EFFECTS OF TIMBER HARVEST ON ALLOCHTHONOUS ENERGY BUDGETS OF STREAM ECOSYSTEMS IN THE DOUGLAS-FIR TYPE

by

John W. Grondalski

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

June, 1975

EFFECTS OF TIMBER HARVEST ON
ALLOCHTHONOUS ENERGY BUDGETS OF
STREAM ECOSYSTEMS IN THE
DOUGLAS-FIR TYPE

Approved by the Master's Thesis Committee

John W DeWitt Chairman

Terry D Roelofs

[illegible] Jr.

[illegible]

Approved by the Graduate Dean

Alba M. Gillespie

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. John DeWitt who suggested this project, obtained funds for it and made many helpful suggestions throughout this study. I would like to thank Bill Hunt for igniting an interest in me for stream energetics and information from his previous study. Also, thanks to the Forest Service and Dr. Gerald Partain for the financial assistance from the McIntire-Stennis fund.

I would like to thank Dr. Terry Roelofs for providing guidance in the absence of Dr. DeWitt and along with Dr. F. Dean Freeland reviewed and offered many helpful suggestions in the preparation of this manuscript. I would like to thank Dr. Dave Bryant for the use of his lab.

I would like to thank Andy Sadie for helping locate suitable study sites, Jeanne Hunt for analyzing the vegetation on my study sites, Kevin Williams, Sherry Skillman and Bill Brock for their calorimetry work, and Pat Collins and Paul Woods for their suggestions with the statistical and computer analysis.

A special thanks to Annette for her help in the field, proofreading the manuscript, and support throughout this study.

INTRODUCTION

Man often alters the amount and kind of streambank vegetation by logging, grazing and other activities. The degree of alteration can affect the amount and quality of vegetation falling into a stream, and thus the amount of energy available for utilization by the aquatic community. Some alterations reduce the amount of energy being contributed to a stream, while others increase the input.

The present study was designed after Hunt (1974) who reported on the quantity of potential energy contributed to Ryan Creek, Humboldt County, California, from each of three distinctly different types of streamside vegetation. The meadow (clear-cut), red alder (Alnus rubra) and second-growth redwood (Sequoia sempervirens) types were selected to represent three successional stages which typically occur after logging has taken place in a redwood forest (Hunt 1974). Five vegetative classes were selected in my study to represent successional and man-altered stages after logging has taken place in a douglas-fir (Pseudotsuga menziesii)forest. The quantity of potential energy contributed to Fourmile and Hawkins Creeks by allochthonous vegetation was determined from a virgin douglas fir, second-growth douglas-fir, ponderosa pine (Pinus ponderosa), red alder, and clear cut douglas-fir types typical of the various successional and altered stages of the region (Sadie personal communication).

Ecosystems are often thought of as fixed physical units encompassing interacting biotic and abiotic components. Continual operation of ecosystems is usually envisioned as depending mainly upon a continual flux of energy in the form of solar radiation into the ecosystem. Some ecosystems, however, particularly small streams and estuaries, and parts of others such as forest floors and the shorelines of lakes, are dependent mainly upon solar energy fixed elsewhere by photosynthesis and transported into the ecosystem in the form of reduced carbon compounds. This may be termed an allochthonous energy system (Fisher and Likens 1973).

Energy fixed by photosynthesis passes through a series of trophic levels (primary producer, primary consumer, secondary consumer, and so on) recycling basic materials of carbon, nitrogen, phosphorus, sulfur and other elements to their original form (Hynes 1970). This concept applies to terrestrial ecosystems as well as lakes; it does not, however, apply to running water ecosystems. Energy in a stream ecosystem moves downstream and is not recycled back to where it entered the ecosystem. Any cycling which occurs is displaced in a downstream direction (Hynes 1970).

Fisher and Likens (1973) showed that allochthonous organic material is of considerable importance to the aquatic community of Bear Brook, New Hampshire. Of the energy entering the stream, 99 percent was of allochthonous origin and only one percent was derived from stream photosynthesis by mosses. Of the allochthonous input, it was estimated that 66 percent was exported downstream and 34 percent was processed to carbon dioxide. Allochthonous vegetation has been reported to contribute from 50 to 100 percent of the energy available to the consumer organisms of aquatic ecosystems (Teal 1957; Nelson and Scott 1962; Minshall 1967; Egglishaw 1968; Efford 1969).

The main objective of this study is to report on the effects of different kinds of alterations of streamside vegetation on the quantity of energy available to the aquatic community and test the following null hypothesis: In similar streams, there is no significant difference in calories per unit area contributed by allochthonous vegetation falling into the stream (or onto its bed) under five distinctly different conditions of streamside vegetation.

The results of this study may help in the understanding of the effects of various degrees of timber harvest on stream productivity.

STUDY AREAS

General Location and Description

Fourmile Creek is located within Six Rivers National Forest, Humboldt County, California, 3.5 air miles southwest of the city of Willow Creek which is located approximately 45 miles east of Eureka on Highway 299. The Fourmile Creek watershed is located in section 13, Range 4E, sections 7, 17, 18, 19, and 20, Range 5E, Township 6N, Humboldt Meridian (Figure 1.). The mean slope of the main channel is 22 percent. The creek drains 2.3 square miles or 1,472 acres of douglas-fir forest and has a basin perimeter of 6.7 miles. The basin relief (the difference in height between the mouth of the stream and the highest point of land) is 3,350 feet, the general aspect (exposure) of the stream is southeasterly, and the drainage density (length of stream per unit of area) is 2.86 miles per square mile. Fourmile Creek drains into Madden Creek which drains into the South Fork of the Trinity River approximately 1.3 miles from the confluence of Madden and Fourmile Creeks.

Hawkins Creek is also located within Six Rivers National Forest, Trinity County, 7.5 air miles southeast of the city of Willow Creek. The Hawkins Creek watershed is located in sections 4, 8, 9, 10, 15, 16, 20, 21, 22, 28, and 29, Range 6E, Township 6N (Figure 1.). The mean slope of the main channel is 13 percent. Hawkins Creek drains 5.4 square miles

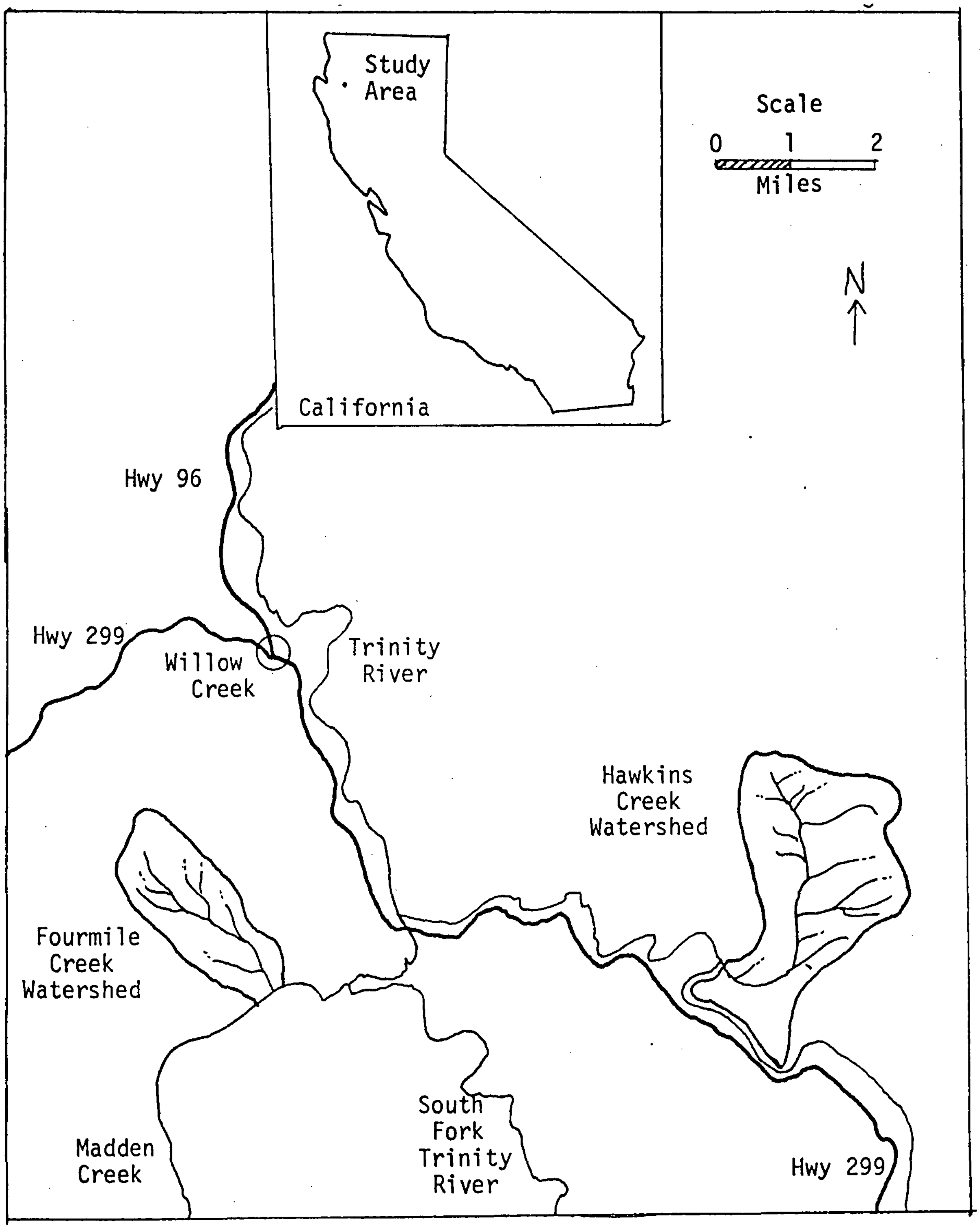

Figure 1. Location of the Fourmile and Hawkins Creek watersheds.

or 3,456 acres of douglas-fir forest and has a basin perimeter of 12.2 miles. The basin relief is 3,875 feet. The general aspect of the stream is southeasterly, and has a drainage density of 2.57 miles per square mile. Hawkins Creek drains directly into the main fork of the Trinity River.

Study Sections

Study sections were selected that were distinctly different from standpoints of timber species dominance and age. It was not possible to find the five vegetative types mentioned previously on the same stream to help reduce the importance of uncontrolled variables, such as differences in wind and precipitation patterns, slope, direction of streamflow, species composition, and vigor of streamside vegetation among sections. Therefore, two streams with similar characteristics and located approximately 8 air miles from each other were selected. Sections on very small streams were chosen in order to reduce the possibility of the washing out of the allochthonous vegetation collection equipment during high water.

One study section, located on an ephemeral tributary of Fourmile Creek, NW¼ of the SW¼ of section 18, Range 6E, Township 6N (Figures 2, 3 and 4), was established in a stand of virgin douglas-fir (hereafter referred to as the "Virgin" section) (Table 3). A complete species list for all study sections is presented in Tables 1 and 2.

