammonia is further reduced in two steps to nitrate, a process called nitrification. First nitrite bacteria reduce NH_3 to NO_2 by the following reaction: $NH_3 + 1\frac{1}{2}O_2 = HNO_2 + H_2O$. Then nitrate bacteria further reduce it as such: $KNO_2 + \frac{1}{2}O_2 = KNO_3$. In the form of nitrate (NO_3^-), nitrogen is soluble in water and is readily assimilated through the roots of plants. Some of the nitrate is converted to gaseous nitrogen (N_2) by dentrifying bacteria, and is released to the atmosphere.

Bacteria are responsible for the breakdown of most nitrogen stored in organic substances. Animals accomplish much of the breakdown of non-nitrogenous substances. There are many overlappings in function.

There is a distinct zonation of detritus on top of the soil.

Fresh detritus is found on top while each successive layer is more decomposed than the one above. The top layer is called litter, and includes leaves, twigs, branches, logs, and stumps. The fall of litter is continuous in coniferous forests and seasonal in deciduous forests. The next layer is plant residue, which consists primarily of partially decayed litter. Breakdown of non-nitrogenous substances occurs in this layer. K, P, N, Ca, and Mg are leached out, being water soluble. Leaves turn dark brown in color and wood crumbles. The top two layers are known as the ectohumus because they are primarily organic in nature. The underlying mobile- or endohumus is a mixture of organic and inorganic (Bunting, 1965). The organic part of mobile humus consists of residual decay-resistant compounds such as lignin, tannin, organic acids, and resynthesized substances, also resistant to decay, known as humic acids. At first these humic acids, complex compounds of C, O, and H, dominate the mobile humus layer. They are insoluble in water and have an acid pH. In some soils soluble fulic acids are formed, which contain more C, O, and H and less N. The ratio of these elements to one another is a measure of the state of decomposition of any layer in the humus.

Fungi

The fungi are a class of plants, the majority of which members are saprophytic, that is, they use the dead or decomposing tissues of plants and animals as their food source. A few species are parasites of living organisms. Fungi do not possess chlorophyll, hence they cannot manufacture their own food using water, CO_2, and sunlight. Saprophytic fungi are an important constituent of the decomposers in the detritus food chain. Along with animal decomposers and bacteria they return nutrients stored in plants and animal tissues to the soil.

The fungal structure is a branching network of hollow tubes filled with cytoplasm, known as the mycelium. The tubes, or hyphae, are divided at regular intervals by cell walls, or septa. An open pore in the center of each septa permits exchange of nutrients and the flow of cytoplasm between cells. The hyphae walls and septa are composed of either cellulose or chitin. As the mycelium grows the hyphae extend at their tips. When each reaches a certain length a new septa forms. A few primitive fungi lack septae. Hyphae can "leap" across non-suitable substrates to reach suitable ones.

Enzymes are secreted and nutrients absorbed over the entire surface of the mycelium. Vacuoles in older cells hasten absorption. Hyphae are capable of penetrating strong substrates such as wood. They take the path of least resistance by growing in sap channels and between cell walls, physically prying apart the cells and breaking them down with enzymes.

Fungi reproduction varies from simple to complex, depending on the species. Fungi in a "perfect" state produce sexual spores; "imperfect" fungi produce asexual spores. The spore-producing or fruiting bodies vary from microscopic growths in the mycelial surfaces to the familiar mushrooms of higher fungi. The mushroom is characterized by a vertical stalk, horizontal cap, and vertical gills. Spores are produced on the surface of the gills on special cells called basidia. They are ejected forcefully from the basidia a distance of 0.1 mm, sufficient to clear the gills and drop into the air. Air currents disseminate the spores. The spores, millions on one mushroom, are thick or thin-walled.

Genetic change in fungi is encouraged by various combinations of chromosomes and genes during reproduction. Combinations

of sexual and asexual generations and such genetic mechanisms as heterothallism and alleopathy are employed.

The fungi found on organic substrates, such as s stump, are mostly decomposers of non-nitrogenous organic compounds. A few species feed on either dead fungi or bacteria. Garrett (1963) sums up succession of fungi on organic substrates:

Senescent tissue	Dead tissue		
Stage 1a	Stage 1	Stage 2	Stage 3
Weak parasites	Primary saprophytes Sugar fungi living on sugars and carbon compounds simpler than cellulose.	Cellulose decomposers and associated secondary fungi, sharing products of cellulose decomposition.	Lignin decomposers and associated fungi.

Senescent tissue is neither dead or alive.

The first stage, breakdown of simple sugars and carbohydrates, is readily accomplished. These compounds are stored in the sap. Fungi attacking sap are known as sap rots. Decomposition of cellulose is more difficult and takes longer to accomplish. Cellulose is stored in the sapwood and heartwood of trees. After these areas have rotted all that is left is the bark and cell walls, which are composed of lignin, a complex protein form-

ing strong fibers resistant to decay. Lignin is very difficult to decompose.

The saprophytic sugar fungi of stage 1 compose an abundant variety of species, mostly members of the class Phycomycetes, with a few species of Chytridiales. Common sugar fungi on Northwest coniferous dead woods include Polyporus abietinus (pitted sap rot), P. versicolor, and Lensites sepiara (brown pocket rot) (Buchanan, 1940).

Cellulose decomposers are relatively few in number and of these only a few also decompose lignin. Most of the species are higher fungi in the classes Basidiomycetes and Ascomycetes. These fungi, many of which produce mushrooms, are evolutionarily more advanced than the sugar fungi. Non-mushroom producing cellulose decomposers in Northwest conifers (Buchanan, 1940) include Fomes annosus (rootrot), F. pinicola, and Ganiderma origonense. Those that also decompose lignin include Polyporsa sulphureus and Fomes ruscus. Fomes annosus is especially widespread because it survives either as a vigorous parasite on living trees or as a saprophyte.

Mushrooms commonly found on decayed coniferous wood include

Clitocybe aumntica (false chanterelle), Omphalina umbellifern, Pleurotus porrigens (Angel wings), Xeromphaliaa campanella (Golden trumpets), Pholioea squarrosa, and Hericium coralloides (on Douglas-fir).

Some of these species grow only in the sapwood, others in both the sapwood and the heartwood.

The fungi of stage 2 do not always immediately succeed the sugar fungi. Availability of nitrogen is a limiting factor. Decomposition of sugar and carbohydrates occurs faster than ammonification and nitrification. The cellulose fungi germinate as soon as sufficient nitrogen is released by bacteria and animals.

The sugar fungi are adapted to their colonizing role by 1) their abundance in numbers and species and 2) their rapid spore germination and mycelial growth. Some of them are exclusively colonizers. Others linger on as secondary fungi, dependent on by-products of cellulose and lignin decomposition.

The competitive saprophytic ability of fungi is determined by 1) the growth rate of the hyphae, 2) the secretion of enzymes, 3) the production of antitoxins, and 4) the resistance to toxins.

The first two factors together compromise the inoculum potential. The growth rate of sugar fungi favors them as colonizers but the secretion of stronger enzymes eventually favors cellulose and lignin fungi. Competition is keenest during stage 1 and decreases with successive stages.

Many fungi secrete toxins which inhibit the growth of other fungi or bacteria. Likewise bacteria inhibit fungal growth with their own toxins, creating a condition known as fungistasis.

Fungal growth is limited by physical factors too. Only the thermopholic fungi can survive at temperatures of 65-75 degrees Centigrade. Excess moisture was shown to be a limiting factor to fungi on the undersides of logs in the Olympics (Bucharan, 1940). The acid pH of highly organic substrates prevents the growth of fungi which prefer more mineral substrates. Acid pH also breaks down some toxins, a factor which reduces the competitive ability of fungi which secrete those toxins.

Lichens

The lichens are actually two different plants, fungi and green algae, living together in a symbiotic relationship.. The main lichen structure is the thallus, a scaly thin body adhering to the substrate. The thallus is distinctly layered. The upper cortex is dry and tough. Underneath it lies the algal layer, where algal cells are enmeshed in a network of fungal hyphae. Next comes the medulla, a layer of intertwining hayphae without algal cells, and finally the lower cortex. The thallus is entirely composed of fungal cells, excluding the algal layer.

Lichens grow in three forms. The crustose lichens grow as thin sheets over bare rock and are the very first colonizers. Foliose lichens have thicker thalli forming leafy lobes. They grow on rocks or organic substrates. Fruticose lichens are stalked or branched, and grow primarily on organic substrates. The common lichens on dead wood are mostly members of the Cladonia family. They consist of a lobed or squamulose base, adhered to the rock. Out of this grow erect, branched or unbranched podetia. The podetia are simply extensions of the thallus. Instead

of being layered from top to bottom they are layered around a hollow central core.

Lichens reproduce by two methods. One method is the growth of soredia. These are eruptions of the algal layer through the upper cortex to the surface of the thallus. Each soredia consists of a few algal cells enmeshed in a tube of fungal hyphae, the whole encased in protective gelatin. The soredia are carried away by wind or rain. Simple fragmentation of lichens is also a common method of reproduction. New lichens will grow from fragments of the thallus, provided the fragment contains some algal cells.

The fungal component of the lichens also produces fruiting bodies. These spore-bearing apothecia appear on the surface of the thallus. In Cladonia, they are on the tips of the podetia. These spores are wasted, however, because they will not grow without the prescence of the algae. Lichens also produce asexual structures which may be responsible for the production of apothecia.

The algae can grow without the fungus, but not vice versa. Together, they benefit each other. The fungi absorbs nutrients

from bare rock, mineral soil, or organic substrates, depending on what species it is. If growing on rock, the lichen secretes acids which dissolve the rock. The fungus absorbs dissolved minerals in the acid and its hyphae physically break up the rock. It depends on the algae for the rest of its nourishment, which is manufactured through photosynthesis. In return the fungus provides a well-protected and moist environment for the algae.

The fungi in lichens growing on highly organic substrates are saprophytic and depend less on the algae as a food source. The algae do provide the lichen with a distinct advantage in colonizing burnt wood, where fungi alone have difficulty growing. Lichens growing on decayed wood are called nitrophiles because of their tolerance of high nitrogen in the substrate. The fungal component, in this case, plays a role in the detritus cycle.

Limiting factors to lichen growth include heat, moisture, and light. Lichens with thick cortexes are adapted to extremes of heat and can tolerate drought for long periods of time. The algae vary in their light requirements. Some prefer shady woods, others open areas. Lichens can survive for years in dry, cold environments exposed to harsh sunlight, such as the arctic tundra.

Mosses and Liverworts

The mosses and liverworts are simple small green plants with stems and leaves but lacking flowers or a true vascular system. The class Bryophyta seldom grow over 5 cm tall or 20 cm long. The mosses consist of two distinct, separate parts. The gametophyte is the leafy part of the plant. It is anchored at the base by a network of reddish rhizoids, little rootlets whose only purpose is anchorage. They do not absorb water or nutrients. The erect or trailing stem is green when young and red when old. The leaves are attached all around the stem. The gametophyte may be unbranched or branched many times over.

The sporophyte, which emerges usually from the crest of the gametophyte, consists of a long, brownish stalk, or seta, with a roundish capsule at the top. The capsule is capped at the other end by a sort of lid, the operculum. When this falls off it reveals a ring of pointed teeth, the peristome.

The mosses' life cycle involves a sexual generation (gametophyte) and an asexual generation (sporophyte). Sexual organs appear each year at the tops of two specialized branches of the

gametophyte. The female branch bears the archegonium, a flask-shaped organ holding eggs in a liquid, distinctly different from the normal leaves. The male branch bears the antheridium, an elliptical body containing sperm surrounded by a layer of sterile cells. When it rains the antheridium bursts and the sperm swim through the rainwater, attracted towards the archegonium by the fluid which diffuses out of it. When a sperm unites with an egg it forms a zygote, the first cell in the future sporophyte. The male branch dies but the new seta eventually emerges from the end of the female branch, clasped at its base by a special set of perichaetial leaves. The asexual spores are borne on the peristome. When the operculum falls off the peristome dry out and flick spores into the air. Upon germination the spores grow into new gametophytes. These spores require specific moisture regimes and substrates to germinate.

Mosses grow in clumps, spreading outward. They consist of three broad groups: 1) Aquatic mosses, which live in the water. 2) Terrestrial mosses, which live on land and can tolerate low moisture. 3) Mixed types, which require a moderate water supply, (Bland, 1971).

The mosses we studied are probably all of the mixed category. It rained frequently during the fall and winter but it is dry here in the summer. The stumps do have the advantage for mosses of retaining moisture after rains.

Mosses obtain nutrients from organic substances in the soil or on rotting wood. Cellulose is manufactured through photosynthesis. Water is supplied either from the substrate or by rain.

Liverworts are very similar to mosses. They undergo the same reproductive cycle and exist in the same habitats. They differ in structure, always growing flat with two rows of leaves growing on either side of the stem of the gametophyte. A third row of smaller underleaves may be present. The large leaf cells are distinctly hexagonal in shape.

The bryophytes do not play any role in the decomposition of organic substrates. They do play an important role in colonizing barren rocks after lichens have started the process. On stumps and logs, mosses provide shelter for lichens and other germinating plants. On top they die and enrich the substrate there.