A second-growth douglas-fir area (the "Second-growth"

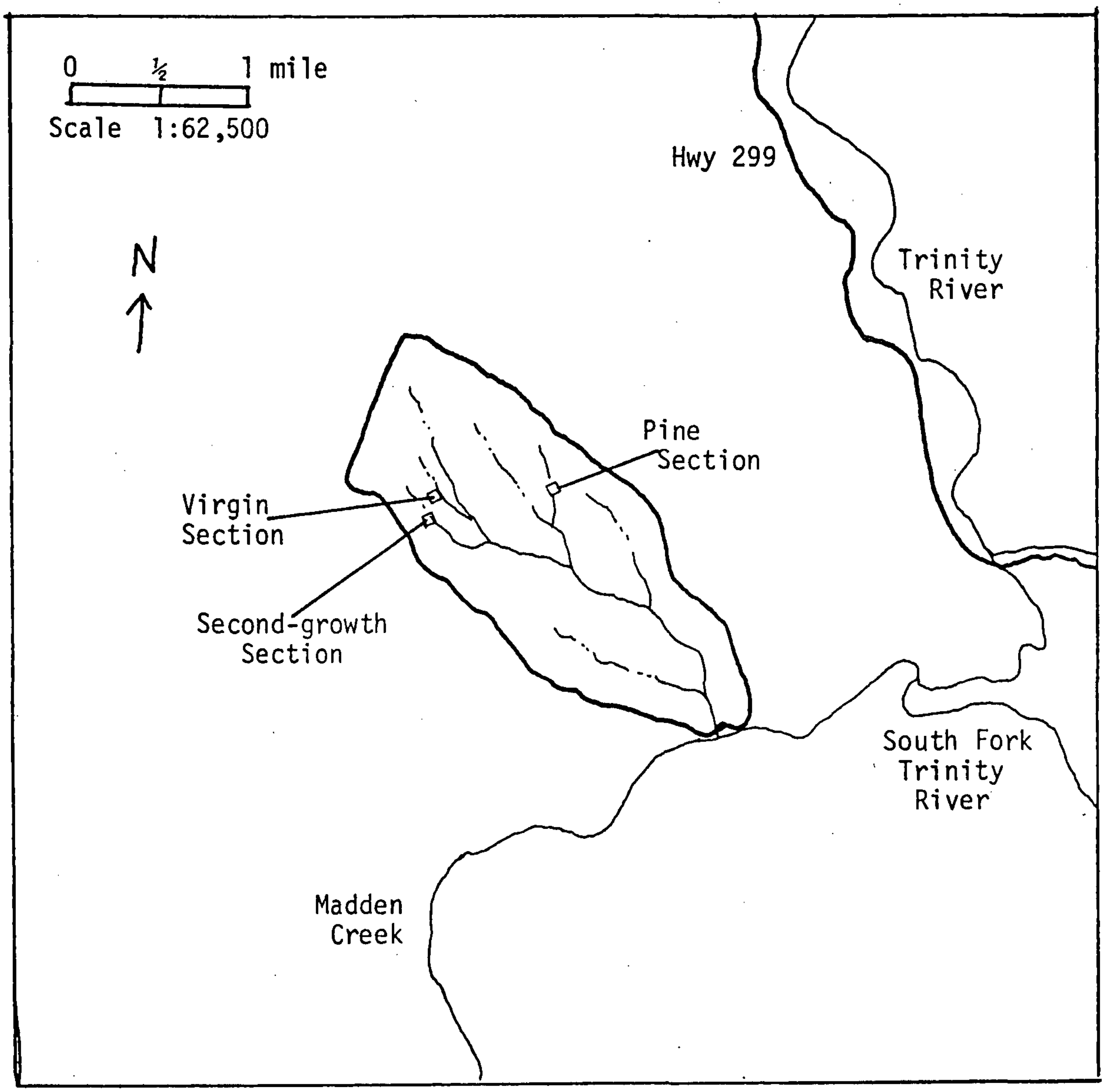

Figure 2. The Fourmile Creek watershed with locations of the Virgin, Second-growth, and Pine study sections.

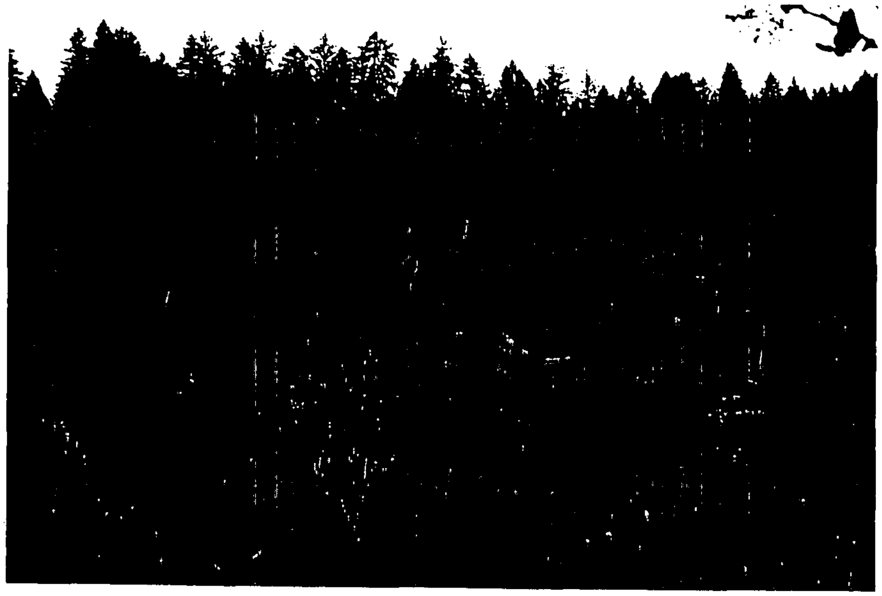

Figure 3. The Fourmile Creek Virgin section used in this study.

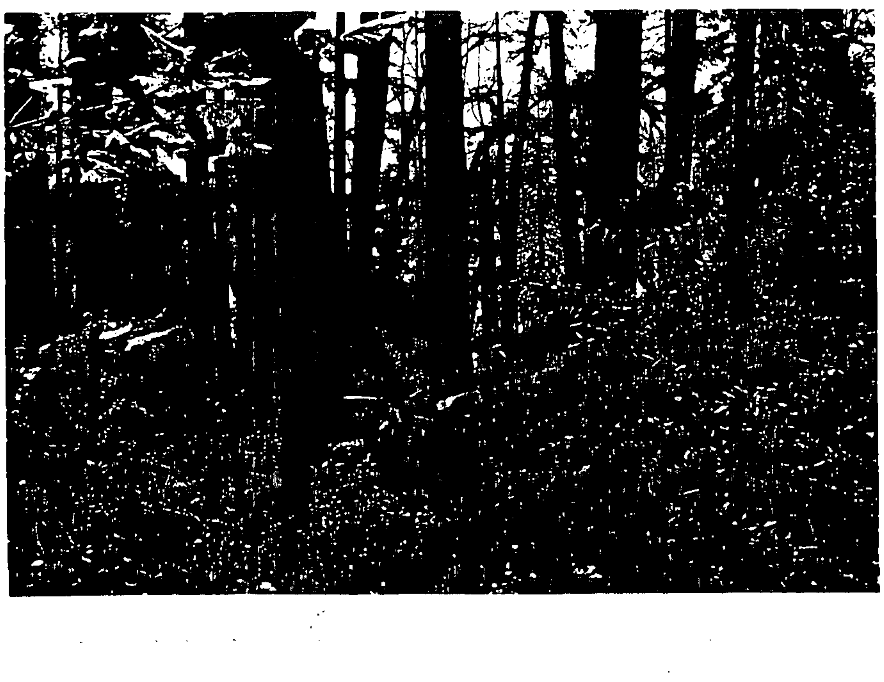

Figure 4. Typical understory vegetation in the Virgin section.

Table 1. Vegetation species list for the five study sections of Fourmile and Hawkins Creeks, October, 1974, from keys of Munz (1959) and Randall and Keniston (1973).

Bigleaf Maple -- Acer macrophyllum Pursh.
Red Alder -- Alnus rubra Bong.
Madrone -- Arbutus menziesii Pursh.
Manzanita -- Archtostaphylos Adans. sp.
Greenleaf Manzanita -- Arctostaphylos patula Greene.
Dwarf Oregon-grape -- Berberis nervosa Pursh.
Incense-cedar -- Calocedrus decurrens
Deerbrush -- Ceanothus integerrimus Hook. & Arn.
Pacific Dogwood - Cornus nuttallii Aud.
California Hazel -- Corylus cornuta Marsh. var. californica (A. DC.) Shar
Horsetail -- Equisetum L. sp.
Ocean Spray -- Holodiscus discolor (Pursh.) Maxim.
Tanoak -- Lithocarpus densiflora Blume.
Ponderosa Pine -- Pinus ponderosa Dougl. ex P. & C. Lawson
Sword Fern -- Polystichum munitum (Kaulf.) Presl.
Douglas-fir -- Pseudotsuga menziesii (Mirb.) Franco.
Bracken Fern -- Pteridium aquilinum (L.) Kuhn var. pubescens Undew.
Canyon Live Oak -- Quercus chrysolepis Liebm.
Oregon White Oak -- Quercus garryana Dougl.
Gooseberries -- Ribes L. sp.
Little Wood Rose -- Rosa Gymnocarpa Nutt.
Thimbleberry -- Rubus parviflous Nutt.
Wild Blackberry -- Rubus vitifolius C. & S.
Willow -- Salix L. spp.
Blue Elderberry -- Sambucus caerulea Raf.
Spreading Snowberry -- Symphoricarpos mollis Nutt.
Pacific Yew -- Taxus brevifolia Nutt.
Poison-oak -- Toxicodendron diversiloba
Wild Grape -- Vitis californica Benth.
Yerba de Selva -- Whipplea modesta Torr.

Table 2. Vegetation present in each of the five study sections of Fourmile and Hawkins Creek, October, 1974.

	Study Section				
	Virgin	Alder	Pine	Second-Growth	Clear-Cut
Bigleaf Maple	X		X	X	
Red Alder		X			
Madrone	X		X	X	X
Manzanita				X	
Greenleaf Manzanita			X		
Oregon grape	X			X	X
Incense cedar	X				
Deerbrush		X	X	X	X
Pacific Dogwood	X				
California Hazel	X		X	X	
Horsetail		X		X	
Ocean Spray	X				
Tanoak	X		X	X	X
Ponderosa Pine			X		
Sword Fern	X	X		X	
Douglas-fir	X	X	X	X	X
Bracken Fern	X			X	X
Canyon Live/Oak	X		X	X	
Oregon White Oak					
Gooseberry			X	X	X
Little Wood Rose	X				
Thimbleberry		X		X	X
Wild Blackberry	X	X	X	X	
Willow		X		X	
Blue Elderberry			X	X	
Spreading Snowberry				X	
Pacific Yew	X				
Poison-oak	X			X	
Wild Grape		X			X
Yerba de Selva	X	X	X	X	X

Table 3. Vegetation species composition and stand analysis on the Virgin section. Fourmile Creek, October, 1974.

Overstory: Douglas fir

B.A. 210[1] Average height 95 ft. Average D.B.H.[2] 30 in.

% crown closure 30 % live crown 30

	C/A[3]	D/S[4]
Douglas fir	5	1
Bigleaf maple	2	2
Madrone	2	2
Pacific dogwood	2	3
Canyon live oak	1	4*
Tanoak	2	2
Incense-cedar	1	4
Pacific yew	2	4
Understory:		
Rose	2	3
Tanoak	4	1
Canyon live oak	2	2
Yerba de selva	2	5
Wild blackberry	2	5
California hazel	3	1
Ocean spray	2	2
Grasses & herbs	4	4
Maple seedlings	2	5
Sword fern	2	4
Bracken fern	2	5
Dwarf Oregon-grape	2	5
Douglas fir seedlings	2	5
Poison oak	2	4

* approx. 18 ft. tall

1) B.A. -- Basal area
sq. ft./acre

2) D.B.H. -- Diameter at breast height (4.5 ft.)

3) C/A -- Cover/abundance--a measure of cover and abundance based on the following classes of ground cover:

1--one specimen	4--10 to 25%
2--sparse	5--25 to 50%
3--less than 10%	6--50 to 75%
	7--more than 75%

4) D/S -- Dominance by stature--a relative rating of species according to height, with the tallest species rated as number one.

section) was established on the perennial main channel of Fourmile Creek, SW¼ of the SW¼ of section 18, Range 6E, Township 6N (Figures 2 and 5). This section was tractor-logged in 1954. It was replanted between 1958 and 1960 and now supports a stand of approximately 15-year-old douglas-fir (Sadie personal communication) (Table 4).

Another section on an ephemeral stream of Fourmile Creek, SE¼ of the NE¼ of section 18, Range 6E, Township 6N (Figures 2 and 6), was selected on a nearly pure stand of ponderosa pine (the "Pine" section) (Tables 5 and 6). This section was also tractor logged in 1954. It was replanted with pine instead of douglas-fir between 1956 and 1959 and is now approximately 15 years old (Sadie personal communication). A road separates the lower pine from the upper pine sections.

On the Hawkins Creek watershed, a study section was established on a perennial section where the main tributary discharges into the main channel of Hawkins Creek, SW ¼ of the SE¼ of section 16, Range 5E, Township 6N (Figures 7 and 8). This area was selectively logged for insect killed douglas-fir trees in 1966 and 1967. Red alder (the "Alder" section), was planted along the stream from seed in 1967 to protect the stream from erosion and exposure due to the opening of the douglas-fir canopy along the stream (Sadie personal communication). Alder is also a product of natural and man-made soil disturbance and thrives naturally without man's replanting (Freeland, personal communication). The

Figure 5. The Fourmile Creek Second-growth section used in this study.

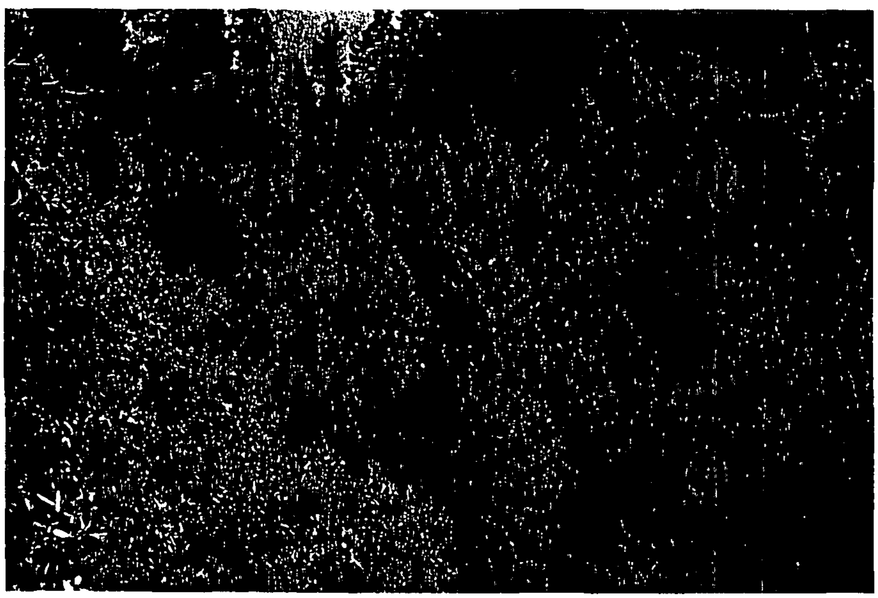

Figure 6. The Fourmile Creek Pine section used in this study.

Table 4. Vegetation species composition and stand analysis on the Second-growth section, Fourmile Creek, October, 1974 (See Table 3 for abbreviation definitions)

Overstory: Douglas-fir*

B.A. 30 Average height 15 ft. Average D.B.H. 3 in.

% crown closure <10 % live crown > 95

	C/A	D/S
Douglas-fir	3	1-2**
Bigleaf maple	2	2-1
Tanoak	2	3
Madrone	2	3
Willows	3	4
Understory:*		
Blackberry	3	6
Thimbleberry	2	8
Horsetail	4	5
Gooseberry	2	4
Blue elderberry	2	1
California hazel	2	1
Deerbrush	2	2-3***
Dwarf Oregon-grape	2	9
Manzanita	1	9
Bracken fern	2	3
Madrone	2	3
Maple seedlings	2	8
Spreading snowberry	1	10
Douglas-fir seedlings	2	7
Poison oak	2	7
Canyon live oak	2	4
Sword fern	2	6
Tanoak	2	3
Grasses	2	5
Herbs	2	10

* approx. same height, hard to distinguish "overstory" from "understory".

** First numbers indicate those collection boxes more upstream, second numbers those more downstream.

*** Deer browse- some stubby.

Table 5. Vegetation species composition and stand analysis on the Pine (lower) section, Fourmile Creek, October, 1974. (See Table 3 for abbreviation definitions.)

Overstory: Ponderosa pine

B.A. 60 Average height 18 ft. Average D.B.H. 4.5 in.

% crown closure 10 % live crown 60

	C/A	D/S
Ponderosa pine	4	1
Tanoak	2	2
Madrone*	2	>1
Douglas-fir*	2	>1

Understory:

	C/A	D/S
Gooseberry	4	4
Blue elderberry	2	1**
Deerbrush	4	3
Canyon live oak	1	2
Wild blackberry	1	5
Yerba de selva	3	6
Grasses & herbs (dried)	4	6
Tanoak	3	2

* Back from streambed- should not be contributing to litter drop.

** Could be considered as overstory due to height (10 ft.).

Table 6. Vegetation species composition and stand analysis on the Pine (upper) section, Fourmile Creek, October, 1974.
(See Table 3 for abbreviation definitions.)

Overstory: Ponderosa pine

B.A. 150 Average height 25 ft. Average height D.B.H. 4-6.5 in.**

% crown closure 40 % live crown 40

	C/A	D/S
Ponderosa pine	5	1
Douglas-fir	1	2
Tanoak*	2	≥1
Madrone*	2	≥1
Bigleaf maple*	2	1
Understory:		
Gooseberry	2	3
Blackberry	2	4
Yerba de selva	3	6
Deerbrush	3	2
Tanoak	2	1
Grasses & herbs (dried)	2	5
Douglas fir (sapling)	1	1
Greenleaf manzanita	2	3
Madrone	2	4
Canyon live oak	1	1
California hazel	1	2

* Away from area, not contributing litter.

** Right around 3 of the collection boxes the trees are taller with larger D.B.H.'s than around the others, which are more dense, shorter, and thinner.

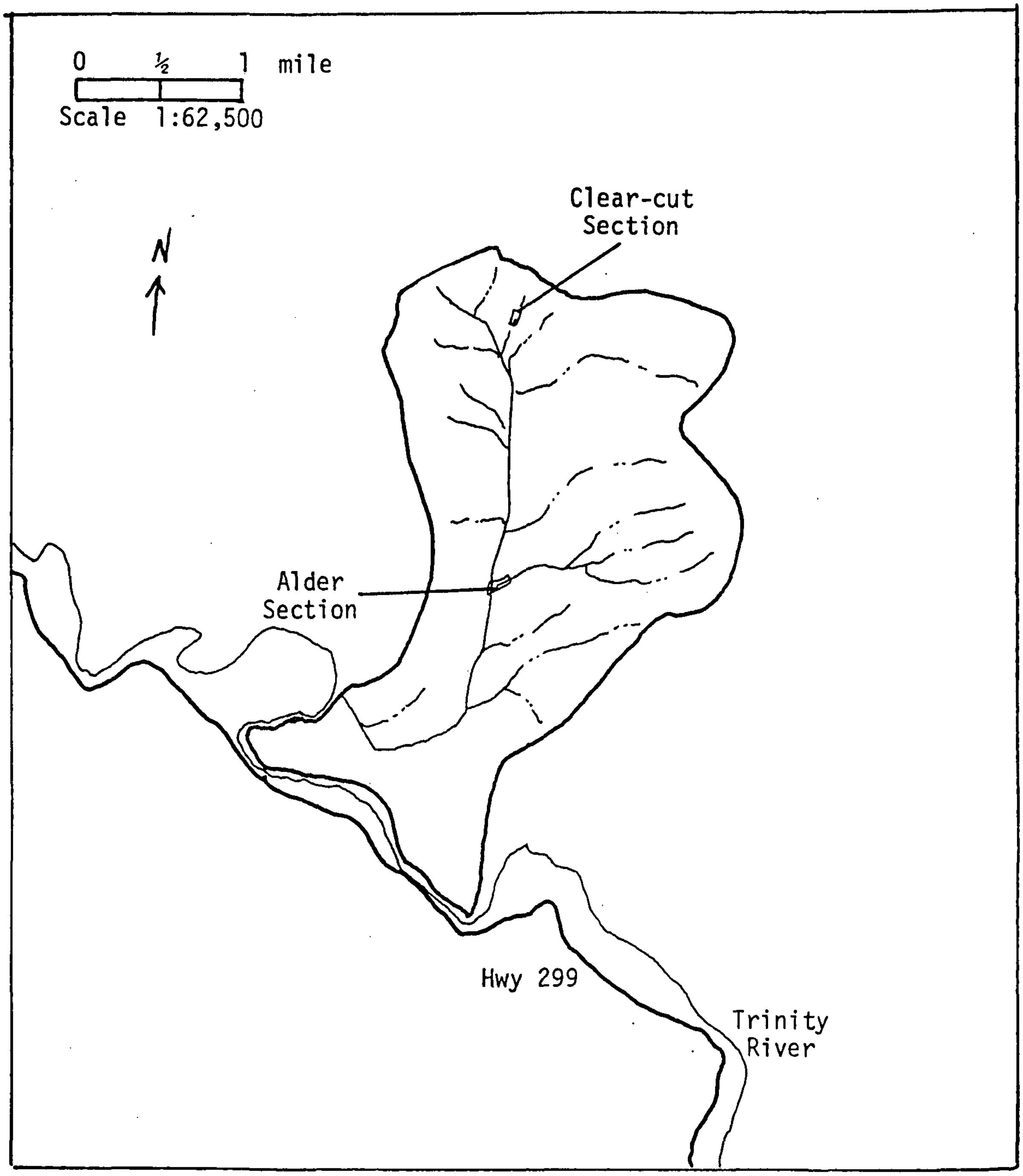

Figure 7. The Hawkins Creek watershed with locations of the Alder and Clear-cut study sections.

Figure. 8. The Hawkins Creek Alder section used in this study.

alder is now approximately 7 years old. Vegetation analysis is presented in Table 7.

Also on Hawkins Creek, a clear-cut area (the "Clear-cut" section) was selected on an ephemeral channel, NW ¼ of the NE ¼ of section 9, Range 5E, Township 6N (Figures 7 and 9.). This section was logged in 1973 using high lead cable due to the steep slope of 60 to 70 percent. It was burned also in 1973 and replanted with 2-year-old douglas-fir in 1974 (Sadie personal communication) (Table 8).

Streamflow in Fourmile Creek was estimated to be as high as 20 to 30 CFS during the winter and as low as 1 or 2 CFS in the summer. Streamflow in Hawkins Creek was estimated at 40 to 50 CFS in the winter and 1 to 5 CFS in the summer.

Juvenile rainbow trout (Salmo gairdneri), possibly steelhead trout (Salmo gairdneri) were seen in Hawkins Creek. No fish were seen in Fourmile Creek.

Table 7. Vegetation species composition and stand analysis on the Alder section, Hawkins Creek, October 1974. (See Table 3 for abbreviation definitions.)

Overstory: Red alder

B.A. 330   Average height 40 ft.   Average D.B.H. 5 in.

% crown closure >95   % live crown 70

	C/A	D/S
Red alder	7	1
Douglas-fir*	2	2

Understory:

	C/A	D/S
Wild blackberry	3	2
Sword fern	2	5
Thimbleberry	2	4
Douglas-fir seedling**	1	7
Wild grape	2	vine in canopy
Grasses & herbs	3	5
Horsetail	2	5
Deerbrush	1	3
Willow	1	1

* Back from stream.