They also retain water in the wood underneath.

Mosses are limited in growth by temperature, moisture, and sunlight in a similar manner to lichens. They can withstand drought and cold, but not to the same degree as lichens.

Insects

Insects play a key role in the detritus cycle of the forest. Fallen tree trunks and stumps are recognized as constituting an ecological stratum in the forest and there is a succession of insects within the rotten wood (Savely, 1939). The first insects to enter logs feed on the phloem layer, where simple starches and sugars are stored. These are primarily cerambycids (beetles) and scolytids. Following the loosening of the bark by the activity of various beetles feeding on the phloem, another group of insects with different feeding habits appear. These are Collembolans, mites, and Dipterans. They feed on fungi or decaying animal and vegetable matter, and some associated species prey on these detritus feeders. The holes carved by the phloem feeders permit more water to get under the bark and aid decay.

Some insect larvae secrete enzymes which breakdown dellulose into a digestable form. Others rely on bacteria and other microorganisms living in their guts to break it down. The simple starches and sugars are easy to digest and are the first to go.

The second stage of insects break down the cellulose and lignin, crumbling the wood. By this time, the phloem and sapwood

layers are totally eaten by the phloem feeders. The wood turns punky. Species diversity slowly diminishes, in the same manner as the fungi, as only those species which can digest complex organic compounds persist.

Savely (1939) documented the time span of insect succession on pine and oak logs. After the first year since cutting down, the phloem had completely disappeared. During the second year the sapwood turned punky and the phloem feed ers slowly disappeared. During the third year species diversity greatly diminished, until only cellulose and lignin decomposers remained.

Over the years the stump or log slowly merges with the soil and species more characteristic of the humus replace those feeding exclusively on wood. In addition, the differences in species composition between insects in various types of logs disappear as the logs merge with the soil, until all logs boast the same species composition. We did not discover how long it takes for stumps to merge with the soil, but we did find out that it varies according to the type of wood, the prescence or absence of bark, whether the log is fractured or split, the microclimate of the air surrounding the log, and the prescence of sheltering vegetation over it, which would protect detritus feeders from physical stress.

Stump	pH[1]	nitrate[1] (lbs./acre)	nitrite	phosphorus[1] (lbs./acre)	magnesium[2]	calcium[2] (ppm)
Douglas-fir grove:						
Stump A	6.6/4.6/6.0	20/10/10	negligible	150/50/100	very high medium high	1400 over 2800 over 2800
Stump B	4.8/4.6/4.6	20/20/20	negligible	150/100/100	high low medium	1400 over 2800 2800
Open field:						
Stump A	6.4/4.4/4.6	10/15/20	negligible	100/100/50	high medium low	1700 2100 2100
Stump B	6.6/4.2/4.4	10/10/10	negligible	100/100/100	high high high	1400 2100 2100
Mixed conifers:						
Stump A	4.6/4.4/4.4	10/10/10	negligible	100/150/100	high medium high	1400 2500 over 2800
Stump B	4.2/4.1/4.4	20/10/15	negligible	100/50/100	high medium high	1400 2500 over 2800
Alder grove:						
Stump A	6.2/5.6/5.0	15/15/10	negligible	100/150/150	high high high	1400 2100 2100
Stump B	6.2/4.6/4.4	10/15/20	negligible	150/100/100	high medium medium	1400 2800 over 2800

[1] Values listed in order: south, west, top

[2] Values listed in order: bottom, east, middle

RESULTS

Species Survey

All of the stumps had herbaceous plants growing on top of them, except those stumps in the Douglas-fir grove. They all had tree seedlings. The bigleaf maple seeds did not sprout until March. The hemlock and cedar seedlings were of various ages. The tallest was a hemlock sapling two feet tall on Stump A in the mixed conifers area.

The most common plants on the stumps were salal, wild blackberry, and the Vaccinium species. The blackberry vines actually were rooted in the ground and merely used the stumps for support. Oregon grape was common on Stump A in the open field, where it grew on the root area.

No plants had their roots anchored on top of either of the open field stumps, except for a single whortleberry growing out of a crack on Stump A. This was probably due to a lack of litter and little decomposition of the wood. The cedar on Stump B had sprouted at the roots on that stump.

The conifer seedlings on top were confined to the mixed

conifer stumps, because of the acid litter on top. These species require highly organic, acid substrate to germinate. The maple seedlings appeared to be reponding only to moisture.

The Vaccinium species varied in size from shrubs two feet high to tiny sprouts. The plantain was observed on other stumps than those studied in both the alder grove and the mixed conifers.

The number of moss species was 17, the most diverse of any class of plants surveyed. The largest number of different species occurred on Stump A in the alder grove. There was no consistent pattern of species diversity among the stumps, but the total area coverage of the stumps by mosses varied distinctly. The stumps in the mixed conifers and alder grove had approximately half of their surface area covered by mosses. The tops were especially well-covered. Coverage of the Douglas-fir grove stumps was somewhat less, while in the open field only Stump A exhibited much coverage. The mosses were mostly confined to the top. Stump B boasted only a few tufts of moss growing out of cracks.

Fresh sporophytes appeared on few of the mosses until March. No sexual organs were observed on any of the species. Some could still be identified in part by the dried and twisted sporophytes left over from the previous fall.

All the stumps had lichens, often growing amid the mosses. Coverage was widespread for all the stumps. Areas of burnt wood had little moss coverage but considerable lichen growth. Cladonia coniocraea appeared to be the common colonizer of burnt wood, although it also gre elsewhere on the stumps. It started as a sort of green stain on the stumps, consisting of tiny squamules lacking podetia. Not until it was well established, with large squamules, did podetia appear. C. coniacraea was also the most common lichen overall, occurring on six of eight stumps, perhaps because of its colonizing ability.

Three liverwort species were identified. The most common was Scapania bolanderi. All of them grew among mosses.

Two fungi were identified as to genus on Stump A in the alder grove. They did not appear until March. Neither was over 2 inches tall, and both produced only a few mushrooms each.