** 2 years old.

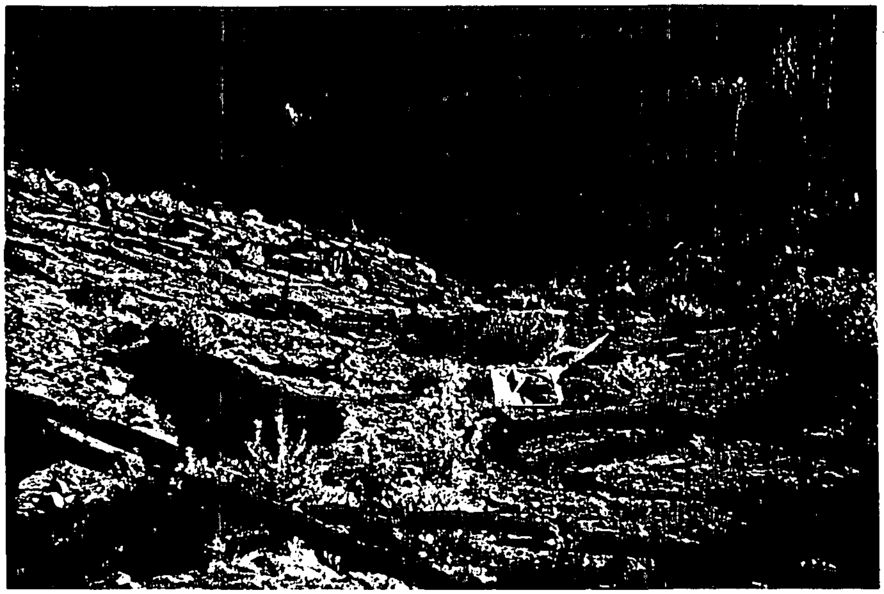

Figure 9. The Hawkins Creek Clear-cut section used in this study.

Table 8. Vegetation species composition and stand analysis on the Clear-cut section, Hawkins Creek, October 1974. (See Table 3 for abbreviation definitions.)

Overstory: NONE

Understory:

	C/A	D/S
Douglas-fir seedlings*	2	4
Deerbrush	2	4
Gooseberry	2	3
Tanoak	3	1
Bracken fern	2	3
Madrone	2	1
Grasses & herbs	2	2**
Thimbleberry	2	5
Dwarf Oregon-grape	1	6

* Douglas fir in 4 x 4 meter plot - 2 (planted, 2 year olds).

** Thistle was tall.

METHODS AND MATERIALS

Field Collection of Samples

Vegetation falling upon the stream surface in each study section was collected in one-square-meter boxes from September, 1974, to February, 1975. The collection (drop) boxes used are similar to those described by Hess (1969), who employed them for collecting insects falling into Casper Creek, California, and identical to those used by Hunt (1974), who employed them for collecting vegetation in his Ryan Creek study.

During the dry season, the boxes were not filled with water as was the case in Hunt's (1974) study, due to the high evaporation rate at that time, and lack of water on the ephemeral stream study areas. In the winter, water collected in the boxes and became a problem when it froze, trapping the litter and making collection difficult.

Ten collection boxes were placed randomly in each study area along the streambed over a distance of approximately 100 yards (Figures 10 to 13.). Random placement was accomplished by drawing numbers from a random numbers table as described by Zar (1974). The boxes were placed directly on the ephemeral streambed in the Pine, Virgin, and Clear-cut sections. Since the stream flow was perennial in the Alder and Second-growth sections, it sometimes was impractical to place the boxes directly on the streambed because of deep water or

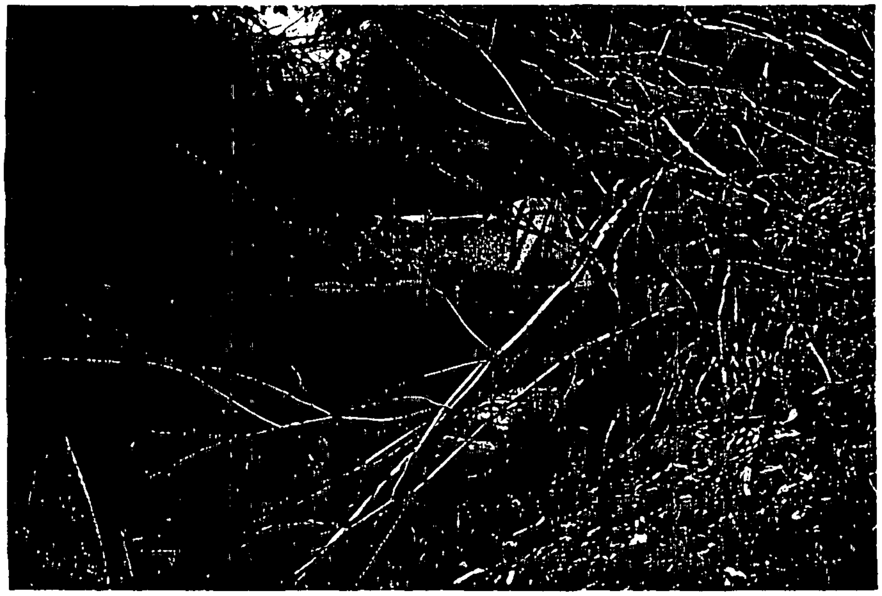

Figure 10. Typical placement of collection boxes in the Fourmile Creek Second-growth section.

Figure 11. Typical placement of collection boxes in the Fourmile Creek Pine section.

Figure 12. Typical placement of collection boxes in the Hawkins Creek Alder section.

Figure 13. Typical placement of collection boxes in the Hawkins Creek Clear-cut section.

obstructions, such as boulders or logs. Where this was a problem, the collection boxes were placed on the stream bank and leveled. To prevent the collection boxes from being washed away at high flow during the winter months, it became necessary to move some of the collection boxes onto the bank in all sections. The boxes that were relocated were moved only a few feet, without essential change in the quality of the vegetative canopy over each box (Figures 14 to 18.). It was assumed that the movement would not significantly affect the quality or quantity of the vegetation falling into a box. Leaf litter falls approximately in a circle around the base of the tree with a radius of the circle equaling the height of the tree (Hursey, personal communication).

The collection of accumulated leaves in each collection box in each study area took place at the end of each month (Figures 19-22.). The material from each box was placed into a plastic bag, labeled, and transported to the laboratory. The boxes were cleaned and the plastic bottoms restapled or replaced when necessary.

Photographs were taken of the study sections and box placement. Vegetation and stand analysis were performed using standard forestry techniques and measurements (Hunt, Jeanne personal communication).

Figure 14. Typical canopy over the Fourmile Creek Virgin section.

Figure 15. Typical canopy over the Fourmile Creek Second-growth section.

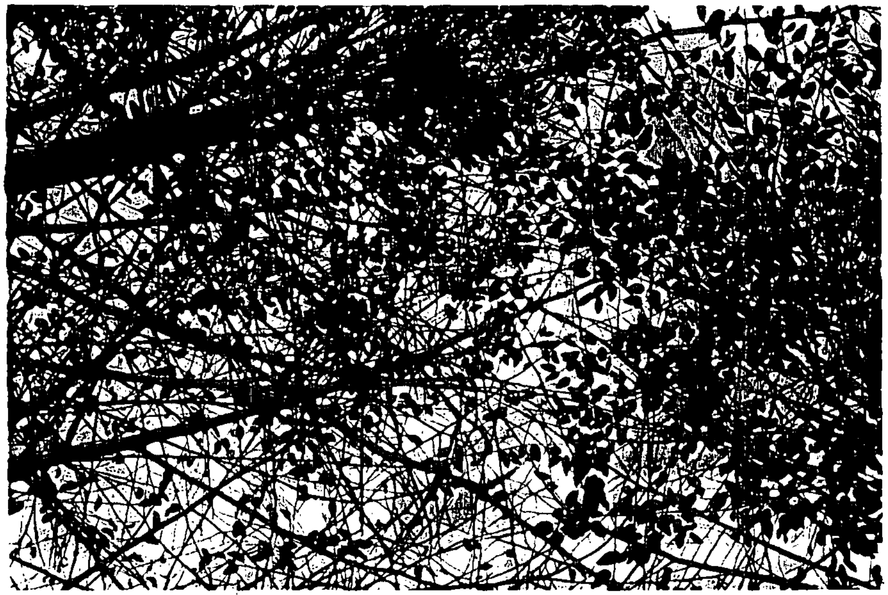

Figure 16. Typical canopy over the Hawkins Creek Alder section, November, 1974.

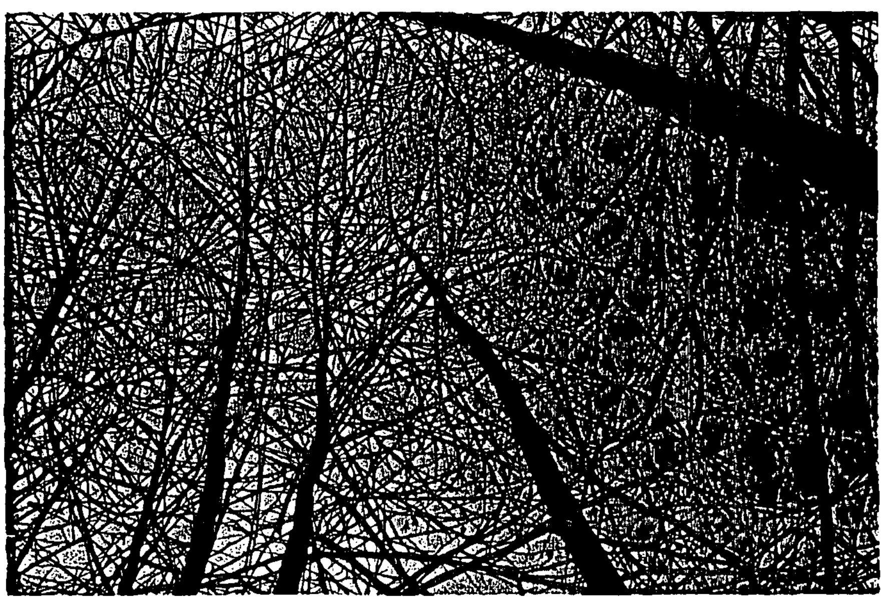

Figure 17. Typical canopy over the Hawkins Creek Alder section, March, 1975.

Figure 18. Typical canopy over the Fourmile Creek Pine section.

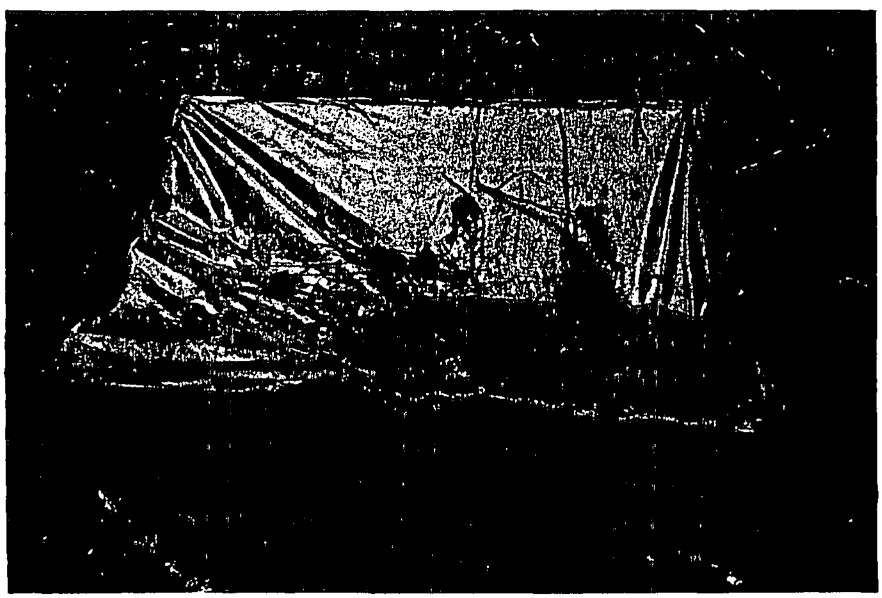

Figure 19. Typical one month accumulation of fallen vegetation from the Fourmile Creek Virgin section.