	Douglas-fir grove		Open field		Mixed conifers		Alder grove	
	A	B	A	B	A	B	A	B
Acer macrophyllum (Bigleaf maple)					3		3	1
Berberis nervosa (Dwarf Oregongrape)			13			1		
Gaultheria shallon (Salal)	4	5			1			
Goodyera oblongifolia (Rattlesnake plantain)						1	2	
Polypodium vulgare (Licorice fern)								
Polystichum munitum (Sword fern)							1	7
Pteridium aquilinum (Bracken fern)						1		1
Rubus vitifolius (Wild blackberry)			4	5			4	1
Thuja plicata (Western redcedar)				1		4		
Tsuga heterophylla (Western hemlock)					7	2		
Vaccinium membranaceum (Big whortleberry)			1		2	2	3	
Vaccinium ovatum (Evergreen huckleberry)	11							
Vaccinium parvifolium (Red huckleberry)	3	27						
Vicia americana (Wild pea, vetch)				1				

Soil Tests

The pH values for the stumps were consistently acid, with the exception of Stump A in the Douglas-fir grove and Stump B in the open field, which were neutral on top. They were all acidic at the roots. No explanation for the neutral values could be determined. The surrounding soil was either acidic or neutral. Both samples in the alder grove were neutral, probably because the litter layer was not very deep and was entirely deciduous leaves and sticks. The deep acid litter of the mixed conifers produced acid pH values for the soil. The same was true of one sample in the Douglas-fir grove. The other neutral sample was taken down in the ditch adjacent Stump A. The soil under the litter was originally about two feet underneath the surface, until the ditch-digging exposed it. This would account for its lack of organic matter and neutral pH, despite the litter layer that had accumulated on it. The soil in the open field was slightly alkaline and highly mineral. The humus layer was very thin, since only herbaceous plants and grasses grew on top of it.

There was a significant amount of nitrate in all the stumps,

but only negligible nitrite. Albeit these values were inaccurate, still a tentative conclusion might be drawn that nitrification of the woody tissues was almost completed in the stumps. That is, ammonia had already been reduced to nitrite and further to nitrate. In contrast, breakdown of cellulose and lignin was obviously not completed, since the stumps were largely whole and uncrumbled, and since mycelial networks were visible here and there, and mushrooms appeared on one stump, and since these fungi are dependent on nondecomposed sugars and carbohydrates for nourishment. Thus there would appear to be a time lag between breakdown of nitrogenous compounds and breakdown of non-nitrogenous compounds. We foun no reference to such a time lag in the literature, however, so this conclusion is not substantiated.

There was an abundance of phosphorus, magnesium, and calcium in the wood. These are primary plant nutrients. Indeed, plants grow on top of all the stumps, even Stump A in the open field, with a negligible litter layer on top. P and Mg had no consistency in values but calcium showed an increase from top to bottom to soil. Calcium being soluble, this might indicate a leaching downwards. Values at the top were the same for all stumps. The

thick plant growth on the stumps with deep litter layers might be stimulated in part by Ca in the litter, since Ca is concentrated in the foliage of trees (Bunting, 1965).

The pH test was the only really accurate test, since more than one color chart comparison was made for each sample. The other tests involved a single comparison with subtle shades of the same color, leaving them open to arbitrary interpretation. In addition, these soil test kits were intended for soil and not wood, so the values for the tops and roots may not be accurate. The values reached were not useful in the form of lbs. per acre or high/low/medium except for comparisons between each other.

Litter

The calculated ratios of dry litter weight/surface area on top of stump were consistent with what we expected. The ratio averaged highest under the closed canopy of the mixed conifers and the Douglas-fir grove, somewhat less under the open canopy of the alder grove, and very low in comparison in the open field, even with the alder trees growing adjacent two of the stumps there. Within each study area, differences in litter fall could be accounted for by (1) differences in the time elapsed since the various stumps were cut and (2) the presence of deep cracks and fissures on the stumps. Clearly, a stump which was cut 10 years earlier than another would have a greater litter accumulation, provided that ther were trees growing above the stump when it was cut. In actuality, the stumps were probably cut during the same year in each area, and were left standing in open areas completely cleared of trees.

Cracks and fissures accumulated large amounts of litter and decompositon of litter was greatest in these pockets. Gaps between the bark and the wood held the greatest amounts of litter. This was the case especially with Stump 2 in the mixed conifers.

Larger plants such as salal and huckleberry tended to grow out of these pockets of litter.

The deeper the litter, the more gradual the interface between the decomposing litter and the decomposing wood. Decomposition of wood appeared to proceed faster under a litter layer, perhaps because of the shelter the litter affords to decomposing organisms.

The litter actually formed humic layers on top of the stumps with the largest accumulations, ie, a top undecomposed layer and an underlying plant residue layer. An endohumus could not form because of lack of contact with the mineral soil. This phenomenon might be termed "secondary decomposition" on top of stumps.

Errors in the surface area values could have been caused by not taking the irregular contours of the stump perimeters into account. The circumference was simply measured with a tape, not following every contour. Thus the surface area values were probably a little greater in actuality and this slightly reduced the litter/area ratio. No significant errors were expected in measuring the weight of the litter.

Stump	Wt. of wet litter (grams)	Wt. of dry litter (grams)	Area of top of stump (cm^2)	Ratio Wt. of dry litter to surface area of Cypress (gm/cm^2)
Douglas-fir grove Stump 1	1996.7	469.5	3021.7	15.5×10^{-2}
Douglas-fir grove Stump 2	718.1	177.9	4285.7	4.1×10^{-2}
Douglas-fir grove Stump 3	871.8	197.3	2267.0	8.7×10^{-2}
Open field Stump 1	86.7	65.0	5321.8	1.2×10^{-2}
Open field Stump 2	39.1	29.4	4100.5	0.7×10^{-2}
Open field Stump 3	247.9	124.8	17375.9	0.7×10^{-2}
Mixed conifer Stump 1	549.4	206.1	3175.3	6.5×10^{-2}
Mixed conifer Stump 2	919.6	568.2	3881.0	14.6×10^{-2}
Mixed conifer Stump 3	1446.5	401.9	4923.8	8.2×10^{-2}
Alder grove Stump 1	637.1	132.1	6915.4	2.2×10^{-2}
Alder grove Stump 2	1053.4	501.5	4454.4	11.5×10^{-2}

Temperature

General weather conditions for each twelve hour reading are as follows:

February 19 AM: not recorded
February 19 PM: not recorded
February 20 AM: Light wind in open area, overcast with occassional mist.
February 20 PM: Calm, overcast, occasional light rain.
February 21 AM: Calm, some light rain.
February 21 PM: Light SW breeze in open, partly cloudy, occasional rain showers.
February 22 AM: Light NW breeze in open, occasional snow flurries, partly cloudy.
February 22 PM: Clear, cold, moderate W breeze in open.

Tables one through four show the results of temperature according to area. Graphs one through four show the reading periods plotted against temperature for each of the areas.