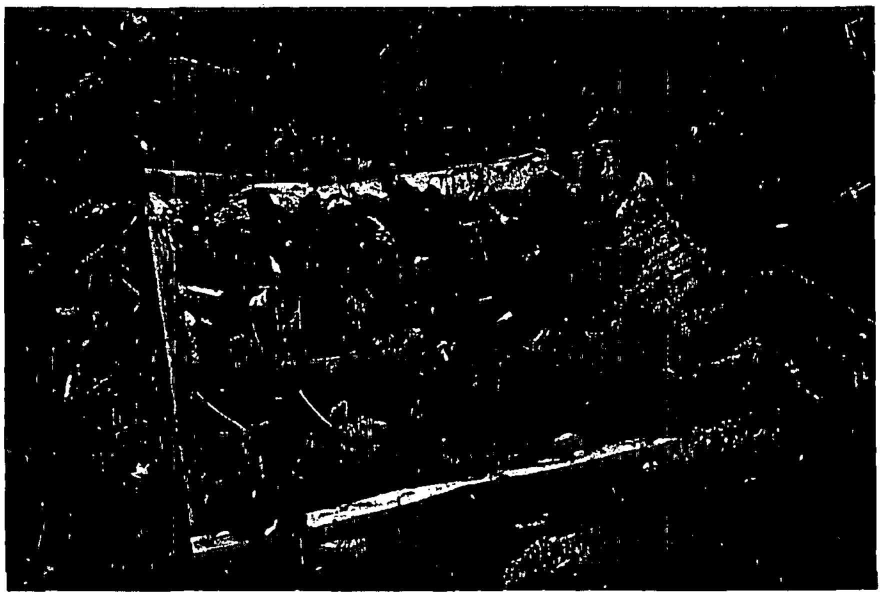

Figure 20. Typical one month accumulation of fallen vegetation from the Hawkins Creek Alder section, November, 1974.

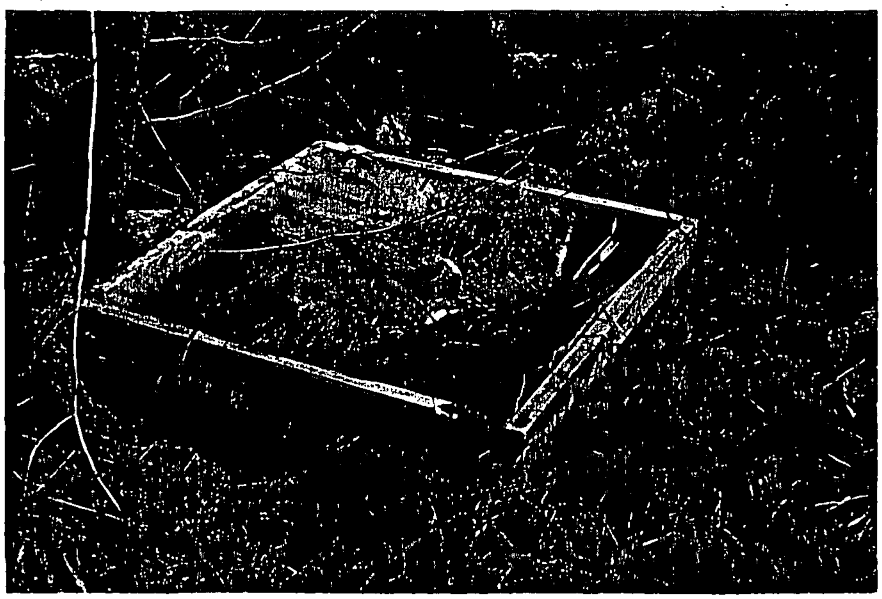

Figure 21. Typical one month accumulation of fallen vegetation from the Hawkins Creek Alder section, March, 1975.

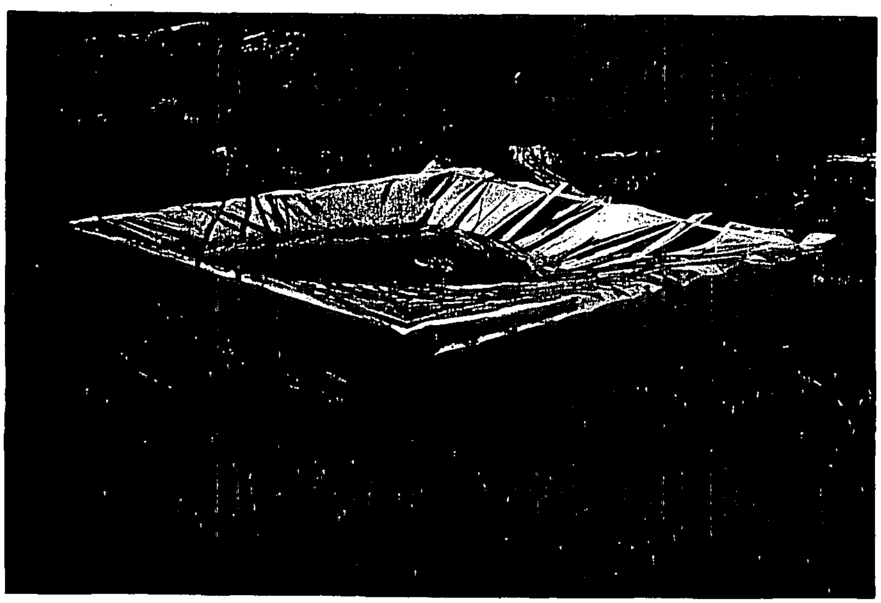

Figure 22. Typical one month accumulation of fallen vegetation from the Fourmile Creek Pine section.

<u>Laboratory Methods</u>

Each litter sample collected was placed in an aluminum pan and oven-dried for three to four days at 65°C. At the end of two days, samples were weighed to the nearest 0.05 gram and placed into the oven again and reweighed daily until there was no difference in the weights from two consecutive days. When all samples were thoroughly dried, they were weighed and the dry weights in grams per square meter recorded.

The dried leaf litter was ground in a Wiley vegetation grinding mill fitted with a 60 mesh-to-the-inch screen. The samples from each study section were pooled and thoroughly mixed to ensure a homogeneous mixture. Subsamples from pooled sections were then sealed in jars until analyzed for energy content.

The energy content analyses were conducted with a Parr isothermal-jacket bomb calorimeter on duplicate pelleted samples of the ground material, to determine total calories per gram of material. The combustion techniques followed are those recommended by Parr Instrument Company (1970). An average of the results of two runs was computed in reporting the calorific values per gram of litter. Calories per gram were then multiplied by grams per square meter to estimate the amount of energy reaching the stream in calories per square meter.

Corrections in energy content for sulfur and inorganic residues were not made. Generally, when calculating biomass and production, gross calorific values are used, while ash-free values allow for easy recognition of differences in the chemical composition of different materials (Scott 1965).

Statistical Analyses

The non-parometric Kruskal-Wallis single classification analysis of variance by ranks was employed due to heterogenous variances. Dunn's multiple comparisons test was also employed (Sokal and Rohlf 1969; Zar 1974; Hollander and Wolfe 1973). The data collected in this study and the statistical analysis of those data were designed to test the following null hypothesis: In similar streams, there is no significant difference in calories per unit area contributed by allochthonous vegetation falling into the stream (or onto its bed) under five distinctly different conditions of stream-side vegetation.

RESULTS

During the seven-month collection period, the Alder section contributed the most allochthonous vegetation to the stream followed by the Virgin, Pine, Second-growth and Clear-cut sections, respectively (Table 9). The dry weights of each square meter sample of vegetation collected in each section per month are presented in Appendices 1a-1f. During January, snow closed the roads and made collection of samples impossible, so samples were collected in February. The average weight and caloric content of the February sample was used in reporting the data for January and February.

The canopies in the Virgin, Pine and Clear-cut sections remained relatively unchanged during the study period. The Second-growth section canopy showed a slight change in November when a few deciduous trees completely defoliated. The most notable change in canopy occurred in the Alder section; by November, the canopy was sparse and by December was completely defoliated. Allochthonous vegetation from each study section is presented in Table 10.

The caloric contents of monthly subsamples of allochthonous vegetation from each study section were determined (Table 11). The Virgin and Pine sections averaged the same caloric amount for the study period followed by the Alder, Second-growth and Clear-cut sections, respectively. Caloric differences between each study section were quite small,

Table 9. Monthly mean dry weights in grams of ten one-square-meter samples of vegetation falling on the study sections from September, 1974 through March, 1975.

	STUDY SECTIONS				
Month	Virgin	Alder	Pine	Second-growth	Clear-cut
Sept.	22.76	17.67	45.78	2.73	0.17
Oct.	25.56	122.40	16.52	1.48	0.36
Nov.	85.30	158.69	31.74	12.73	3.52
Dec.	16.21	28.57	23.81	3.62	2.07
Jan. & Feb.	17.76	2.96	9.97	1.28	2.91
March	22.07	37.64	8.27	1.58	0.82
Total Weight	207.42	370.89	146.06	24.70	12.76
Mean	29.63	52.98	20.87	3.53	1.82
Variance	613.66	3845.95	193.77	17.24	1.86

Table 10. The composition of allochthonous vegetation collected from the five study areas from September, 1974 to March, 1975.

Section	Allochthonous Vegetation
Virgin	bark branches & twigs occasional cone needles leaves from understory
Second-growth	occasional twigs needles leaves
Clear-cut	bark needles leaves
Alder	
Sept. to Dec.	occasional twigs leaves
Jan. to March	twigs branches
Pine	twigs needles

Table 11. Monthly caloric content (in Kcal/gram) of subsamples of allochthonous vegetation taken each month on each study section.

	STUDY SECTIONS				
Month	Virgin	Alder	Pine	Second-growth	Clear-Cut
Sept.	4.89	4.23	4.74	4.25	2.56
Oct.	5.04	4.55	4.98	4.21	2.76
Nov.	5.04	4.73	4.97	4.56	4.29
Dec.	4.86	4.85	5.06	4.36	4.41
Jan. & Feb.	5.00	4.69	5.05	4.24	3.42
March	4.89	4.53	4.87	4.04	4.32
Mean	4.96	4.61	4.96	4.27	3.60
Variance	0.01	0.04	0.01	0.03	0.58

except for the Clear-cut section. But, analysis with the Kruskal-Wallis test showed a significant difference at the 0.01 level. Dunn's multiple comparison test showed that the Virgin, Alder and Pine were significantly greater than the Second-growth and Clear-cut sections at the 0.05 level. No differences were detected among the Virgin, Alder and Pine sections as a group, or the Second-growth and Clear-cut sections as a group (Table 12).

Among the five study sections, the Alder contributed the most potential energy to the stream, followed by the Virgin, Pine, Second-growth and Clear-cut sections, respectively (Table 13). Figure 23 illustrates the differences among the study sections in the mean monthly amounts of potential energy contributed to the streams by allochthonous vegetation. The accumulation of energy in kilocalories (Kcal) per square meter for each section per month is recorded in Appendices 2a-2f.

An analysis with the Kruskal-Wallis test on the Kcal/m^2/month data showed significant differences at the 0.01 level for all months tested (Table 14). Dunn's multiple comparison test further showed significant similarities and differences among the five study sections (Table 14). Generally, the Virgin, Alder and Pine sections as a group contributed significantly more potential energy than the Second-growth and Clear-cut did as a group.

Each study section was then analyzed separately to determine whether monthly differences existed. The Kruskal-

Table 12. Results of Kruskal-Wallis and Dunn's tests on the caloric content contributed (in Kcal/gram) from the five study sections from September, 1974 to March, 1975.

Section	Average of the sum of ranks		H*
	September to March	0.05**	
Virgin	24.33	A	
Alder	14.17	A	
Pine	24.50	A	23.18***
Second-growth	8.33	B	
Clear-cut	6.17	B	

* The Kruskal-Wallis test statistic.

** Indicates special protection level against finding false significant differences.

*** Significant at the 0.01 level.

Ranks followed by the same letter do not differ significantly.

Table 13. Monthly mean caloric content (in Kcal) of square meter samples of allochthonous vegetation contributed to the study sections from September, 1974 to March, 1975.

	STUDY SECTIONS				
Month	Virgin	Alder	Pine	Second-growth	Clear-Cut
Sept.	111.21	64.79	217.19	11.57	0.43
Oct.	143.20	557.09	82.21	6.24	0.99
Nov.	430.07	750.05	157.70	58.07	15.10
Dec.	78.37	138.66	120.55	15.78	9.14
Jan. & Feb.	88.91	13.86	50.36	5.43	9.96
March	107.90	170.51	40.25	6.38	3.54
Total Energy Contribution	1048.57	1708.82	718.62	108.90	49.12
Mean	149.80	244.12	102.66	15.56	7.02
Variance	15726.18	29.83	4375.05	366.57	84775.70

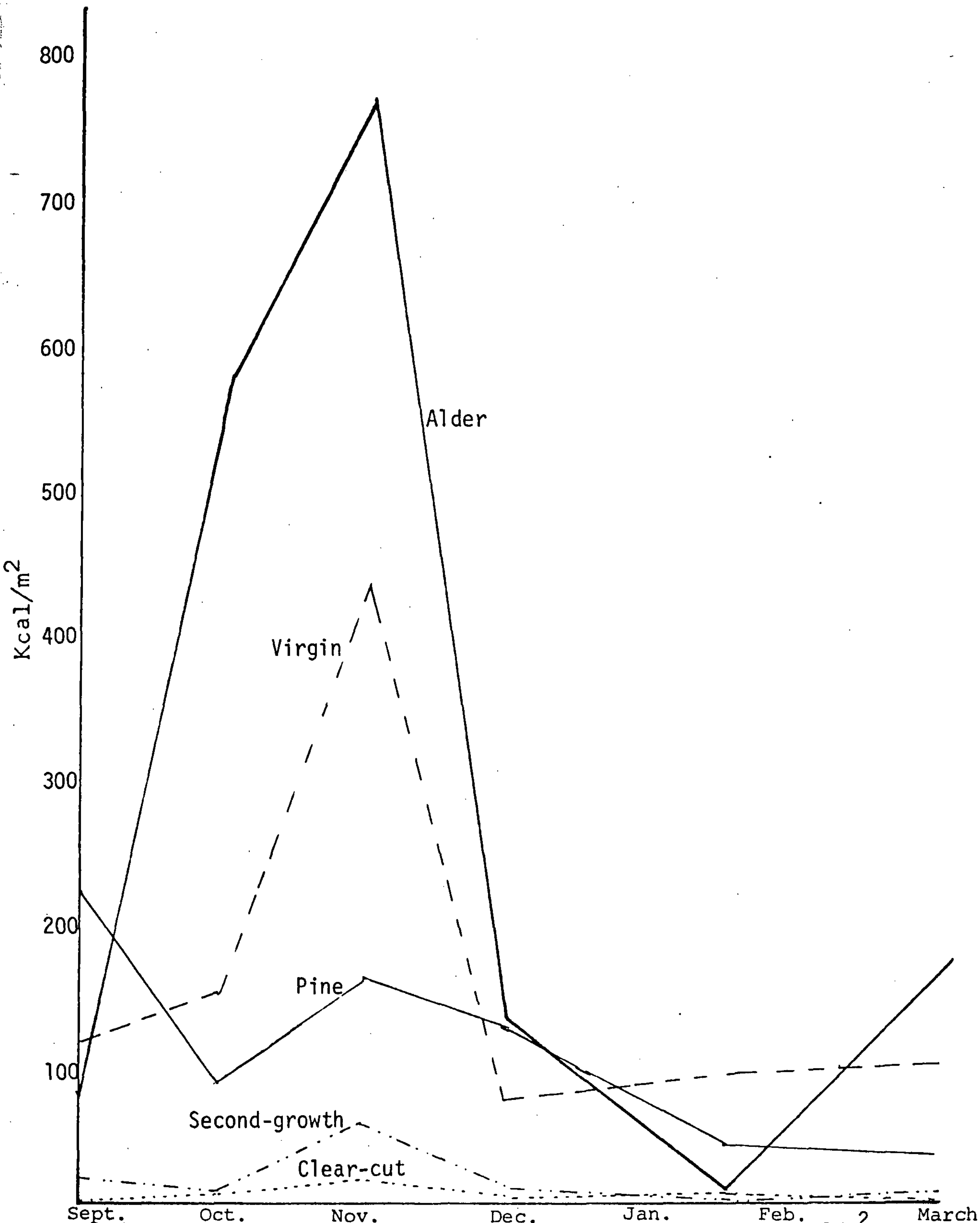

Figure 23. Total energy of allochthonous vegetation, in Kcal/m^2, contributed to the streams by Virgin, Alder, Pine, Second-growth and Clear-cut section from September, 1974 to March, 1975.

Table 14. Results of Kruskal-Wallis and Dunn's tests on potential energy (in Kcal) of square meter samples of allochthonous vegetation on study sections from September, 1974 to March, 1975.

Section	Average of the sum of ranks	0.05	H*
	September	0.05**	
Virgin	32.50	AB	
Alder	25.60	AB	
Pine	35.30	AB	32.61***
Second-growth	15.17	A C	
Clear-cut	5.60	C	
	October	0.05*	
Virgin	31.22	AB	
Alder	41.70	A	
Pine	25.60	AB	40.58***
Second-growth	14.13	ABC	
Clear-cut	6.10	C	
	November	0.05*	
Virgin	35.50	A	
Alder	42.90	A	
Pine	22.90	AB	40.30***
Second-growth	14.50	BC	
Clear-cut	7.44	BC	

Table 14, continued

Wallis and Dunn's tests were used to see whether there were monthly differences in energy input within each study section. Again, it was found that significant differences existed between months at the 0.01 level. Dunn's test further revealed monthly differences and similarities (Table 15). Generally, the largest difference between months for all study sections occurred in November, as shown in Figure 23.

The data from Hunt's 1973-74 study conducted on a redwood watershed were reanalyzed for comparison with the present study conducted on two similar douglas-fir watersheds (Appendices 3a-c). Reanalysis of Hunt's data did not show significant differences in potential energy contributed between the Redwood and Alder sections as previously reported (Hunt 1974). Examination by month showed October and November to be significantly higher than the other months tested for both the Redwood and Alder sections. The fall months, October and November, were also observed to contribute more potential energy in the present study. No significant differences were noted for any month in the Meadow section. The caloric content of the vegetation contributed by the Alder section was significantly greater than the Redwood and Meadow sections at the 0.01 level.

The statistical analysis of the data derived in the present study indicates a high degree of significance with respect to allochthonous energy input, although the following null hypothesis was not rejected entirely: In similar streams, there is no significant difference in calories per unit area

Table 14. Continued

Section	Average of the sum of ranks		H*
	December	0.05**	
Virgin	29.22	AB	
Alder	36.40	A	
Pine	32.40	A	33.05***
Second-growth	12.33	ABC	
Clear-cut	7.33	C	
	January & February	0.05**	
Virgin	40.50	A	
Alder	23.10	AB	
Pine	30.60	ABC	28.93***
Second-growth	8.67	B D	
Clear-cut	17.33	BCD	
	March	0.05**	
Virgin	30.00	A	
Alder	36.50	A	
Pine	24.70	AB	33.10***
Second-growth	10.71	BC	
Clear-cut	6.00	C	

* The Kruskal-Wallis test statistic.
** Indicates special protection level against finding false significance.
*** Significant at the 0.01 level.

Ranks followed by the same letter within each month do not differ significantly.

Table 15. Results of Kruskal-Wallis and Dunn's tests on potential energy (in Kcal) of square meter samples of allochthonous vegetation examined by study sections.

Month	Average of the sum of ranks		H*
	Virgin	0.05**	
Sept.	28.30	AB	
Oct.	36.44	AB	
Nov.	52.50	B	29.98****
Dec.	19.67	A	
Jan. & Feb.	22.10	A	
March	17.70	A	
	Alder	0.05**	
Sept.	20.30	A C	
Oct.	46.50	B	
Nov.	52.50	B	48.17****
Dec.	29.70	ABC	
Jan. & Feb.	5.60	A	
March	28.40	ABC	

Table 15, continued

Table 15. Continued

Month	Average of the sum of ranks		H*
	Pine		
		0.10**	
Sept.	38.56	AB	14.05***
Oct.	28.20	AB	
Nov.	40.80	A	
Dec.	33.90	AB	
Jan. & Feb.	20.50	AB	
March	18.90	A	
	Second-Growth		
		0.05**	
Sept.	24.33	ABC	18.49****
Oct.	17.13	AB	
Nov.	37.50	A C	
Dec.	33.22	ABC	
Jan. & Feb.	15.89	AB	
March	17.86	ABC	

Table 15, continued

Table 15. Continued

Month	Average of the sum of ranks		H*
	Clear-cut		
		0.05**	
Sept.	11.05	A	
Oct.	12.90	AB	
Nov.	42.17	C	37.08****
Dec.	39.33	C	
Jan. & Feb.	39.89	C	
March	26.00	ABC	

* The Kruskal-Wallis test statistic.

** Indicates special protection level against finding false significant differences.

*** Significant at the 0.05 level.

**** Significant at the 0.01 level.

Ranks followed by the same letter within each group do not differ significantly.

contributed by allochthonous vegetation falling into the stream (or onto its bed) under five distinctly different conditions of streamside vegetation.

DISCUSSION

Caloric contents of each vegetative type differed over a small range. The caloric contents are within the range of values reported by Golley (1961) for a number of different plant materials.

Zavitovski and Newton (1971) reported that litter production in stands of red alder from two to 33 years old was higher than that reported for any other plant community in the temperate region, 1.65 tons/acre/year to 2.45 tons/acre/year. The mean grams per square meter per month for each study section were converted to tons per acre per year in order to make comparisons with other studies. The Alder section was found to contribute 2.84 tons/acre/year. The Virgin section contributed 1.6 tons/acre/year of allochthonous vegetation. Miller, Williamson and Silen (1974) reported that for the Pacific Northwest the average annual litterfall (needles and twigs) in old-growth douglas-fir stands is approximately one ton/acre/year. Large limbs, bark and understory hardwoods, however, contribute an additional one ton/acre/year. The Pine section contributed 1.12 tons/acre/year. The two study sections with the most timber harvest disturbance contributed the least amount of allochthonous vegetation: Second-growth (0.19 tons/acre/year) and the Clear-cut (0.10 tons/acre/year).

The results of this study, for the most part, show significant differences in the amount of potential energy contributed to the stream from the Virgin, Alder and Pine sections compared to the Second-growth and Clear-cut sections. No differences in potential energy inputs were detected between the Virgin, Alder and Pine sections as a group or the Second-growth and Clear-cut sections as a group. Although these differences were not statistically significant, there may be important differences in the energy transfer of different types of vegetation, once in the aquatic system. A similarity was noticed between the potential energy of the allochthonous vegetation contributed (Kcal/m^2) and the weight of allochthonous vegetation contributed. The sections with the highest weight values contributed the highest amounts of potential energy while the sections with the lowest weight values contributed the lowest amounts of potential energy.

A distinct seasonal peak of allochthonous vegetation was contributed in November. Carlisle, Brown and White (1966), Nelson and Scott (1962), Minshall (1967), and Teal (1957) also found leaf drop to be concentrated in a rather short autumnal period with a pronounced peak in October or November. Annual variation in litter production in conifer stands is considerable. This variation is related to needle pathogens and needle, flower, and seed production (Millar 1974). Severe environmental factors, such as drought and storms can affect needle fall (Millar 1974). Two large snow storms occurred during January and March of this study. The snowfall did not increase the litterfall in any of the sections as was anticipated (except for a slight increase in the Alder section consisting mainly of twigs and branches).

One of the factors which might be expected to affect the amounts of litterfall in a forest stand is the species composition. Lutz and Chandler (1946) found, however, that differences in litterfall between tree species were rather small. When sites with similar soil type and climatic conditions were compared, the variation within a single species was almost as large as the variation between the different species growing on the sites. This variation within a single species was also seen in the present study.

Three study sections in the present study were compared to similar sections in Hunt's 1974 study. The Redwood, Alder and Meadow (Second-growth redwood) were compared to the Virgin, Alder and Second-growth sections. The caloric content of the allochthonous vegetation contributed by the Virgin section was significantly higher than the Redwood. The caloric content of the Alder from the redwood watershed was significantly higher than that from the Alder in the douglas-fir watershed. The caloric contents of the Second-growth and Meadow sections were not significantly different (Appendix 4a).