The sampling is limited, but some general observations may be noted from reading the graphs for this specific experiment. We had generally believed that temperatures inside the stumps (core and ½) would remain more stable than the outside (surface and air) temperatures. In the results of the Douglas-fir grove and the open field this appears to be more so true than in the results of the mixed conifers and alder grove. Much greater fluctuations of temperature can be observed for surface and air readings in all area. Also, the two inner readings in all areas seem to follow their own general pattern, while the air and sur-

face readings follow their own. On the 21st and 22nd the weather took a colder turn, the results of which can be observed in the graphs. Although surface and air temperatures reflected this change in temperature immediately, the core and ½ readings did not reflect it until the 22nd AM readings. While the average drop in temperature for the two outer readings was 4 degrees C, the inner readings dropped an average of only 1.5 degrees C. An implication of this might be that it would be more feasible temperature-wise for insects to live in the inner portions of the stumps, so as not to be subjected to extremes in temperature.

Table #1
Douglas-Fir Grove In ^{o}C

		Tuesday 19th	Wednesday 20th	Thursday 21st	Friday 22nd
AIR	AM	3.2	3.3	3.8	0.7
	PM	3.0	5.0	3.1	1.2
CORE	AM	5.2	5.0	4.9	4.9
	PM	5.0	4.9	5.0	4.4
½	AM	5.0	4.7	5.0	4.5
	PM	4.9	4.8	4.9	4.2
SURFACE	AM	4.5	4.0	5.1	1.9
	PM	4.3	5.5	4.9	2.6

Table #2
Old Field In ^{o}C

		Tuesday 19th	Wednesday 20th	Thursday 21st	Friday 22nd
AIR	AM	3.2	3.3	3.7	0.6
	PM	3.0	4.2	2.7	1.1
CORE	AM	5.2	4.8	5.2	4.6
	PM	5.0	5.3	5.6	4.5
½	AM	4.8	5.2	5.3	4.7
	PM	4.8	5.3	5.5	4.1
SURFACE	AM	4.3	3.5	4.3	1.2
	PM	4.4	4.8	3.8	1.8

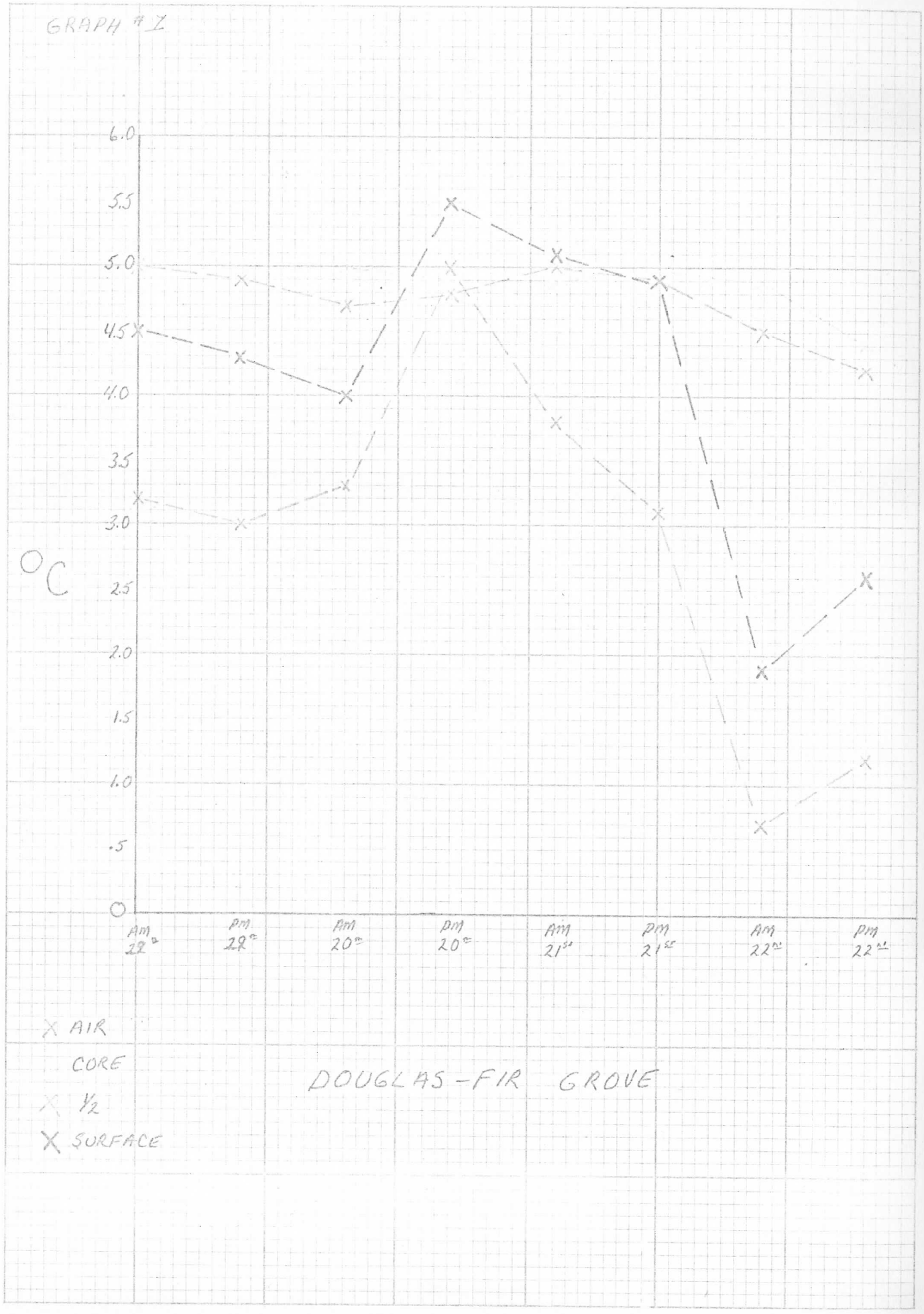
Table #3
Mixed Conifer Forest In ^{o}C

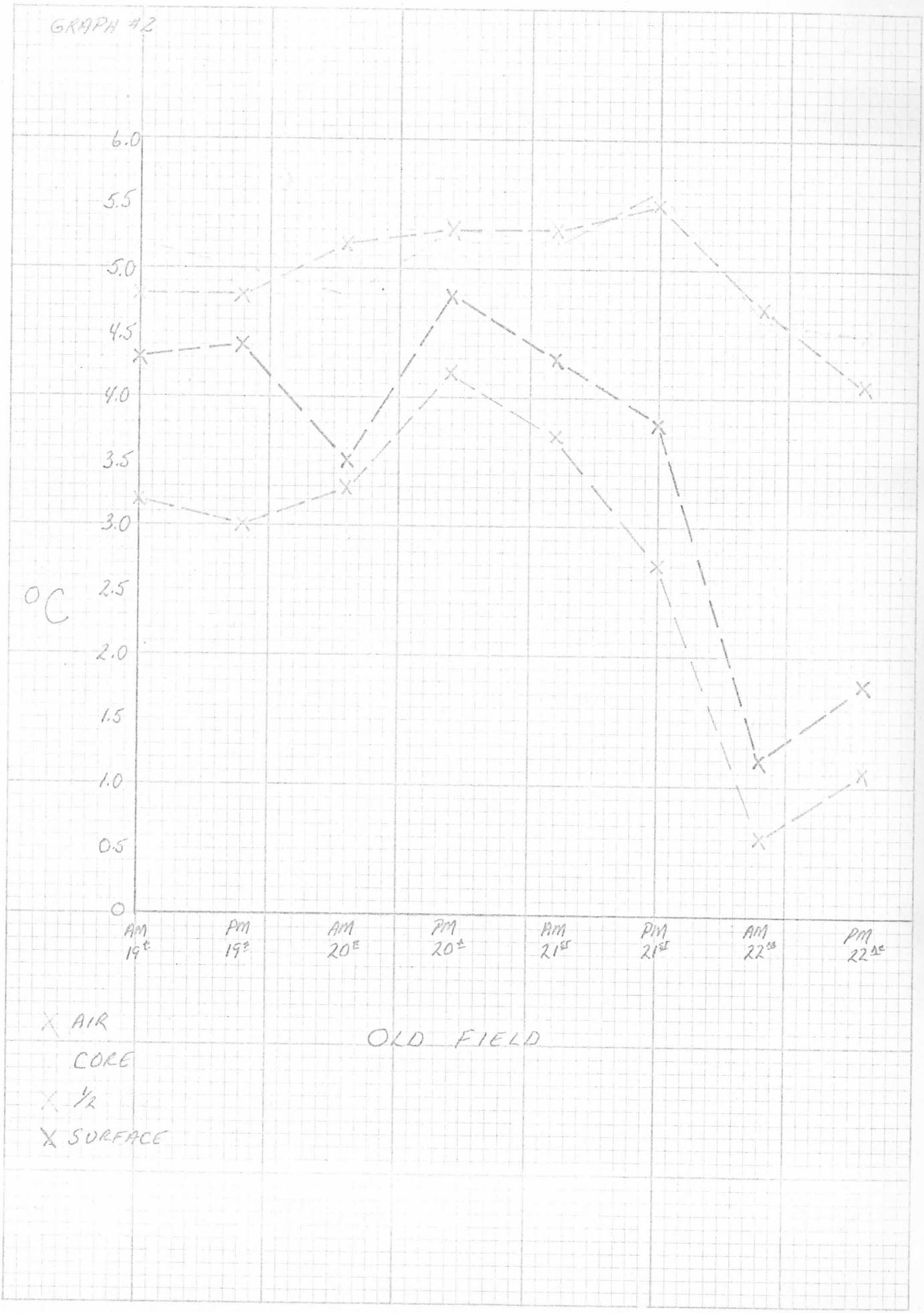
		Tuesday 19th	Wednesday 20th	Thursday 21st	Friday 22nd
AIR	AM	3.5	3.5	3.7	1.0
	PM	3.0	5.1	3.4	2.0
CORE	AM	5.2	4.6	5.0	3.8
	PM	5.0	4.9	5.1	2.8
½	AM	4.8	4.4	4.9	3.1
	PM	4.7	5.1	5.0	3.0
SURFACE	AM	4.5	4.1	4.2	1.7
	PM	4.3	5.3	3.8	2.6