The Redwood section contributed significantly more potential energy than the Virgin section did for the period of September to December, the only period of overlap in the two studies (Appendix 4b). The redwood associated Alder section contributed more potential energy in September and December than the douglas-fir associated Alder section, but there was no significant difference between the two Alder sections during October and November (Appendix 4c). The Meadow section contributed significantly more potential energy than the Second-growth section for September, October and December, but there was no difference for November (Appendix 4d).

The age of the Redwood section is approximately 45 years compared to the approximately 250 years of the Virgin douglas-fir section. The Meadow is six years old compared to 15 years of the Second-growth. All these areas were clear-cut except the Virgin section. It appears significant that the coastal redwood watershed contributes more potential energy than the inland douglas-fir watershed at such an early stage of its regeneration. The coastal redwood could have more favorable site and climatic conditions, regenerate faster, or may have been harvested in a less disruptive manner than the inland douglas-fir.

The redwood associated red alder is approximately 25 years old compared to the seven years old red alder associated with the douglas-fir. It also appears significant that in seven years, the Alder section of the douglas-fir can contribute equivalent amounts of allochthonous material as the older redwood associated Alder.

Removal of all vegetation, especially streamside vegetation, during timber harvesting causes considerable damage to the stream ecosystem. Without a "buffer strip" for protection, the aquatic organisms are faced with increased water temperatures, decreased dissolved oxygen of the water and streambed, logging debris and sediment entering the stream, streambank instability, deterioration of the chemical quality of the water, stream runoff increases causing heavy gravel shifting, and the disruption of the stream's energy source (Gibbons and Salo 1973; Chapman 1962; Johnson 1953; Brown 1974).

Based on the present study, it appears that some years are required for the recovery time for the energy source of the douglas-fir aquatic communities in douglas-fir watersheds. Fifteen years have passed since the clear-cut timber harvest on the Second-growth section took place, and it is only contributing one percent of the amount of potential energy that the Virgin section is contributing. The Alder section, on the other hand, had little disturbance, is seven years old, and is contributing 163 percent more potential energy than the Virgin section. This difference between the deciduous alder and coniferous douglas-fir regeneration time and energy contributions to streams is considerable. The present study shows that alder is an important streamside contributor of energy to the aquatic community after timber harvest operations. Much longer time periods are required for a douglas-fir stand to recover to pre-logging levels of energy input to streams.

Streamside vegetation management for protecting and even enhancing stream productivity of the Pacific Northwest after timber harvest can be accomplished by replanting the streamside alder (or some other phreatophyte) or by leaving protective buffer strips of the natural vegetation, or a combination of planting and non-harvesting along streams.

Recommendations

The collection boxes from the present study should be modified if used for future studies. Some vegetation was seen blowing out of the collection boxes. The sides of the boxes should be extended to prevent any loss due to wind. The plastic lining of the collection boxes trapped water, as well as allochthonous vegetation. The water froze during the winter months, making collection of samples difficult. A fine mesh, plastic screen should be used instead of the plastic to avoid this problem. Also, the plastic lining began to crack and break up after approximately six months in the field. Smaller collection boxes, one-half or one-quarter the present one meter size, could be used to save on material costs. They also would be easier to transport (and a better sampling distribution could be obtained with the use of more boxes for approximately the same cost).

Follow-up studies on the present study could include: 1) The rate of breakdown and transport downstream of allochthonous vegetation, 2) Species diversity, population density and possible recovery rate of aquatic communities before and after timber harvest, and 3) Energy studies of other deciduous and coniferous tree and plant species along streams for comparison.

SUMMARY

Allochthonous vegetation was collected from September, 1974 to March, 1975 from five streamside study sections that had previously experienced various degrees of timber harvest and regeneration. The five study sections supported virgin (old-growth) douglas-fir, second-growth douglas-fir, ponderosa pine, red alder, and sparse vegetation on a recent clear-cut. The Alder section contributed more potential energy than did the Virgin section, followed by the Pine, Second-growth and Clear-cut sections, respectively. Differences between the Virgin, Alder, and Pine sections were not statistically significant, nor were the differences between the Second-growth and Clear-cut sections. Statistical analysis of the caloric content of the allochthonous vegetation followed the same pattern as the potential energy. The mean caloric content of the Virgin and Pine sections was the highest and also identical.

A distinct seasonal peak of energy contributed was noted during November. In comparison to Hunt's (1974) study, the redwood watershed appears to be contributing more potential energy than the douglas-fir watershed (except for the alder sections). The seven-year-old alder section of the douglas-fir study contributed nearly the same amount of potential energy as the 15-year-old alder section of the redwood study during the autumn months.

Removal of all streamside vegetation (Second-growth and

Clear-cut sections) caused a significant decrease in the amount of potential energy contributed to the stream. After a recovery time of 15 years, neither of these sections is contributing as much allochthonous energy as the unlogged virgin section. The potential energy contribution by the Alder section surpassed the Virgin section by 163 percent in just seven years.

Streamside vegetation management for protecting and enhancing stream productivity of the Pacific Northwest after timber harvest can be accomplished by replanting with alder (native to the area), by leaving protective buffer strips of the natural vegetation, or a combination of planting and non-harvesting along streams.

LITERATURE CITED

Brown, G. W. 1974. Fish Habitat. In: Environmental Effects of Forest Residues Management in the Pacific Northwest. A state-of-knowledge compendium. USDA Forest Service General Technical Report PNW-24. E1-E15.

Carlisle, A., A.H.F. Brown, and E. J. White. 1966. The Organic matter and nutrient elements in the precipitation beneath a sessile oak (Quercus petraea) canopy. J. of Ecol. 54(1):87-98.

Chapman, D. W. 1962. Effects of logging upon resources of the west coast. J. For. 60(8):533-537.

Efford, I.E. 1969. Energy transfer in Marion Lake, British Columbia, with particular reference to fish feeding. International Association of Theoretical and Applied Limnology. 17(1):104-108.

Egglishaw, H. J. 1968. The distributional relationship between the bottom fauna and plant detritus in streams. J. of Animal. Ecol. 33:463-476.

Fisher, S. G. and G. E. Likens 1973. Stream ecosystem: organic energy budget. BioScience. 22(1):33-35.

Gibbons, D. R. and E. O. Salo. 1973. An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada. USDA Forest Service General Technical Report PNW-10. 145 pp.

Golley, F. B. 1961. Energy values of ecological materials. Ecology. 42(3):581-584.

Hess, L. J. 1969. The effects of logging road construction on insect drop into a small coastal stream. M. S. Thesis. Humboldt State University. 58 pp.

Hollander, M. and D. A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, New York. 503 pp.

Hunt, W. H. 1974. The effects of logging on the potential energy contributed to a stream by streamside vegetation. M. S. Thesis. Humboldt State University. 55 pp.

Hynes, H. B. N. 1970. The Ecology of Running Waters. Univ. of Toronto Press. Toronto. 555 pp.

Johnson, F. W. 1953. Forests and trout. J. For. 51(8):551-554

Lutz, H. J. and R. F. Chandler. 1946. Forest Soils. John Wiley, New York. 514 pp.

Millar, C. S. 1974. Decomposition of Coniferous Leaf Litter. Page 105 to 128 in Biology of Plant Litter Decomposition. Vol. 1, Ch. 4. Academic Press, New York. 241 pp.

Miller, R. E., R. L. Williamson, and R. R. Silen. 1974. Regeneration and Growth of Coastal Douglas-Fir. In: Environmental Effects of Forest Residues Management in the Pacific Northwest. A state-of-knowledge compendium. USDA Forest Service General Technical Report PNW-24. 516pp.

Minshall, G. W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology. 48:139-149.

Nelson, D. J. and D. C. Scott. 1962. Role of detritus in the productivity of a rock outcrop community in a piedmont stream. Limno. and Ocean. 7(3):396-413.

Parr Instrument Company, 1970. Oxygen Calorimetry and Combustion Methods. Manual no. 130. Moline, Illinois. 56 pp.

Scott, D. 1965. The determination and use of thermodynamic data in ecology. Ecology. 41:673-680.

Sokal, R. R. and J. Rohlf. 1969. Biometry. W. H. Freeman and Company. San Francisco. 776 pp.

Teal, J. M. 1957. Community metabolism in a temperate cold spring. Ecol. Monograph. 27(3):283-302.

Zar, J. H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 620 pp.

Zavitokovski, J. and M. Newton. 1971. Litterfall and litter accumulation in red alder stands in western Oregon. Plant and Soil. 35:257-268.

PERSONAL COMMUNICATION

Freeland, F. Dean. Watershed Professor, Humboldt State University, California.

Hunt, Jeanne. Forestry Graduate Student. Humboldt State University, California.

Hursey, Robert. Forestry Professor. Humboldt State University, California

Sadie, Andrew. District Silviculturist Lower Trinity Ranger District. U.S. Forest Service. Willow Creek, Calif.

APPENDIX 1

Accumulation of Allochthonous Vegetation by Dry Weight in Grams Per Square Meter on Virgin, Alder, Pine, Second-growth, and Clear-cut Study Sections

Appendix 1a September accumulation of allochthonous vegetation by dry weight in grams per square meter on five streamside study sections.

	STUDY SECTIONS				
Sample #	Virgin	Alder	Pine	Second-growth	Clear-Cut
1	33.15	12.30	36.50	0.50	0.60
2	25.10	17.75	71.40	3.30	0.15
3	20.00	17.60	101.55	1.35	0.50
4	19.60	27.30	19.05	6.90	0.20
5	23.50	7.65	29.90	1.20	0.25
6	34.10	19.35	1.55	3.10	0.00
7	17.10	6.65	0.30	-	0.00
8	17.55	20.15	64.60	-	0.00
9	12.85	35.15	36.25	-	0.00
10	24.60	12.75	96.65	-	0.00
Mean	22.76	17.67	45.78	2.73	0.17
Variance	46.77	75.80	1319.66	5.41	0.05

Appendix 1b October accumulation of allochthonous vegetation by dry weight in grams per square meter on five streamside study sections.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-Cut
1	25.10	210.65	6.65	3.00	0.30
2	34.25	169.85	1.30	0.30	0.75
3	17.25	100.35	27.15	0.85	1.50
4	33.10	95.90	2.70	1.40	1.05
5	27.60	124.00	15.40	0.85	0.00
6	12.50	36.50	15.45	3.20	0.00
7	32.15	39.20	39.90	1.40	0.00
8	34.60	97.20	14.00	0.85	0.00
9	39.00	171.00	34.10	-	0.00
10	-	179.30	8.50	-	0.00
Mean	28.39	122.40	16.52	1.48	0.36
Variance	76.23	3529.58	173.53	1.12	0.30

Appendix 1c November accumulation of allochthonous vegetation by dry weight in grams per square meter on five streamside study sections.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-Cut
1	126.35	252.55	5.15	2.35	2.40
2	170.90	174.65	6.40	9.10	3.30
3	104.75	181.25	15.45	7.30	4.20
4	89.10	82.10	25.05	10.25	1.90
5	72.45	203.70	49.85	32.35	3.90
6	68.65	124.80	38.10	1.00	1.00
7	55.45	178.35	43.30	17.00	5.75
8	59.75	93.30	71.40	30.45	9.25
9	43.85	120.70	28.00	16.20	0.00
10	61.75	175.50	34.70	1.25	-
Mean	85.30	158.69	31.74	12.73	3.52
Variance	1518.23	2778.00	417.44	128.35	7.64

Appendix 1d December accumulation of allochthonous vegetation by dry weight in grams per square meter on five streamside study sections.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-Cut
1	27.50	34.90	36.50	3.80	3.00
2	10.55	48.20	50.90	3.70	1.70
3	5.10	43.85	18.00	1.65	1.70
4	25.15	25.65	26.00	2.10	1.50
5	21.05	27.00	41.90	10.90	2.15
6	17.45	21.85	5.00	2.80	3.65
7	12.55	17.35	4.60	3.55	2.20
8	10.85	22.55	4.85	2.50	1.40
9	14.85	38.30	51.00	1.55	1.35
10	-	6.00	3.30	-	-
Mean	16.21	28.57	23.81	3.62	2.07
Variance	53.96	164.58	379.81	8.18	0.62

Appendix 1e January and February accumulation of allochthonous vegetation by dry weight in grams per square meter on five streamside study sections.