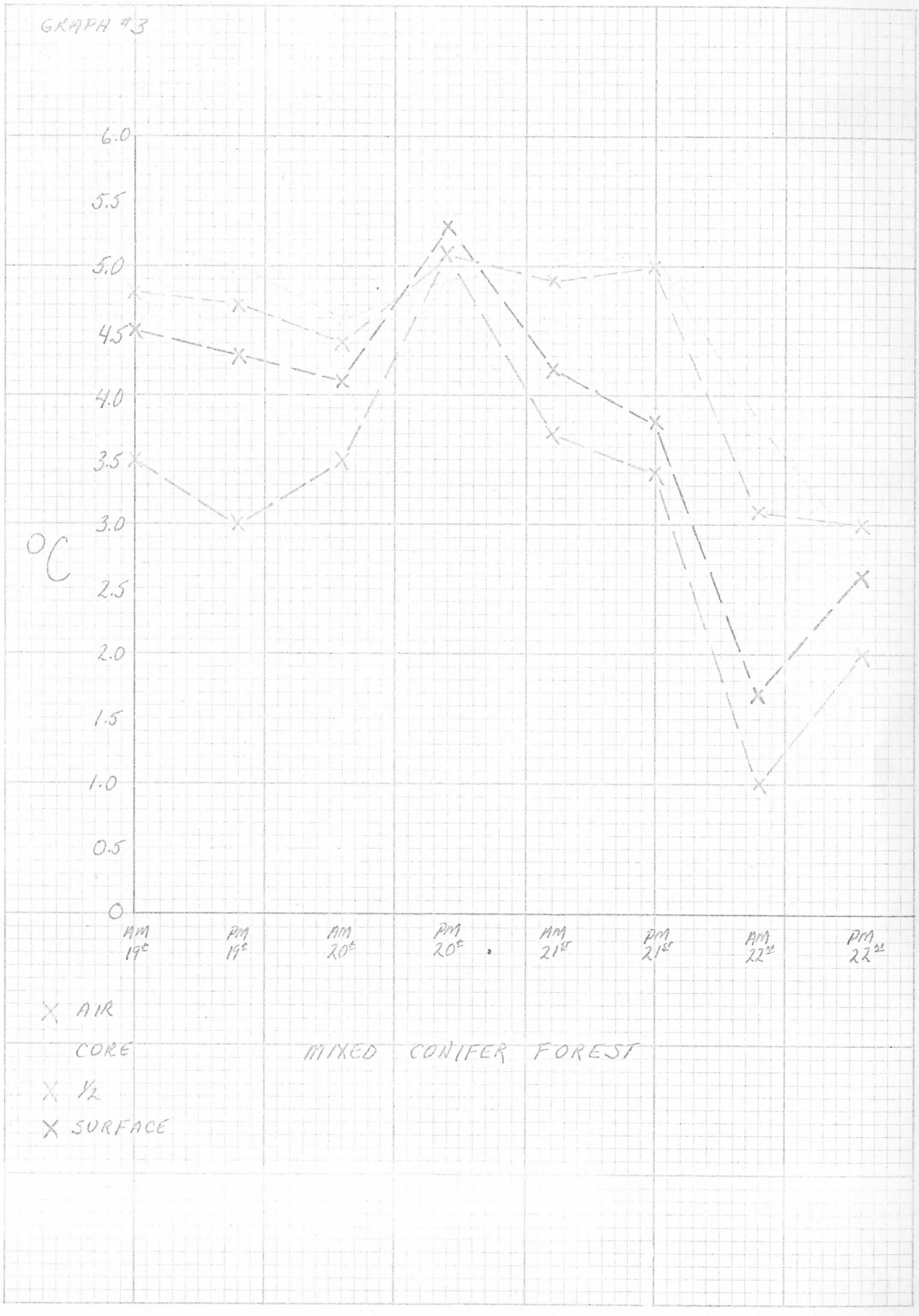
Table #4
Alder Grove

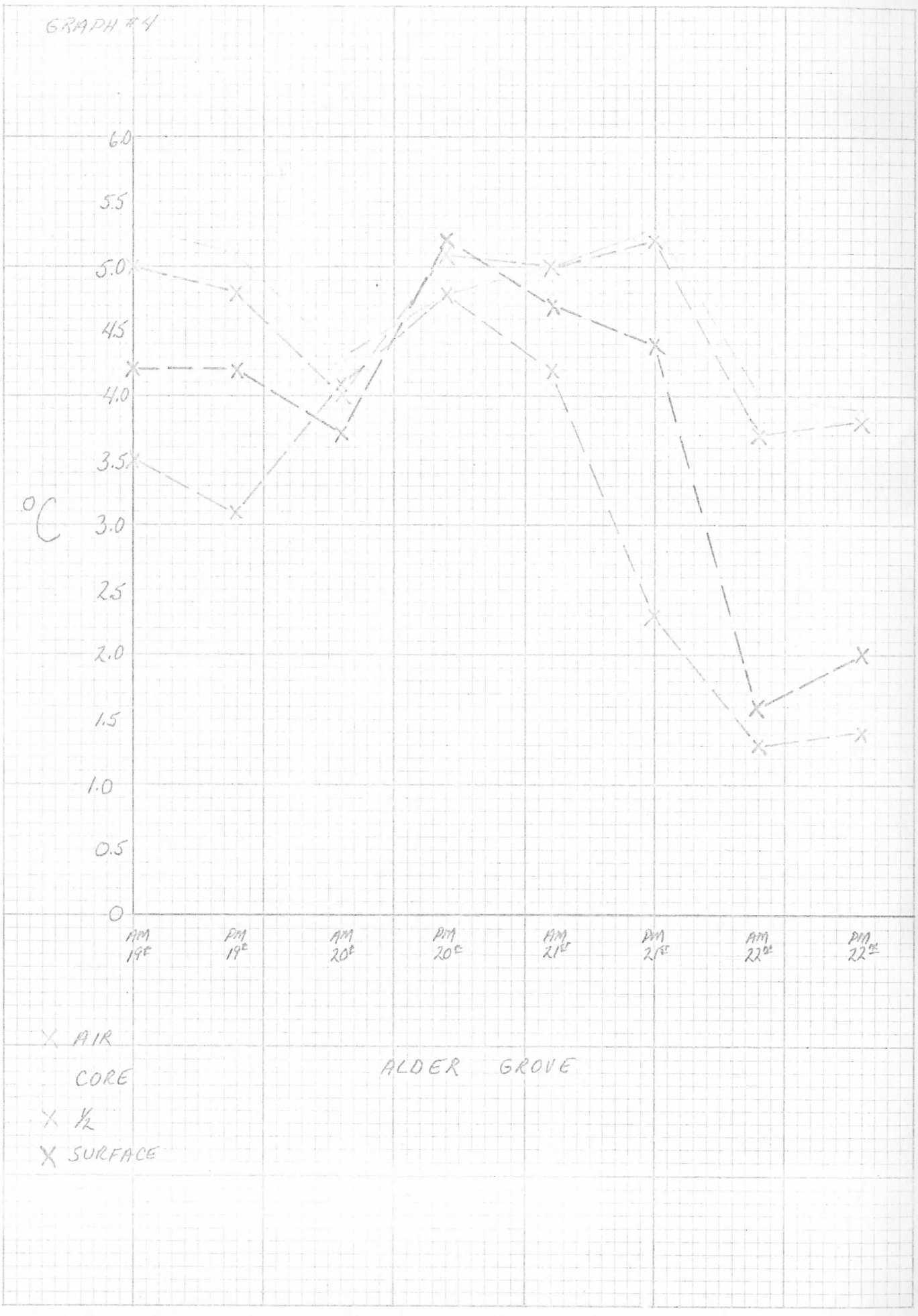
In ^{0}C

		Tuesday 19th	Wednesday 20th	Thursday 21st	Friday 22nd
AIR	AM	3.5	4.1	4.2	1.3
	PM	3.1	4.8	2.3	1.4
CORE	AM	5.3	4.3	5.0	4.0
	PM	5.1	4.8	5.3	3.9
$\frac{1}{2}$	AM	5.0	4.0	5.0	3.7
	PM	4.8	5.1	5.2	3.8
SURFACE	AM	4.2	3.7	4.7	1.6
	PM	4.2	5.2	4.4	2.0









Moisture content

In Table #1 the stumps referred to are:

Stump A in the Douglas-fir grove
Stump A in the old field
Stump B in the mixed conifer grove
Stump A in the alder grove

A fact to be taken into consideration when evaluating the data would be that both Stump B in the mixed conifer grove and Stump A in the alder grove have hollow centers. Our supposition was that the outer portions of the stumps would have a higher moisture content than the inner portions due to more exposure to moisture in the atmosphere. This supposition holds true in the first two cases, but not where the stumps have hollow centers. Where the centers are hollow the reverse is true; the centers have a higher moisture content than the outer portions. Because of the limited sampling it is difficult to say if this would be a definite trend in either case.

In Table #2 the stump utilized was Stump A in the Douglas-fir grove. In Table #3 Stump B in the Douglas-fir grove was used. In this experiment we were testing out two ideas. One, to see if there was a vertical trend in moisture content, rather than hor-

izontal as in Table #1, and two, to see if there was a trend in soil moisture content right at the base of the stump as opposed to further away. In the first case, we were not sure what to expect. In Table #3 with Stump B the moisture content of the outer samples follows a trend of less moisture content as you move down the stump, but this is not mirrored in Table #2 with Stump A. With the inner samples, less moisture is observed moving vertically down in Table #2, but this is not observed in Table #3. A field observation may partially explain this. While drilling 2B, the mid-inner sample, a large gush of water flowed from the hole. The amount of water was perhaps 6 ounces in volume. Upon investigation with a stick, an inner hole or pocket could not be located. Again, a very limited sampling is involved. Perhaps, though, it could be argued that moisture content is rather specific according to the characteristics and locality of a particular stump. As we had expected with the soil samples, moisture content of the soil nearest the stumps was higher than that of the soil approx. two feet away. We believe this can be attributed to runoff of water from the stump, giving the soil at the base of the stump the higher moisture content.

Moisture content of the stumps may vary with different times of the year. Our project, carried out during the wettest season in the Pacific Northwest, undoubtedly yielded different values than could be obtained in the drier summer season. A further question that could be asked is, would the centers of the stumps show a higher moisture content during drier seasons than the outer portions because they would not be exposed to the extremes of weather?

MOISTURE CONTENT ANALYSIS DATA

Table #1
Samples taken at mid-stump

	#1	#2	#3	#4	#5	#6
1A Douglas-Fir Grove Outer	7.65g	15.35g	10.70g	4.65g	3.05g	152.46%
1B Douglas-Fir Grove Inner	7.50g	16.75g	12.85g	3.90g	5.35g	72.90%
2A Old Field Outer	8.00g	20.70g	13.70g	7.00g	5.70g	122.81%
2B Old Field Inner	7.90g	17.10g	13.35g	3.75g	5.45g	68.81%
3A Mixed Conifer Outer	8.00g	13.85g	12.15g	1.70g	4.15g	40.96%
3B Mixed Conifer Inner	7.95g	16.25g	11.65g	4.60g	3.70g	124.32%
4A Alder Grove Outer	7.70g	17.35g	12.00g	5.35g	4.30g	124.42%
4B Alder Grove Inner	7.60g	17.45g	11.00g	6.45g	3.40g	189.71%

Table #2
Cedar Stump in Douglas-Fir Grove

	#1	#2	#3	#4	#5	#6
1A Top Outer	7.65g	18.50g	10.80g	7.70g	3.15g	244.44%
1B Top Inner	7.50g	18.10g	10.75g	7.35g	3.25g	226.15%
2A Mid Outer	8.00g	18.30g	12.30g	6.00g	4.30g	139.53%
2B Mid Inner	7.90g	19.05g	12.30g	6.75g	4.40g	153.41%
3A Bottom Outer	8.00g	19.85g	11.40g	8.45g	3.40g	248.53%
3B Bottom Inner	7.95g	18.10g	13.00g	5.10g	5.05g	100.99%
4A Soil Roots	7.70g	22.70g	11.10g	11.60g	3.40g	341.18%
4B Soil Outer	7.60g	24.65g	13.20g	11.45g	5.60g	204.46%

MOISTURE CONTENT ANALYSIS DATA (CON'T.)

Table #3
Douglas-Fir Stump in Douglas-Fir Grove

	#1	#2	#3	#4	#5	#6
1A Top Outer	7.70g	19.65g	12.00g	7.65g	4.30g	177.91%
1B Top Inner	7.50g	16.00g	10.20g	5.80g	2.70g	214.81%
2A Mid Outer	8.00g	19.50g	12.90g	6.60g	4.90g	134.70%
2B Mid Inner	7.90g	30.40g	13.70g	16.70g	5.80g	287.93%
3A Bottom Outer	8.00g	21.70g	14.00g	7.70g	6.00g	128.33%
3B Bottom Inner	7.95g	17.20g	12.85g	4.35g	4.90g	88.78%
4A Soil Roots	7.70g	26.90g	16.20g	10.70g	8.50g	125.88%
4B Soil Outer	7.60g	24.90g	17.50g	7.40g	9.90g	74.75%

CONCLUSIONS

The study of tree stumps on the TESC campus supported the following conclusions:

Stumps with little litter on top had little plant growth on top. Those with moderate litter layers had salal and *Vaccinium* species growing on top. Those with the greatest amount of litter had tree seedlings growing on top as well. The greatest moss coverage was in the mixed conifers and the alder grove. Coverage was somewhat less in the Douglas-fir grove and was least in the open field. Lichen coverage was similar for all stumps. *Cladonia coniocraea* was the most widespread lichen and was the exclusive colonizer of burnt wood.

Most pH values on the stumps were acid, as expected. Soil acidity was determined by the depth of the humus and its characteristics. The prescence of nitrate but the lack of nitrite might indicate that nitrification of the wood was almost completed, but that breakdown of all but the simplest sugars was incomplete. There appears to be a time lag between the breakdown of nitrogenous compounds and that of nonnitrogenous compounds. Calcium appears to leach downwards, giving greater values at the roots than

on top. Calcium concentrated in the litter may stimulate plant growth on top of the stumps.

Litter fall was greatest under the mixed conifers and the Douglas-fir grove, somewhat less under the alders, and was least in the open field. The denser the canopy of the overstory, the greater the litterfall. Cracks and fissures collect large amounts of litter. Decomposition of wood is faster under a litter layer than without one. Prescence of an ectohumus, but lack of an endohumus on top of stumps could be termed "secondary soil succession" on top of stumps.

Inner temperatures of stumps are higher than the surface and air temperatures and the magnitude of the daily fluctuations is less on the inside. The inner readings also manifest a time lag in response to changes in outside temperature.

Moisture content is greatest at the surface or where the wood is exposed to the air. Vertical moisture zonation could not be proved. Soil moisture is greatest adjacent stumps due to runoff of water from the stumps.

The favorable microclimate and nutrient content of rotten stumps may be favorable to certain species of plants and animals

which could not survive elsewhere. Stumps also play an important role in the detritus cycle of the forest ecosystem, as their decomposition returns nutrients stored in the biomass to the soil, for future uptake, and because they help support a detritus-grazing chain of great importance in the forest ecosystem because of the large amounts of energy which flow through it.

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		Douglas-fir grove		Open field		Mixed conifers		Alder grove	
		A	B	A	B	A	B	A	B
Mosses	Amblystegium serpens							X	
	Aulconium palustre							X	
	Ceratodon purpureus							X	X
	Clinopodium crispifolium						X		
	Dicranella heteromalla								X
	Dicranoweisia cirrhata			X					
	Dicranum cirrhatum				X				
	Dicranum fuscescens		X		X	X		X	
	Dicranum scoparium				X				
	Dicranum strictum	X							X
	Eurynchium oreganum					X		X	X
	Eurynchium stokesii								X
	Hypnum subimponens		X	X		X			
	Isothecium spiculiferum	X	X				X		
	Rhizomnium glabrescens		X					X	
	Plagiothecium denticulatum		X			X		X	
	Tetraphis pellucida				X			X	
Liverwort	Calypogeia muelleriana					X			
	Lepidozia (species unknown)						X		
	Scapania bolanderi		X			X	X		X
Lichens	Cladonia bellidiflora			X	X				
	Cladonia coniocraea	X	X	X	X			X	X
	Cladonia fircata							X	
	Cladonia squamosa					X	X		
	Evernia mesomorpha			X					
Fungi	Coprinus (species unknown)							X	
	Hygrophorus (species unknown)							X	

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