	STUDY SECTIONS				
Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	34.03	3.25	0.73	1.68	2.98
2	10.50	2.63	1.53	2.33	2.58
3	15.98	2.73	1.75	0.30	0.53
4	11.03	2.90	3.30	2.55	4.10
5	20.93	2.68	11.63	0.43	4.68
6	25.05	2.23	13.78	0.53	5.50
7	33.50	1.70	13.00	1.75	2.20
8	7.70	5.83	21.18	1.38	2.50
9	14.65	3.95	13.03	0.60	1.15
10	4.25	1.68	19.78	-	-
Mean	17.76	2.96	9.97	1.28	2.91
Variance	107.80	1.48	58.49	0.73	2.60

Appendix 1f March accumulation of allochthonous vegetation by dry weight in grams per square meter on five streamside study sections.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	10.70	129.70	9.65	1.40	1.40
2	4.65	5.60	21.25	1.40	0.30
3	12.10	68.05	3.80	0.60	0.50
4	5.30	12.25	2.40	3.35	0.65
5	66.00	21.80	2.35	1.70	0.55
6	4.50	30.25	2.05	1.15	0.75
7	88.80	46.00	19.80	1.45	1.35
8	4.60	28.85	3.30	-	1.45
9	3.00	8.75	11.25	-	-
10	21.00	25.15	6.80	-	-
Mean	22.07	37.64	8.27	1.58	0.82
Variance	908.31	1390.48	51.92	0.73	0.17

APPENDIX 2

Accumulation of Energy in Kilocalories
per Square Meter by Allochthonous Vegetation
on Virgin, Alder, Pine, Second-growth and Clear-cut
Study Sections

Appendix 2a September accumulation of energy in Kilocalories per square meter derived by the product of the dry weight of allochthonous vegetation and caloric values for each study section.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	162.01	52.07	173.18	2.12	1.53
2	122.67	75.15	338.78	14.01	0.38
3	97.74	74.51	481.83	5.73	1.28
4	95.79	115.58	90.38	29.30	0.51
5	114.85	32.39	141.87	5.10	0.64
6	166.65	81.92	7.35	13.16	0.00
7	83.57	28.15	1.42	-	0.00
8	85.77	85.31	306.51	-	0.00
9	62.80	148.82	172.00	-	0.00
10	120.23	53.98	458.58	-	0.00
Mean	111.21	64.79	217.19	11.57	0.43
Variance	1117.12	1358.70	29709.50	97.62	0.34

Appendix 2b October accumulation of energy in Kilocalories per square meter derived by the product of the dry weight of allochthonous vegetation and caloric values for each study section.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	126.59	958.78	33.10	33.10	0.83
2	172.73	773.08	6.47	1.26	2.07
3	87.00	456.75	135.15	3.58	4.14
4	166.93	436.49	13.44	5.90	2.90
5	139.19	564.39	76.66	3.58	0.00
6	63.04	166.13	76.91	13.49	0.00
7	162.14	178.42	198.62	5.90	0.00
8	174.50	442.41	69.69	3.58	0.00
9	196.69	778.32	169.75	-	0.00
10	-	816.09	42.31	-	0.00
Mean	143.20	557.09	82.21	6.24	0.99
Variance	1938.85	73120.91	4300.28	19.97	2.29

Appendix 2c November accumulation of energy in Kilocalories per square meter derived by the product of the dry weight of allochthonous vegetation and caloric values of each study section.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	637.04	1793.68	25.59	10.72	10.29
2	861.65	825.48	31.80	41.53	14.15
3	528.13	856.68	76.78	33.31	18.01
4	449.23	388.05	124.49	46.77	8.15
5	365.28	962.79	247.43	147.62	16.72
6	346.12	589.87	189.34	4.56	4.29
7	279.57	842.97	215.18	77.57	24.66
8	301.25	440.98	354.82	138.95	39.67
9	221.08	570.49	139.15	73.93	0.00
10	311.33	829.50	172.44	5.70	-
Mean	430.07	750.05	157.70	58.07	15.10
Variance	38594.10	62059.96	10303.22	2672.76	140.42

Appendix 2d December accumulation of energy in Kilocalories per square meter derived by the product of the dry weight of allochthonous vegetation and caloric values of each study section.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	133.72	169.40	164.80	16.58	13.24
2	51.30	233.96	257.71	16.15	7.50
3	24.80	212.85	91.14	7.20	7.50
4	122.30	124.51	131.64	9.16	6.62
5	102.35	131.06	212.14	47.57	9.49
6	84.85	106.06	25.32	12.22	16.10
7	61.02	84.22	23.29	15.50	9.71
8	52.76	109.46	24.56	10.91	6.18
9	72.21	185.91	258.22	6.76	5.96
10	-	29.12	16.71	-	-
Mean	78.37	138.66	120.55	15.78	9.14
Variance	1275.98	3877.76	9736.19	155.83	12.04

Appendix 2e January and February accumulation of energy in Kilocalories per square meter derived by the product of the dry weight of allochthonous vegetation and caloric values for each study section.

STUDY SECTIONS

Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	171.25	15.24	3.69	7.10	10.19
2	52.50	12.31	7.73	9.86	8.82
3	79.88	12.78	8.84	1.27	1.81
4	55.13	13.60	16.67	10.81	14.02
5	104.63	12.55	58.73	1.80	16.01
6	125.25	7.97	69.59	2.23	7.52
7	167.50	10.44	65.65	7.42	8.55
8	38.50	27.32	106.96	5.83	18.81
9	73.25	18.53	65.80	2.54	3.93
10	21.25	7.86	99.89	-	-
Mean	88.91	13.86	50.36	5.43	9.96
Variance	2715.21	32.51	1491.46	13.07	30.44

Appendix 2f March accumulation of energy in Kilocalories per square meter derived by the product of the dry weight of allochthonous vegetation and caloric values for each study section.

	STUDY SECTIONS				
Sample #	Virgin	Alder	Pine	Second-growth	Clear-cut
1	52.32	587.54	47.00	5.66	4.32
2	22.74	25.37	103.49	5.66	1.30
3	59.17	308.27	18.51	2.42	2.16
4	25.92	55.49	11.69	13.53	2.81
5	322.74	98.75	11.44	6.87	2.38
6	22.01	137.03	9.98	4.65	3.24
7	434.23	208.38	96.43	5.86	5.83
8	22.49	130.69	16.07	-	6.26
9	14.67	39.64	54.79	-	-
10	102.69	113.93	33.12	-	-
Mean	107.90	170.51	40.25	6.38	3.54
Variance	21719.46	28533.94	1231.28	11.89	3.16

APPENDIX 3

Reanalysis of Hunt's 1974 Caloric Content
and Accumulation of Energy Data by Kruskal-Wallis
and Dunn's tests

Appendix 3a Results of Kruskal-Wallis and Dunn's tests on caloric content contributed (in Kcal/gram) from Hunt's 1974 study.

Section	Average of the sum of ranks		H
	July to December		
		0.05*	
Redwood	8.05	AB	
Alder	14.50	A	14.24**
Meadow	3.00	AB	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.01 level.

Ranks followed by the same letter do not differ significantly.

Appendix 3b Results of Kruskal-Wallis and Dunn's tests on potential energy contributed (in Kcal) per square meter from Hunt's 1974 study.

Section	Average of the sum of ranks	0.05*	H
	July		
Redwood	4.50		11.29**
Alder	12.50	A	
	August		
Redwood	12.60	A	19.17**
Alder	22.67	A	
Meadow	6.00		
	September		
Redwood	13.80	A	18.47**
Alder	20.56	A	
Meadow	4.00		
	October		
Redwood	13.50	A	18.24**
Alder	19.50	A	
Meadow	4.50		

Appendix 3b, continued

Appendix 3b, Continued

Section	Average of the sum of ranks	0.05*	H
	November		
Redwood	12.75	AB	
Alder	20.78	AB	20.73**
Meadow	4.50	A	
	December		
Redwood	14.38	AB	
Alder	20.44	AB	16.70**
Meadow	5.78	A	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.01 level.

Ranks followed by the same letter within each month do not differ significantly.

Appendix 3c Results of Kruskal-Wallis and Dunn's tests on potential energy (in Kcal) per square meter examined by study sections from Hunts 1974 study.

Month	Average of the sum of ranks	0.05*	H
	Redwood		
July	5.00	A	
August	15.30	AB	
September	42.10	C	39.58**
October	40.63	C	
November	29.88	BC	
December	25.00	ABC	
	Alder		
July	4.50	A	
August	17.00	AB	
September	33.44	BC	37.16**
October	36.75	BC	
November	45.11	C	
December	20.89	ABC	

Appendix 3c, continued

Appendix 3c, Continued

Month	Average of the sum of ranks		H
	Meadow	0.05*	
August	23.00	A	
September	16.71	A	
October	25.13	A	2.75
November	18.76	A	
December	18.67	A	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.01 level.

Ranks followed by the same letter within each section do not differ significantly.

APPENDIX 4

Results of Kruskal-Wallis and Dunn's tests on Hunt's 1974 Redwood Watershed Energy Data Compared to the Present 1975 Douglas-Fir Watershed Energy Data

Appendix 4a Results of Kruskal-Wallis and Dunn's tests on caloric content (in Kcal/gram) of douglas-fir watershed energy compared to redwood watershed energy.

Section	Average of the sum of ranks	0.05*	H
	September to December		
Virgin	9.50	A	8.37***
Redwood	3.50	B	
	September to December		
Douglas-fir Alder	4.17	B	5.03**
Redwood Alder	8.83	A	
	September to December		
Second-growth	6.83	A	0.83
Meadow	5.00	A	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.05 level.

*** Significant at the 0.01 level.

Ranks followed by the same letter within each monthly group do not differ significantly.

Appendix 4b Results of Kruskal-Wallis and Dunn's tests on energy contributed (in Kcal) per square meter comparing the Virgin study section to the Redwood study section of Hunt's 1974 study by month.

Section	Average of the sum of ranks	0.05*	H
	September		
Virgin	5.50	B	14.29***
Redwood	15.50	A	
	October		
Virgin	5.00	B	12.00***
Redwood	13.50	A	
	November		
Virgin	12.50	A	7.11***
Redwood	5.75	B	
	December		
Virgin	6.28	B	5.56**
Redwood	12.06	A	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.05 level.

*** Significant at the 0.01 level.

Ranks followed by the same letter within each month do not differ significantly.

Appendix 4c Results of Kruskal-Wallis and Dunn's tests on energy contributed (in Kcal) per square meter comparing the douglas-fir Alder section to the redwood Alder study section of Hunt's 1974 study by month.

Section	Average of the sum of ranks	0.05*	H
	September		
Douglas-fir Alder	5.50	B	13.50**
Redwood Alder	15.50	A	
	October		
Douglas-fir Alder	10.40	A	0.64
Redwood Alder	8.38	A	
	November		
Douglas-fir Alder	11.30	A	1.13
Redwood Alder	8.56	A	
	December		
Douglas-fir Alder	6.60	B	7.71**
Redwood Alder	13.78	A	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.01 level.

Ranks followed by the same letter within each month do not differ significantly.

Appendix 4d Results of Kruskal-Wallis and Dunn's tests on energy contributed (in Kcal) per square meter comparing the Second-growth study section to the Meadow study section of Hunt's 1974 study by month.

Section	Average of the sum of ranks	0.05*	H
	September		
Second-growth	4.33	B	5.22**
Meadow	9.29	A	
	October		
Second-growth	4.50	B	11.38***
Meadow	12.50	A	
	November		
Second-growth	9.70	A	0.03
Meadow	9.25	A	
	December		
Second-growth	6.33	B	6.33**
Meadow	12.67	A	

* Indicates special protection level against finding false significant differences.

** Significant at the 0.05 level.

*** Significant at the 0.01 level.

Ranks followed by the same letter within each month do not differ significantly.